

Below 2°C

Insurance for a low carbon economy

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Contents

Executive summary	5
1. Introduction	12
Background and objectives	12
Impact channels	15
Technical methodology	17
Selection of priority sectors	18
2. Sectoral impacts	20
Overview	20
Fossil fuels	21
Heavy industry	22
Aviation and marine transport	23
Road transport	24
Power	26
Construction	27
Agriculture	28
3. Insurance implications	29
Energy	30
Aviation	30
Marine	30
Motor	31
Construction	31
Property	32
Credit, financial guarantee and M&A	32
Product liability and recall	32
Other liability	33
4. Geographic landscape	36
Europe	36
North America	36
Latin America	37
Asia Pacific	37
Australasia	37
Middle East and Africa	37
5. Conclusions	38
Appendix 1: Net-Zero Toolkit Methodology	43
Appendix 2: Transition impact in priority sectors	46

Executive summary

This report provides a strategic overview of the potential effects of the low carbon transition on the general insurance market. Vivid Economics and experts from the London School of Economics Grantham Research Institute were engaged by Lloyd's to review the effects of decarbonisation scenarios on sectors and regions of the global economy, and the attendant opportunities and challenges this poses for the insurance sector. The work focuses on the impact of transition and liability risks on general insurance, seeking principally to understand sectoral trends up to 2030, which will inform risks and opportunities over the next 3-5 years.

Low carbon transition up to 2030 will entail far-reaching change across a host of key global sectors. Economy-wide modelling carried out for this study shows that decarbonisation on the scale required to limit expected global temperature rises to less than 2°C leads to very significant shifts in economic activity between sectors and regions, even as compared to a baseline in which existing climate commitments are followed through. A comparison with a future where existing climate commitments are not delivered reveals even greater shifts. Decarbonisation is driven by regulation and policy incentives, and sustained through a rebalancing of economic activity and widespread deployment of low emissions technologies.

The impacts of decarbonisation on the insurance sector are analysed in this report through three 'impact channels', consistent with the risk and opportunity framing developed by the Taskforce on Climate-related Financial Disclosure (TCFD). These are:

- Activities within sectors ([production and competition](#))
- Relationships between sectors ([supply chains and customer interactions](#))
- Interactions between sectors and the legal system ([litigation and liability](#))

Key findings

Impacts on business sectors

The consequences of the transition to a low carbon economy are expected to be particularly pronounced in seven business sectors, with implications for both existing insurance contracts and new insurance business (see *Table 1*).

- [Fossil fuel](#), where producers are expected to see steep declines in revenue, particularly for coal and oil, with significant stranding of coal assets by 2030 affecting their risk profiles. The sector has been a focus of lawsuits for physical climate damages, which may increase as attribution science develops.
- [Heavy industry](#), which decarbonises less rapidly than other sectors, but nonetheless sees shifts in inputs and technological processes in certain subsectors, with greater electrification of processes and recycling of inputs. The future regulatory treatment of heavy industry is subject to particular uncertainty.
- [Air and marine transport](#), where, in the absence of viable low carbon technologies, the short-term effect of decarbonisation is principally that of slowing the growth in demand. For marine, there is a particular shift in risk due to changes in the composition of cargo demand, as fossil fuel trade declines.
- [Road transport](#) is expected to see the widespread adoption of electric vehicles (EVs) in urban areas by 2030, which are more reliable but also more expensive to repair than internal combustion engines. EV technology, which is relatively low cost at high mileage, can complement the emergence of autonomous vehicles and pay-per-use models of car use, both of which are expected to change the nature and allocation of risks.

- **The power sector** will undergo radical change, with rapid growth in renewable generation, supported by new contractual relationships between suppliers, users and networks to manage intermittency. Fossil fuel generators are expected to remain a focus of litigation against physical damages they may have been caused by the emissions they have generated.
- **Agriculture** is not expected to undergo fundamental transformation before 2030, though increasing pressure on land resulting from population and income growth is expected to be compounded by demands for biomass.
- **Construction and the built environment** will see decarbonisation driven by regulatory standards, giving rise to liability risks related to disclosure and compliance. Decarbonisation is expected to accelerate the spread of off-site construction techniques, which affects both the level and allocation of risks.

Table 1: Heatmap of sectoral impact

	Production and competition shift in sector revenue or deployment of new technologies	Supply chain and customer interactions shift in either the sector's customer base, suppliers or nature of interactions.	Transition-related litigation and liability risk
Fossil fuels	>30%	10-30%	Major activity has been observed in at least one of the five types of climate-related litigation listed in Figure 2.
Heavy industry	10-30%	10-30%	Significant increase in the risk of litigation in at least one of the five areas listed in Figure 2.
Aviation & marine transport	10-30%	10-30%	No significant increase.
Road transport	>30%	10-30%	Significant increase in the risk of litigation in at least one of the five areas listed in Figure 2.
Power	>30%	>30%	Major activity has been observed in at least one of the five types of climate-related litigation listed in Figure 2.
Agriculture	<10%	<10%	No significant increase.
Construction	<10%	10-30%	Significant increase in the risk of litigation in at least one of the five areas listed in Figure 2.

Source: Lloyd's and Vivid Economics, 2020

Impacts on insurance

These sectoral impacts will lead to shifts in the overall size of insurance markets, with some growing and others shrinking, and will change insurers' underlying risk profiles. The insurance impacts of low-carbon transitions are expected to be particularly pronounced in seven sectoral areas and ten lines of business, with implications for both existing insurance contracts and new business opportunities.

Table 2 (below) maps the likely effects of decarbonisation of sectors onto insurance business lines, setting out in relative terms expected shifts in market size, changes in claims under existing contracts, and the scope for potential new contracts to manage emerging risks. The table highlights material changes in all business classes, with the most radical shifts expected in energy, motor, credit, financial guarantee and casualty

Table 2: Heatmap of the transition impact on major insurance business classes by 2030

Class of business	Existing contracts		New contracts		Insurance demand and size	
Energy – fossil fuel	Asset stranding and liabilities from production sites will have impact		Introduction of carbon capture storage S and co-firing with biomass		Decline in sectoral size due to product demand contractions	↓↓↓
– renewables	Evolving regulations and business models		Risks in power purchase agreements can be better insured		Growth in sectoral size due to move away from fossil fuels	↑↑↑
Aviation	Performance of new fuels unclear		Limited change in technology pre-2030		Sectoral slowdown due to modal shift	↓↓
Marine	Risks from retrofitting ships, new fuels and cargo types		Handling of new fuels and cargo types		Unclear: slowdown but risks emerge with new fuels and cargo	-
Motor	Internal combustion engine driven more in rural areas		New business models involving electric vehicles and pay-per-use		Unclear: growth varies across vehicle types and usage	-
Construction	Perils change, but impact on claims is unclear		Tighter building standards and energy efficiency requirements		Retrofits and new materials; but offsite construction lowers risks	↑
Credit, financial guarantee and M&A	Profits and business interruption		New sources of revenue risks faced by various businesses		New technical and business environments require insurance	↑↑
Property	Perils change, but impact on claims is unclear		Changes in supply chains require insurance for properties		Unclear: changes in exposure vary a lot by property type	-
Product liability and recall	Liabilities from energy efficiency and sustainability standards		New liabilities associated with low carbon products		New technologies and fuels require insurance	↑↑
Other liability	Increasing pressure from climate change litigations		Provide cover for climate change related settlements and litigation		Magnitude of risks increases expected to result in growth	↑↑↑

Notes: For existing contracts and new contracts, the darker the shade of red, the greater the magnitude of changes. These could be positive or negative from the perspective of insurers. For insurance demand and size, upward arrows suggest an increase and downward arrows suggest a decrease.

Source: Lloyd's and Vivid Economics, 2020 Source: Lloyd's and Vivid Economics, 2020

In-depth analysis by business sector

As part of this research, Lloyd's has also published five sector deep dives (*available as a separate report*) that draw out implications from decarbonisation for insurers in greater detail. The case studies look at a range of impacts on various stakeholders, including sectors that are expected to grow or decline as a result of the transition to a low carbon economy. A summary of the key opportunities and challenges revealed by the case studies is set out in *Table 3*.

Table 3: Key opportunities and challenges identified in the sector deep dives

	Opportunities	Challenges
Coal	<ul style="list-style-type: none"> - Products to support repurposing of assets for carbon capture and storage (CCS) and biomass generation - Liability insurance for physical damages 	<ul style="list-style-type: none"> - Reputational factors - Decline in market size - Uncertainty of liability insurance for CCS and physical damages
Marine	<ul style="list-style-type: none"> - Increased hull insurance premiums as vessels adopt new technologies - Liability insurance for regulatory risks 	<ul style="list-style-type: none"> - Decline in fossil fuel market - Uncertainty over technological / regulatory pathways and risks
Biofuels	<ul style="list-style-type: none"> - Support investment by assisting producers in managing supply chain and regulatory risks 	<ul style="list-style-type: none"> - Uncertainty over regulatory pathways - Reputational concerns related to food security and water use
Solar	<ul style="list-style-type: none"> - Growth in demand for existing products - Support emergence of 'prosumers', new power purchase agreement contracts, new contractual relationships with grids 	<ul style="list-style-type: none"> - Pressure on risk management standards - Growth in domestic and small commercial players rooftop installations with lower insurance demand
Construction	<ul style="list-style-type: none"> - Reduction in attritional losses - Increase in regulatory and liability risks 	<ul style="list-style-type: none"> - Uncertainty over division of liability between manufacturers and contractors for modular build

Source: Lloyd's and Vivid Economics, 2020

Impact by region

The report also looks at the impact of decarbonising on the world. The findings are summarised as follows.

North America

Transition impact in North America will vary significantly depending on state and provincial legislations. In particular, California is notable for its commitment to become carbon neutral by 2045. This has come with policy actions across several key areas, including incentives for distributed, self-generated renewable energy, funding for electric vehicle infrastructure and support for the development of microgrids (a small network of electricity users with a local source of supply that is usually attached to a centralised national grid but is able to function independently). Climate-related litigation and liability risks are increasing in the US in general. There are more than 1,000 such cases in the US to date compared to 300 in the rest of the world (*Sabin Center for Climate Change Law, 2019*).

Europe

Climate legislation is proceeding rapidly within the EU, although national policies will determine the extent of transition impact in different countries. This is expected to accelerate the policy-driven transition impact across all sectors, but particularly in the energy and buildings sectors. Momentum is also building for an EU-wide net zero target, with the support of several countries including France, Spain, Belgium and the UK.

Latin America

Water scarcity regulations in Argentina, Bolivia and Chile could constrain the supply of lithium, a key input to batteries, which are used in various low carbon applications, such as electric vehicles and renewable energy storage. Exporters in Colombia and Brazil can expect sharp shifts in the level and composition of demand for coal and biofuels. Colombia is Latin America's largest exporter of coal, with more than half of its coal exports heading to the US. As global demand for coal declines, albeit at a slower pace in the US, coal mines within the country will face increasing financial pressure. Meanwhile, Brazil is the world's second largest exporter of biofuels after the US. Companies in or dependent on biofuels could demand greater insurance to cover technology, regulatory, litigation and supply chain risks.

Asia Pacific

Developing economies in Asia Pacific will continue to be the largest market for renewable energy. China already has the largest installed capacity in solar and wind generation, at 175 GW and 184 GW respectively in 2018, or roughly 30% of the global installed capacity in both technologies. Although China will still dominate the market for both solar and wind power this decade, growth in India and ASEAN countries is expected to catch up gradually over time. Off-grid solar is a much more popular option for remote areas that lack a grid infrastructure, so the insurance required for off-grid solar power could be a significant opportunity for insurers who can accurately price the variety of risks faced by residents and businesses.

Australasia

Despite often being considered together, Australia and New Zealand have taken remarkably divergent paths on climate policy. While New Zealand has set a target of Net Zero emissions by 2050, Australia, one of the world's largest per capita green house gas emitters, has not improved on its climate policy since 2017 and is unlikely to meet its 2030 target set under the Paris Agreement (*UN Environment, 2018*). Nevertheless, both countries have seen a significant number of climate related litigation cases, which may increase demand for liability insurance products. In terms of sectors, Australia is the world's largest coal exporter, with considerable assets and reserves at risk of stranding under a low carbon transition. At the same time, Australia is one of the world's reserves of lithium, demand for which is expected to grow significantly in line with battery technology.

Middle East and Africa

Many economies in the Middle East and Africa are reliant on exporting minerals and oil and will therefore experience significant transition impact despite the lack of stringent climate policies. Insurance can support companies in adapting to the new operating environment transferring risks associated with political instability and supply chain interruption. The expansion of solar is expected to be particularly pronounced in Africa, where offtake (the risk of not getting paid for the power output) and regulatory risks are more pronounced, and off-grid solar power is expected to account for a relatively large share of investment.

Opportunities and challenges for insurers

Overall, the transition to a low carbon is an opportunity for insurers to help manage new risks and support investment in expanding low-carbon sectors. Insurers could grow their business in new markets, through its risk expertise, innovation commitment and ability to price uncertain risks. These include:

- **Regulatory risks.** Global decarbonisation depends to a large extent on policies and regulations, which are uncertain and vary over time and between regions. Regulatory risk, which can affect company revenues and liabilities, is therefore pervasive across growing and declining sectors, as well as sectors such as marine, where its size makes it unlikely to be sensitive to policy. Key challenges for insurers in meeting this demand include designing and pricing contracts, given the uncertainty over future regulatory pathways, and the high potential costs of regulatory changes that may render existing business activities illegal.
- **Project finance.** In growing low-carbon sectors, such as solar and biofuels, as well as those such as coal where there is scope for existing assets to be repurposed, significant new investment can be unlocked through reduced regulatory, counterparty, and technology risks. In these sectors, insurers can play a significant role in supporting the transition to a low carbon economy and acting as business enabler.
- **Risk allocation.** Another way in which insurers can facilitate the transition is through proactively supporting the development of efficient contracting and risk management standards, which in turn can underpin the development of new insurance markets. This is relevant in sectors where new low-carbon technologies are set to be deployed, such as in marine transport and construction, and where new supply relationships are expected to emerge, such as solar power and electric vehicles.

Key challenges for insurers stem from rapidly changing risk profiles and structural changes to several business sectors, including:

- **Risk management,** where traditional ways to set premiums may no longer be as effective. For example, in solar power, it has proved difficult to maintain risk management standards as the sector engages inexperienced suppliers to keep up with growing demand.
- **Reputation management.** Shifting public attitudes can present a barrier to offering insurance. This has already been observed in coal, where more than a third of reinsurance providers no longer offer services, but it could affect other sectors that are rapidly decarbonising. Pressure from investors and environmental groups could be significant and might impact on companies' reputation and their own ability to attract investments. Increased pressure from insurers' own investors on climate issues could result in stronger internal mandates to drive progress on managing climate-related risks and opportunities.
- **Market structure.** Changes in risk profiles between areas covered by different business lines may cause insurance providers to lose market share, for example as the economy's move towards alternative energy sources, such as biomass, the relative importance of cargo transported will change and with it, the risk profile of global trade.
- **Misaligned horizons.** Insurance policies are typically 12-36 months long (with some key exceptions) with strategy and capitalisation decisions often relatively short-sighted, while climate change impacts and adaptations will materialise over a longer period of time.
- **Lack of climate-related data and tools specific to underwriting portfolios.** Insurance analytics for environmental, social and governance (ESG) factors are typically less advanced than investment portfolio tools. Climate data generally suffers from quality and availability issues, and many models do not integrate forward-looking projections.
- **Uncertainty.** This may lead to mispricing of certain regulatory, technological and liability risks.

Next steps for insurers and brokers

This report analyses some of the most significant impacts of decarbonisation on insurance across key business lines and on key business sectors over the next 3-5 years. These impacts are likely to be caused by global policies and regulations aimed at reducing emissions. These will change the economics of multiple sectors and regions and will change how insurers use technology and design insurance contracts. Implications of a low-carbon transition include changes in demand for insurance, changes to the number of claims under existing contracts and significant opportunity to develop new products, fuelled by increasing demand. The report shows that all insurance lines could be affected, with particularly radical changes anticipated in energy, motor, credit, financial guarantee, M&A and casualty.

There are a number of actions insurers could take to prepare themselves and their customers for the transition. These include the followings.

Insurers should work with brokers and policyholders to build a new generation of climate-supportive products and services, and foster demand by actively sharing their knowledge of climate risk. This will encourage insurers to think about risk mitigation and how they adapt to the transition to a low-carbon world, enabling them to build an insurance ecosystem that supports the 'green economy'

Insurers and brokers will need to respond to decarbonisation strategically if they are to meet clients' evolving needs and help them make the transition to a low carbon world. This will involve activity in three areas:

- Engagement with existing insureds
- New product development
- Evolution of strategic responses to climate change

These activities will promote the important role insurance can play in managing transition risks and thereby reducing the cost of the transition.

Increased customer engagement can ensure insurers will continue to support effective risk management despite changing risk profiles. The benefits of speaking with risk managers and brokers is twofold. It can increase insureds' awareness of the changes to their risk profiles and associated insurance premiums, allowing them to prioritise the issues they face appropriately and adapt their risk transfer approach accordingly. It can also help underwriters take a holistic view of their clients' risk management strategies, and thus understand how they can add value in the context of transition. This might be through greater tailoring of products – for example, hull insurance tailored for more energy efficient ships – or through contracting or behavioural standards that can underpin better value insurance.

Insurers and brokers will need to design new products and services to make the most of the opportunities set out in this report. New insurance products will help insureds to manage increasing regulatory risks and to ramp up investment in growing sectors, such as renewable energy and biofuels, and new technologies, such as carbon capture and storage. Insurers could develop new products with customers to understand demand as well as technology providers to understand what technical standards are feasible. A coordinated approach can be valuable where products span multiple business lines: for example, regulatory risks may be relevant for financial lines and casualty.

Insurers and brokers will also need to start considering the impact on climate change created by their products and services. They will need to align their operations with the UN's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals.

Insurers and brokers will need to build a strategic response to climate change. This report has established a conceptual framework for tracing the impacts of transition through the global economy to insurance markets. The insurance market will be able to develop further their strategic response to climate change by:

- Participating in climate-related collaborative initiatives such as ClimateWise and starting to use the TCFD framework to develop climate decisions
- Raising awareness and engaging with senior decision makers on climate-related risks and opportunities in underwriting and operations, as well as taking a holistic approach to climate-related issues across departments and portfolios
- Exploring the use of climate-related data and forward-looking climate scenarios for risk and pricing models to show how decarbonisation can affect premiums for specific insurance products; including climate change within investment strategies and increasing low-carbon investments.

Insurers and brokers will need to carry out further analytical work and develop of climate-related underwriting and portfolio management tools. Having identified key impact channels and priority opportunities and risks, quantitative analysis can project the effect of decarbonisation on key insurance lines and can help develop more focused strategies for insurers within certain market segments. As countries such as the UK, Sweden and Norway pledge to achieve net-zero emissions targets by 2050 or sooner, stronger emphasis will be put on clearer paths to achieve these goal and sectors will decarbonise faster, providing insurers opportunities to enable companies to do so in a safe way. More detailed analysis can quantify the effects of these pathways on contract volumes and premiums – looking beyond the traditional one-year horizon in order to anticipate and respond to future market trends.

This can support in depth engagement with risk managers to develop appropriate standards and new products to meet emerging needs.

With mandatory Task Force on Climate-related Financial Disclosures-aligned (TCFD) requirements becoming more likely across regions in the coming years, [insurers and brokers should also start formulating their climate strategies as environmental risks become increasingly financially material](#). The TCFD Framework and insurance initiatives such as the ClimateWise Principles will help insurers to develop company-wide climate strategies and holistic thinking on climate-related issues, which will in turn impact product development and underwriting.

In conclusion, the transition to a low carbon economy will need to be managed carefully by both insurers and their customers. While there are a number of challenges to overcome, insurers can play an important role in helping businesses make the necessary changes and develop new insurance markets as a result.

1. Introduction

Background and objectives

Recent calls for greater climate action will require rapid and far-reaching structural changes to the global economy. The 2015 Paris Agreement sets out a policy framework and process that could trigger a global response to limit global warming to well below 2°C. Under the agreement, 185 countries have pledged to report and curb emissions in line with their Nationally Determined Contributions (NDCs).

Climate policies agreed during the 2015 Paris Agreement are estimated to result in between 2.6°C and 3.4°C of warming, way above the limit of 2°C.

A range of climate policies have been legislated on major emitting sectors including power, industry, transport and buildings. These policies include carbon pricing, subsidies for low carbon technologies and innovation, and command and control regulations to outlaw carbon intensive practices. However, various studies assessing current pledges estimate that they are limited to result in between 2.6°C and 3.4°C of warming by the end of the century, well above the 2°C target. In 2018, the Intergovernmental Panel on Climate Change (IPCC) Special Report on the impacts of global warming of 1.5°C highlighted the urgency of strong climate action. The report emphasised the significant differences in physical impacts between the 1.5°C and 2°C pathways, as highlighted in Table 4. Reaching this ambitious target would require much more disruptive policies, such as the forced retirement of coal-fired power plants and the rapidly accelerated adoption of low carbon technologies, including renewable energy, smart grids and electric vehicles (EVs). Such a low carbon transition could transform competitive landscapes and supply chains across the global economy.

Low carbon transitions therefore present risks and opportunities for insurance underwriters. The widespread Regulators are pushing for greater consideration of climate-related risks and opportunities by insurers.

structural changes in the economy expose businesses to new types of risks and influence value chains and productive processes, which in turn can alter their demand for insurance and the cost of providing insurance. For example, some companies that are traditionally outside of the energy sector are now investing in renewable energy projects and hence may face liability risks when supplying electricity to the grid. Underwriters who understand and cater to this evolving demand could benefit from the low carbon transition. More broadly, as momentum around climate grows, insurance company clients and investors are taking a greater interest in the way climate-related risks and opportunities are managed. As this intensifies, insurers will face increasing pressure to understand and plan around the effects of low carbon transitions for their business.

Table 4: The global impact of climate change at different degrees of warming

Impact	1.5°C	2°C	3°C	4°C
Sea level rise by 2100	48cm	56cm	/	0.5-2m
Increase in ocean acidity by 2100	+9%	+24%		
Probability of an ice-free arctic summer in any one year	3%	16%	63%	
Average warming across drylands	2.4-3.0°C	3.2-4.0°C		
Average drought length (months)	+2	+4	+10	
Proportion of mammal species losing 50% of climate range	4%	8%	/	41%
Global population exposed to extreme heatwaves at least once every 20 years	700m	2,000 m		
Annual flood damages (US\$)	10.2 tn	11.7 tn		
Reduction in global GDP per capita in 2100	8%	13%		

Data for 3°C and 4°C not always available.

Source: Carbon Brief (2018), Nicholls et al. (2011), Weber (2018)

Although there is a growing evidence base for climate-related risks, many companies fail to account for climate change and systematically underestimate its impact on investments.

Driven by concern on the stability of the financial system, G20 Finance Ministers and Central Bank Governors asked the Financial Stability Board (FSB) to review how the financial sector can take account of climate-related issues.

In 2015, Prudential Regulation Authority (PRA) launched its first report about climate change, providing a framework for considering the risks arising from climate change through the lens of the PRA's statutory objectives in relation to insurers. This has developed into regulatory guidance on strategies to manage climate risks, which include stress tests for general and life insurers (PRA, 2019).

Environmental, Social and Governance (ESG) ratings have also risen in popularity among investors and customers who have started focusing more heavily on matters of sustainability. Since 2015, credit rating agencies, including Moody's, Standard & Poor's and Fitch Group, have been building their capacity to better analyse how climate change can be factored into the financial stability of companies and governments around the world. However, rating agencies might be miscalculating the impacts of climate change as they are taking a 'business-as-usual' approach to fossil fuel investments. By not factoring in the transition risks related to these investments, they may be overinflating the credit ratings and value of companies that are contributing to global warming, putting investors at risk, and opening themselves up to potential legal liability (Moodie, 2019).

In 2017, the Task Force on Climate-related Financial Disclosures (TCFD) published a report to set out recommendations for investors, lenders, and insurers. The TCFD recommendations urge companies to use scenario analysis to assess and disclose the 'actual and potential impacts' of climate-related risks and opportunities on their business as well as how they manage them, as further detailed in the *Box on page 14*.

The objective of this study is to understand and prioritise the impacts of low carbon transition on property and casualty insurance underwriting. This report differs from existing literature by focusing on the impact of transition and liability risks rather than physical risks on underwriting: it therefore seeks to complement studies whose focus is on physical risks, including by Lloyd's (2014), Deutsche Asset Management and Four Twenty Seven (2017) and UNEP FI and Acclimatise (2018). This report explores how policy and technology shifts under emissions reduction scenarios affect the size of different sectors, the way they do business, and their exposure to litigation and liability risk, considering two decarbonisation scenarios that represent 1.75°C and 2°C global average temperature increase by the end of the century. The work draws out the implications of this for the demand for insurance, the cost of underwriting, and new types of products that could be brought to market. It focuses on underwriting in general insurance, considering the global implications of trends up to 2030 and the resulting risks and opportunities for underwriters over the next 3-5 years.

The remainder of this report is structured as follows:

- The rest of *Section 1* sets out a framing, detailing three causal channels through which transitions can affect insurance underwriting and outlines the methodology for estimating the transition impact on individual sectors along these channels;
- *Section 2* presents the results of an assessment of how key sectors are affected by the transition to a low carbon economy;
- *Section 3* highlights the implications of sectoral impacts for different classes of insurance;
- *Section 4* highlights geographical variations in the magnitude of transition and liability risks; and
- *Section 5* concludes with the role insurers can play to respond to climate change at strategic level.

As the first exercise of its kind, this report provides a foundation to build upon in future work. Implementation of TCFD recommendations will naturally require multiple phases as practices evolve and new data emerges from industry practitioners, corporates, policymakers and climate modellers.



Task Force on Climate-related Financial Disclosures (TCFD) and ClimateWise

In 2015, the Financial Stability Board (FSB) established the TCFD an industry-led task force to develop clear recommendations for voluntary climate-related financial disclosures, and provide decision-useful information to lenders, insurers, and investors. The TCFD's 31 members were chosen by the FSB to include both users and preparers of disclosures from across the G20's constituency covering a broad range of economic sectors and financial markets.

The Task Force considers the physical and transition risks associated with climate change and what constitutes effective financial disclosures across industries. The recommendations apply to financial-sector organisations, including banks, insurance companies, asset managers, and asset owners, and are designed to be adoptable by all organisations and jurisdictions.

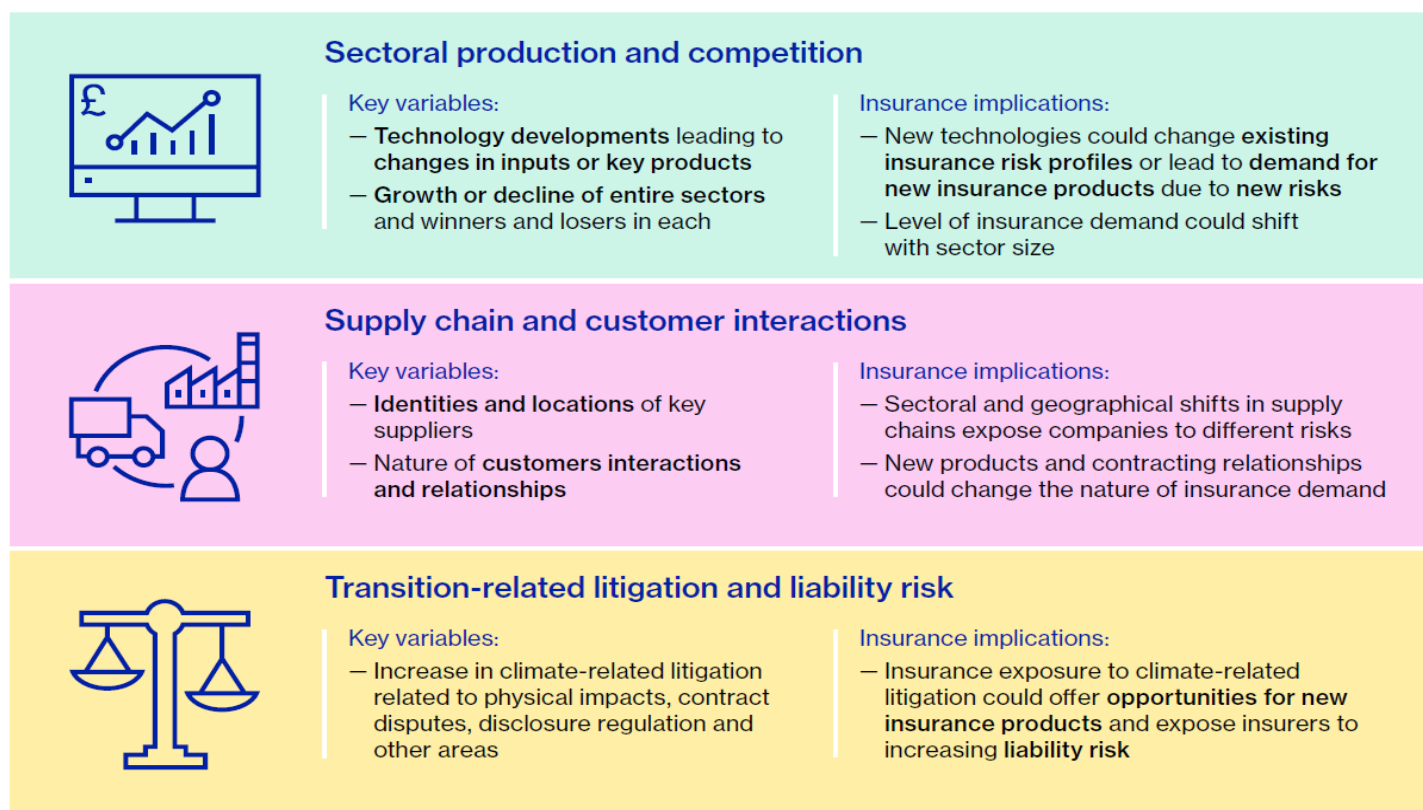
The recommendations are structured around four key themes: governance, strategy, risk management and metrics and targets. The governance theme recommends companies disclose the extent to which boards and management oversee climate-related risks and opportunities. The strategy theme encourages companies to assess the materiality of climate change to their business including through forward-looking scenario-based analysis and to disclose on their exposure to climate-related risks and opportunities. The risk management theme recommends companies report on their integration process for identification, assessment and management of climate risks and opportunities into their existing risk management frameworks. For metrics and targets, institutions are encouraged to include climate-related metrics and to set targets aligned with the material risks and opportunities identified through the process in regular financial reporting.

Lloyd's has been voluntarily disclosing against climate-related risks since 2007, when it became one of the founding members of ClimateWise. Over 30 insurance companies are members, including ten managing agents in the Lloyd's market. The ClimateWise Principles guide members' contributions to the transition to a low carbon, climate-resilient economy and integrate a response to the climate risk protection gap – the growing divide between economic and insured losses – across their business activities. Part of ClimateWise membership obliges members to report annually on their individual actions, allowing members to benchmark progress against their peers. An annual, public review highlights the overall progress being made by the ClimateWise community. From 2019, the new ClimateWise Principles – aligned fully with TCFD recommendations – came into force. ClimateWise members have been at the forefront of climate-related disclosure for over a decade, voluntarily reporting against a large part of the TCFD recommendations. It is therefore a natural progression to align with the recommendations without losing the elements of ClimateWise reporting that fall outside the scope of TCFD (such as in informing public policy) to demonstrate the leadership shown by members.

Impact channels

This report considers three 'impact channels' through which low carbon transitions could affect sectoral outcomes – and thus the demand for and cost of insurance, as illustrated in *Figure 1*.

Figure 1: The three impact channels examine transition impacts on key economic variables and insurance

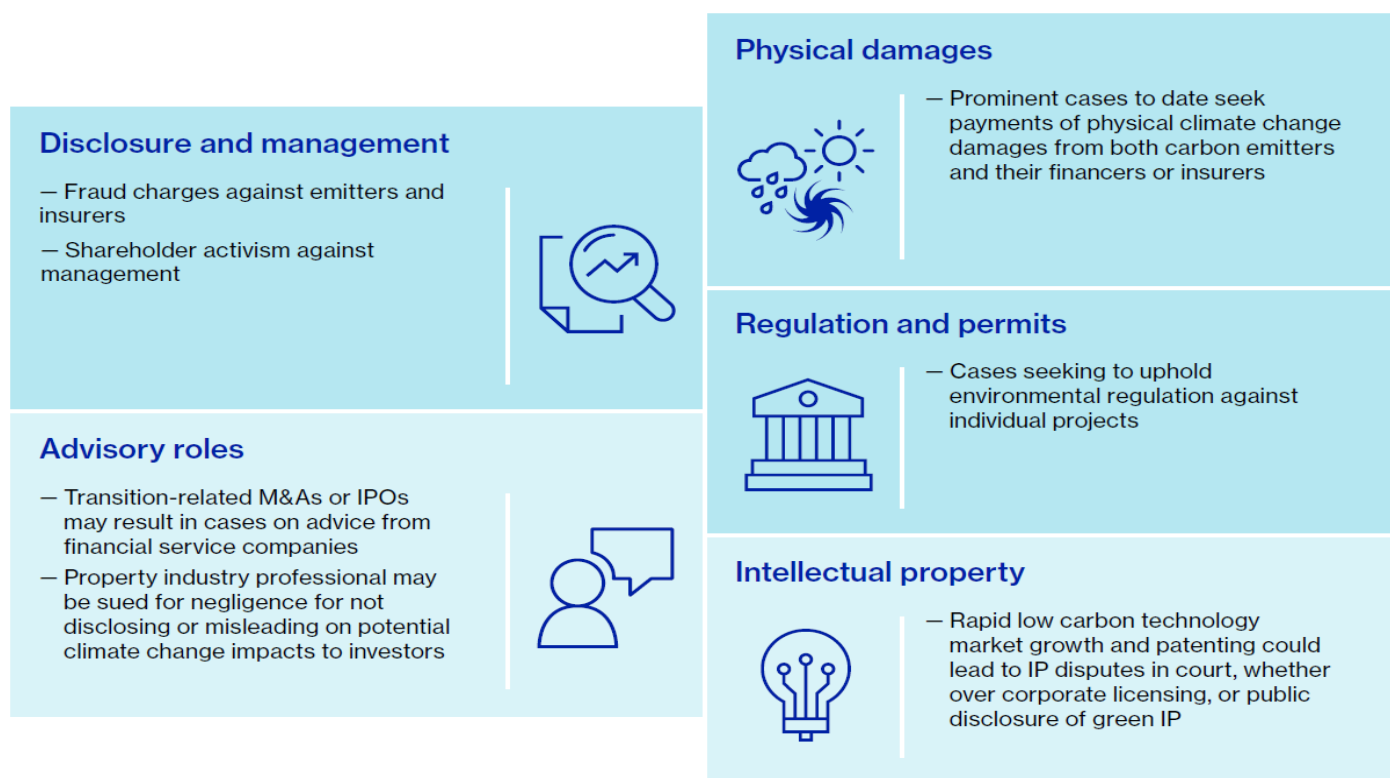


Source: Lloyd's and Vivid Economics, 2020

The impact channels are:

- **Production and competition.** Tightening climate policies and the emergence of low carbon technologies can have a direct impact on production and profitability within sectors. Examples include policy requirements to phase out of coal power generation to incentive policies to encourage the uptake of biofuels and EVs. These transitions will affect the size, concentration, and deployment of technologies in a variety of sectors. This in turn might affect the demand for various specific types of insurance and the nature and magnitude of risks faced by companies in sectors.
- **Supply chain and customer interactions.** As well as affecting the size and configuration of different sectors, low carbon transitions have impacts on the ways sectors interact with each other. Changes in product demand and business models can lead to shifts in customer bases and the contractual relationships that underpin sales: for instance, the growth of modular construction to improve energy efficiency will entail a greater share of off-site manufacturing where building components are pre-fabricated by contractors.
- **Transition-related litigation and liability risk.** Regulatory interventions under low carbon transition are likely to create a host of new reporting and compliance obligations while in some cases, companies may be found to be liable for physical consequences of climate change. Furthermore, the potentially disruptive emergence of new business models may affect litigation risks relating to advisory support in M&A transactions, debt defaults or bankruptcies, if the volume of these events increases. Strong growth in patent filings for green technologies (Geary, 2018), which are enforced through the civil legal system, may also increase company exposure to litigation. This report groups these issues into five distinct types of litigation and liability risk, which are presented in Figure 2 below. Litigation risk involves not just damages claims, but also the cost of defending litigation, the reputational harm of being associated with such litigation and the consequential impacts on operations and value.

Figure 2: Five types of litigation cases that could be affected by a low carbon transition



Source: Lloyd's and Vivid Economics, 2020

The three channels cover the full set of risks and opportunities outlined in the TCFD recommendations, as illustrated in Table 5. The classification framework for climate-related risks and opportunities set out by TCFD is designed for *individual companies* to examine their own exposure, whereas the three channels identified for this report serve to provide an analytical framework to differentiate the various types of transition impacts at the *sector level*. For further information on the TCFD recommendations, refer to the *Box on page 14*.

Table 5: The three impact channels comprehensively cover TCFD's risk and opportunity categories

	TCFD framework categories	Description	Production and competition	Supply chain and customer interactions	Transition-related litigation and liability risk
Risks	Policy and legal	Risk from constraining/promoting policies and climate-related litigation claims			✓
	Technology	Risk from impacts of emerging technologies on demand, consumer behaviour, etc.	✓	✓	✓
	Market	Shifts in supply and demand for some commodities, products or services due to climate risk	✓	✓	
	Reputation	Changing customer perceptions of organisational contributions to climate change	✓	✓	✓
Opportunities	Energy source	Major developments toward cleaner energy sources	✓	✓	
	Products and Services	Low-emission products and services that serve new markets	✓	✓	
	Markets	New types of assets and shifts in existing market size and structure, new markets	✓	✓	

Source: Lloyd's and Vivid Economics, 2020

Technical methodology

The findings presented in this report are based on a quantitative analysis of each sector with respect to the three impact channels, desk-based research and expert interviews to substantiate this analysis, and detailed case studies that seek to draw out practical implications for participants in insurance markets. This section briefly outlines the technical component of the methodology and how it was supplemented by qualitative research. Appendix 1 explains the analytical work in more depth.

Quantitative modelling

The quantitative analysis is performed using the Net-Zero Toolkit, a proprietary model developed by Vivid Economics to assess the impact of decarbonisation scenarios on economic sectors and individual companies. For this analysis, the Net Zero Toolkit modelled the effects of low carbon transitions on 2,500 publicly listed companies across 137 sectors. It operated in three stages: scenario selection, value stream modelling and derivation of company and asset level impacts.

Step 1: scenario selection

The IEA's Energy Technology Perspectives (ETP) scenarios are key inputs to the model, corresponding to commonly used scenarios for policymakers and business leaders. Three decarbonisation scenarios of various strengths form the basis of this work:

- the [IEA's ETP Reference Technology Scenario \(RTS\)](#), which acts as a benchmark scenario,
- the [2°C Scenario \(2DS\)](#) that lays out a pathway that limits emissions to levels that give a greater than 50% chance of global warming no greater than 2°C, with carbon neutrality achieved in 2100.
- And [Beyond 2°C Scenario \(B2DS\)](#) that goes further in assuming maximal deployment of current low carbon technologies, achieving net zero emissions in 2060, with a 50% chance of limiting global warming to 1.75°C^a.

These scenarios include projections of energy demand, carbon prices by region and sector, and a range of technology deployment trends. Vivid's scenario modelling capabilities were used to project carbon prices under each of the three scenario emissions pathways.

Under the RTS, countries fulfil their current NDCs to the Paris Agreement, a level of intervention that, while more ambitious than a historic 'business as usual' scenario, is not consistent with the Paris Agreement objective of limiting global warming to 2°C above pre-industrial temperatures by 2100.

Step 2: value stream modelling

The Net-Zero Toolkit assesses the effect of these scenarios on the economy using three value stream models. These bottom up models are designed to capture the major channels through which transition risk might impact companies and assets:

- [Demand destruction](#). Under stringent climate policy, demand for fossil fuel products will fall due to the increasing costs associated with their emissions intensive consumption. The demand-destruction component of the model captures the effects of this on oil, gas, coal and automobile producers, accounting for asset stranding and reductions in profit margins.
- [Cost and competition](#). All emitting companies experience direct increases in costs due to increases in global carbon prices. Companies can respond to cost increases by realising emissions abatement opportunities or passing through costs to consumers. Using a microeconomic model on sectoral competition and data on financials and emissions of individual companies in 137 sectors, these mechanisms are modelled.
- [Cleantech markets](#). Demand for low carbon technologies grows in response to the shifts in their costs relative to traditional fossil fuels. Using data on green patents and existing market share, the model estimates impacts on individual company growth in cleantech markets, including renewables equipment and EV manufacturers, as well as miners of minerals for batteries and biofuel producers.

Step 3: company and asset-level impacts

Company and asset level impacts are estimated as the difference between net present value profits under the 2DS and B2DS relative to the RTS and aggregated to the sector level. Profit impacts are modelled over the period to 2050 and discounted to net present value using a standard equity discount rate. All impacts under the 2DS and B2DS are expressed relative to the RTS. As an example, if estimates of aggregate profits under the 2DS in a sector were 30% below profits under the RTS in 2050, the profit impact of the 2DS would be -30%. Changes in firm count relative to today are estimated to 2030.

^a Model results are as of December 2018. Carbon budgets used in the ETP are based on the IPCC AR5 (*IPCC, 2013*), and are outdated as of the IPCC 1.5SR (*IPCC, 2018*)

Analysis of the three impact channels for each sector draws on the Net-Zero Toolkit results as outlined in *Figure 3*. Results on aggregate sectoral characteristics and technology shifts, abatement potential, market characteristics and sectoral revenue, profit and market size impacts provide important indicators of shifts in sectoral production and competition. Analysis of the supply chain and customer interactions relies on the toolkit's data on marginal abatement cost (MAC) curves, cost pass-through and demand responsiveness as evidence for major changes in supply chains or customer base. For transition-related litigation and liability risk, model estimates of sectoral firm closure provide an indication of the litigation risks associated with bankruptcies and sectoral consolidation.

Qualitative research

Qualitative research, which comprised interviews with sectoral experts and literature reviews, supplemented the insights generated by the Net-Zero Toolkit. It extended the quantitative findings from the Net Zero Toolkit to relevant aspects of low carbon transitions not covered by modelling:

- **Systemic shifts.** The model does not cover systemic changes in consumer behaviour or major technological breakthroughs beyond currently feasible technical developments. Desk research and expert interviews provide insights into potential systemic shifts.
- **Abatement costs.** Sectoral abatement cost curves were constructed based on literature review and expert opinion and identify relevant abatement opportunities and their significance for each industry.
- **Sectoral coverage.** The model covers 137 sectors in total, with the most granular sector coverage in energy and industry. Agriculture and land-use sectors are comparatively underrepresented, and as a result, analysis of these sectors relied on literature review and expert interviews.
- **Emergence of new firms.** In the model, firms exit the market when they have made continuously negative profit. Entry into markets (for example in markets for green technologies) is not modelled due to the lack of data on potential future entrants. Markets still grow according to the scenario specifications; however, profits are distributed among firms already present in the market. Qualitative research considered the prospects for entry by new firms.
- **Climate related litigation.** Although sectoral firm closure estimates indicate the extent of litigations related to advisory roles (through M&A and bankruptcy cases), a key trend in the low carbon transition is the emergence of litigations related to other factors.

Sectoral exposure to such litigations cannot be captured by the scenarios used and hence are left out of the model. A majority of analysis related to litigation and liability risks therefore rely on desk research and expert interviews.

Selection of priority sectors

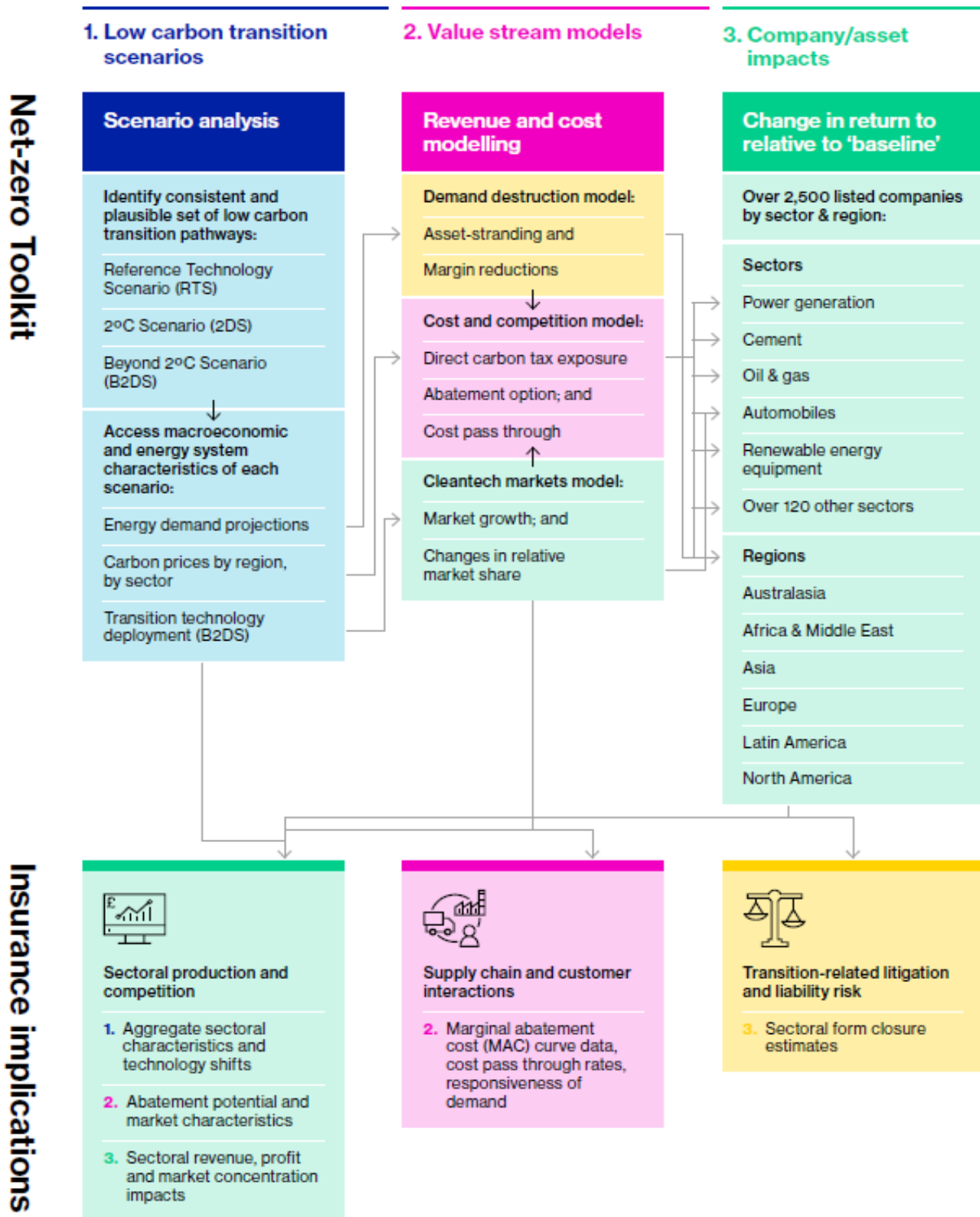
The quantitative analysis and initial qualitative research process identified seven priority sectors from the 137 economic sectors covered by the Net-Zero Toolkit, where impacts are expected to be most significant. Quantitative indicators on the 137 sectors were summarised in a sectoral heatmap showing high or low exposure relative to the average across the sample. From this heatmap, 20 sectors are selected based on: direct carbon costs, which show the relevance of decarbonisation policies to the sector, revenue impacts (upside and downside) and a qualitative assessment of exposure under the 2DS and B2DS relative to the RTS, based on the team's understanding of the sector, informed by indicators such as cost pass-through and the responsiveness of demand. These 20 sectors were then consolidated into seven priority sector groupings, for example, by summarising power generation, solar and wind sectors as power. Expert interviews and desk research further identified agriculture and construction as two additional priority sectors, where the Net-Zero Toolkit outputs are unable to capture impact channels sufficiently. Full Net-Zero Toolkit outputs for the priority sectors are included in the Appendix where available.

The following seven sectors groupings were identified as priority sectors:

- Fossil fuels (extraction and distribution), covering coal, oil and gas.
- Heavy industry, including concrete and cement, iron and steel, and aluminium as well as growing lithium and minerals sectors.
- Air and shipping.
- Road transport, including conventional vehicles and EVs.
- Power, including traditional power generation (fossil, nuclear, hydro), wind and solar generation, and electricity transmission and distribution.
- Construction, including heavy and home construction, as well as activities in retrofitting existing buildings.
- Agriculture. Note the sector is not covered by the version of the Net-Zero Toolkit used for this study.

Appendix 2 lays out the 20 sectors covered within the priority groupings and the modelling indicators that were used in their assessment. Section 2, which follows, provides a more detailed assessment of the expected shifts within these sectors.

Figure 3: The Net-Zero Toolkit translates low carbon transition scenarios into sector and firm level impacts



Source: Vivid Economics, 2019

2. Sectoral impacts

This section discusses in more detail the low carbon transitions across in key sector groupings that is relevant to the insurance sector. It presents a summary 'heatmap', which rates the changes in each sector as 'high', 'medium' or 'low' along each of the three impact channels, before explaining in greater depth the evidence behind these ratings for each sector. Sectoral growth rates are all sourced from the IEA's 2017 ETP publication, unless otherwise stated (IEA, 2017).

Overview

For each sector, the significance of the three impact channels are classified as either 'high', 'medium' or 'low', based on the criteria outlined below in Table 6. The criteria are quantitative for the first two impact channels and qualitative for transition-related litigation and liability risk due to lack of available data. Each set of criteria examine the impacts of a low carbon transition on a set of key variables. It should be noted that the model provides impact estimates for both the 2DS (2°C Scenario) and B2DS (Beyond 2°C Scenario, i.e. less than 2°C), but the following classification uses the 2DS results. The impacts for each sector are highly similar across the 2DS and B2DS, but some exceptions exist. The sectors in which the revenue impact under B2DS are over 50% larger in absolute terms relative to the 2DS revenue impact are: aluminium mining, automobiles, gold, EVs, minerals, iron ore and nickel mining, oil and gas transmission and distribution, power generation, air transport and rail transport.

Table 6 below presents a summary heatmap of the relative significance of the three impact channels for each of the seven selected sectors. The remainder of Section 2 outlines the analysis underlying the heatmap for each of the priority sectors in details.

Table 6: Heatmap of sectoral impact

	Production and competition shift in sector revenue or deployment of new technologies	Supply chain and customer interactions shift in either the sector's customer base, suppliers or nature of interactions.	Transition-related litigation and liability risk
Fossil fuels	>30%	10-30%	Major activity has been observed in at least one of the five types of climate-related litigation listed in Figure 2.
Heavy industry	10-30%	10-30%	Significant increase in the risk of litigation in at least one of the five areas listed in Figure 2.
Aviation & marine transport	10-30%	10-30%	No significant increase.
Road transport	>30%	10-30%	Significant increase in the risk of litigation in at least one of the five areas listed in Figure 2.
Power	>30%	>30%	Major activity has been observed in at least one of the five types of climate-related litigation listed in Figure 2.
Agriculture	<10%	<10%	No significant increase.
Construction	<10%	10-30%	Significant increase in the risk of litigation in at least one of the five areas listed in Figure 2.

Source: Lloyd's and Vivid Economics, 2020

Fossil fuels

Production and competition

Climate policies up to 2030 are set to reduce the demand for fossil fuels significantly, leading to reduced profitability and consolidation in the coal and oil extraction. Direct regulations and carbon pricing will result in significant reductions in demand for coal and oil in the 2DS relative to the RTS over the period to 2060. This will create downward pressure on coal and oil prices, reduce company profitability, and encourage sectoral consolidation. By contrast, there is limited impact on the demand for gas up to 2030, because during this phase of the transition it substitutes for coal and oil. In absolute terms, the impact of decarbonisation is greatest for coal: while gas primary energy demand is projected to grow by 9% and oil demand to fall by 10% by 2030 in the 2DS, coal demand falls by 40% (see *Figure 4*).

Expected shifts in demand vary significantly by region. These shifts in demand and competitive dynamics are sensitive to policy incentives that vary across geographies. In particular, the phasing out of coal is expected to occur the earliest in the EU. Regional variations in climate policies and economic growth will also rebalance fossil fuel demand towards emerging economies. In the 2DS, the non-OECD share of fossil fuel demand is estimated to rise from the 60% in 2014 up to almost 70% by 2030.

Supply chain and customer interactions

Changes in fossil fuel demand vary substantially between sectors, with industry accounting for a larger share of coal and gas. In particular, the use of coal for electricity and heat generation will drop by 55% by 2030 in the 2DS. This means that the demand for lignite, used predominantly in power generation, falls more than other forms of coal. The share of coal that is consumed by industry correspondingly increases from a current level of 31% up to 45% in 2030 under the 2DS.

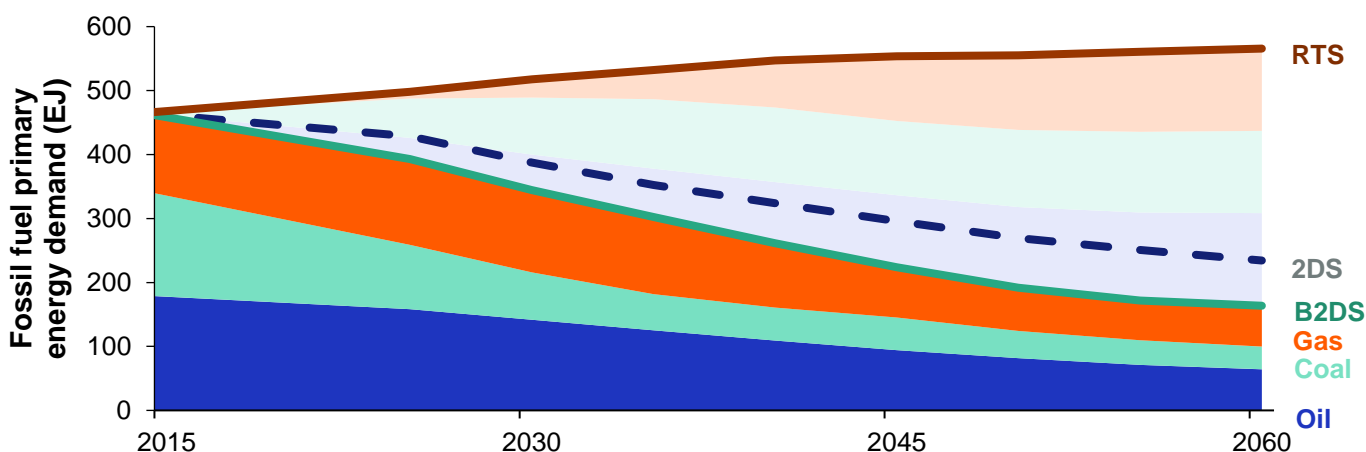
Fuel and feedstock-switching to gas by industry means that the share of gas consumed by industry increases from 23% up to 28% over the same period, while for oil, the transport sector will remain its largest consumer, at roughly 75% of global oil demand.

Litigation and liability

Fossil fuel companies appear relatively exposed to liability litigation, the withdrawal of insurance, and litigation related to sectoral consolidation.

- **Fossil fuel companies** already face lawsuits related to environmental damages. Although there are no successful cases so far, in the context of improving scientific evidence and shifting public and political opinion, cases such as *Oakland v. BP* represent an increasing risk for the sector. As is explained in *Section 3*, lawsuits can be based on the carbon emissions which fossil fuel companies generate, characterised as a form of nuisance, trespass, negligence, civil conspiracy, environmental laws and human rights laws. Beyond exposure to damages claims, these cases may result in financial and reputational costs to companies, disruption to operations, and enforcement of financial disclosure requirements.
- **Environmental, Social and Governance (ESG)** policies of large insurers may make it harder for fossil fuel extractors to purchase insurance. For instance, major insurers have restricted underwriting further coal projects as part of their commitments to mitigate their impact on the climate.
- **Sectoral consolidation** induced by falling fossil fuel demand will increase M&A and bankruptcy events, which can lead to increased litigation against directors and advisors. Facing reduced profitability, the Net-Zero Toolkit estimates that up to 46% of coal firms in the RTS by 2030 will exit the market under the 2DS.

Figure 4: Global fossil fuel primary energy demand



Source: Lloyd's and Vivid Economics based on IEA ETP, 2017

Heavy industry

Production and competition

Although heavy industry as a whole is relatively slow to decarbonise, some subsectors are exposed to significant impacts from climate policies and related technological shifts. In the scenarios under consideration, heavy industry is the last sectoral grouping to decarbonise due to the lack of cost competitive solutions that can deliver deep cuts in emissions. Under increasing carbon prices, the cement, steel and aluminium sectors in particular therefore see increases in costs due to their high emissions intensity, but the lack of substitutes for these basic materials meant that up to 95% of cost increases are passed through to customers. This provides some protection for company profit margins in these sectors but will still, according to estimates from the Net-Zero Toolkit, result in a 25-30% fall in firm count in the 2DS relative to the RTS in 2030.

The effects on company profitability are expected to be particularly sensitive to government policy. For a variety of reasons, including lobbying and fears of international competition ('carbon leakage' whereby emissions in one country is displaced to another country with looser policies), decarbonisation policies have tended to treat industry differently to other sectors, by exempting them from direct regulations or allocating free allowances to companies under emissions trading schemes (ETS).

Smaller sub-sectors such as lithium mining and minerals are likely to benefit from a low carbon transition as they are important inputs to battery technologies.

Supply chains and customer interactions

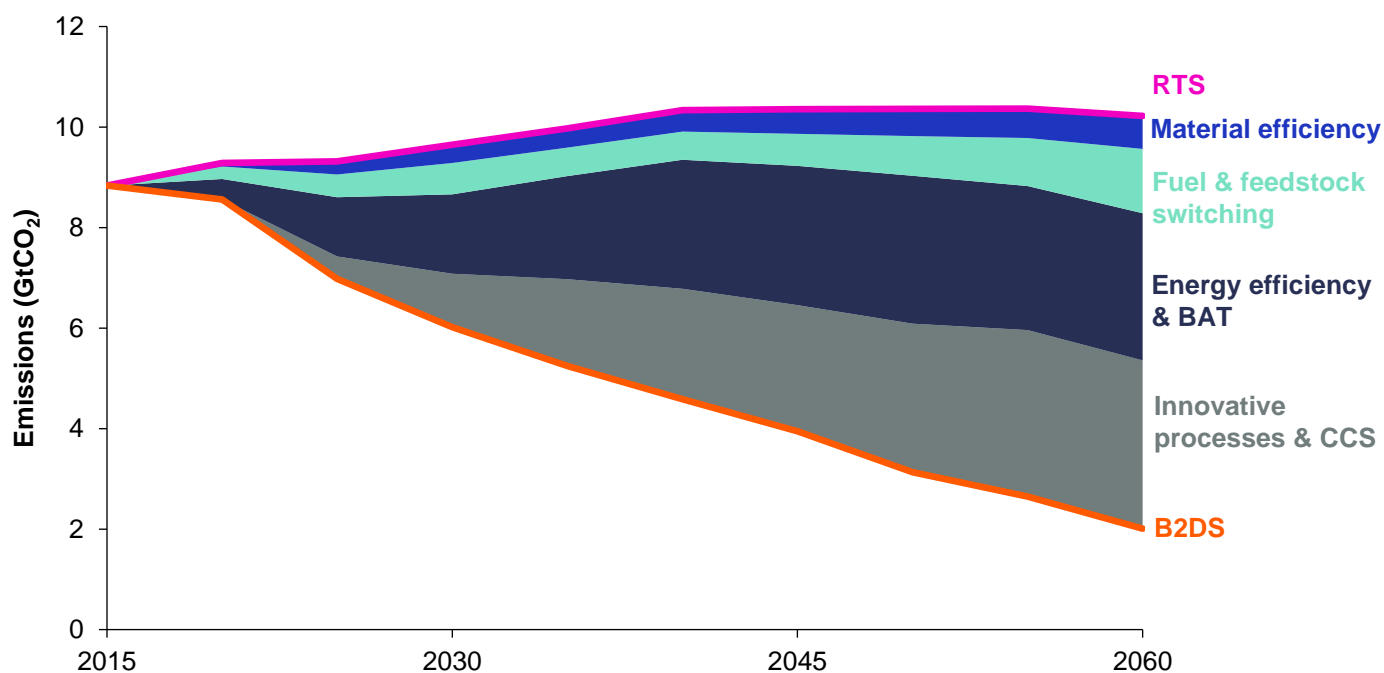
The adoption of cleaner production methods and further recycling are expected to change the supply chains for heavy industry. A variety of technologies can deliver incremental emissions reductions, such as material efficiency, fuel and feedstock switching and energy efficiency (see *Figure 5*).

Litigation and liability

Heavy industry faces growing litigation and liability risks related to low carbon transitions:

- heavy industry has yet to be a focus of lawsuits over the physical damages of climate change, despite their major contribution to greenhouse gas emissions. This is potentially because, relative to fossils and energy companies, industrial companies are often smaller in size and receive less public attention. However, as the scientific base and public concern for climate change grows over time, the risk of litigation could become a pressure on industrial companies.
- disclosure and compliance requirements imposed on industrial activities are expected to create risks for the sector. This is because achieving more ambitious climate targets will require turning voluntary schemes around energy performance and audits into mandatory requirements.

Figure 5: Abatement channels for heavy industry



Source: Lloyd's and Vivid Economics based on IEA ETP 2017

Aviation and marine transport

Production and competition

Low carbon transition pathways limit rather than reverse growth in the aviation and shipping sectors, as

Figure 5 highlights. In the absence of radical new low carbon technologies, sectoral abatement in aviation and shipping will be primarily determined by fuel efficiency improvements and the use of drop-in biofuels.

- In aviation, without breakthrough developments in advanced biofuels, solar or electric planes, meeting an ambitious policy target involves the restriction of demand growth, with passenger miles estimated as 22% lower in the B2DS than the RTS in 2030. In the 2DS, up to 55% of aviation demand in highly populated areas could shift away from short haul flights to high speed rail by 2060. In the B2DS, passenger kilometres in rail would be around 20% higher relative to the RTS by 2030. This transition will create demand to upgrade existing tracks as well as to build new high-speed tracks.
- In shipping, activity growth is similarly expected to be lower in the (B)2DS than in the RTS. This is additionally driven by a lower global demand for fossil fuels, which currently comprises a third of global maritime trade. However, long term growth is less affected than in aviation, with activity still expected to triple to 2060 under the B2DS scenario.

Supply chain and customer interactions

Tightening climate policy is likely to accelerate the switch to low sulphur bunker fuel, leading to shifts in existing supply chains for aviation and shipping. The impact on shipping is already felt globally as the industry prepares for the International Maritime Organization’s 0.5% sulphur cap on fuel content that will take effect in 2020. The shortage of low sulphur fuel makes it expensive and will encourage some to fit sulphur-removing scrubbers to their engines. Furthermore, low sulphur fuels are less stable and contain compounds that can cause greater damages to engines. The related safety risks and maintenance costs will add to the costs for shipping.

The growth of biofuels is expected to cause further evolution in supply chains. Aviation and shipping will be increasingly dependent on the biofuel supply chain as biofuel becomes the majority fuel for both air and marine transport by 2060. However, progress to 2030 is expected to be modest: biofuels are estimated to meet only 10% of aviation energy consumption and less than 5% of shipping energy consumption.

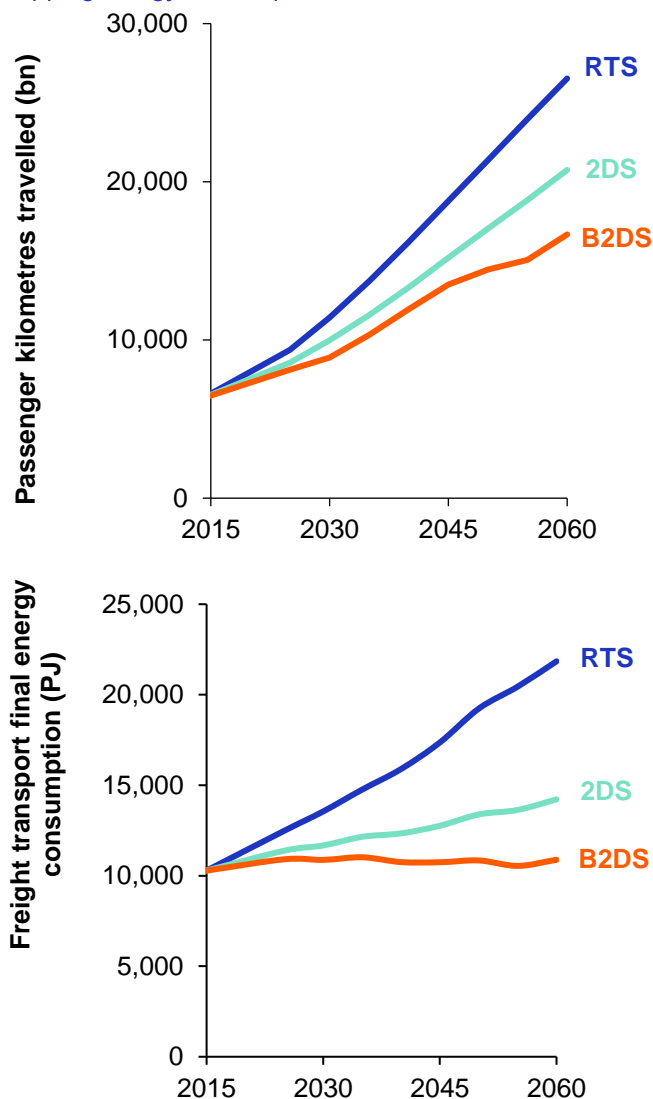
Nonetheless, biofuel demand in the transport sector in the 2DS is 68% higher in 2030 than in the RTS. This will entail a shift in the distribution of fuel supply sources for marine and

air transport because upstream suppliers of biomass are unlikely to be the same as suppliers of oil.

Litigation and liability

The transition towards biofuels exposes aviation and shipping companies to a new set of litigation and compliance risks. Unlike conventional jet fuels, lifecycle emissions of biofuels vary substantially. This uncertainty can be attributed in part to different farming practices – more sustainable agricultural practices result in lower lifecycle emissions. For some advanced biofuels that are under development, it is even possible to achieve negative emissions, meaning that over the lifecycle of the energy crop, carbon sequestration outweighs emissions when used as a biofuel (EESI, 2016). Though one would typically expect regulators to define standards, any ambiguity could lead to compliance risks for companies in the sector.

Figure 5: Passenger kilometres in aviation (top) and freight shipping energy consumption (bottom)



Source: Vivid Economics based on IEA ETP, 2017

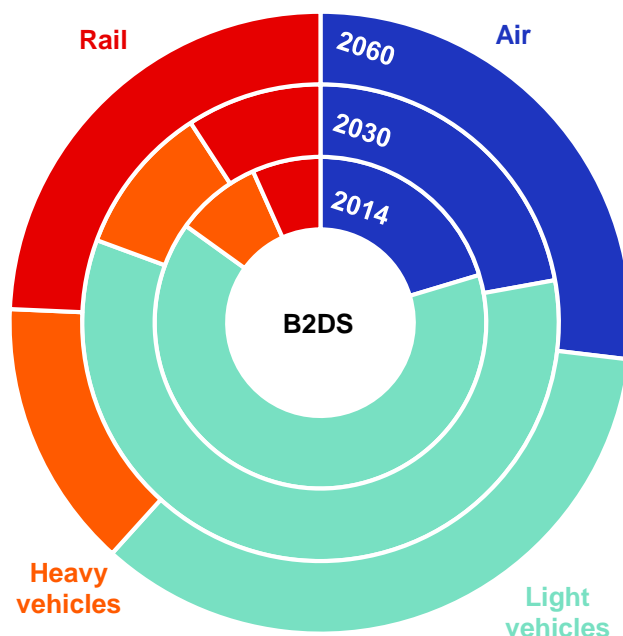
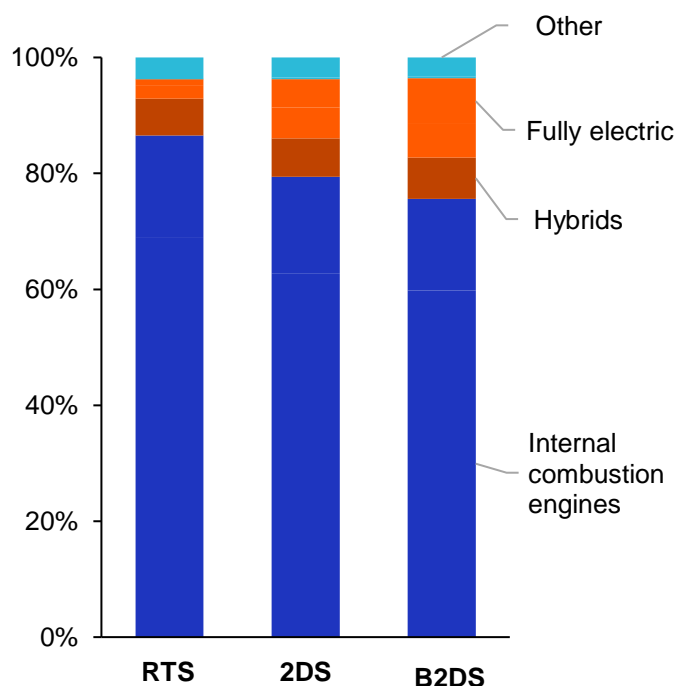
Road transport

Production and competition

There is expected to be a shift towards electric vehicles (EVs) in the road transport sector. The growth rate of EVs is uncertain as it depends on reductions in the operating costs of EVs as well as policy incentives to encourage substitution away from internal combustion engine (ICE) vehicles. In the 2DS, ultra-low or zero-emissions vehicles constitute 20% of global vehicle stock by 2030 (*bottom panel in Figure 7*), replacing a majority of vehicles in cities in OECD economies, though ICEs continue to dominate outside of urban areas and in developing economies. While EVs are expected to become increasingly popular, their growth takes place in the context of a rising global stock of hybrid electric and ICEs up until 2030. Overall, the Net-Zero Toolkit estimates that profits and revenues for the traditional automotive industry will be 16% lower in the 2DS than in the RTS by 2050, while those for EV production will be 71% higher. Nonetheless, as major car manufacturers enter the market for EVs, transitions are not expected to cause a major shift in the make-up of the sector.

Public or shared transport is also expected to increase its share of journeys. Beyond the electrification of vehicles, various modes of ride-sharing, as well as public transport in the form of rail and bus, will contribute to reducing road transport emissions in cities. Under the B2DS, the shift towards public transport reduce urban vehicle kilometres in passenger light duty vehicles by 29% in 2060. This can reduce the vehicle stock in the longer term, weakening the demand for light duty vehicles in particular (*Figure 7*).

Figure 6: Light duty vehicle stock (top) and transport modes by passenger kilometre travelled (bottom)



Source: Vivid Economics based on IEA ETP, 2017

Supply chains and customer interactions

The transition towards EVs will accelerate the development of battery supply chains, charging infrastructure and self-driving technologies, encouraging new business models.

- **Battery supply chains:** Under decarbonisation scenarios, lithium resources and battery supplies will be increasingly relevant to investment decisions by the car sector. Because EV batteries are much larger than batteries for devices like smartphones, EVs are expected to account for 90% of the lithium-ion battery demand by 2025 (*Roskill, 2018*). Currently, known lithium resources are in Argentina, Bolivia, Chile, China and the US, while most lithium ion battery production is located in China, although production in the US and EU are also growing (*Lloyd's, 2018*).
- **Charging infrastructure:** the development of charging infrastructure will demand grid reinforcements to deal with capacity limitations. Meeting a more ambitious climate target will therefore require relatively rapid upgrades to existing infrastructure. In an EV adoption scenario by McKinsey (*Engel, Hensley, Knupfer and Sahdev, 2018*) where the number of EV chargers across the US, EU and China reach 42 million in 2030, the cumulative investment in charging infrastructure is estimated at US\$ 50 billion. The types of charging infrastructure vary across regions, with more domestic charging expected in the US (45%-65%) and more public-based charging in China (80-85%) as measured by the location of energy demand.
- **New business models:** EVs, which are more cost competitive versus ICEs when run at high mileage, can encourage a wider adoption of new business models of shared ownership or 'pay-per-use'. This could be complemented by the digitalisation and self-driving technologies that are enabled by EV usage, which have the further advantage of reducing congestion and emissions. The Institute for Mobility Research's baseline scenario sees fully autonomous vehicles reach a 11-17% share of vehicle stock by 2035 in Germany and the US (*Ifmo, 2016*). This promises new business models for car manufacturers, logistics and mobility services companies ranging from ride hailing to fleet management. For example, the 'pay-per-use' model could accelerate amortisation of capitals costs, lower the stock of vehicles required to meet transport demand, and enable safer travel. Although the development of these technologies is *not* completely driven by the low carbon transition, climate policies can significantly contribute to a favourable landscape for these technologies.

Litigation and liability

EV producers face novel regulatory and compliance risks around the environmental impact of battery production and end-of-life responsibility. In Latin America, water scarcity regulations could constrain the supply of lithium. The salt flats that cover parts of Argentina, Bolivia and Chile hold more than half of the global supply for lithium. However, the substantial water resources required for the evaporation pools in lithium extraction has come into direct competition with local interests and received growing calls for policy intervention. For example, Chile's General Directorate of Water recently imposed a ban on new permits to extract water in the Atacama region. Similarly, pollution from cobalt and nickel mining has received scrutiny. In Philippines, a major nickel supplier, the government ordered the closure of 23 mines in 2017 amidst environmental concerns. Furthermore, there is still significant uncertainty surrounding battery lifecycle emissions, with estimates varying by a factor of ten. Such uncertainty introduces compliance risks to EV manufacturers. Finally, end-of-life responsibilities for EV batteries are not yet well established. Because EV batteries contain materials with economic importance and environmental risk, regulatory policies are likely to introduce uncertainty for EV supply chains.

Power

Production and competition

The ongoing transition away from fossil fuels and towards renewables brings significant changes to the power sector. Regardless of the strength of climate policy, the global final demand of electricity will grow by around half by 2030, driven largely by increasing economic activity in developing countries. However, to meet an ambitious climate target, early retirement of coal-fired plants is unavoidable, affecting around 75% of installed capacity in 2014. Investors in coal-fired plants will therefore face increasing risks of asset stranding and it remains unclear if, or how, policymakers will compensate them. Gas-fired plants are not expected to be stranded before 2030 given the role they play in helping countries to move away from coal. Meanwhile, the growth in the share of renewables in electricity and heat generation is also sensitive to the strength of climate action: the demand for solar and wind energy in the 2DS is estimated to be 40% greater than in the RTS in 2050. However, the greater capital intensity and reduced operational flexibility of renewable assets means investors in capacity in the sector may face greater risks. Overall, the share of renewables used in electricity and heat generation reaches 36% in the 2DS by 2030, compared to 24% in the RTS.

These shifts in the generation mix are expected to be accompanied by changes to storage and network infrastructure. Significant investments on existing grid systems will be required to accommodate the higher share of variable renewable energy (VRE), including interconnectors to provide additional flexibility. Improved storage technologies and active demand response are also expected to be crucial to mitigating peak demand and reducing whole system costs. The provision of this infrastructure hinges on regulatory incentives, for example in the development of

capacity, leaving investors more exposed to policy risks. Overall, estimates suggest that changing market conditions will result in a roughly 15-20% reduction in firm count in the 2DS to 2030.

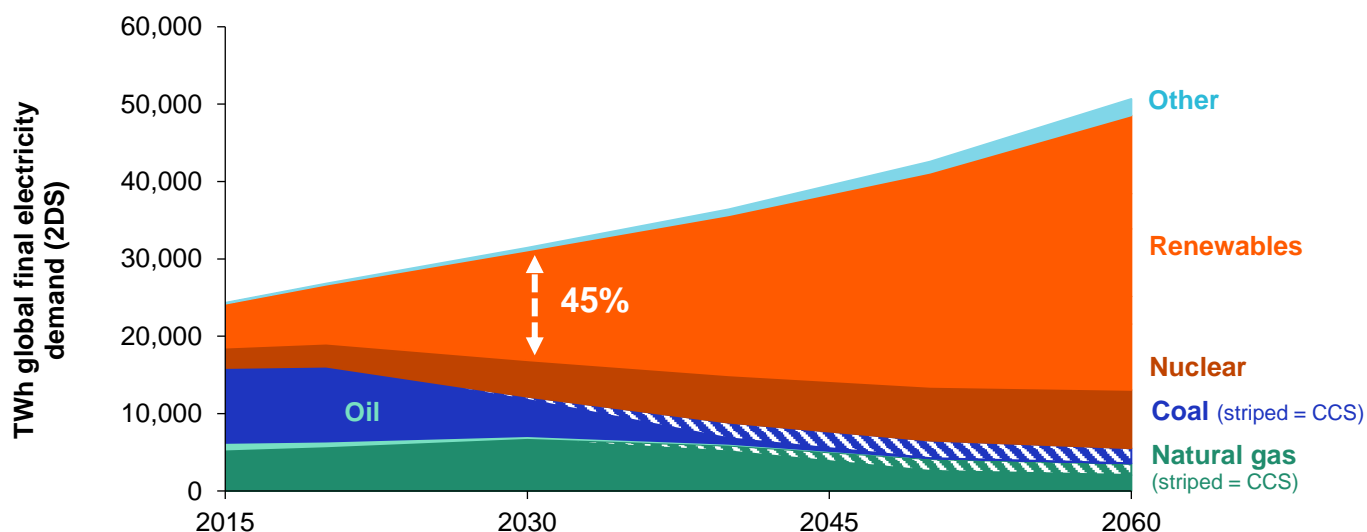
Supply chains and customer interactions

Technological shifts will lead to new types of relationship between suppliers and customers in the power system. On the supply side, the increased share of renewables in the power system will lower the reliance on fossil fuels. The global deployment of CCS technologies will cover 8% of gross electricity generated by coal by 2030 and rapidly accelerate to 99% by 2050 in the 2DS. On the demand side, global deployment of active demand response (e.g. smart meters to shift consumer energy demand to off-peak hours) could increase up to 400% by 2030. New contractual relationships will emerge to support grid stability, for example in the case of electricity 'prosumers' (e.g. technology companies that invest in renewable projects to supply their own energy demand). Similarly, as storage facilities are not necessarily operated by power companies, their role in the system will create a more complicated market environment.

Litigation and liability

Power generators already face lawsuits related to their impact on the climate, while liability for increasing grid instability may lead to new exposure. As Section 3 explains, fossil fuel power generators face significant risks associated with climate change litigation, particularly in the US. Furthermore, greater power system imbalances as electricity grids integrate higher shares of VRE could lead to greater risks of negligence charges for power companies. Finally, as in the case of the fossil fuel sector, bankruptcy and M&A activities induced by tightening climate policies might create litigations in the power sector.

Figure 7: Global final electricity demand by energy source



Source: Vivid Economics based on IEA ETP, 2017

Construction

Production and competition

The impact of low carbon transitions on the size of the construction sector is expected to be small, though it is likely to change inputs and production techniques. The construction sector is in a unique position compared to the sections mentioned earlier – it does not have a significant emissions footprint but is closely related to two important sources of emissions: industry, through embodied carbon in inputs such as steel and cement, and buildings, which emit carbon principally through heating and cooling. Policies on industry and buildings therefore create a shift in the construction methods and materials, rather than affecting the overall size of the sector. This is likely to involve a shift towards low carbon building materials, which is a trend reinforced by certification schemes and voluntary efforts in the construction sector to lower embodied carbon in buildings. Furthermore, growing regulatory requirements on energy efficiency will boost demand for energy efficiency retrofits, a market that is expected to grow 86% globally between 2014 and 2023 (*Navigant Research, 2014*), though the size of this market is just 1% of the global construction sector (*Orbis Research, 2018*).

Supply chains and customer interactions

Although the low carbon transition does not have a material impact on the overall size of the construction sector, it changes the supply chain and customer base for construction. Three shifts are particularly relevant here. The first shift comes from the switch to low carbon building materials, demanding resources that are not traditionally a part of the supply chain. For example, scaling up clinker substitution for producing low carbon cement will depend critically on the availability of other cementitious materials, such as coal fly ash or blast furnace slag. Similar concerns emerge over the supply of recycled materials and timber. The second shift is the growing popularity of modular construction, which involves the use of prefabricated elements. It conserves energy demand by shifting some part of construction activities to centralised, offsite locations. This will result in shorter on-site construction duration and greater dependence on contractors. Finally, shifts in customer demands create both risks and opportunities for construction companies, depending on their specialisation. For example, in heavy construction, the demand for fossil fuel power plants will fall while the demand for clean energy infrastructure will rise.

Litigation and liability

The growing importance of building energy efficiency and climate-related risk disclosure could increase exposure to compliance and liability risks. Regulations on building energy efficiency are expected to tighten, most notably in the EU given its commitment to most new buildings being 'near zero-energy' by 2021 (*Council directive 2010/31/EC*). Engineering and construction companies could become liable for meeting these standards.

Agriculture

Production and competition

Transition impacts on the food-oriented agricultural sector are expected to be marginal, mostly involving the adoption of new production methods. Irrespective of the strength of climate policies, agricultural production is estimated to increase alongside population growth and rising incomes by around 20% by 2030 (OECD/FAO, 2015). Growth in the demand for higher energy foods is estimated to be particularly high due to shifts in the diets of households in low and middle-income countries. For example, meat consumption per capita is projected to grow by 30% by 2030 (GRAIN, 2018). However, these estimates are subject to some uncertainty, as significant policy or preference shifts that might affect dietary consumption, particularly of meat, are possible (Lloyd's of London, 2019b).

More radical changes, such as lab-grown meat and indoor or vertical farming, are not expected to significantly impact the market for proteins before 2030. The consensus projection is that lab-grown meat will take 3-5 years to reach initial market introduction, in the form of premium speciality stores, and another 2-3 years for early adoption by supermarkets (Drovers, 2017).

The regional distribution in the growth of agricultural production will be sensitive to local policies on forestry, biodiversity protection and land-based negative emissions, as well as efforts to reduce trade barriers. As the intensification of agriculture in developing countries increases demand for inputs, low carbon technologies in agriculture are largely focused on increasing crop yields. The development of conservation agriculture and precision agriculture will reduce emissions, but do not fundamentally change the nature of production in the sector.

Supply chains and customer interactions

Under transition scenarios significant demand growth is expected for bioenergy crops, meaning value chains will become increasingly affected by changes in energy markets. Energy crops act as the feedstock to the production of biofuels, which are critical for the decarbonisation of industry, aviation and shipping. In all decarbonisation scenarios, fuel-switching to bioenergy is highlighted as an area for policy action. Under a scenario compatible with a 2°C warming, biofuel production in 2050 will require approximately 500 million hectares of land, or 10% of total agricultural land,

representing a fifteen-fold increase from current levels (IEA Bioenergy, 2018). This can have a significant impact on some food commodities. The competition for land use between the production of food and biofuels began an active area of debate with the rise of food prices in 2007. The actual impact of biofuel supply on food prices remains contested, although most studies have found that biofuels were a contributing factor (Tomei and Hellinwell, 2016). Nonetheless, there is clear evidence of co-movement between soybean, corn and crude oil prices (Zafeiriou et al., 2018). This relationship is driven by the fact that biomass is a partial substitute to crude oil, and that landowners decide between cultivating energy crops and food crops by forming expectations of their relative returns. The growing interlinkages of agriculture and energy markets will therefore make the supply of crops such as sugar cane, soybean and corn fluctuate depending on the demand and supply of energy.

Litigation and liability

Climate policies and public awareness will drive stricter certification on sustainability, introducing liability risks for producers and along the supply chain. To achieve ambitious climate targets, governments in developed countries appear likely to bring the agricultural sector under tighter certification schemes. In the EU, there is a commitment to ensure reliable accounting of emissions and offsetting between 2012 and 2030. In New Zealand, there have been calls to bring agriculture into the emissions trading scheme. Over the longer term, any incentive policies for negative emissions through land-based methods such as biochar and enhanced weathering will require monitoring and reporting standards. Producers will be exposed to greater compliance and liability risks as certification schemes are increasingly utilised. In addition, public awareness of climate issues such as deforestation and environmental degradation will demand greater certification of agricultural products. These could take the form of voluntary schemes such as the Rainforest Alliance Certified™ and Soil Association Certification, or mandatory requirements set out by government procurement standards or food regulators. Food retailers and wholesalers will also place greater pressure on suppliers to comply with sustainability standards by using their market power. With substantial financial and reputational consequences at stake, the liability risks related to the reporting of sustainable agricultural practices will become significant for producers.

3. Insurance implications

This section examines how a low carbon transition and specifically transition and liability risks caused by it can influence key insurance business classes by investigating impacts on insurance demand and supply across the seven priority sectors. Changes in the competitive dynamics, means of production, supply chain and customer base of an industry could (1) change the size and frequency of claims on existing insurance contracts, (2) create opportunities for new types of insurance contracts, and (3) affect the overall demand for insurance.

The section presents insurance implications of the sectoral impacts discussed in the previous section. While it examines the potential direct effects of a low carbon transition on Lloyd's classes of business, it does *not* consider the effects of changing public opinion on the provision of insurance to certain industries over others. For example, Europe's four largest insurers have limited direct insurance cover for coal. Some reinsurers similarly limited their cover for coal. On the investment side, a minimum of 19 major insurers have divested from coal, accounting for 20% of the insurance industry's assets globally in 2018 (Bossard, 2018).

The heatmap in Table 6 summarises the extent of impact on different classes of business. Energy and casualty classes are expected to experience the most significant impacts.

Table 6: Heatmap of the transition impact on major insurance classes by 2030

Class of business	Existing contracts	New contracts	Insurance demand and size
Energy – fossil fuel	Asset stranding and liabilities from production sites will have impact	Introduction of carbon capture storage S and co-firing with biomass	Decline in sectoral size due to product demand contractions
– renewables	Evolving regulations and business models	Risks in power purchase agreements can be better insured	Growth in sectoral size due to move away from fossil fuels
Aviation	Performance of new fuels unclear	Limited change in technology pre-2030	Sectoral slowdown due to modal shift
Marine	Risks from retrofitting ships, new fuels and cargo types	Handling of new fuels and cargo types	Unclear: slowdown but risks emerge with new fuels and cargo
Motor	Internal combustion engine cars driven more in rural areas	New business models involving electric vehicles and pay-per-use	Unclear: growth varies across vehicle types and usage
Construction	Perils change, but impact on claims is unclear	Tighter building standards and energy efficiency requirements	Retrofits and new materials; but offsite construction lowers risks
Credit, financial guarantee and M&A	Profits and business interruption	New sources of revenue risks faced by various businesses	New technical and business environments require insurance
Property	Perils change, but impact on claims is unclear	Changes in supply chains require insurance for properties	Unclear: changes in exposure vary a lot by property type
Product liability and recall	Liabilities from energy efficiency and sustainability standards	New liabilities associated with low carbon products	New technologies and fuels require insurance
Other liability	Increasing pressure from climate change litigations	Provide cover for climate change related settlements and litigation	Magnitude of risks increases expected to result in growth

Notes: For existing contracts and new contracts, the darker the shade of red, the greater the magnitude of changes. These could be positive or negative from the perspective of insurers. For insurance demand and size, upward arrows suggest an increase and downward arrows suggest a decrease.

Source: Lloyd's and Vivid Economics, 2020 Source: Lloyd's and Vivid Economics, 2020

Energy

Energy insurance covers a variety of onshore and offshore property and liability sectors, including construction, exploration, production, refining and distribution. Offshore and onshore property may cover losses from physical damage to offshore and onshore structures as well as the associated business interruption. Liability insurance of offshore and onshore production facilities covers operators and workers at these facilities as well as pollution incidents.

In terms of existing relationships with insureds, contractions in fossil fuel sectors could lead to asset stranding and raise questions around liability for former production sites. Demand for coal falls by 70% by 2050 in the 2DS relative to the RTS and demand for oil and gas exploration and production falls by 65% in the 2DS over the same period according to Net-Zero Toolkit analysis. Stranded coal assets can have far-reaching effects on land stability and water resources and associated liabilities could have very long lifetimes. Insurers in the mining sector have assessed similar risks (*Willis Towers Watson, 2019*), though it is unclear to what extent stranded coal assets will be covered by insurance companies in the context of recent coal divestment. In general, where assets are mothballed or poorly utilised, owners' incentives to maintain them or protect them from hazards such as fire or vandalism are weakened (in extreme cases, they may even be incentivised to allow damages to occur): this would be expected to increase claims under existing contracts.

As the majority of power generation transitions towards renewables, new insurance contracts are likely to be exposed to more capital intensive, remote and variable energy generation than previous contracts. Low carbon energy sources are (on average) more capital intensive, remote and variable than traditional fossil fuel generation. New energy sector contracts will therefore consider significantly different insured risk profiles. For example, property insurance of offshore wind installations will deal with the uncertainties associated with a relatively nascent industry, ranging from the interruption of marine wildlife and shipping paths and cabling incidents to turbine lifespans (such as corrosion). These risks may not be currently be sufficiently well understood to ensure risk and premiums are balanced on new insurance contracts. Solar generation forms one of the five case studies discussed in Section 4 and highlights some of these impacts in greater detail. Nuclear is similarly expected to grow significantly during a low carbon transition. In 2060, expected gross nuclear electricity capacity is expected to be around 50% higher in the B2DS relative to the RTS. In contrast to solar, risks associated with nuclear are better understood and hence not explored in depth in this report.

Strong energy demand is expected to continue throughout a low carbon transition and the composition of the market is likely to change, with more small-scale generation resulting in fewer large utilities. This could also represent an opportunity to cross-sell existing insurance products, such as for solar home generators and storage. If insurers can adjust to the changes in risk profiles of energy producers, the size of the overall market should not change significantly as a result of a low carbon transition.

Aviation

Aviation insurance is geared specifically to the risks involved in aviation and can cover aircraft hull and liability, general aviation and products liability, aviation cargo and aircraft crew personal accidents.

The implementation of energy efficiency measures and the partial shift to biofuels could affect risks associated with existing aviation hull and liability insurance contracts. More energy-efficient planes may be associated with unforeseen risks if inadequately tested prior to release. For example, planes designed to be more fuel efficient can have larger engines that affect their aerodynamics and handling in the air, potentially resulting in unanticipated changes to risk profiles. Similarly, use of biofuels in aviation could alter the risk profile of planes. To illustrate, if the alternative fuel has different freezing points at high altitudes or other attributes different from traditional fuels, this could affect the risk of accidents. These changes in risk would affect underwriters of both hull and cargo insurance.

Due to the lack of emissions abatement options, there will be some demand reductions in the aviation sector relative to the reference technology pathway, which could affect the size of the insurance market. This could reduce demand for insurance products and lead to market consolidation. Demand for air transportation is likely to shift partially to high speed rail.

Marine

Marine insurance covers ship hull and liability, marine cargo, insurance for charterers and mortgagees and crew personal accidents.

Energy efficiency measures and the increasing use of biofuels could affect risk profiles of existing vessels and thereby affect ongoing contractual relationships with insurers. Retrofitting existing ships with more energy efficient equipment could have unforeseen consequences for hull and cargo insurance if these affect the risk of accidents due to insufficient prior research or crew training. For example, energy efficient practices like slow steaming could *reduce* the risk of accidents. At the same time, switching to increasing use of biofuels could affect risk profiles due to potential differences in costs of sea spillage, flammability and other fuel-related hazards.

On a separate note, there is some potential for new products from energy efficiency improvements, such as weather derivatives where wind power is used to reduce fuel consumption.

Shifts in supply chains and shift in materials shipped and routes travelled could result in new cargo insurance contracts that have to consider different risk profiles compared to today. In the long term, while marine transport of fossil fuels – which currently accounts for a third of marine trade – falls significantly due to demand destruction, it could be replaced by marine trade of battery minerals, lithium and other low carbon technology inputs like biofuels. The largest global lithium reserves are in South America, Australia and China (*United States Geological Survey, 2017*). It is therefore likely that global manufacturers of lithium batteries will have to rely on complex international, seaborne supply chains. The different handling requirements of these new technologies in transit compared to traditional fossil fuels, their susceptibility to core hazards like fire and the environmental repercussions associated with their sinking will all have to be considered and reflected in new cargo insurance contracts. As an example, lithium batteries have been classified as dangerous goods in transport due to their corrosive, flammable, toxic and explosive properties, which under improper handling can result in fires, explosions and release of harmful chemicals into the environment (*Huo et al., 2017*).

While some reductions in marine transport activity are expected due to the decline of fossil fuels, there is potential for new cargo, technologies and routes which should maintain a different, insurance market, but similar in size.

Motor

Motor insurance covers losses arising from physical damages to a motor vehicle and the legal liability for third party damages of the vehicle owner or driver. Insurance can be taken out on individual vehicles, fleets, or vehicles in stock or repair.

Large scale deployment of electric vehicles (EV) in the automobile sector affects a multitude of risks underlying existing insurance contracts, including accident liability, theft and breakdown. On the one hand, this is due to the difference in direct risks to EVs compared to internal combustion engine (ICE); on the other hand, environmental factors will play an important role in determining relative exposure. In terms of direct risks, EVs require less frequent maintenance and break down less often, however, repairs require more technical skills than required by ICE repairs, and thus tend to be more expensive. Environmental factors could include the shift of ICEs to predominantly rural transportation, while EVs become the majority share of urban vehicles. This reduces the exposure of ICEs to collision and theft risk but may increase other risks depending on the rural area, as well as repair costs for more remote locations.

A transition to EVs could also be coupled with pay-per-use transport models and driverless vehicles, which will create opportunities for new types of insurance contracts in the sector. Interactions between automobile manufacturers and their customers are expected to undergo significant changes. These include an increase in pay-per-use transport, which may lead to demand for more customisable, short term insurance products based on a pay-as-you-drive model, or potentially insurance in bulk provided to rental companies rather than individual drivers. Similarly, increased use of EVs could happen in parallel to a transition towards driverless vehicles, which may lead to reduced accidents from improved safety and could present opportunities for professional liability insurance for manufacturers. These shifts in consumer behaviour would be expected primarily in urban areas in developed countries, where the share of EVs is projected to grow the fastest under the 2DS.

The overall motor insurance market size is unlikely to be significantly affected by the transition. Demand for road transport is not expected to change significantly under transition scenarios, but some of this demand, particularly in urban areas, will shift toward public and alternative transportation.

Construction

Construction insurance covers risk of damage by perils to contract works, associated property, machinery and plants. A prominent type of construction insurance is Contractors' All Risk (CAR) cover, which covers all phases of construction for all project types, including buildings, civil engineering and general construction work. This flexible cover provides protection against any damage that occurs within the construction process, be it to property or third parties.

Susceptibility of construction assets and workers to key perils could change as the sector adopts low carbon construction materials such as timber, though such substitution is not expected to be widespread. Considering the decarbonisation trajectory of industry under a low carbon transition, some lower-carbon construction materials are likely to become more widely employed, which could affect the vulnerability of construction to a range of perils. For example, substituting timber for cement in construction could increase fire risk. However, the scope for this is likely to be small provided building regulations advance and the industry develops more reliable materials, such as cross laminated timber.

Separately, the trend of moving away from onsite construction towards offsite construction is likely to reduce the overall level of risks in construction because more processes will be performed under highly controlled environments. At the same time, the value of pre-fabricated building components transported to construction sites will increase affecting cargo insurance too. Overall, the impact on claims ratio for construction insurance is unclear.

Demand for construction insurance is expected to remain relatively stable during a low carbon transition as the size of the construction sector is not expected to change materially. While energy efficiency retrofits are expected to grow by 2023 (*Navigant Research, 2014*), the size of this market is currently just 1% of the global construction sector (*Orbis Research, 2018*).

Property

Property insurance covers against losses due to physical damage to property from most perils, including fire, theft and some weather damages. Insurance of property in the aviation and marine, energy, motor and construction segments has been covered as part of the preceding sections and is therefore not included here. Instead, this section focuses on the impacts on property insurance from shifts observed in the heavy industry sector.

Overall, the size of the property insurance market is not expected to be significantly impacted by transition risks but will be greatly impacted by climate change physical risks.

Credit, financial guarantee and M&A

Credit, financial guarantee and M&A cover a broad range of areas, ranging from financial guarantee, contract frustration and trade credit. Financial guarantee insurance compensates the insured in the event of financial failure, lack of profits or fluctuations in prices, interest rates, exchange rates and property values. Contract frustration protects insureds against losses associated with contracts and the financing thereof. Trade credit insurance covers failure of debtors to pay their debts. Insurance against business interruptions covers the financial losses associated with an event impeding the operations of a business.

Existing contracts may require revision in sectors that face declines under low carbon transition. Instances of financial failure and price fluctuations are expected to increase in frequency and duration during a low carbon transition in many high emissions sectors. For example, the Net-Zero Toolkit estimates drops in coal revenues and profits of 70-80% over the period to 2050 under the two decarbonisation scenarios compared to the RTS, with impacts on profits of similar magnitude experienced in the oil and gas exploration and production sectors. As a result, underwriters could be exposed to significant risks in these sectors while the demand for and volume of contracts could increase as a result of increased exposure.

Some low carbon technologies, such as renewables and biofuel production, may present opportunities for insuring against revenue risk. Renewable power generation relies critically on weather elements such as temperature and solar radiation. Managing the uncertainty around weather fluctuations could play an increasingly important role as the share of renewables in electricity generation grows over time

to 45% of final energy demand in 2030 under the 2DS. Demand for parametric insurance or related financial loss insurance products could also come from producers or users of biofuels, which will be subject to seasonal fluctuation (*Lloyd's of London, 2019c; d*). At the same time, demand for products like the cover for carbon credits introduced by Tokio Marine Kiln and Parhelion in 2011 (*Davies, 2011*), is expected to grow during a low carbon transition.

While financial loss insurance demand could grow overall, whether it can be met by supply is a question dependent on insurers' ability to understand and quantify the above risks. There is considerable uncertainty associated with future global policy action. As a result, more companies across the economy may be interested in taking out financial loss covers, resulting in an increase in demand. Whether insurers will be able to provide this insurance will depend on their ability to quantify the potential risks and opportunities involved.

Product liability and recall

This section focuses on product liability insurance often taken out to cover against liability for damages to third parties caused by a company's products.

Products from high carbon producers could become subject to increasing scrutiny during a low carbon transition and be linked to physical climate change. Cases could arise in the industry and fossil fuel sectors if their products are found to lead to more environmental harm than previously anticipated as more attention is paid to product sustainability. Further discussion of precedents and outlook for related litigation cases is included in the following section on litigation and liability.

Novel, low carbon products with uncertain risk profiles may present challenges to underwriters of new product insurance in sectors affected by the low carbon transition. Due to the relative novelty of the underlying technologies and the uncertainty in client risk profiles, insurers may find difficult to price these risks. For example, it is unclear who should bear the responsibility for battery end-of-life treatment. Similarly, lifecycle emissions of biofuels vary widely by feedstock, and many different estimates exist even for the same feedstocks. In renewable energy equipment manufacturing, though manufacturers may want to purchase warranty and product insurance, the long-term risk profiles in unknown terrain are often highly uncertain, as demonstrated in a later case study on solar power generation. These risks may also impact public liability insurance for sites where these products are in use.

The low carbon transition will result in growing product insurance demand from industries such as battery, EV and renewable equipment manufacturers, as well as biofuel producers.

Other liability

Other liability lines include public liability, products liability and recall, Directors and Officers (D&O) liability, Errors and Omissions (E&O) and Professional Indemnity (PI) insurance. Public liability insurance covers the insured's legal liabilities to third parties for damages to person or property arising from the insured's business activities. D&O insurance covers the personal liabilities of the company's directors and officers resulting from their (alleged or actual) acts while acting in their capacity. E&O and PI insurance covers the third-party liabilities arising from errors, omissions or negligence committed over the course of professionals' and service providers' performance of their duties.

This section covers those segments of the casualty business class related to the potential impacts of a low carbon transition on litigation cases. The most significant segments of the casualty market are general liability and professional liability. The largest markets for the casualty segment are the US, the UK, Canada and Australia (*Setzer and Byrnes, 2019*). There has been an increase in the number of climate related litigation cases over recent years, with 1,300 global cases listed across various databases to date (*Nachmany, Fankhauser, Setzer and Averchenkova, 2018*). Across the five categories of climate change related litigation outlined in Figure 2, three have already been observed in court, while the other two are expected to materialise over the course of a low carbon transition.

Across the five types of litigation cases this report examines, the following trends are expected to emerge during a low carbon transition:

1. **Physical damages.** These encompass cases seeking compensation payments for physical climate change damages from major carbon emitters, their financiers or insurers (*Clyde & Co, 2018*). Examples include the lawsuits brought by the cities of San Francisco and Oakland against major fossil fuel producers, including BP, Chevron and Royal Dutch Shell for compensation of the costs of dealing with climate change. Some of these cases brought against the oil industry focus upon an allegation that the oil industry has, for the last 50 years, sold and marketed petroleum, despite knowing about the harmful effects of burning carbon-based products. By characterising petroleum as a 'defective product', these lawsuits aim to hold distributors of fossil fuels liable for the defective products that they commercialise and for failure to warn of the risks associated with their use. Rather than alleging fault (such as negligence or tortious intent by the defendant), these cases claim strict liability for 'design defects,' - i.e. flaws or errors in a product's design that render it inherently dangerous. Similar to the arguments used in the tobacco litigation, in these cases fossil fuels (such as crude oil, coal or natural gas) are the product and the defect is the impact of the emissions and the known safety and injury risks associated with them.

Most of these cases are still ongoing and are concentrated in the US. Looking at the precedent of the tobacco litigation, cases based on physical damages have resulted in significant settlements, as during the Tobacco Master Settlement Agreement in 1998 in the US. This settlement resulted in a series of initial, annual and strategic payments from tobacco companies to the settling states of approximately \$206 billion over 25 years, now limited from 2018 to US\$9 billion per year in perpetuity (*Public Health Law Center, 2018*). The scope of litigation risk from climate-related physical damage cases will depend on whether climate science advances toward reliable attribution calculations and causation assessments. With a growing evidence base and public awareness of climate science, cases attributing physical damages to individual companies could rise. These cases could affect the risks associated with and demand for D&O and PI insurance. The split of losses between classes or steepness of trend could be higher or lower depending on specifics of any real event and the decisions of the courts.

In addition to tort claims, there could also be liability resulting from insufficient consideration of physical risks resulting from climate change in the context of significant investments. This would be the case, for example, where companies are sued for investing in a hotel on a beach that will be affected by sea level rise or a factory in an area exposed to increased likelihood of flood.

2. **Climate-related disclosure.** With the introduction of many new climate-related reporting standards and regulations including the TCFD recommendations and France's Article 173, companies face increasing pressure to disclose their climate-related risks and opportunities. Litigation against financial services firms can be brought as a result of failure to disclose climate-related financial risks, as well as a result of the quality of the disclosed information. If companies are perceived to have under disclosed on their risks from climate change, including their own impacts on the climate, investors may seek compensation for withheld information. In October 2018, People of the State of New York filed a case against Exxon Mobile Corp. claiming the company behaved fraudulently by downplaying the risks of climate change to its business to shareholders, which has yet to be resolved. A few months prior, ClientEarth reported Admiral, Lancashire Holdings Limited and Phoenix Group Holdings to the Financial Conduct Authority over non-disclosure of climate-related risks and opportunities in their annual reports. During a low carbon transition, regulation on climate-related disclosure is expected to become more stringent in line with governments' policy. It is expected that disclosure cases could grow in number and significance over time, which will affect the risk landscape around D&O and PI insurance.

There is precedent for large-scale disclosure litigation cases, most notably the US\$7.2 billion settlement awarded to Enron shareholders following the account fraud committed prior to the company's bankruptcy. This settlement was paid by major banks that had been in business with Enron, including JP Morgan, Chase and Citigroup, and is the largest securities class action settlement reached in the US to date (*Hays, 2008*).

- 3. Regulation and permits.** These cases seek to uphold or establish environmental regulation against individual projects that could have significant impact on the local environment or global climate. Cases filed against the TransCanada Keystone XL pipeline by the Indigenous Environmental Network (amongst others) represent prominent examples of this type of litigation. Most recently, in November 2018, a federal judge in Montana ruled that the Trump administration failed to conduct the necessary environmental reviews of the project before approving it in 2017 (*Harris, 2018*). The pipeline would transport heavy crude from Alberta to Nebraska. Over the course of a low carbon transition, the incidence of these cases is expected to increase and will primarily affect the risks associated with the underwriting of public liability insurance. As global policymakers tighten climate policy stringency during a low carbon transition, they are expected to be held to a higher standard by local communities and other organisations over contracts signed with corporations that could affect climate outcomes.

- 4. Advisory roles and M&A.** The low carbon transition could result in significant M&A activity in contracting sectors, as well as IPOs in expanding green sectors. Given the increased M&A activity, there will also be more demand for financial services companies' advisory services. Therefore, increased number of lawsuits related to M&A activity are expected, including cases against directors and officers or inadequate advice by third parties resulting in financial loss for shareholders. In the US, 73% of M&A deals for publicly traded companies valued over US\$100 million resulted in shareholder lawsuits in 2017 and 43% of cases were resolved prior to the deal closing (*Sinha, 2018*). These lawsuits could therefore become a significant component of low carbon transition related M&A activity and will primarily be covered by D&O and PI insurance. Further cases against advisors may focus on property design professionals, who could be sued for negligence when not disclosing or misleading on the risks associated with climate change impacts to investors.
- 5. Intellectual property.** The number of green energy (defined as solar power, wind energy, biofuels, hydropower, geothermal energy and waste-generated energy) patents filed globally doubled over the period 2013-17 (*Geary, 2018*). Over the course of a low carbon transition, significant innovation across all low carbon technologies is expected. In response, firms in markets with high associated growth potential will try to ensure they receive a proportion of the benefits of this growth. These developments could lead to IP disputes in court, for example over corporate licensing or public disclosure of green IP. The most relevant existing insurance product to these cases will be intellectual property legal expense insurance.

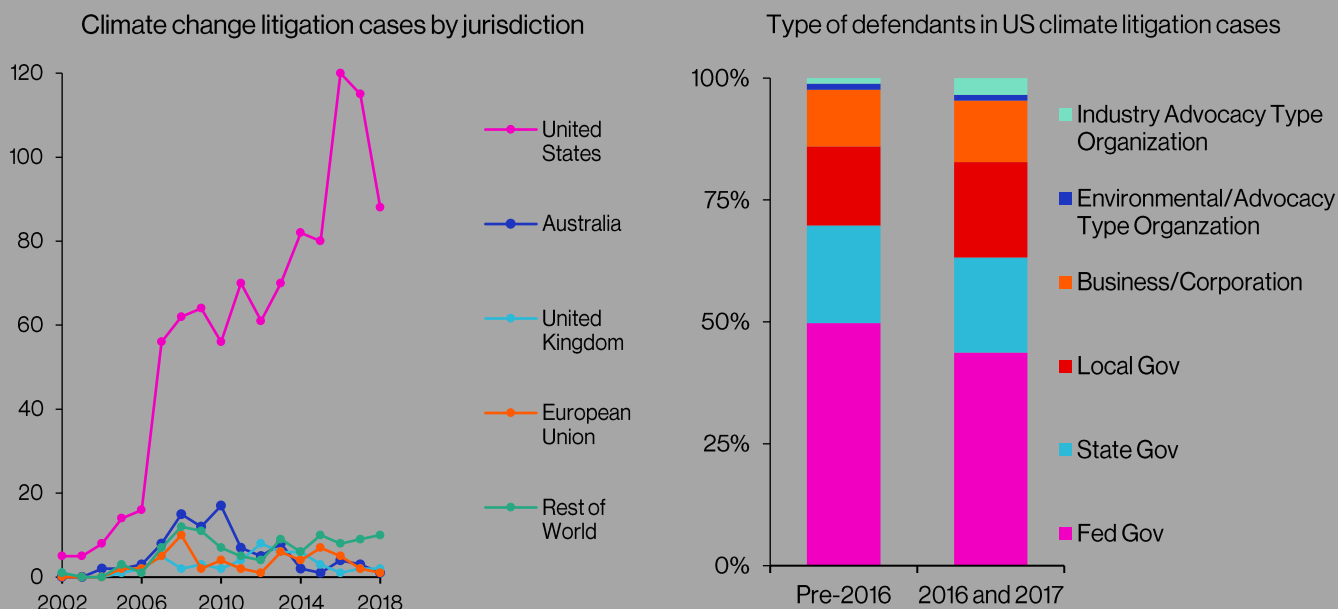


Global trends in climate litigations

As of May 2019, over 1,300 climate change litigation cases have been recorded across 28 countries in addition to several regional and international courts. Of this total, over 75% of cases have been filed in the US. Outside of the US, jurisdictions that have seen higher climate change litigation activities include Australia, UK, Canada and New Zealand.

In the US, the most common cases are brought by NGOs against local or national governments regarding regulatory and policy decisions. However, cases against business corporations have risen in recent years.

Figure 8: Climate change litigation by jurisdiction and types of defendants



Source: Grantham Research Institute on Climate Change and the Environment (2019), Climate Case Chart (2019), Right: McCormick et al. (2018)

4. Geographic landscape

This section highlights key region-specific transition impacts and investigates what role insurance can play in alleviating these. This synthesis draws on the preceding analysis, including results produced by the Net Zero Toolkit and in-depth sectoral evidence base. Such geographical variations broadly depend on policy developments, macroeconomic outlooks, natural resource endowments and their role in supply chains.

Europe

Climate legislation is proceeding rapidly within the EU, although national policies will determine the extent of transition impact in different countries. In June 2019, final EU legislation on the Clean Energy Package was completed. The Clean Energy Package consists of eight legislative acts, spanning buildings, renewables, energy efficiency, electricity market design and national energy and climate plans. Member states now have 1-2 years to transpose the complete package of eight legislative acts into national law. This is expected to accelerate the policy-driven transition impact across all sectors, but particularly in the energy and buildings sectors. In December 2019 the European Commission published The European Green Deal a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. Nevertheless, industry lobbying and various political considerations will continue to influence the direction and speed at which national policies develop, as exemplified by Poland and Germany's reliance on coal and France's suspended fuel tax increase. The opportunities and challenges for insurers will vary accordingly depending on these national policy developments.

North America

Transition impact in North America will vary significantly depending on state and provincial legislations. In the US, 22 states have adopted specific greenhouse gas emissions targets (c2es, 2019). In particular, California is notable for its commitment to become carbon neutral by 2045. This has come with policy actions across several key areas, including incentives for distributed, self-generated renewable energy, funding for EV infrastructure, and support for the development of microgrids. The far-reaching impact of state legislation is expected to grow in significance amidst an uncertain policy outlook on a federal level. Nevertheless, the potential impact of federal commitments should not be underestimated either. The US government has been relatively supportive of low carbon innovations. For example, the section 45Q tax credit for CCS projects has been enhanced in 2018 in response to widespread opinion that previous tax credits were too low to spur greater adoption.

Climate-related litigation and liability risks are strongest in the US. Under the climate change litigation database provided by the Sabin Center for Climate Change Law, there are over 1000 such cases in the US to date compared to 300 in the rest of the world. Although a large part of this difference reflects the generally higher reliance placed on litigation in the US compared to other regions, the pervasiveness of activist investors is also a key driver for this trend. Furthermore, as compared to Europe, physical infrastructure in the US is more prone to weather-related risks such as hurricanes and wildfires. The fact that some US areas are more vulnerable to natural disasters is well known to insurers who price such weather-related risks. The low carbon transition can amplify liability risks for companies that do not adequately mitigate and/or adapt to climate change.

Latin America

Water scarcity regulations in Argentina, Bolivia and Chile could constrain the supply of lithium, a key input to batteries. The salt flats between these three countries hold roughly half of the global supply for lithium. However, the substantial water resources required for the evaporation pools in lithium extraction has come into direct competition with local interests and received calls for policy intervention. For example, Chile's General Directorate of Water recently imposed a ban on new permits to extract water in the Atacama region. Such regulations therefore pose a significant risk to companies throughout the battery supply chain, creating a larger appetite for financial loss insurance against business interruptions.

Exporters in Colombia and Brazil can expect sharp shifts in the level and composition of demand for coal and biofuels. Colombia is Latin America's largest exporter of coal, with over half of its coal exports heading to the US. As global demand for coal declines, albeit at a slower pace in the US, coal mines within the country would face increasing financial pressure. Meanwhile, Brazil is the world's second largest exporter of biofuels after the US. Biofuel companies are expected to benefit from the demand for low carbon transportation fuels. In this process, significant liability risks can emerge due to concerns over food security, water scarcity and habitat destruction. Companies engaged with this supply chain could demand greater insurance.

Asia Pacific

Developing economies in Asia Pacific will continue to be the largest market for renewable energy. Currently, China already has the largest installed capacity in solar and wind generation, at 175 GW and 184 GW respectively in 2018, or roughly 30% of the global installed capacity in both technologies. Although China will still dominate the market for both solar and wind in the next decade, growth in India and ASEAN countries is expected to catch up gradually over time. The growth of this market comes with both opportunities and challenges for insurers as described in previous sections. Business models for renewables in developing economies can be different from those in American and Europe: for example, off-grid solar is a much more popular option for remote areas that lack a grid infrastructure. The insurance required for off-grid solar could be a significant opportunity for insurers who can accurately price the variety of risks faced by residents and businesses.

Australasia

Despite often being considered together, Australia and New Zealand have taken remarkably divergent paths on climate policy. While New Zealand has set a target of Net Zero emissions by 2050, Australia, one of the world's largest per capita green house gas emitters, has not improved on its climate policy since 2017 and is unlikely to meet its 2030 target set under the Paris Agreement (*UN Environment, 2018*). Nevertheless, both countries have seen a significant number of climate related litigation cases, which may increase demand for liability insurance products. In terms of sectors, Australia is the world's largest coal exporter, with considerable assets and reserves at risk of stranding under a low carbon transition. At the same time, Australia is one of the world's reserves of lithium, demand for which is expected to grow significantly in line with battery technology.

Middle East and Africa

Many economies in the Middle East and Africa are reliant on exporting minerals and oil and will therefore experience significant transition impact despite the lack of stringent climate policies. The abundance of natural resources in the region mean that many countries are closely tied to supply chains that are being transformed by the low carbon transition. Insurance can support companies adapt to the new operating environment.

- **Oil.** The slowdown in the growth of oil demand is encouraging major oil producers in the region, including Saudi Arabia, Iran, Iraq, UAE, and Kuwait to diversify their economies. Political risks in the region will increase as this process creates instability (*Lloyd's of London, 2009*).
- **Cobalt.** As a key component in batteries, global demand for cobalt is expected to increase at 8% a year until 2023. Currently, the Democratic Republic of Congo (DRC) supplies more than half of the world's cobalt production (*Market Research Future, 2019*). Political and supply chain risks are therefore a significant concern for downstream businesses. Leading downstream companies have started internally re-classifying cobalt as a 'conflict mineral' and treat it with the same scrutiny as tin, tantalum, tungsten and gold, which are subject to conflict minerals legislation in the United States and the EU (*RCS Global, 2017*).

As in Asia, significant growth in the deployment of renewables is expected. The expansion of solar is expected to be particularly pronounced in Africa, where offtake and regulatory risks are more pronounced and off-grid solar is expected to account for a relatively large share of investment.

5. Conclusions

The low carbon transition up to 2030 will entail far-reaching change across a host of key global sectors. Economy-wide modelling carried out for this study shows that decarbonisation on the scale required to limit expected global temperature rises to below 2°C leads to very significant shifts in economic activity between sectors and regions, even as compared to a baseline in which existing commitments are followed through. Decarbonisation is driven by regulatory requirements and policy incentives and sustained through a rebalancing of economic activity and the more widespread deployment of low emissions technologies.

Impacts on insurance of the transition can be understood through three 'impact channels', consistent with the framing developed by the Taskforce on Climate-related Financial Disclosure (TCFD). These channels cover the effect of transition on activities within sectors ('production and competition'), relationships between sectors ('supply chains and customer interactions'), and interactions between sectors and the legal system ('litigation and liability'). Changes in risk across these three impact channels, which cover comprehensively the categories of opportunity and challenge identified by the TCFD, can then be mapped to implications for insurance business lines.

Insurance-relevant impacts of low carbon transitions are expected to be particularly pronounced in seven sectoral areas across ten lines of business, with implications for the demand for and risk profiles of existing insurance contracts as well as the potential for new business.

Detailed case studies shed light on some of the key opportunities and challenges that the transition presents underwriters. Opportunities encompass roles for insurance markets in enabling investment by transferring technology and regulatory risk from project developers, and in promoting efficient risk management by setting appropriate contractual standards. Challenges stem from rapid shifts in risk profiles and structural changes that traverse business lines, all of which require proactive management.

More broadly, the insurance market can play a role in their companies' strategic response to climate change by:

- Participating in climate-related collaborative initiatives such as ClimateWise and starting to use the TCFD framework to develop climate decisions.
- Raising awareness and engaging senior decision makers on transition risks and opportunities in underwriting and insurance operations as well as pursuing connected thinking and responses to climate related issues across departments and portfolios.
- Exploring the use of climate-related data and forward-looking climate scenarios for risk and pricing modelling to show under a range of scenarios how decarbonisation can affect premia for specific insurance products.
- Including climate into investment strategies and potentially expanding the scale of their low carbon investments.

This strategic review provides a basis for further analytical work as data, tools, and methodologies will evolve over time. Having identified key impact channels and priority opportunities and risks, quantitative analysis can project forward the effect of decarbonisation on the size of key insurance lines and develop more focused strategies for insurers within market segments. As countries such as the United Kingdom, Sweden and Norway pledge to achieve net-zero emissions targets by 2050 or sooner, stronger emphasis will be put on clearer paths to achieve this goal. Sectors will decarbonise faster, creating opportunities for insurers to enable companies to do so in a safer way.

References

Bartlett, J.S., Naranjo, M. and Plungis, J. 2017. Guide to the Volkswagen Emissions Recall [online]. Consumer Reports. Available at: <https://www.consumerreports.org/cro/cars/guide-to-the-volkswagen-dieselgate-emissions-recall->

Bosshard, P. 2018. Insuring Coal No More: The 2018 Scorecard on Insurance, Coal and Climate Change UnfriendlyCoal, (December).

c2es. 2019. State Climate Policy Maps

Carbon Brief. 2018. The impacts of climate change at 1.5C, 2C and beyond [online]. Available at: https://interactive.carbonbrief.org/impacts-climate-change-one-point-five-degrees-two-degrees/?utm_source=web&utm_campaign=Redirect#

Carbon Tracker Initiative. 2018. Powering down coal: Navigating the economic and financial risks in the last years of coal power (November).

Climate Case Chart. 2019. U.S. Climate Change Litigation [online] Available at: <http://climatecasechart.com/us-climate-change-litigation/>

Clyde & Co. 2018. Climate change: A burning issue for businesses and boardrooms.

Council directive 2010/31/EC. [online] Available at: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:en:PDF>

Davies, P.J. 2011. Carbon emissions insurance to be launched [online]. FT. Available at: <https://www.ft.com/content/0cefe376-691d-11e0-9040-00144feab49a>

Deutsche Asset Management. and Four Twenty Seven. 2017. Measuring physical climate risk in equity portfolios Deutsche Asset Management Global Research Institute, [online] (November), p.32. Available at: http://427mt.com/wp-content/uploads/2017/11/Physical_Climate_Risk_FourTwentySeven_November2017.pdf

Drax. 2018. Drax closer to coal-free future with fourth biomass unit conversion [online]. Available at: https://www.drax.com/press_release/drax-closer-coal-free-future-fourth-biomass-unit-conversion/

Drovers. 2017. Synthetic Meat Unlikely to Impact Protein Market in Near Term [online]. Available at: <https://www.drovers.com/article/synthetic-meat-unlikely-impact-protein-market-near-term>

EESI. 2016. Biofuels versus Gasoline: The Emissions Gap Is Widening [online]. Available at: <https://www.eesi.org/articles/view/biofuels-versus-gasoline-the-emissions-gap-is-widening>

Engel, H., Hensley, R., Knupfer, S. and Sahdev, S. 2018. Charging ahead: Electric-vehicle infrastructure demand [online]. McKinsey & Company: Automotive & Assembly. Available at: <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand>

European Commission. 2019. Biomass [online]. Available at: <https://ec.europa.eu/energy/en/topics/renewable-energy/biomass>

Eurostat. 2018. Shedding light on energy in the EU: A guided tour of energy statistics [online]. Available at:

<https://ec.europa.eu/eurostat/cache/infographs/energy/index.html>

Feuvre, P. Le. 2019. Transport biofuels [online]. IEA Tracking Clean Energy Progress Transport Biofuels. Available at: <https://www.iea.org/tcep/transport/biofuels/>

Geary, J. 2018. Green Energy Patents Jump 43% in a Year [online]. EMW Law. Available at: <https://www.emwllp.com/latest/green-energy-patents/>

Global CCS Institute. 2018. Global Carbon Capture and Storage intelligence database: Facilities [online]. Available at: <https://co2re.co/FacilityData>

GRAIN. 2018. Emissions impossible: How big meat and dairy are heating up the planet. [online]. Available at: https://www.grain.org/article/entries/5976-emissions-impossible-how-big-meat-and-dairy-are-heating-up-the-planet#_edn2

Grant, A. 2018. CCS: important, but not a 'get out of jail free' card [online]. Carbon Tracker Blogs. Available at: <https://www.carbontracker.org/ccs-important-but-not-a-get-out-of-jail-free-card/>

Grantham Research Institute on Climate Change and the Environment. 2019. Climate Change Laws of the World [online]. LSE. Available at: <http://www.lse.ac.uk/GranthamInstitute/climate-change-laws-of-the-world/>

Harris, A.M. 2018. Keystone XL Pipeline Project Blocked by Judge in Montana [online]. Bloomberg. Available at: <https://www.bloomberg.com/news/articles/2018-11-09/keystone-xl-pipeline-project-blocked-by-judge-in-montana>

Hays, K. 2008. Enron settlement: \$72 billion to shareholders [online]. Houston Chronicle. Available at: <https://www.chron.com/business/enron/article/Enron-settlement-7-2-billion-to-shareholders-1643123.php>

Huo, H., Xing, Y., Pecht, M., Züger, B.J., Khare, N. and Vezzini, A. 2017. Safety requirements for transportation of lithium batteries. *Energies*,

IEA. 2017. Energy Technology Perspectives 2017: Catalysing Energy Technology Transformations Together Secure Sustainable [online] Available at: www.iea.org/etp2017

IEA. 2019. Energy Efficiency: Buildings

IEA Bioenergy. 2018. Annual Report 2017.

Ifmo. 2016. Autonomous Driving: The Impact of Vehicle Automation on Mobility Behaviour

IPCC. 2013. Climate Change, 2013: The Physical Science Basis, IPCC Fifth Assessment Report.

IPCC. 2018. Global Warming of 15 °C.

Ireland, R. 2018. International Trade in Wood Pellets: Current Trends and Future Prospects U.S. International Trade Commission, (September 2018), pp.2017–2018.

IRENA. 2018. Renewable Power Generation Costs in 2018.

Irlam, L. 2017. Global Costs of Carbon Capture and Storage 2017 Update Global CCS Institute, (June).

John, G.M. 2019. New PPAs – de-risk solutions.

Lazard. 2018. Lazard's Levelized Cost of Energy Analysis—Version 120.

Lloyd's. 2018. Unearthing opportunity: Risk considerations for a new era of mining.

Lloyd's of London. 2009. Climate change and security.

Lloyd's of London. 2014. Catastrophe Modelling and Climate Change.

Lloyd's of London. 2019a. Annual Report 2018: Sharing risk to create a braver world. Available at: <https://www.lloyds.com/investor-relations/financial-performance/financial-results/annual-report-2018>

- Lloyd's of London. 2019b. Evolving risks in global food supply.
- Lloyd's of London. 2019c. Triggering Innovation – How smart contracts bring insurance to life.
- Lloyd's of London. 2019d. Triggering Innovation – Parametric insurance.
- Lloyd's Register. and UMAS. 2017. Zero-Emission Vessels 2030. How do we get there? *Low Carbon Pathways 2050 series*.
- Market Research Future. 2019. Cobalt Market.
- MarketsandMarkets. 2018. Modular Construction Market.
- McCormick, S., Glicksman, R.L., Simmens, S.J., Paddock, L., Kim, D. and Whited, B. 2018. Strategies in and outcomes of climate change litigation in the United States Nature Climate Change, [online] (8), pp.829–833. Available at: <https://www.nature.com/articles/s41558-018-0240-8>
- Nachmany, M., Fankhauser, S., Setzer, J. and Averchenkova, A. 2018. Global trends in climate change legislation and litigation: 2018 snapshot [online] (May), p.8. Available at: www.lse.ac.uk/Grantham%0Ahttp://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/04/Global-trends-in-climate-change-legislation-and-litigation-2018-snapshot-3.pdf
- Nair, S.K. and Emerson, R.M. 2019. 2019 Project Peer Review Feedstock Logistics U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO). [online] Available at: [https://www.energy.gov/sites/prod/files/2019/04/f61/Biomass Supply Chain Risk Standards_NL0019449.pdf](https://www.energy.gov/sites/prod/files/2019/04/f61/Biomass_Supply_Chain_Risk_Standards_NL0019449.pdf)
- Navigant Research. 2014. Energy Efficiency Retrofits for Commercial and Public Buildings
- Nicholls, R.J., Marinova, N., Lowe, J.A., Brown, S., Vellinga, P., De Gusmão, D., Hinkel, J. and Tol, R.S.J. 2011. Sea-level rise and its possible impacts given a 'beyond 4°C world' in the twenty-first century In: *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. Royal Society, pp.161–181.
- Norton Rose Fulbright. 2018. Proxy revenue swaps for solar
- OECD/FAO. 2015. OECD-FAO Agricultural Outlook 2015. [online]. Available at: http://dx.doi.org/10.1787/agr_outlook-2015-en
- OECD/IEA. 2017. Technology Roadmap Delivering Sustainable Bioenergy
- Orbis Research. 2018. Global Construction Outlook to 2022
- Public Health Law Center. 2018. The Master Settlement Agreement: An Overview Tobacco Control Legal Consortium, [online] (November), pp.1–11. Available at: <http://www.publichealthlawcenter.org/sites/default/files/resources/tclc-fs-msa-overview-2015.pdf>
- RCS Global. 2017. The battery revolution: balancing progress with supply chain risks.
- Roskill. 2018. Lithium-ion Batteries: Outlook to 2028.
- Setzer, J. and Byrnes, R. 2019. Global trends in climate change litigation: 2019 snapshot.
- Shannon, N., Wit, E. de. and Seneviratne, S. 2019. Wrong place at the wrong time: greenhouse gas emissions contribute to coal mine refusal [online]. Norton Rose Fulbright. Available at: <https://www.nortonrosefulbright.com/en/knowledge/publications/1e16d63a/greenhouse-gas-emissions-contribute-to-coal-mine-refusal>
- Sharma, B., Clark, R., Hilliard, M.R., Webb, E.G. and Webb, E.G. 2018. Simulation Modeling for Reliable Biomass Supply Chain Design Under Operational Disruptions 6(September), pp.1–15.
- Shell. 2018. Sky: Meeting the goals of the Paris Agreement, an overview
- Sinha, R. 2018. Shareholder Litigation Involving Acquisitions of Public Companies Review of 2017 M&A litigation *Conerstone Research*. [online] Available at: <https://corpgov.law.harvard.edu/2018/07/19/shareholder-litigation-involving-acquisition-of-public-companies-review-of-2017-ma-litigation/>




-
- Smith, T., Raucci, C., Hosseinloo, S.H., Rojon, I., Calleya, J., Fuente, S.S.D. La., Wu, P. and Palmer, K. 2016. CO2 Emissions from International Shipping: Possible reduction targets and their associated *UMAS*.
- Smith, T.W.P., Jalkanen, J.P., Anderson, B.A., Corbett, J.J., Faber, J., Hanayama, S., O'Keeffe, E., Parker, S., Johansson, L., Aldous, L., Raucci, C., Traut, M., Ettinger, S., Nelissen, D., Lee, D.S., Ng, S., Agrawal, A., Winebrake, J.J. and Hoen, M., A. 2015. Third IMO Greenhouse Gas Study 2014. London.
- Solar Power Europe. 2019. Global Market Outlook 2019-2023.
- Takriti, S. El., Pavlenko, N. and Searle, S. 2017. Mitigating International Aviation Emissions Risks and Opportunities for Alternative Jet Fuels The International Council on Clean Transportation White Paper, (March).
- Tomei, J. and Helliwell, R. 2016. Food versus fuel? Going beyond biofuels.
- UNEP FI. and Acclimatise. 2018. Navigating a New Climate [online] (July). Available at: <http://www.unepfi.org/wordpress/wp-content/uploads/2018/07/NAVIGATING-A-NEW-CLIMATE.pdf>
- UNFCCC. 2016. Shipping Aviation and Paris [online]. Available at: <https://unfccc.int/news/shipping-aviation-and-paris>
- United Airlines. 2019. Expanding our commitment to powering more flights with biofuel [online]. Available at: <https://hub.united.com/united-biofuel-commitment-world-energy-2635867299.html>
- United States Geological Survey. 2017. Lithium - Worldwide production and use *National Minerals Information Center*. [online] Available at: <https://minerals.usgs.gov/minerals/pubs/commodity/lithium/mcs-2017-lithi.pdf>
- Weber, C. 2018. 15 ° C is the new 2 ° C
- Zafeiriou, E., Arabatzis, G., Karanikola, P., Tampakis, S. and Tsiantikoudis, S. 2018. Agricultural Commodities and Crude Oil Prices: An Empirical Investigation of Their Relationship Sustainability, 10(4), p.1199.

Appendix 1: Net-Zero Toolkit Methodology

The quantitative analysis is performed using the Net-Zero Toolkit, a proprietary model developed by Vivid Economics to assess the impact of decarbonisation scenarios on economic sectors and individual companies. The Net-Zero Toolkit's three step methodology consists of scenario selection, value stream modelling and derivation of company and asset level impacts. The analysis presented in this report covers 2,500 publicly listed companies across 137 sectors. This section briefly outlines the core elements of the methodology while Appendix 1 provides a more in-depth explanation.

The IEA's Energy Technology Perspectives (ETP) scenarios form the key inputs to the model, as they are commonly used scenarios for policymakers and business leaders. To illustrate two possible pathways, three scenarios form the basis of this work: the IEA's ETP Reference Technology Scenario (RTS), which acts as a benchmark scenario, and the 2°C Scenario (2DS) and Beyond 2°C Scenario (B2DS) as decarbonisation scenarios. These scenarios include projections of energy demand, carbon prices by region and sector, and a range of technology deployment trends. Vivid's scenario modelling capabilities were used to project carbon prices under each of the three scenario emissions pathways. Under the RTS, countries fulfil their current Nationally Determined Contributions (NDCs) to the Paris Agreement. While more ambitious than a historic 'business as usual' scenario, this scenario is not consistent with achieving the global climate objective outlined in the Paris Agreement of limiting global warming to 2°C above pre-industrial temperatures by 2100. To provide a scenario where this objective is likely to be achieved, the 2DS lays out a pathway to limiting CO₂ emissions to levels consistent with a greater than 50% chance of limiting global warming to 2°C, with carbon neutrality achieved in 2100. Going one step further, the B2DS assumes maximal deployment of current low carbon technologies, achieving net zero emissions in 2060, with a 50% chance of limiting global warming to 1.75°C. These scenarios are summarised in Figure 9.

Figure 9: For this report, the Net-Zero Toolkit relied on three IEA scenarios

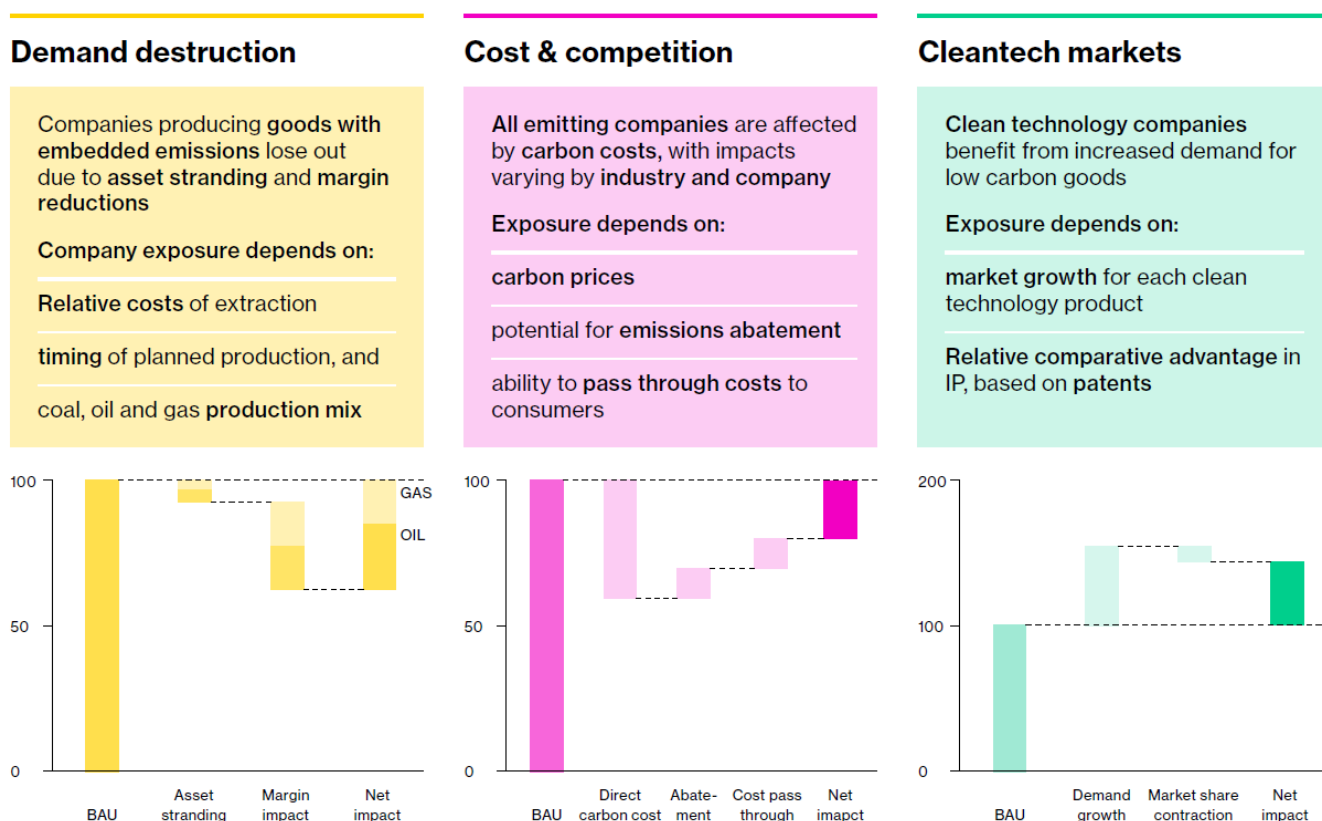
Scenario	Scenario description	Scenario outputs
 Reference Technology Scenario	Countries fulfil their current Nationally Determined Contributions (NDCs) to the Paris Agreement. This scenario will serve as a benchmark for comparison of results from more ambitious climate action.	Fossil fuels demand projections Oil Gas Coal
 2°C Scenario	Global warming is kept to 2°C. This scenario lays out a path for an energy system and CO ₂ emissions consistent with >50% chance of limiting warming to 2°C. Carbon neutrality ('net-zero') by 2100.	Transition technology deployment levels Solar, wind, hydro and other renewables EVs Biofuels
 Beyond 2°C Scenario	Global warming is kept to well below 2°C. This scenario assumes maximal deployment of current low-carbon technologies. Net-zero is achieved in 2060; 50% chance of limiting warming to 1.75°C.	Carbon price trajectories By region and sector

Source: Vivid Economics, 2019

The Net-Zero Toolkit translates these scenarios into company and asset level impacts using three value stream models. These bottom up models are designed to capture the major channels through which transition risk might impact companies and assets, as illustrated in Figure 10:

- **Demand destruction.** Under stringent climate policy, demand for fossil fuel products will fall due to the increasing costs associated with their emissions intensive consumption. This model captures the effects of this destruction of demand on oil, gas, coal and automobile producers, specifically in terms of asset stranding and reductions in profit margins. Company exposure to these impacts depends on the relative costs of extraction (or production), timing of planned production and the production mix – either between coal, oil and gas (for fossil fuel producers) or between ICEs and EVs/hybrid EVs (for automobile manufacturers).
- **Cost and competition.** All emitting companies experience direct increases in decarbonisation scenarios due to increases in global carbon prices. Companies can respond to cost increases by realising emissions abatement opportunities or passing through costs to consumers. Using a microeconomic model on sectoral competition and data on financials and emissions of individual companies in 137 sectors, these mechanisms are modelled.
- **Cleantech markets.** Demand for low carbon technologies grows in response to the shifts in their costs relative to traditional fossil fuels. Using data on green patents and existing market share, the model estimates impacts on individual company growth in cleantech markets, including renewables equipment and EV manufacturers, as well as miners of minerals for batteries and biofuel producers.

Figure 10: The three value stream models capture the major impact channels of the low carbon transition

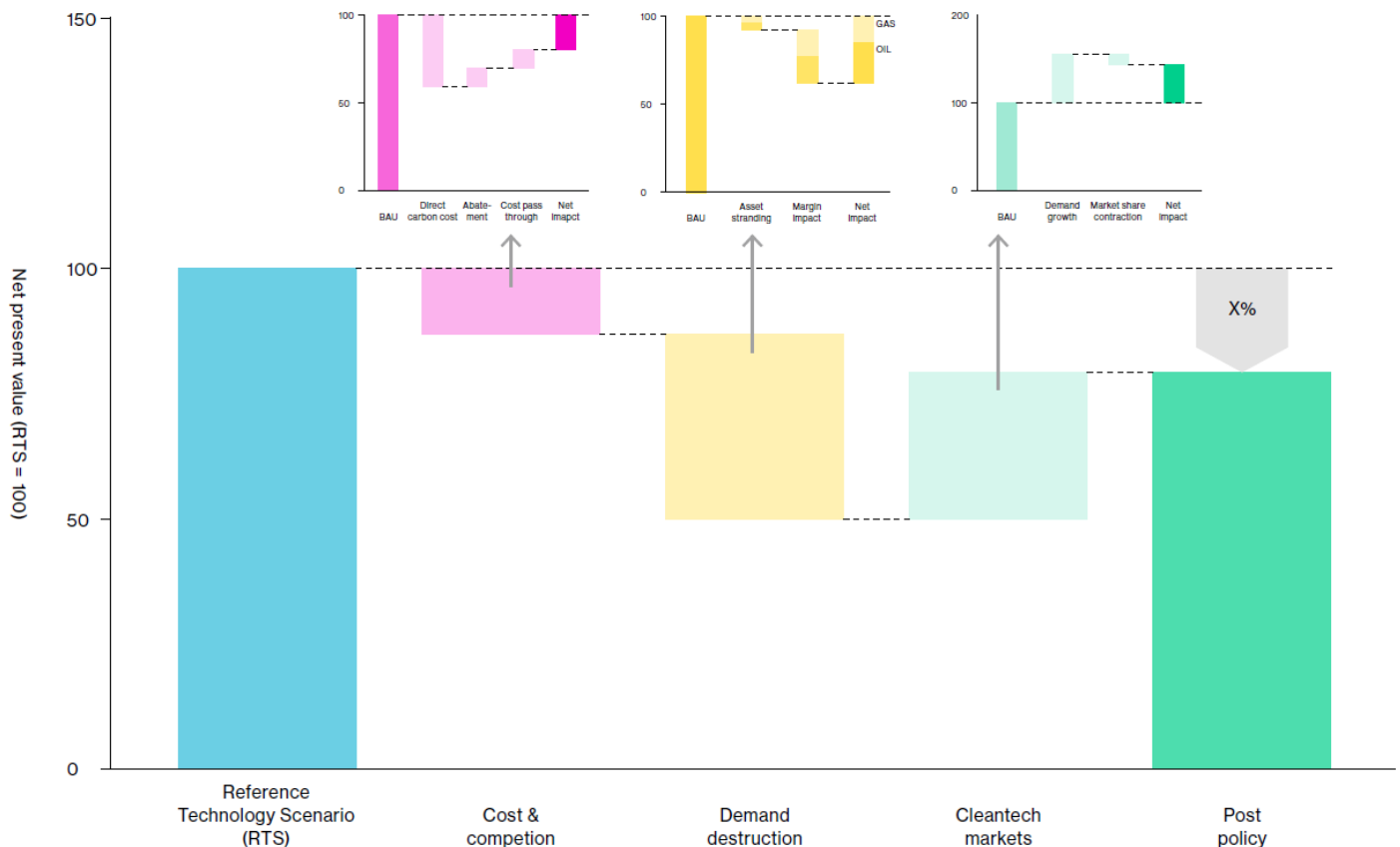


Source: Vivid Economics, 2019

Company and asset level impacts are estimated as the difference between net present value profits under the 2DS or B2DS relative to the RTS and aggregated to the sector level. Profit impacts are modelled over the period to 2050 and discounted to net present value using a standard equity discount rate. All impacts under the 2DS and B2DS are expressed relative to the RTS. As an example, if estimates of aggregate profits under the 2DS in a sector were 30% below profits under the RTS in 2050, the profit impact of the 2DS would be -30%. Note that changes in firm count are calculated to 2030.

Analysis of the three impact channels draws on the Net-Zero Toolkit results as outlined in *Figure 13*. Results on aggregate sectoral characteristics and technology shifts, abatement potential, market characteristics and sectoral revenue, profit and market size impacts provide important indicators of shifts in sectoral production and competition. Analysis of the supply chain and customer interactions relies on the toolkit's data on marginal abatement cost (MAC) curves, cost pass-through and demand responsiveness as evidence. For transition-related litigation and liability risk, model estimates of sectoral firm closure provide an indication of the key trends that could result in litigation, such as sectoral growth and decline. While companies in a growing sector may seek IP insurance, in a declining sector, long term liability and M&A activity might result in legal action.

Figure 11: The value stream models translate scenarios into company and asset level impacts



Source: Vivid Economics, 2019

Qualitative research is used to add colour in the following areas where the Net-Zero Toolkit results lack the level of depth needed for analysis of the insurance sector:

- **Systemic shifts.** The model does not cover systemic changes in consumer behaviour or major technological breakthroughs beyond currently feasible technical developments. Desk research and expert interviews provide insights into potential systemic shifts.
- **Abatement costs.** Sectoral abatement cost curves were constructed based on literature review and expert opinion and identify relevant abatement opportunities and their significance for each industry.
- **Sectoral coverage.** The model covers 137 sectors in total, with the most granular sector coverage in energy and industry. Agriculture and land-use sectors are comparatively underrepresented, and as a result, analysis of these sectors relied on literature review and expert interviews.
- **Sectoral size.** In the model, firms exit the market when they have made continuously negative profit. Entry into markets (for example in markets for green technologies) is not modelled due to the lack of data on potential future entrants.

Appendix 2: Transition impact in priority sectors

Table 7: Transition impact in Air & marine transport, road transport and fossil fuels

		Current values					2DS				B2DS			
Sector grouping	Sector	Market capitalization (million USD)	Emissions intensity (tCO ₂ /USD)	Abatement potential (% sectoral emissions)	Avg abatement cost (USD/tCO ₂)	Cost pass through rate (% change in price*)	Demand side impact	Profit impact	Revenue impact	Delta firm count (2030)	Demand side impact	Profit impact	Revenue impact	Delta firm count (2030)
Air & marine transport	Aviation	291,928	1.01	24%	17.95	94%	0%	-11%	-	-	0%	-	-	-
	Shipping	80,335	0.86	24%	NA	94%	0%	-4%	-	-	0%	0%	-	-
	Biofuels	54,729	0.32	12%	0.01	95%	+22%	+32%	+11%	-4%	26%	40%	12%	-7%
Road transport	Automobiles	1,024,559	0.01	14%	0.01	95%	-16%	-17%	-	0%	26%	27%	26%	-2%
	EVs	170,585	0.01	14%	0.01	95%	+71%	+71%	+71%	-1%	119%	119%	120%	-1%
Fossil fuels	Coal	133,605	1.46	30%	27.48	88%	-71%	-72%	-	-	74%	76%	79%	61%
	Coking coal	10,827	1.12	30%	29.77	81%	0%	3%	-17%	44%	0%	-6%	-21%	56%
	O&G T&D	479,782	0.40	29%	36.84	88%	-13%	-16%	-	-1%	16%	21%	23%	-1%
	Exploration & production	1,681,270	0.34	29%	33.77	96%	-	-	-	-2%	79%	79%	86%	-2%

Table 8: Transition impact in heavy industry, power and construction

		Current values					2DS				B2DS			
Sector grouping	Sector	Market capitalization (million USD)	Emissions intensity (tCO ₂ /USD)	Abatement potential (% sectoral emissions)	Avg abatement cost (USD/tCO ₂)	Cost pass through rate (% change in price*)	Demand side impact	Profit impact	Revenue impact	Delta firm count (2030)	Demand side impact	Profit impact	Revenue impact	Delta firm count (2030)
Heavy industry	Concrete & cement	157,773	5.18	26%	15.43	94%	0%	20%	35%	31%	0%	22%	45%	55%
	Iron & steel	386,810	1.57	27%	42.09	95%	0%	7%	33%	25%	0%	5%	37%	45%
	Aluminium	22,582	1.00	27%	41.06	82%	0%	13%	30%	25%	0%	25%	42%	25%
	Petrochemicals	1,898,191	0.29	36%	23.02	97%	13%	14%	14%	-5%	16%	19%	19%	-7%
	Lithium	18,002	0.10	27%	41.85	83%	NA	NA	NA	NA	NA	NA	NA	NA
	Minerals	1,136	0.06	13%	0.00	74%	NA	NA	NA	NA	NA	NA	NA	NA
Power	Power generation	1,160,304	3.20	54%	28.83	92%	0%	-4%	13%	17%	0%	-7%	20%	26%
	Solar	95,860	0.05	15%	0.02	98%	42%	42%	40%	-1%	44%	46%	41%	-2%
	Wind	25,400	0.01	14%	0.01	85%	41%	41%	41%	-2%	44%	44%	42%	-2%
Construction	Heavy construction	377,055	0.03	17%	0.03	95%	0%	0%	-1%	0%	0%	0%	-1%	-2%
	Home construction	128,528	0.02	15%	0.00	89%	0%	0%	0%	0%	0%	-1%	0%	0%

* Cost pass through is in % price change per 1% change in unit cost. All 2DS and B2DS impacts are in % of ETP/RTS figures, on a time horizon to 2050 unless otherwise stated.

Notes: Model results are as of December 2018. Carbon budgets used in the ETP are based on the IPCC AR5 (2013) report and are outdated as of the IPCC 1.5SR (2018). The model does not provide insightful results on the agricultural sector. Green indicates high positive exposure, orange indicates medium exposure and red indicates high negative exposure (in relative terms, high/low exposure defined as +/- ½ standard deviation from the cross-sectoral mean).