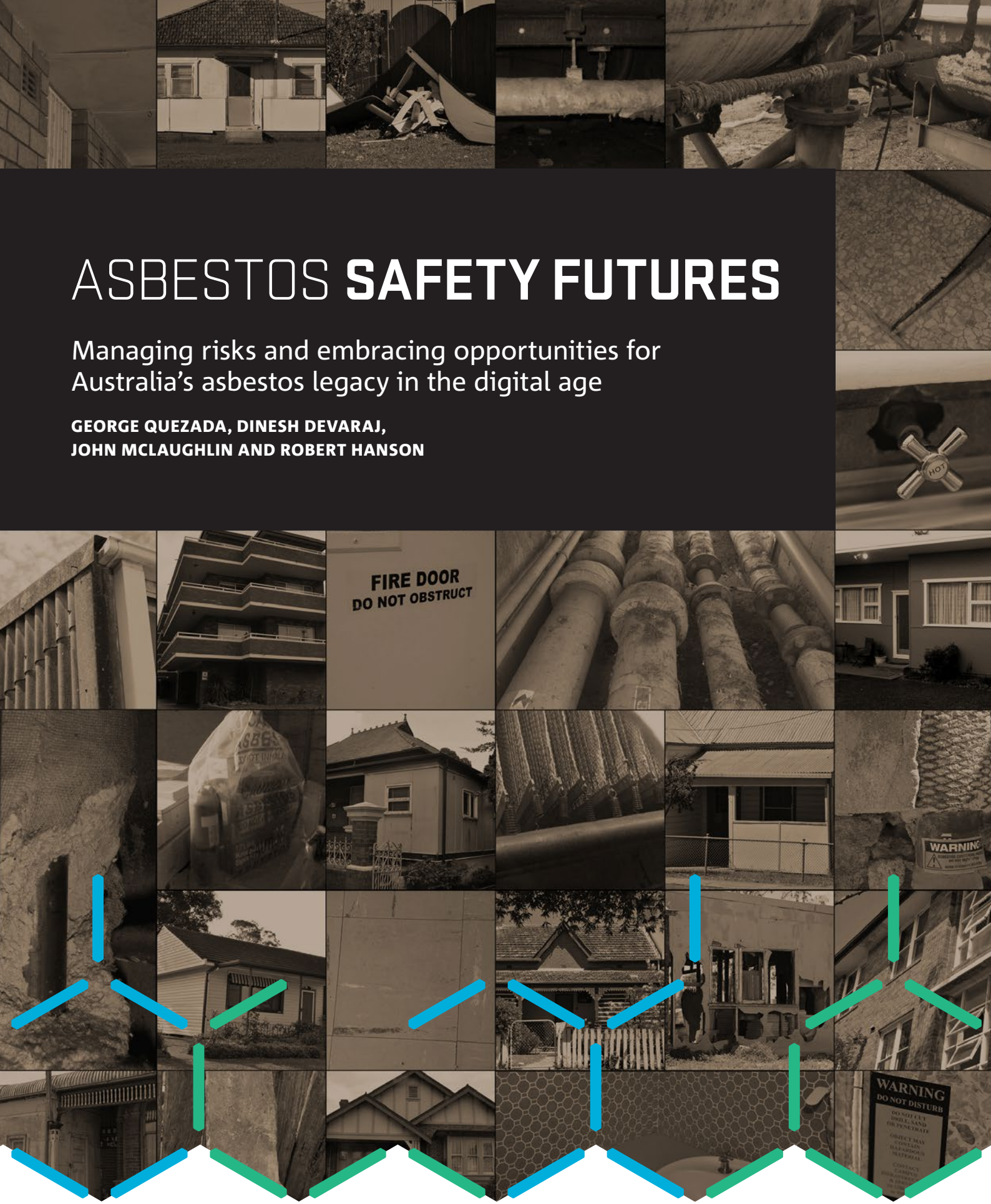

ASBESTOS **SAFETY FUTURES**

Managing risks and embracing opportunities for Australia's asbestos legacy in the digital age

GEORGE QUEZADA, DINESH DEVARAJ, JOHN MCLAUGHLIN AND ROBERT HANSON

IN PARTNERSHIP WITH THE ASBESTOS SAFETY AND ERADICATION AGENCY

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- ASEA's Building, Construction and Demolition Sectors Committee
- ASEA's Technical Research Advisory Committee, and
- Interviewees who have provided valuable and practical insights from various stakeholder perspectives.

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EXECUTIVE SUMMARY

This report identifies issues and trends that will impact on asbestos-related work over the next 10-20 years, with implications for exposure risk. The economy is changing rapidly – new digital technologies, demographic changes, continued integration of the global economy and environmental change are among many powerful forces reshaping the workforce, available jobs and required skills.

Developed in partnership with the Asbestos Safety and Eradication Agency (ASEA) this report uses strategic foresight techniques to explore the impact of these drivers of change and is concerned with exposure risks to the community and any work that might be carried out directly with asbestos-containing materials (ACMs) in Australia.

As part of this review, an analysis of the issues and uncertainties for the future of asbestos-related work and industries was conducted through interviews and workshops with ASEA stakeholders, along with a rigorous scan of relevant trends and scenario planning. The analysis identified seven megatrends, while the scenario planning process developed four plausible futures for asbestos-related work (see Figure 1). Megatrends are deep-set trajectories of change based on a composite of national and global trends. Scenarios are stories of the future that are informed by trends analysis. Scenarios put these megatrends in the context of alternative futures. Because the future is uncertain and unknowable, multiple futures need to be considered.

Scenarios for this report were based on two critical factors with the most uncertainty and impact on asbestos-related work:

1. The extent to which there are technologies to address asbestos exposure risks associated with in-situ management, and removal and disposal
2. The extent to which governments, industry and the general public are aware of the threat of asbestos exposure and proactively manage the risks.

WHAT THE MEGATRENDS AND SCENARIOS TELL US

The aim of developing megatrends and scenarios for asbestos-related work is to explore important drivers and plausible futures that could have implications for exposure risks. This information can inform asbestos management policy, research and practice to ensure Australia is well-placed to prevent future asbestos-related diseases. The report identifies three areas for targeted strategic action that can have significant impact on preparing the workforce and mitigating exposure risks:

1. Develop **data infrastructure** to enable effective assessment and management of exposure risk
2. Track the **pipeline for asbestos-related technology innovation** with proper vetting of, and training in, new and emerging hazmat technologies.
3. Monitor the **labour market** balance between supply of workers and demand for asbestos-related work

WHERE TO FROM HERE?

The next step is to use this material to start the conversation across the many stakeholders involved in asbestos safety, and consider important initiatives for the next phase of the National Strategic Plan for Asbestos Management and Awareness.

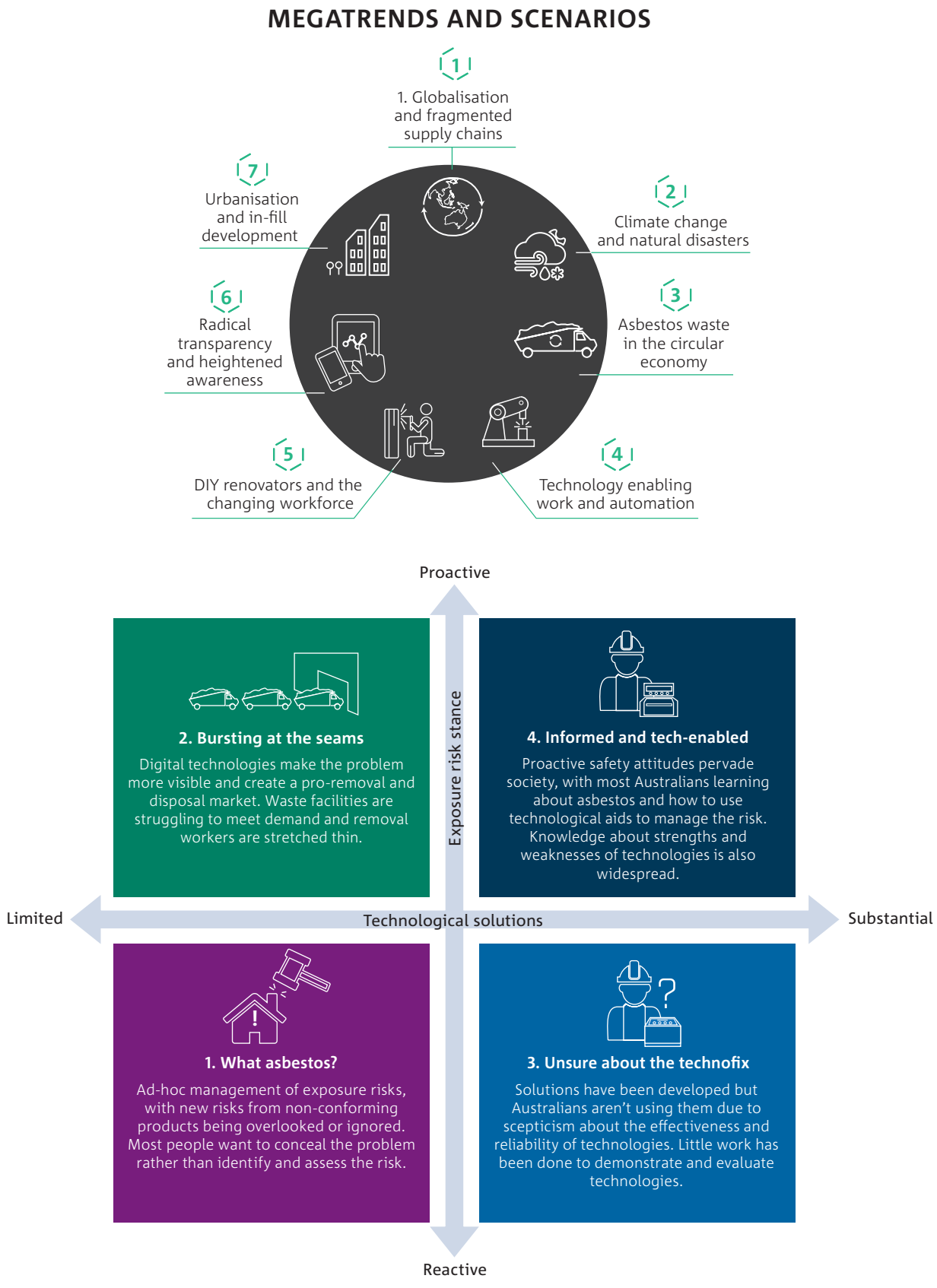


Figure 1. Megatrends and scenarios for the future of asbestos-related work

1 INTRODUCTION

This report aims to inform asbestos management policy, research and practice to ensure Australia is well-placed to prevent future asbestos-related diseases. It does this by examining the intersection of ageing asbestos in Australia with megatrends and scenarios about the future of asbestos risks and work. Asbestos-containing materials (ACMs) were used extensively in building construction and piping during the 20th century, with consumption peaking in the 1970s, and declining following a ban on mining and manufacturing with the material in 1987, and a total ban in 2003.[1] The stock of asbestos is aging and the waste stream is growing[5]. Skilled workers involved with management, removal, transportation and disposal are needed to meet this challenge.

Meanwhile, the world of work is changing rapidly through the emergence of new technologies, the rise of the gig economy, demographic changes and continued integration of the global economy. Online platforms can quickly match workers with jobs, and machines can automate or assist with dangerous, dull and difficult tasks. The workforce is ageing and younger members are aspiring to higher skilled jobs, which raises questions about the availability of qualified workers in the asbestos removal and disposal fields.

HOW COULD THESE TRENDS SHAPE THE FUTURE OF ASBESTOS-RELATED WORK?

Outlined in this report is a set of megatrends and scenarios exploring answers to this question. Megatrends are powerful drivers of change that occur at the intersection of numerous trends. Megatrends build gradually, but eventually push governments, industries and communities into fundamentally different futures. Scenarios are stories about the future, informed by trends and megatrends, which assist decision makers with developing future-focused policies and strategies.

As asbestos in the built environment continues to age the nature of work with asbestos will need to shift from managing in-situ to removal and disposal. It is inevitable that asbestos will need to be removed because once it is disturbed it is no longer in situ. This disturbance can take place due to updating the building stock or because of natural events. This has been happening ever since the ban was put in place in 2003 (and before that for more dangerous forms of asbestos). There is potential for the rate of removal to increase beyond the industry's capacity to manage, posing a risk of exposure to untrained workers, as well as renovators and the wider community. There is a need to ensure that the availability of skilled workers grows in parallel with the need to remove ageing asbestos.

This report is concerned with any activities that might be carried out directly and indirectly with asbestos-containing materials in Australia in non-work and work contexts. This includes renovators, labourers, licensed tradespeople, asbestos removal workers, drivers of trucks transporting asbestos, workers involved in disposal and waste management facilities, and workers involved in prefabricated construction and recycling facilities.

Through identifying megatrends and developing a plausible set of future scenarios, the report outlines potential challenges and opportunities in asbestos management, removal and transport industries over the coming decades.

The report was commissioned by the Asbestos Safety and Eradication Agency (ASEA) as an input to the next phase of Australia's National Strategic Plan for Asbestos Management and Awareness. The report is designed to support constructive discussion and planning with relevant policy makers and the industries that manage ACMs and exposure risks on a day-to-day basis.

The report draws upon the findings of recent CSIRO | Data 61 reports including *Tomorrow's Digitally Enabled Workforce,*[2] *Farsight for Construction*[3] and *Our Future World,*[4] as well as parallel work being conducted with Safe Work Australia on the impact of digital technologies, shifting employment patterns, the ageing workforce and rising levels of stress and chronic disease on Workplace Health and Safety and Workers' Compensation.[107]

2 STATE OF PLAY WITH ASBESTOS MANAGEMENT

Australia's asbestos legacy means that asbestos is dispersed throughout Australia's built environment. Despite being prohibited, small amounts of asbestos have been detected in imported building products, as well as friction and consumer products.[1] The vast majority of asbestos consumed in Australia was incorporated in cement products – sheeting and piping. These are referred to as asbestos-containing materials (ACMs). While it is difficult to quantify asbestos in situ and in waste streams, estimates suggest that over 12 000 kilotonnes of asbestos was consumed in Australia from 1920 until the material was banned in 2003.[1]

2.1 Research and data suggests much of the asbestos stock is being managed in situ

Stocks and flows modelling of ACMs suggests that the product peaked in Australia during the 1980s, and should decline until the end of the 21st century (see Figure 2). This is based on the assumption that the product's life is unlikely to exceed 100 years. Estimates of waste flows indicate that disposal of the material should have peaked at 170 kt/year in the early 2000s. However, this does not seem to be playing out in practice: actual data on asbestos waste streams show that disposal is increasing, and the overall quantity of waste is higher than projected. For example, between 2012-13 and 2014-15 the volume of asbestos waste increased from 12% of total hazardous waste to 18%. In 2014-15 asbestos waste was measured at over 1,007 kt – 97% of which was sent to landfill, with the remainder being stored.[5]

This data suggests that much ACM stock has historically been managed in situ and that its removal is trending up. Although, ACM waste is often lumped together with other waste materials, such as concrete and earth. Combined with the discrepancy between modelled and actual waste flows, it is difficult to accurately predict the peak. And it should be noted that this research and waste data does not address prohibited asbestos imports post-2003 ban.

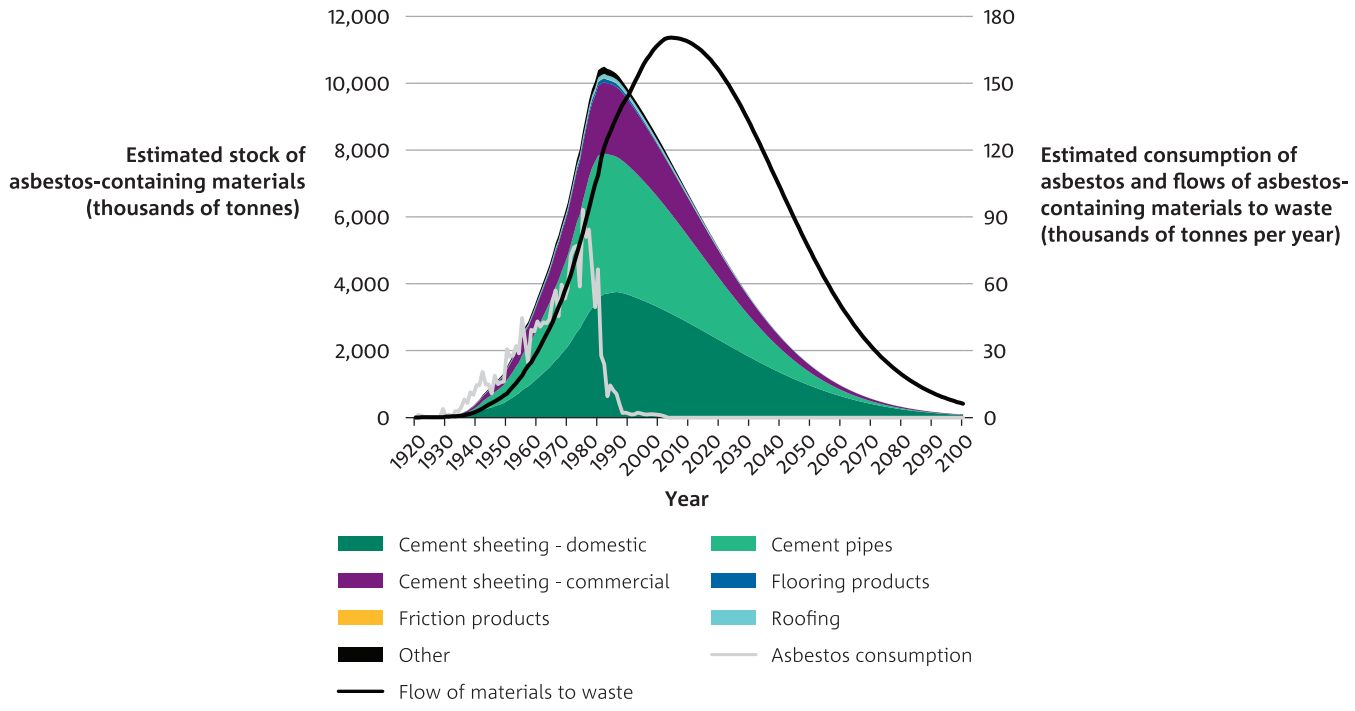


Figure 2. Projected asbestos stocks and flows in Australia

Source: Asbestos stocks and flows model v2-2[2]

1. For information about the detection of prohibited goods containing asbestos, refer to http://www.homeaffairs.gov.au/Busi/cargo-support-trade-and-goods/importing-goods/prohibited-and-restricted/asbestos#goodsthatmightcontainasbesto
2. Unpublished data supplied by ASEA

2.2 Managing asbestos in-situ

Risks of exposure to asbestos fibres must be carefully managed. A recent review of literature and interview study into exposure risks by Gray et al.[6] highlighted a number of issues of in-situ management relating to:

- Weathering from rain, sun, wind and/or frost
- Damage to ACMs due to natural disasters and the prospect of more intense and frequent disasters due to climate change
- Poor post-disaster clean-up practices that do not adequately manage asbestos exposure
- Leaving ACMs in situ due to high cost of removal and replacement
- DIY renovation and asbestos removal
- Incomplete removal and assessment.

Concern has increased regarding non-occupational exposure (e.g. home renovators) and possible increase in asbestos-related diseases, referred to as the 'third wave'[3] (the first and second waves being workers exposed during mining, and manufacturing and construction). Evidence has long been conclusive that risks of developing mesothelioma are higher for individuals working directly with ACMs, while exposure from background levels of asbestos around buildings with ACMs is very low with very low mortality rates.[7]

A series of three large-scale surveys commissioned by ASEA in 2014, 2016 and 2018 revealed that Australians have varying levels of awareness about the dangers of asbestos.[8] Tradespeople (81-84% informed or very informed) were more informed than real estate agents (60-63%), DIY renovators (59-61%) or the general public (47-55%). Furthermore, confidence in one's ability to identify ACMs or high-risk situations was low across the sample, and consistent across surveys – 62-67% for tradespeople, 18-22% for the general public, and 26-29% and 38-40% for DIY renovators and real estate agents respectively (see Figure 3 for 2018 results on these items).

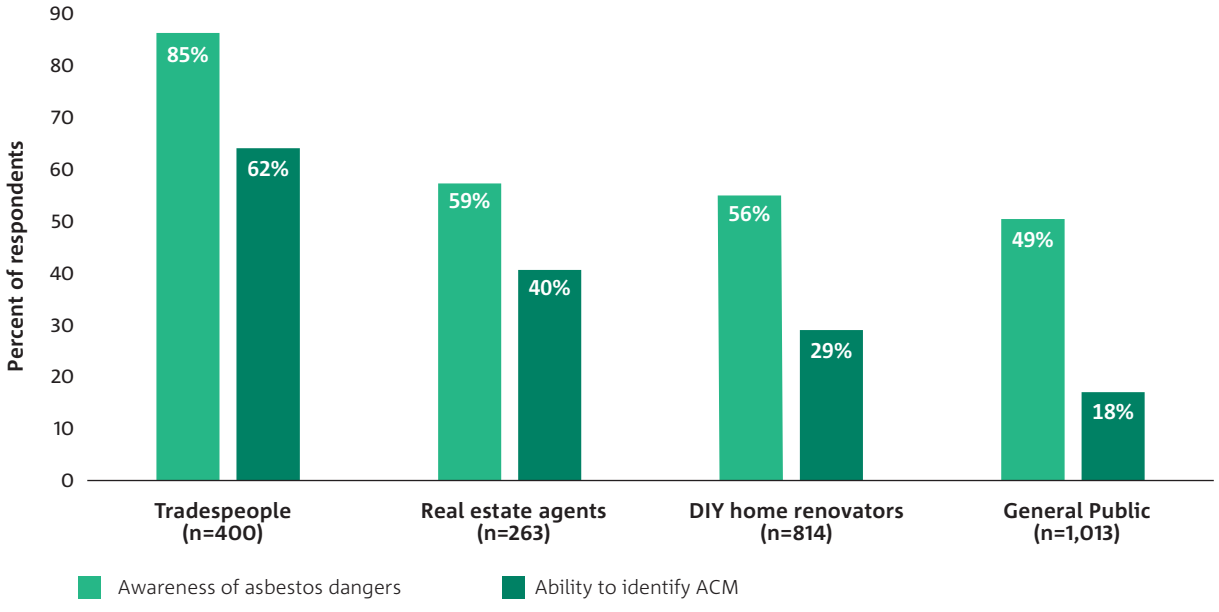


Figure 3. Asbestos awareness in Australia
Data source: Colmar Brunton (2018)[8]

[3] Riley, B., *The Third Wave - Australian Mesothelioma Analysis & Projection* 2016, Asbestos Safety and Eradication Agency: Sydney

2.3 Existing policy settings minimise exposure risks

Australia has one of the highest recorded rates of asbestos-related diseases (ARDs) in the world, and a range of policies have been implemented with the aim of eradicating these diseases.[9] Mining, manufacturing and use of asbestos declined through the latter part of the 20th century, and a total ban on the use, import and export of the product was instituted on 31 December 2003.

Regulations that impact asbestos-related work are implemented primarily by state-based agencies across work health and safety, environment, planning and public health. Specifically, WorkSafe/WorkCover agencies oversee worksite safety practices, asbestos registers, and licensing of removalists. State based EPAs set licence fees and waste levies, issue penalties/fines for non-compliance, prosecute cases of illegal dumping, and conduct in-ground testing of waste facilities and contaminated sites.

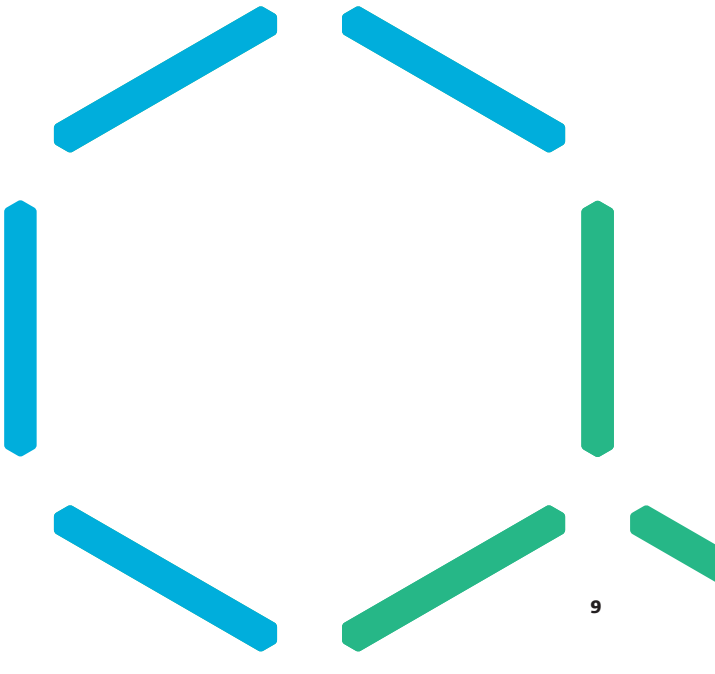
Consumer protection and public safety agencies and local governments have a role in assessing development applications concerning demolition, managing/owning disposal facilities and regulating clean-up following natural disasters.

The federal government, through the Department of Home Affairs (formerly the Department of Immigration and Border Protection) and the Australian Border Force (ABF), regulates the import and export of asbestos.[10] The federal government also founded the Asbestos Safety and Eradication Agency in 2013 "to provide a national focus on asbestos issues that go beyond workplace safety to encompass environmental and public health issues".[11] The agency's specific roles include coordinating, monitoring and reporting on a National Strategic Plan, providing advice to governments, and commissioning research about asbestos safety.

GLOBAL POLICY APPROACHES

Bans on the use and mining of asbestos are in place in many countries around the world. However, some countries still allow the mining of asbestos, notably Russia and China and many countries consume the material, particularly in Asia.[12] The World Health Organization and International Labour Organization are key global bodies leading efforts to eliminate ARDs, including the development of policy guidelines for governments, which Australia has adopted.[13] Key elements of these guidelines include:

- A national programme policy document that outlines the problem and strategies to eliminate ARDs
- An information tool that defines and tracks the consumption of ACMs, populations at risk and progress on goals to eliminate ARDs
- An operational tool referred to as a 'National Asbestos Workplan', which details time-sensitive objectives and mechanisms for accountability, monitoring and evaluation
- A steering committee or taskforce with a mandate to manage the development, implementation and evaluation of the national programme, and to promote multi-stakeholder participation.



Several countries in Europe have made notable strides towards eliminating ARDs, with key policy initiatives highlighted in Table 1 below.

Table 1. Policy initiatives of peer economies in Europe

COUNTRY	INITIATIVES
Poland	The government-funded Programme for Asbestos Abatement – the only removal programme in the world – aims to remove all ACM from the country. It includes education and awareness raising and an online register with spatial information tracking.
The Netherlands	A national roof removal plan aims to remove all asbestos roofs in public, private and residential buildings between 2016 and 2024. It includes voluntary incentives, such as a publicly accessible digital map that identifies schools and hospitals and the status of their asbestos management plan, and a tracking system for asbestos-related work.
United Kingdom	The UK government has implemented a number of initiatives to support voluntary surveys and removal practices, including non-mandatory accreditation for asbestos surveys overseen by an independent non-profit organisation, and an education and awareness-raising app. There is also industry self-regulation undertaken by the UK Asbestos Removal Contractors Association.

Source: Morgan (2015)[14]

2.4 What stakeholders said when asked about future drivers and issues impacting asbestos-related work

This study used strategic foresight methods to construct relevant megatrends and scenarios on asbestos-related work. The foresight process was informed by interviews with 15 subject matter experts drawn from industry and employers, government (policy makers and regulators), unions and academia to capture their views and perspectives. Interviews were semi-structured, consisting of two parts:

1. The first part asked participants about key trends influencing the future of asbestos management and eradication in the coming 10-20 years
2. The second aimed to test the impacts of key issues identified in the literature and by other interviewees regarding climate change, technology development, the gig economy and changing employment models, and the question of prioritised removal

The interviews helped identify a range of emerging trends. Thematic analysis revealed the key themes summarised in Table 2. Note that the themes are not listed in order of importance or frequency of response, but rather highlight the most representative concepts identified across all interviewees and should be read as the views and perceptions of stakeholders.

Table 2. Interview themes about the future of work in relation to asbestos

THEME	DESCRIPTION	IMPLICATIONS
Complex supply chain and global trade	Trade with countries that do not have Australia's strict regulation of asbestos raises the risk that businesses and individuals may inadvertently import ACMs into the country. Some of our trading partners have not banned asbestos mining or manufacture, or have lower standards, such as deeming export products asbestos-free when they contain small amounts of asbestos (e.g. <5%).	New stocks of ACMs may emerge in Australia, even though there is a ban. Exposure risks could be high if business and community do not expect common products to have ACMs.
Waste stream challenges	Proper removal, transportation and waste disposal is expensive; the high cost provides an incentive for illegal dumping. Illegal dumping is perceived to be common, and some question whether the capacity of existing disposal facilities is sufficient to manage a larger ACM waste stream.	Costs can drive unsafe practices and elevate exposure risks for people who participate in illegal dumping activities. Broader public health risk could also be elevated, particularly for those living and working near illegal dumping sites.
Technological solutions	Technological advances present new opportunities to workers. Technologies that could help identify ACMs include infra-red and hyperspectral imaging, GIS mapping and thermal destruction of asbestos fibers. Advances in 3D printing could make local manufacturing of building products more competitive and reduce demand for cheap imported products that have a high risk of containing asbestos.	There are research and development opportunities for technologies that can potentially assist workers and minimise exposure. Funding may be necessary to motivate research on these technologies in relation to the ACM problem domain.
Climate change and natural disasters	Climate change will bring more frequent and intense natural disasters as well as harsher weather conditions that will diminish the life expectancy of ACMs. Bushfires, storms and flood events disturb ACMs and cause serious exposure risk to residents in vulnerable 'fibro belts'. Participants raised questions about the cost and feasibility of effectively managing asbestos exposure risk during large-scale disasters in which thousands of volunteers might be assisting with clean-up operations (e.g. Brisbane/SEQ 2011 floods).	Exposure to damaged ACMs can add to the complexity of post-disaster clean up operations. The decreased life expectancy of ACM buildings and infrastructure will increase their flow into the waste stream, which could meet with constraints on the availability of skilled/ trained workers.
Issues with managing in-situ ACMs and societal perceptions of risk	Future work with ACMs is likely to become more difficult with in-situ management techniques that conceal ACMs under other materials (e.g. plasterboard). This difficulty may create further risks in situations where renovators, who are known to have suboptimal abilities to recognise ACMs, underplay risks (especially if costs of proper treatment/removal are high). The residential sector is difficult to regulate and there are diverse perspectives on whether to remove ACMs during renovation or leave them if in good condition. Authorities find it difficult to communicate effectively with the general public about asbestos risks given that the effects may not be felt for decades. Tradespeople, who historically were skilled at identifying ACMs, are today being trained by project builders and may not have sufficient experience with managing exposure risks.	Even well-trained workers could face exposure risks that cannot be easily identified. Untrained workers may be placed at increased risk.
Changing employment relations and the gig economy	Asbestos work has typically involved itinerant workers with low investment in skills and training; online 'Airtasker-type' platforms may increase the entry of such casual workers, who have little training or experience in the proper handling of ACMs. While work health and safety legislation does not rely on traditional employment relationship definitions, in practice the gig economy is currently perceived as harder to regulate.[4]	Online platforms that facilitate work are a new and emerging issue for regulators in general. For workers involved with ACMs, these platforms require attention and engagement by regulators in order to realise their potential benefits and mitigate risks.
Safe and efficient market performance	The market for safely managing asbestos would benefit from continual government and industry focus. For example, organisations mandating that all their buildings be asbestos-free and introducing mandatory disclosure of ACMs for all buildings being leased and sold could drive investment in awareness and safety training. Disposal costs and availability of disposal sites are areas in which the government can assist industry.	Investment in appropriate policies and positions, in conjunction with programmes for education and safe removal, could be highly influential signals to the market, providing certainty for private sector investment and workforce development.

[4] The model work health and safety laws are flexible and can capture arrangements in the gig economy. They include the concept of Person Conducting a Business or Undertaking (PCBU). This concept was included to capture non-traditional employment relationships. However, varying levels of control by the platforms makes the gig economy a challenge for regulators.

3 MEGATRENDS

Megatrends are large-scale shifts in the landscape that play out over a long time frame. They are a combination of trends from the political, environmental, technological, social or economic domains. The magnitude and direction of these megatrends change over time; consequently, they are often best viewed in hindsight. Their size and patterns, however, often point towards clear directions in the short to medium term and provide clues about potential new risks and implications for the medium to longer term.

These narratives of change, built upon evidence and observation, assist decision makers to make sense of the current and emerging environment. They are also extremely useful as a foundation and backdrop for scenario analysis in support of strategy formulation and stress-testing.

3.1 Globalisation and fragmented supply chains

Identification and tracking of asbestos is difficult and costly in today's globalised economy. This issue is compounded by complex supply chains across countries with different laws, policies and practices regarding asbestos. People can now choose to import lower-cost building and consumer products from Asia, and online platforms are making it easier for individuals to import relatively small volumes of product (e.g. less than a container load).

IMPACT: Despite the Australian ban in 2003, there are incidences of illegal ACMs having been found. While all illegally installed ACMs should be removed, it is possible that workers in the future could encounter post-2003 materials in which unknown quantities of asbestos are present.

POLICY IMPLICATIONS:

- **The risk of ACMs entering Australia through imports remains due to the complexity of globalised trade supply chains and differing international standards**. The import of contaminated products is monitored primarily by importers, as the responsible parties when sourcing goods, and the Australian Border Force (ABF), which must be assured by the importer that identified goods do not contain asbestos. Complexity in supply chains makes border surveillance challenging, and ongoing innovation is needed to better track the source of products and their constituent materials.
- **Lack of rigorous open data published by manufacturers of ACMs within given countries creates ongoing detection challenges for all stakeholders.** Products are labelled by one country, but in practice manufacturing operations are distributed across multiple jurisdictions. This complexity makes the task of undertaking due diligence more difficult for individual importers; however, it is still their responsibility to do so. This highlights the need to continue to focus effort across the supply chain.

KEY FACTS UNDERPINNING THIS MEGATREND:

- *Australian imports have grown massively*. The value of imported goods flowing into Australia grew by around 250% over the past 20 years (see Figure 4).[15] In 2015-16, Australia's top 10 import sources as a share of total imports were China (18.4%), the USA (13.6%), Japan (6.4%), Thailand (4.7%), Germany (4.6%), the UK (4.3%), the Republic of Korea (4.1%), Singapore (3.8%), New Zealand (2.7%) and Malaysia (3.1%). At least 10% of imported goods are made of materials at risk of containing asbestos, including heating and cooling equipment parts, electrical machinery and parts and prams, toys, games and sporting goods.[16]
- *Australia's main import partners themselves import a large share of non-final goods at risk of asbestos contamination*. Using World Bank data on Australia's top five import partners, it was found that their respective import-shares for minerals, raw materials, intermediate goods and machinery and electric goods cumulatively were 67% for China, 57% for the USA, 61% for Japan, 63% for Thailand and 50% for Germany.[17]

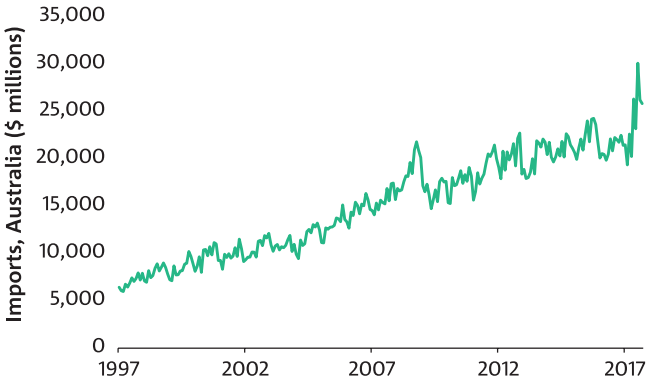


Figure 4. Total merchandise imported into Australia, 1997-2017
Source: Australian Bureau of Statistics[15]

- *Many of Australia's import partners in Asia still consume asbestos*. Based on the United States Geological Survey (USGS), global asbestos production was estimated to be 2,030 kt in 2015, similar to the amounts produced in each year from 2011 to 2014.[18] Russia produced more than half, followed by China, Brazil and Kazakhstan (see Figure 5). Most asbestos is not consumed where it is produced: notably, Asia is estimated to have absorbed almost 86% of global asbestos consumption between 2009 and 2014 (see Figure 6). The five countries topping asbestos consumption in 2014 – China (25.2% of total global consumption), Russia (23.8%), India (18.9%), Brazil (9%) and Indonesia (5.4%) – are either Australia's immediate import partners, or import intermediate goods to our partners.

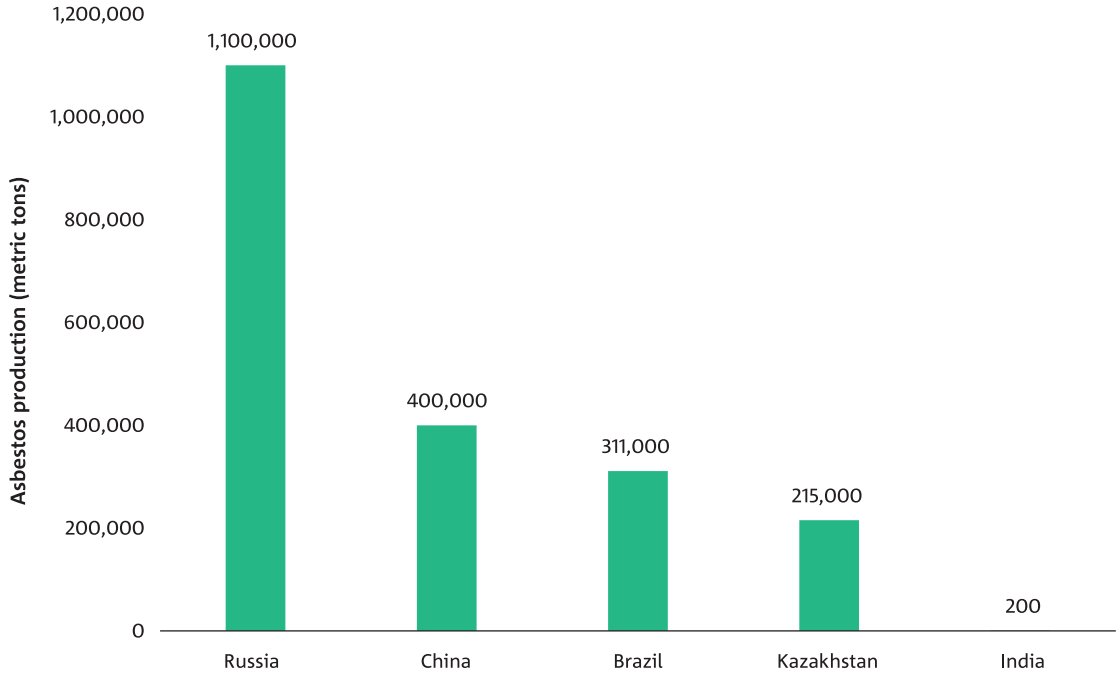


Figure 5. Leading asbestos-producing nations in 2015
Source: Kazan-Allen and Allen [18]

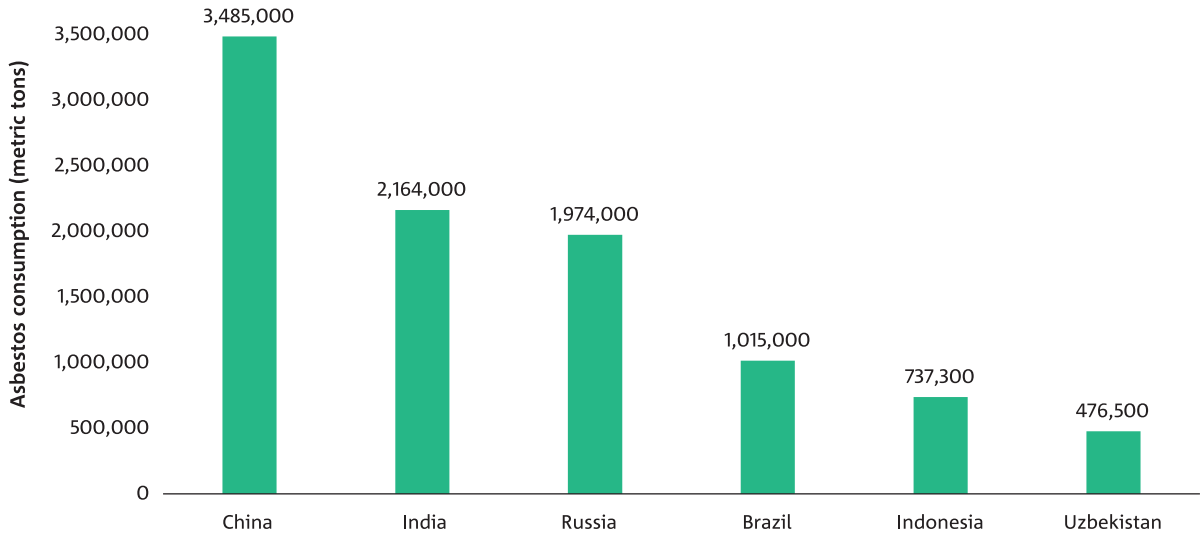


Figure 6. Leading asbestos-consuming nations between 2009 and 2014
Source: Kazan-Allen and Allen [18]

- *Legislative differences around the world make the analysis of asbestos-related risks more complex*. There are many differences amongst countries in legislation on the mining, production and use of asbestos. The International Labour Organization (ILO) Asbestos Convention, 1986 (No.162) has been enforced since 1989, but ratified by only 35 countries (significantly, major importing countries to Australia – such as China, the United States and Thailand – are not among them). Similarly, the Rotterdam Convention on prior informed consent has failed to reach consensus at the Conference of the Parties meetings for the listing of chrysotile asbestos. The variation in laws often occurs because bans may be specific to some of the six asbestos types; they may apply only to mining, production or use; their extent may be more or less drastic; enforcement procedures may differ in rigor; and individual countries may employ different strategies.[19] The legislative limits for asbestos in all jurisdictions are inconsistent: for example, in China, products can legally be labelled 'asbestos free' or 'no asbestos' if their asbestos content is less than 5%.[20] The diversity of international asbestos legislation complicates the ABF's job of enforcing the ban of ACMs.

- *Goods containing asbestos have been detected entering Australia, increasing the risk of exposure and asbestos-related disease*. The ABF has greatly increased its focus on asbestos at the border, and explained that every import undergoes risk assessment prior to or on arrival. When goods at risk are identified, the decision about whether or not to test them for asbestos is made following an assessment of evidence the importer is able to provide that the goods do not contain asbestos. Between 1 July 2015 and 30 September 2017, there were 11 267 consignments assessed by the ABF to be at risk of containing asbestos. Of these, 997 consignments were tested, resulting in 99 detections. There were 50 infringement notices issued, and 13 warning letters. According to the Department of Home Affairs, countries of shipment from which goods containing asbestos have been detected include China, the USA, Japan, Germany, Sri Lanka, Singapore, Indonesia, the UK, the Netherlands, New Zealand, Italy and South Africa.[21]

The ILO convention does not 'ban' all forms of asbestos - it states there should be a total or partial ban of certain types.

3.2 Climate change and natural disasters

Climate change degrades ACMs more quickly and brings the risk of more frequent and intense natural hazards that could release fibres into the environment. Consequently, it may alter the current stocks and flows modelling forecast, bringing forward the transition of ACM into the waste stream. Climate change includes both chronic factors, such as temperature and humidity extremes, and acute factors such as extreme weather events.[24]

In extreme events, the focus for public safety may be responding to and recovering from the natural hazard itself (e.g. fire and heat stress, or flood and water-borne disease) rather than managing exposure hazards from damage to the built environment. Emergency response and recovery resources may be overstretched post-disaster, while home and business owners may be hasty in clean-up operations. Awareness of asbestos dangers and the ability to identify ACM are both suboptimal among the Australian general public.[8]

IMPACT: Workers (including volunteers) conducting building maintenance or post-disaster clean-up and recovery risk operating in environments with damaged and friable ACMs.

The scale of natural disasters and damage may make it challenging to identify and safely dispose of asbestos. This raises questions about the capacity of the waste industry to handle vast volumes of ACMs, communication with authorities and volunteers on risks of asbestos materials, and the risks of soil and water contamination.

POLICY IMPLICATIONS:

- **Climate change may increase the rate of deterioration of asbestos-containing infrastructure in Australia**. Existing studies have not often considered the impact that changes in climate could have on the risk of ACM exposure. This research gap means that unforeseen ACM exposure risks could emerge in the coming decades.
- In the context of large-scale disasters, alerting volunteers to exposure risk can be a difficult task for government authorities. Effective digital solutions for public communications could reduce address this challenge.

KEY FACTS UNDERPINNING THIS MEGATREND:

- *Climate change is occurring at an accelerated rate*. According to NASA, human-caused global warming has mostly occurred within the last 35 years (see Figure 7).[25] Sixteen out of the 17 warmest years over this 35-year period occurred since 2001.[26] In the 10 years to 2009, the relative frequency of particular kinds of disasters in

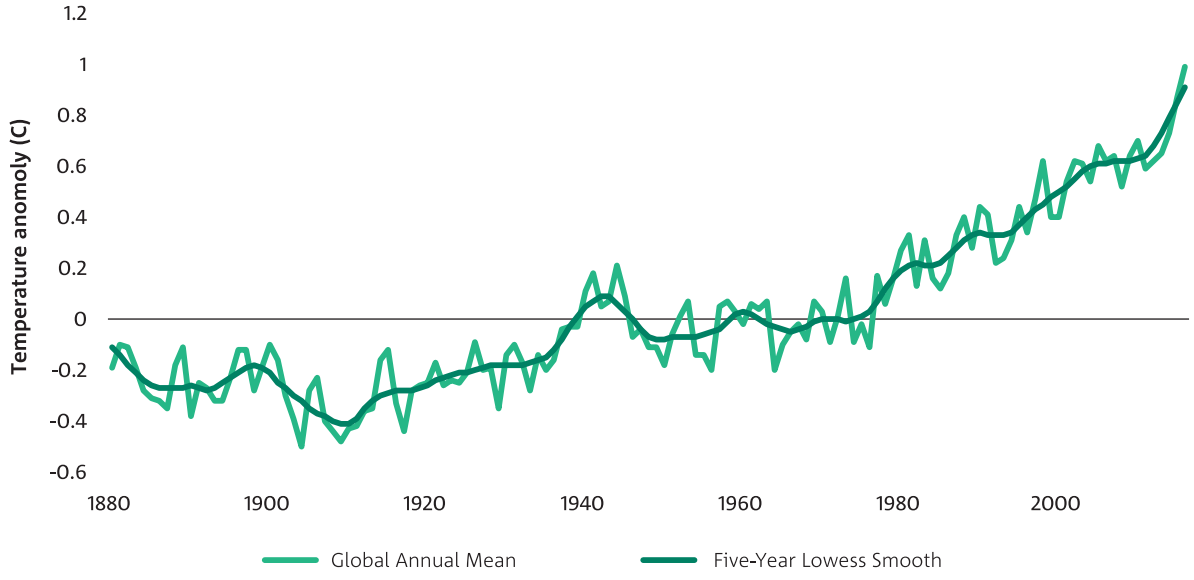


Figure 7. Global mean temperature variation of land and oceans compared with the long-term average (since 1880)
Source: NASA[25]

Australia was dominated by storms including hail (29%), transport emergencies (19%), bushfires (15%) and floods (14%).[27]

- *Climate change will increase extreme fire risks*. The Australian Academy of Science has noted that the number of extreme fire-risk days has grown over the past 40 years. Hotter and drier conditions in the future (particularly in Southeast Australia) will probably increase the number of high fire-risk days along with the length of the fire seasons. Forecasts suggest that the number of days on which the danger will be ranked 'very high' could double by 2050 under high-emission scenarios. Heatwaves will also increase in frequency, especially in the hotter North.[28] Buildings constructed before 1987 are likely to contain asbestos in the form of flat or corrugated sheets that were used in walls, ceilings, roofing, piping, electrical conduits or eaves. Fire could severely damage infrastructure made of asbestos, rendering it friable and a health risk.[29]
- *Asbestos-containing-concrete could deteriorate at an accelerated pace*. Cities across Australia can expect to see an increase in extreme hot days. Sydney for example, could see the average number of days over 35 degrees increase from an average of 3.1 per year to 11 by 2090.[30] CSIRO researchers have found that climate change will increase the rate of concrete deterioration in Australia.[31] A report reviewing the evidence around airborne asbestos fibres released due to weathering and/or corrosion has concluded, based on conditions in 2008, that asbestos release will not be a common event.[32] However, the report notes that the risk to human health of weathering on asbestos-release warrants further study, particularly in the context of longer weathering exposure.[32] Asbestos sheets in walls and roofs are a composite material bonded by cement like concrete. Given that CSIRO research predicts an increased rate of deterioration for concrete, a more targeted study on the implications for asbestos should be undertaken.
- *Coastal infrastructure will deteriorate faster given sea-level rises, more frequent and severe storms, and more flash flooding events*.[33] Coastal areas will experience erosion and infrastructure damage, with implications including the degradation of materials, structures and building foundations. Climate change will thereby reduce the life expectancy of buildings, pushing more materials into the waste stream or recycling processes. Forecast sea-level rises of 1.1 metres could damage around 30 000 km of Australian roads. The potential costs of housing and infrastructure damage are estimated to be more than $226 billion.[28]
- *Infrastructure damage costs will rise generally due to increased frequency and severity of destructive weather*. Deloitte estimates that the economic costs of natural disasters were over $9 billion in 2015, could almost double by 2030 and will average around $33 billion per year by 2050. The Queensland floods of 2010-11 indicate how damaging natural disasters can be: they were estimated to have caused $6.7 billion in tangible costs.

3.3 Asbestos waste in the circular economy

The ACM waste stream is growing and the cost of waste disposal is increasing. Many companies are shifting focus from linear 'produce-use-waste' systems towards circular systems in which used goods are cycled back into production systems. Gaps in asbestos data mean there is a risk that building materials and consumer products that have unidentified asbestos could be recycled, creating an additional asbestos risk for recycled material or product users. Furthermore, landfill sites are becoming attractive for mining expensive elements such as rare earth metals (e.g. extraction of magnesium from asbestos waste), which could involve digging up ACMs and releasing asbestos fibres.

Circular and linear economies have different product cycles. Linear economies typically flow from raw materials to production, distribution, consumption and waste. Circular economies recycle past products as much as is feasible to minimise residual waste and create value.[37]

IMPACT: Workers in the circular economy may be unwittingly exposed to contaminated products.

POLICY IMPLICATIONS:

- **Participants in the circular economy need to be aware of the risks posed by ACM recycling**. This requires recycling industries to have ACM risk profiles that inform their practices.
- **Data across all states could be collected through more standardised and digitised methods**. The tracking and management of ACM-related waste is patchy across states, which presents difficulties in the creation of a national asbestos waste strategy.

KEY FACTS UNDERPINNING THIS MEGATREND:

- *Waste generation is increasing at approximately the rate of population growth.* According to most recent estimates, waste volumes rose by 12% between 2006-07 and 2014-15, amounting to more than 7 million additional tonnes of waste generated annually. Waste generation is expected to rise almost in line with population growth, as waste generation per person experienced an average annual fall of just 0.3% over the last decade. After peaking in 2008-09, waste disposal reached a new five-year high in 2014-2015 with 27 megatonnes of waste disposed of in landfills across Australia. Landfills can impact on air, water and land quality. In 2014-15, around 49% of municipal waste and 36% of commercial, industrial, construction and demolition waste went into landfill.[38]
- *Asbestos is a major source of hazardous waste in Australia*. A report prepared for the Department of the Environment in June 2015 found that asbestos-containing waste was the second most produced type of hazardous waste in the preceding year, accounting for 18% of the total weight – an increase from 12% in 2012-13.[39] Asbestos-containing waste was measured in 2014-15 at 1 007 659 tonnes. Of the total disposed-of asbestos-containing material, 97% went to landfill licenced by regulators for receiving asbestos and the remainder was stored.[5]
- *Waste levies are on the rise, but the trend is inconsistent for asbestos waste.* In recent years, state and territory governments have established policy settings to boost investment in resource recovery infrastructure, including rising landfill levies with significant increases between 2006 and 2016 in NSW (550 percent), Victoria (300 percent), South Australia (310 percent) and Western Australia (710 percent).[41] Fees for ACMs and asbestos contaminated waste have increased in the ACT and NSW in line with general waste. Although, the ACT has two waste facilities that will accept small amounts of domestic asbestos waste for free. [108,109,110] Other states have applied lower levies for asbestos waste, or provided an exemption from fees altogether for certain amounts.[111, 112, 113] One exception is WA where asbestos contaminated waste is subject to the same general landfill levy. [114]
- *Leading economies are implementing strategies to promote the circular economy*. In 2014, the European Commission's Directorate-General for the Environment announced a Europe 2020 Strategy for smart, sustainable and inclusive growth, aiming to stimulate investments in green technologies and sustainable business. The European Resource Efficiency Platform (EREP) aimed in 2014 to increase resource productivity by over 30% in 2030 compared to pre-2008 levels. This is forecast to correspond to an additional 2 million jobs in Europe along with a 1% boost to GDP when compared to the business-as-usual scenario.[37]

- *Australia continues to promote the shift towards a circular economy*. In 2014-15, 58% of Australian waste was recovered for reuse, up from 49% in 2006-07 (see Figure 8).[38] South Australia (SA) is emerging as a leader: a report estimated that 93% of the state's masonry, and 28% of plastics, were subject to resource recovery.[42] If the circular economy concept were to be applied more fully in SA, the report predicts that up to 25 700 additional full-time equivalent jobs could be created by 2030, along with a potential reduction in greenhouse gas emissions of 27% (7.7 million tonnes) over the same period.[42]
- *Asbestos risk will be increasingly important for recycling industries*. According to the EU Construction and Demolition Waste Management Protocol (a world-leading example), one of the key objectives in recycling is the proper decontamination of hazardous waste. Asbestos is specifically identified by the EU as a key contaminant risk to recyclable materials. Possible contamination could lead to reduced market confidence in recycling, which is a potential threat to the maximisation of resource productivity. To ensure that recyclables are not contaminated with asbestos, the EU recommends transparency in waste management and recycling, for which documentation and data collection are fundamental.[43]

Illegal dumping of ACMs in Australia

Examples of successful prosecution of illegal dumping of ACMs include:

- The New South Wales Land and Environment Court in May 2018 sentenced a waste dumper to three years jail, with a non-parole period of two years and three months, for a series of illegal asbestos dumpings in 2015 and 2016. It was the first sentence handed down under anti-dumping legislation that was enacted in 2014, and the offender was also ordered to pay all legal costs and pay for advertisements listing his crimes, in order to deter other dumpers.[106]
- The Victorian Environmental Protection Authority prosecuted a person in May 2016 for illegal dumping, issuing a fine of $5 000 and $95 000 in remediation costs.[23]
- In March 2016, the South Australian Environment, Resources and Development Court fined a person $7 200 for illegal dumping of asbestos and ordered payment of a $13 000 clean-up bill.[23]

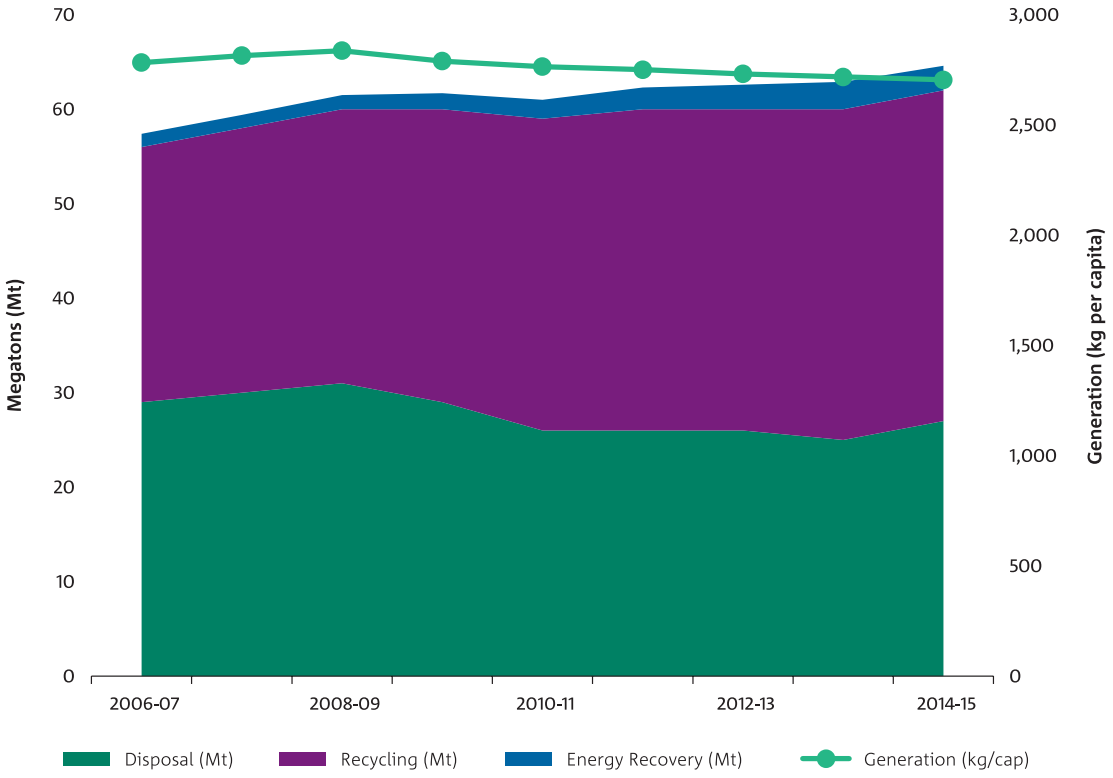


Figure 8. National waste generation and fate between 2006-07 and 2014-15
Source: Department of the Environment and Energy[38]

3.4 Technology enabling work and automation

Advances in laser and hyperspectral imaging techniques along with augmented reality technology could make real-time detection feasible, alerting workers to elevated levels of asbestos fibres or the presence of ACMs in wall, ceiling and floor systems. Advances in robotics and artificial intelligence are paving the way for smart robots that can operate in the built environment and undertake dangerous tasks in place of humans.

IMPACT: Real-time detection can help workers better manage exposure risk, particularly in situations where in-situ ACMs are difficult to identify. Human workers could also be removed from handling ACMs altogether, especially for high-risk scenarios such as post-disaster clean-up operations. However, human users and maintenance crews may not notice if machines become contaminated.

POLICY IMPLICATIONS:

- **Awareness about the proper use of technologies, and their strengths and weaknesses, will become important to minimise the risk of complacency**. This includes awareness among equipment maintenance workers who may not have to handle asbestos directly, but be required to service or monitor equipment that does.
- **Questions about liability for equipment failure, particularly with autonomous systems, will require attention**. This will ensure that all parties have required insurance and risk management in place.
- The degree of investment in research and development, and deployment of ACM identification and handling technologies could impact their speed of development and adoption.
- **Geospatial and satellite technologies can be used to build a real-time national ACM exposure risk map**. Effective management of accurate and complete datasets will be important to help future workers manage exposure risks.

KEY FACTS UNDERPINNING THIS MEGATREND:

- *Real-time environment scanners are increasing the visibility of asbestos exposure*. An example of mobile computing and laser technology being used to help raise awareness about asbestos in the environment is the Asbestos Location Equipment in Real-Time (ALERT) project, initially an EU-funded mix of businesses aiming to develop a cost-effective and mobile way of allowing workers to rapidly assess their external environment. The result was a real-time warning device to detect friable asbestos fibres, functioning much like a smoke detector.[44]

Source: Image courtesy of DAQRI. https://daqri.com/products/smart-helmet/

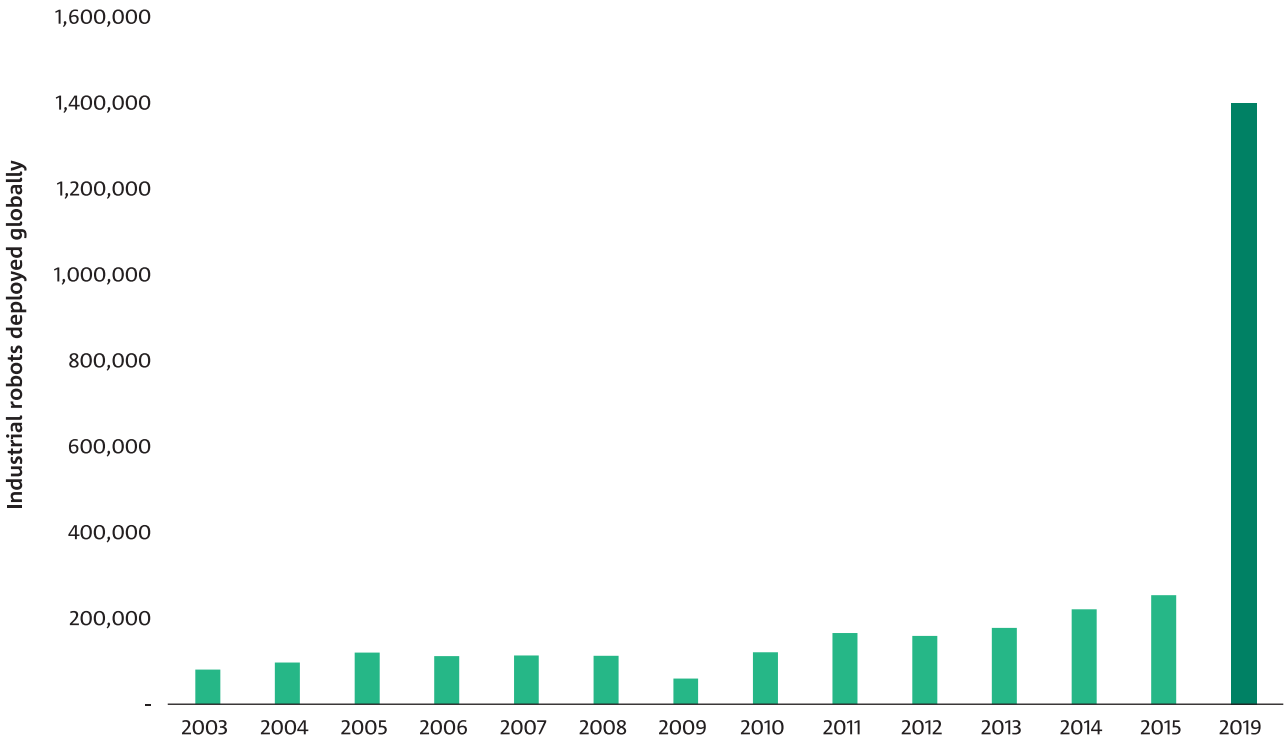


Figure 9. Global deployment of new robots with 2019 projection
Source: International Federation of Robotics[47]

- *Emerging augmented reality safety systems can bring timely workplace risk data and sensor information to workers*. Australian startup The Safety Compass is commercialising a smartphone-based augmented reality application that communicates real-time safety information so that workers have easy access to the information they need to work safely. Such systems will migrate to wearable visors and helmets in the coming years. The company Daqri has developed technologies such as smart helmets and glasses that could enhance human capabilities and awareness in industrial or dangerous environments.[45] These augmented reality capabilities could be combined with real-time asbestos scanning to enhance the awareness of workers dealing with asbestos.
- *Robots are increasingly contributing to the production of goods and services*. Using robot application data gathered from 17 countries (including the UK, the US and Australia) – spanning 14 industries between 1993 and 2007 – researchers found a more than 150% increase in the number of robots used per million hours worked (called 'robot densification').[46] Worldwide annual sales of industrial robots have accelerated from an average of 115 000 units per year between 2005 and 2008 to 183 000 units per year between 2010 and 2015.[47] As shown in Figure 9, this figure is expected to increase almost eightfold by 2019. China in particular is emerging as a global leader in automation, having grown its operational stock of industrial robots from 17 000 units in 2006 to 340 000 in 2016.[48] An increasing share of automated production will change the kinds of jobs that people do, which will alter the patterns of workers' exposure to asbestos.
- *Dangerous manual labour will be increasingly replaced or enhanced by robotic technologies*. The US Defence Advanced Research Projects Agency (DARPA) has been investing heavily in developing smart robots. DARPA conducted a global challenge to accelerate the development of disaster response robots.[49] The challenge concluded in 2015, having covered a range of tasks that robots would need to carry out during disaster reconnaissance and recovery, including driving vehicles, opening doors, walking up stairs and uneven ground, and turning valves.[50] Wearable robotic suits – such as HAL (Hybrid Assistive Limb), developed by the leading robotics company Cyberdyne – have been

Hyperspectral imaging ACMs

Hyperspectral imaging can be a non-destructive, non-invasive tool for asbestos identification. Often mounted on Unpiloted Aerial Vehicles (UAVs), hyperspectral cameras are already being used to remotely sense and identify asbestos in composite roof tiles, map asbestos concrete roofs, and detect uncontrolled disposal of asbestos in rural remote areas.[55-57]

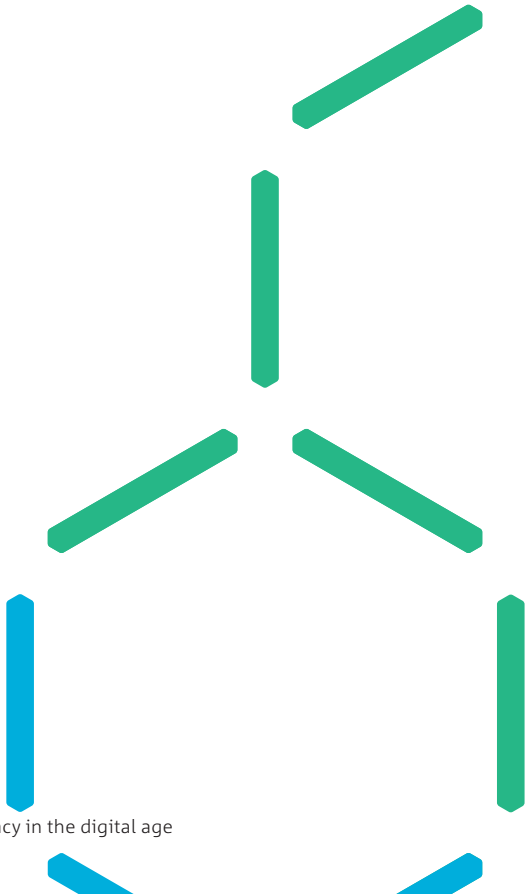
With the advent of new and cheaper sensors, imaging spectroscopy can potentially be developed for on-site hand-held instruments to identify potentially asbestos-containing materials during construction or demolition work. Such instruments would require further research and development to adapt small-form factor sensors and spectral recognition techniques for wider deployment in building-site conditions.

Infrastructure failure prediction analysis

By using the vast datasets of infrastructure providers, data analytics can predict when failure of ACMs – generally in the form of pipes – may occur.[58] This enables preventative maintenance to greatly reduce the number of failures, and consequent need to react to incidents that include damaged ACM.

designed to help the wearer perform heavy lifting and walk on uneven terrain.[51] Also called exoskeletons, these suits can be powered or unpowered. They are being brought to the industrial market by several companies, including leading electronics firm Panasonic.[52]

- *Automated detection is reducing the time and labour required to estimate asbestos concentrations*. Airborne asbestos concentrations in the atmosphere are often estimated using phase contrast microscopy (PCM), which is relatively cheap but requires significant time input from a human expert to distinguish asbestos fibres from other spherical particles. In 2011, scientists reported developing an automated version of PCM called high-throughput microscopy (HTM), which can automate this process, enabling local asbestos concentrations to be measured more quickly.[53]
- *Satellite and digital technologies are increasingly helping to identify concentrations of ACMs*. A report written for the US Geological Survey, in cooperation with the US Environmental Protection Agency, has identified remote sensing technologies as increasingly important for understanding risks related to human health.[54] Hyperspectral remote sensing uses electromagnetic energy across a spectrum of very narrow wavelengths to detect the molecular structure of materials, including asbestos. The technology has been tested beyond the laboratory in geospatial data collection, for example to map asbestos-cement roofing in Europe.[55]



3.5 DIY renovators and the changing workforce

The number of untrained people conducting activities that involve ACMs is on the rise, including home renovators and vulnerable workers in the gig economy. Homeowners have been updating old properties themselves to cut costs, but lack knowledge and experience with managing asbestos exposure risk. Blue-collar jobs are in decline, and an increasing number of gig workers are operating in the 'handyman' and home services market, reaching customers through popular online platforms such as Airtasker. The gig economy is characterised by non-traditional employment relationships.

IMPACT: Potential for more work to be carried out by people with low levels of asbestos awareness and poor risk management practices.

POLICY IMPLICATIONS:

- **Detailed risk profiles of houses containing ACMs are not available to DIY renovators**. There is a lack of specific, up-to-date information for individuals who desire to renovate their houses. They may also be unaware of the risks regarding potential imports with ACMs from platforms such as Alibaba.
- **Changing workforce towards a greater share of white-collar workers could result in a shortfall in trained workers to undertake asbestos-related work**.
- **The growing pool of self-employed workers offering their renovation services via relatively new gig platforms such as Airtasker highlights the importance of maintaining awareness about existing safety laws among platform providers.**

KEY FACTS UNDERPINNING THIS MEGATREND:

- *An increasing share of Australian homeowners are being exposed to asbestos, via DIY renovations*. A Roy Morgan Research study from 2017 estimated that 62% of Australia's 13.6 million homeowners (or 8.4 million people) had done some form of renovation in the previous 12 months, up from 57% (or 7.5 million people) in 2013.[59] A study of the WA Mesothelioma Register has found that asbestos exposure via home renovation is an increasing problem for the State.[60] Since 1981 in WA there have been 87 cases of mesothelioma attributed to asbestos exposure through home maintenance and renovation. Asbestos exposure during renovation was increasingly observed as a cause of malignant mesothelioma over the last four years of the study (between 2005 and 2008), accounting for 8.4% of cases among men and 35.7% among women.
- *A decreasing share of blue-collar jobs could reduce asbestos awareness*. Australian jobs have boomed in the service sector since the 1950s.[61] This post-industrial shift means that white-collar work has been growing as a share of national employment, particularly the occupations of 'community and personal services', 'professionals' and 'managers'. Meanwhile, all blue-collar occupations have experienced a decline in their national employment shares, including occupations such as 'technicians and trades', 'machinery operation and driving' and 'labouring'.[62,63] Figure 10 uses ABS data to illustrate the divergent growth patterns between production and services industries.[63]

- *The annual number of asbestos-related job postings has more than doubled*. Burning Glass Data used web scraping to research the number of job adverts including the term 'asbestos'. While they accounted for only 0.01% of the total, the number grew from 109 in 2013 to 259 in 2017, with NSW and QLD accounting for the largest shares. The main categories were 'asbestos labourers' (12%) and 'asbestos removalists' (11%). Around 30% of asbestos-related jobs required specialised skills involving pollution reduction, removal and remediation.[64]
- *Schools and housing are the most significant sources of prolonged asbestos exposure*. In 2015-16, schools and residential housing comprised 52% and 42.58% of asbestos register cases respectively. In 35.77% of cases, the exposure was non-occupational and in 64.23% it was occupational.[65]
- *The gig economy is small but growing*. The gig economy refers to forms of contingent work arrangements where individuals contract their labour through digital platforms such as Uber, Airtasker, Freelancer or TaskRabbit. Most research suggests the size of the gig workforce in Australia remains small. For example, according to the Grattan Institute, it is likely that less than 0.5 percent of adult Australians (80 000 people) work on peer-to-peer platforms more than once a month.[66] However, these numbers are likely to grow as more gig platforms emerge and existing ones expand. This growth might explain recent ABS data, which shows the 'secondary jobs' market growing faster than 'main jobs' in the past few years.[67]
- *Work in the gig economy is complicating issues of accountability for work health and safety*. Gig economy workers on 'miscellaneous task' platforms (e.g. Airtasker, Gobi, Freelancer, etc.) are likely to encounter a broader range of risks in a variety of environments. The platform may find it difficult to manage these risks and may have limited influence over how or where work is performed. Given that many Australian homes have ACMs, the rise in miscellaneous home-related tasks could increase exposure risks. Although the WHS risk and controls involved in the work of gig workers are well known, risks can be exacerbated by lack of training, lack of certification, lack of knowledge or understanding of relevant regulations, lack of clarity in work specification, lack of safety equipment and clothing and pressure from tight deadlines. Further, gig workers are unlikely to be eligible for workers' compensation if they are injured.[107]

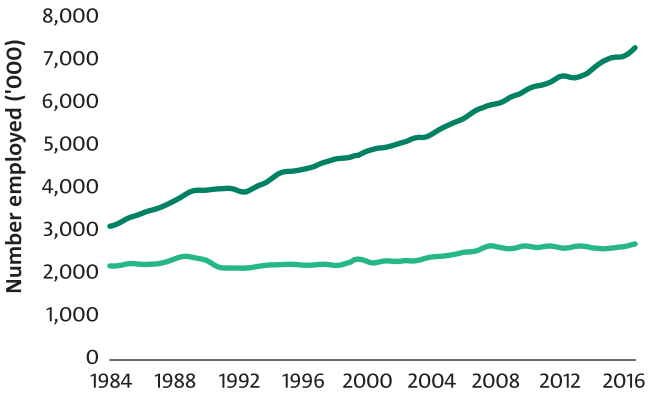
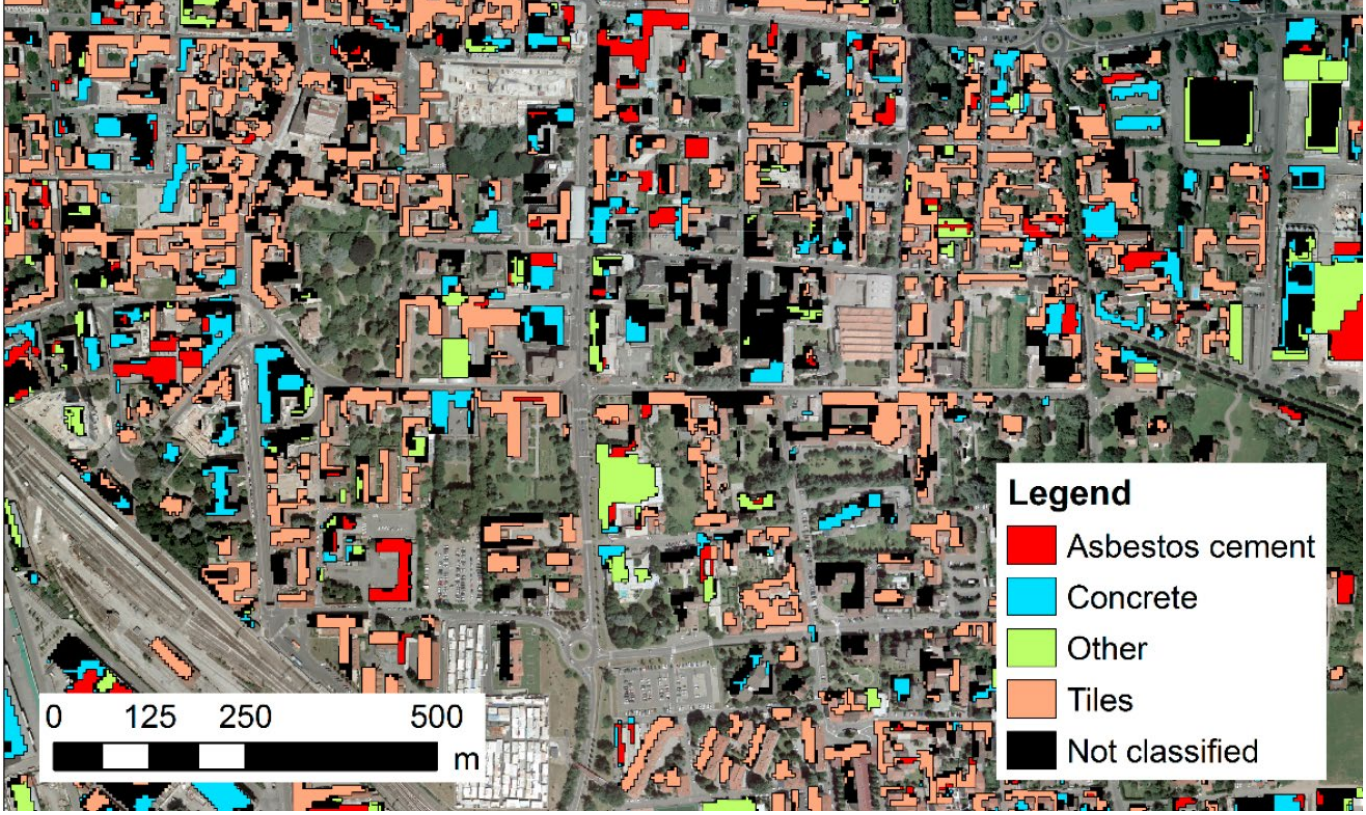


Figure 10. Australians employed in services (dark green) versus production industries

(Production industries include agriculture, forestry and fishing, mining, manufacturing, electricity, gas, water and waste services and construction. Services industries include wholesale trade, retail trade, accommodation and food services, transport, postal and warehousing, information media and telecommunications, financial and insurance services, rental, hiring and real estate services, professional, scientific and technical services, administrative and support services, public administration and safety, education and training, health care and social assistance, arts and recreation services and other services.)

Source: Australian Bureau of Statistics[63]



Source: Cilia, C, Panigada, C, Rossini, M, et al. (2015). Mapping of asbestos cement roofs and their weathering status using hyperspectral aerial images. ISPRS International Journal of Geo-Information, 4, 928-941.

3.6 Radical transparency and heightened awareness

Imaging and mapping techniques and sensors detecting hazardous materials are becoming more sophisticated. This is part of a general trend called Industry 4.0, in which emerging and sophisticated technologies – from smartphones[5] to augmented reality – are replacing older work processes. Increasing adoption of these technologies could raise asbestos awareness substantially. One example is the National Map,[6] a geospatial platform that has the potential to make the location and identification of ACM much easier by allowing the public to interrogate and visualise datasets of ACM stock. The public could check to see if a property is contaminated, or was subject to a removal process.

IMPACT: As awareness grows, so could public health concerns and proactive management of exposure risk. Greater public awareness could cause a push for accelerated removal of ACMs, increasing the waste stream to a point that exceeds the industry's capacity. On the upside, more data about ACMs and their condition can enable more cost-effective inspection and maintenance regimes.

POLICY IMPLICATIONS:

- **Growing share of digital natives in the workforce means that policy makers could leverage digital platforms to improve public communication**.
- **There should be a more ubiquitous and nationally oriented strategy towards ACM-related data collection, storage and use**. Steps could include improving and consolidating data collection strategies across states, incentivising ACM reporting to foster an open data framework, and distributing this data in accordance with local needs to minimise the risks of ACM exposure.
- **ACM-related data needs to be publicly communicated with mindfulness of the potential for causing public hysteria**. Uninformed citizens may have an exaggerated sense of ACM exposure risk.

KEY FACTS UNDERPINNING THIS MEGATREND:

- *The market for sensors and the internet of things*[7] *is booming*. According to a recent Gartner report, there were over 8 billion interconnected devices in 2017, up 31 percent on the previous year. By 2020 that figure is projected to grow to over 20 billion (see Figure 11).[70]

[5] Context Info: Configurable Context Data Collection Platform for Android Devices https://research.csiro.au/data61/context-info-configurable-context-data-collection-platform-for-android-devices/
[6] National Map https://research.csiro.au/data61/national-map-2/
[7] Internet of things (or IoT) refers to a network of objects collecting and exchanging data through embedded sensors. The IoT also includes artificial intelligence algorithms processing vast flows of data to efficiently manage physical assets, products and processes without direct human intervention.

ICT market research organisation International Data Corporation estimates the global market to increase from just over US$800 billion in 2017 to almost US$1.4 trillion by 2021.[71]

- *The world is increasingly digital and investments in artificial intelligence will help manage exploding data volumes*. One estimate suggests that from 2010 to 2014, private investment in AI grew from US$1.7 billion to US$14.9 billion, and was on track to grow again by nearly 50 percent year-on-year in 2015.[72] Statistical analysis of 150 countries between 2004 and 2010 revealed that digitisation – the process of analogue information increasingly becoming available as digital data – is both a direct and indirect cause of GDP growth.[73] Digitisation brings possibilities for radical transparency and heightened awareness regarding asbestos risk and management, and could enable better-informed decision making.
- *Millennials, are concerned about global challenges and ethical consumption*. The global growth of connected devices and P2P platforms has captured an entire generation – and, as these 'digital natives' increasingly come to dominate the population, their preferences will begin to shape market expectations and supply chains. The so-called iGeneration, born between 1986 and 2006, comprised 26.2% of Australia's population in 2014.[74] Members of this generation typically display greater awareness of global issues: a global Deloitte survey of college-educated private sector workers born after 1982 found that 59% felt at least a fair amount of accountability for environmental protection, 53% for social equality and 39% for the behaviour and actions of large businesses.[75] Rising digital literacy will increase expectations around data provision and transparency, particularly for issues relevant to health and environmental sustainability.
- *Health awareness is on the rise*. Given that cancer contributed to more Australian deaths than any other disease in 2013,[76] asbestos-related cancers may increasingly come under the spotlight. A 2017 report by ANU has revealed that 66.8% of respondents were 'very interested' in health issues (rather than moderately interested, or not at all interested).[77] Growing health consciousness is manifesting in many other ways, including through the shift of preferences towards organic and environmentally friendly (green) products in recent years.[78] Woolworths reported a $60 million increase in 2015 in purchases of organic products.[79] Organic certification group Australian Organic reported that buyers' concern for their own and their families' personal health was the strongest driver for 2016 organics growth.[79] Additionally, more emphasis on health is plausible given Australia's ageing population. As noted by the Australian Public Service Commission, older workers are more likely to be aware of work health and safety considerations and possible hazards; they tend to develop their own coping strategies to help reduce injury risk; and they may self-select out of more risky occupations as they age.[80]
- *Indicators of asbestos awareness are rising*. The number of Australians listed in the National Asbestos Exposure Register (NAER) increased by 15.8% from 1528 responses in 2015-16 to 1770 responses in 2016-17.[8] According to the ASEA's records, the number of people registered with the NAER has grown in each year of its operation, totalling 5776 since June 2013.[8]

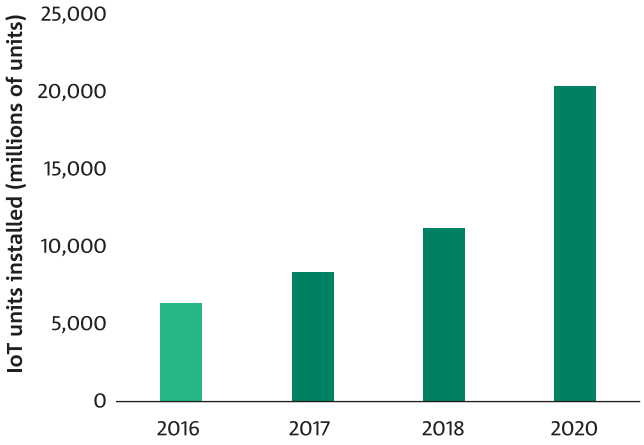


Figure 11. Number of IoT devices in 2016 and projected to 2020
Source: Middleton, et al. [70]

[8] Data provided by ASEA from their official records system.

‘Citizen science’ approach to mapping hazards

Growing awareness about environmental toxicity, coupled with enabling digital technologies, is unlocking the potential for citizen-led science movements that make exposure risks visible. A recent example is Safecast (https://safecast.jp/en/), a global community measuring radiation in the wake of the Fukushima Daiichi nuclear power plant meltdown. The Safecast platform enables members around the world to post regular radiation readings, which in aggregate can help citizens track the spread of radiation. Founders of the project were concerned about the lack of radiation data in the days and months following the accident and developed a simple mobile sensor technology that could be self-assembled from a kit. Radiation data is being used to help people make decisions about where to relocate, and identify hotspots for negative environmental and health impacts.

Other examples of citizen science addressing air quality include the ‘aircasting’ app[83] and the US EPA’s citizen science programme.[84]

3.7 Urbanisation and in-fill development

Australia’s population is projected to grow substantially over the coming decades, and most of this growth is expected to be absorbed by major metropolitan areas. State and local governments are placing greater emphasis on more efficient use of urban land and infrastructure through in-fill development. This focus on increasing spatial efficiency is likely to involve redevelopment of low density suburbs. In-fill development is often found to be optimal within a 25 kilometre radius from a capital city – post-war suburbs where there is a high risk of ACM exposure because construction occurred prior to the 1980s. As a result, urban densification and in-fill development are significant factors to be considered in the national evaluation of asbestos risk management and strategy.

IMPACT: Large scale redevelopment of post-war suburbs will create a higher demand for workers experienced with asbestos identification, removal and transportation. Improper demolition and containment practices could impact nearby construction workers and communities. This demolition activity will also increase pressure on workers in disposal facilities.

POLICY IMPLICATIONS:

- **Managing exposure risk, including identifying and tracking ACMs from the built environment through the waste stream, will require strong property industry cooperation in line with development trends**. The drive for urban planners to maximise space and infrastructure utilisation in and around capital cities will be an impetus for in-fill development and re-urbanisation, in the face of population pressures.

KEY FACTS UNDERPINNING THIS MEGATREND:

- *Australia's population has grown over the last 10 years and is expected to continue growing in the coming decades*. As of 30 June 2016, Australia's estimated resident population (ERP) was 24.2 million, an 18.4% increase (3,759,843 people) on 2006 (see Figure 12).[85] All states and territories grew their population during this period:
  - WA's ERP grew the fastest over the period, with a 24.8% growth rate;
  - VIC grew by 22.1%;
  - QLD grew by 21%;
  - NT grew by 20.4%;
  - NSW grew by 14.8%;
  - SA grew by 10.3%; and
  - TAS grew by 5.8%.
- *Most population growth over the past decade was absorbed by capital cities*. The ABS has noted that Greater Capital Cities in Australia grew by 21.7% (2 890 769 people) in the 10 years to 2016, whilst the Rest of Australia grew at the substantially lower rate of 12.2% (866 845 people). Most of regional and rural Australia has witnessed a decline in population due to rural-urban drift.[85] According to World Bank data, Australia's urban population increased its share of the total from 81.5% in 1960 to 89.6% in 2016.[86]
- *The high cost of expanding urban infrastructure is prompting Australian state and local governments to focus on growing cities through densification*. Many city governments are advocating for 'smart growth', with the country's largest cities now adopting in-fill development targets in the order of 50-70% of new dwellings.[87,88] Studies have shown that the cost of providing infrastructure to greenfields are higher than in-fill development.[89,90] For example, an analysis of the initial capital costs for infrastructure per 1000 dwellings in inner suburban development (redevelopment) in Perth were found to be a little over $50 000 compared to upwards of $130 000 for development on the outskirts of the city.[90]
- *Affordability concerns can be addressed through in-fill development of low density post-war suburbs*. As housing affordability has declined in Australia, the drive towards more affordable solutions will involve wide-scale

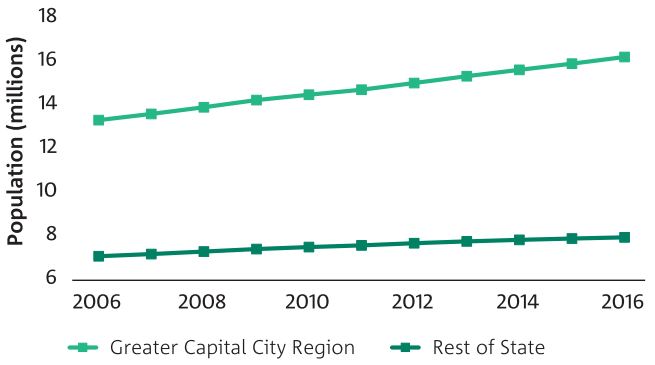


Figure 12. Population growth of Australian capital cities versus rural and regional areas

Source: ABS [85]

redevelopment towards higher density urban form. Population density in major capital cities increased in the 30 years between 1981 and 2011; the increasing population density in and around Australia's capital cities was largely driven by the 'smart growth' and 'New Urbanism'[9] movements of the 1990s.[91] Evidence from Sydney and Perth suggests that rising population densities can be better accommodated by larger-scale and higher density developments that increase space utilisation.[92] Lower prices can be delivered through smaller lot sizes and housing. In a 2011 case study of Melbourne, a Monash University report concluded that in-fill development poses less of a regulatory challenge if done on a wide scale, as opposed to a succession of fragmented small-scale projects. The Monash study recommends suburbs 7 to 25 kilometres from Melbourne's CBD as optimal for in-fill development. Much of this area was developed between 1950 and 1979,[93] and is characterised by higher concentrations of ACMs.[94,95]

[9] New Urbanism is an urban design movement that advocates for more sustainable, compact and walkable neighbourhoods

4 THE SCENARIOS

Scenarios are useful tools for informing strategy. They are particularly good for shining a light on the elephant in the room, or revealing the blind spot or issue that is being overlooked or dismissed as irrelevant. A well-written scenario will challenge orthodoxies and get the audience to move their thinking outside of their comfort zone. Strategies that are informed by the big picture and critical thinking present greater value and manage risk better than those that are not.

Scenarios do not have to be completely right to produce value. The future cannot be predicted and this report does not claim to make forecasts. Asking good questions about plausible situations and thinking about their implications is of primary importance. The scenarios illustrate how certain events could unfold and what may happen if they do. Not all aspects of a given scenario will eventuate in reality, but by rehearsing what could plausibly happen as a thought experiment, decision makers are able to rehearse their responses to these implications ahead of time. This is particularly important when the investment or benefit is a long-term proposition.

The scenario development method used in this report is based on the deductive reasoning approach taught at the Oxford University Scenario Planning School.[97] This process involves identifying two factors with the most uncertainty and impact on the focal topic; in this case, the future of asbestos-related work.

A review of literature and analysis of the interviews revealed a number of important factors shaping the future of asbestos-related work. Data61 worked with ASEA to identify two factors that are likely to have the most impact and uncertainty:

1. The extent to which there are technologies to address asbestos exposure risks associated with in-situ management, and removal and disposal
2. The extent to which governments, industry and the general public are aware of the threat of asbestos exposure and proactively manage the risks

Figure 13 shows these factors crossed to create a four quadrant scenario space.

Figure 13. Scenarios for the future of asbestos management

The microPHAZIR™ AS Asbestos Analyzer

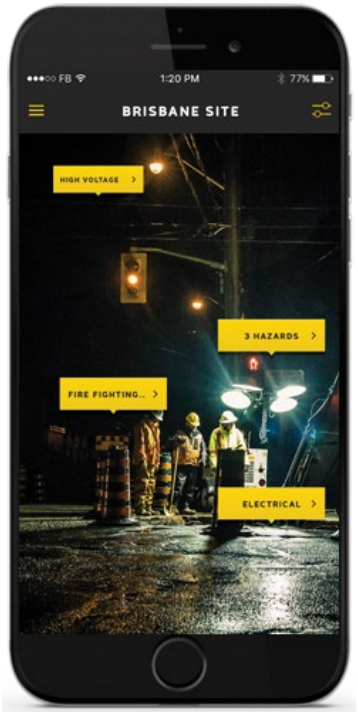
The first axis stems from issues impacting asbestos exposure risk, including in-situ management and cost of removal and disposal. Feedback from expert interviewees suggested that the industry is not structured to incentivise removal. This issue appears to be long-standing, shaping decision making and behaviour towards in-situ management. Some experts intimated that technology has to address the challenge of identifying asbestos in buildings and the high costs of removal and disposal. Some interviewees expressed concerns about the reliability of new technologies such as laser imaging techniques to identify ACMs. The robotics literature on disaster response and assistive technology is growing, and this technology can substitute for humans in unsafe or high-risk tasks. However, there is uncertainty about whether technological solutions will develop and mature in line with industry expectations.

The second axis emerged from consistent concerns expressed by experts in the study about the level of asbestos awareness and capabilities across the industry and society at large. The approach to exposure risk is fundamental to asbestos safety and handling practices, and decisions about whether to manage in-situ or remove. Some interviewees cite concerns that in-situ management will make the material harder to identify and manage in the future (e.g., by painting or sheeting over with plasterboard) – 'out of sight, out of mind'. Education campaigns are raising the profile of asbestos risk, but future generations may be oblivious to or dismissive of the risks if they cannot see the material or do not know it is there.

4.1 Horizontal axis: Technological solutions (limited to substantial)

The horizontal axis relates to the extent to which new digital tools and technologies can address challenges with identifying, removing and disposing of ACMs. Both endpoints represent technological progress from today: a future with the same or less technology than the present is unlikely. Even a minor advancement in tools and technologies to manage ACMs will help address exposure risks.

The Asbestoprobe, a portable asbestos detection device



Safety Compass, real time safety through augmented reality

4.1.1 TECHNOLOGIES TO ADDRESS ASBESTOS WORK CHALLENGES ARE LIMITED

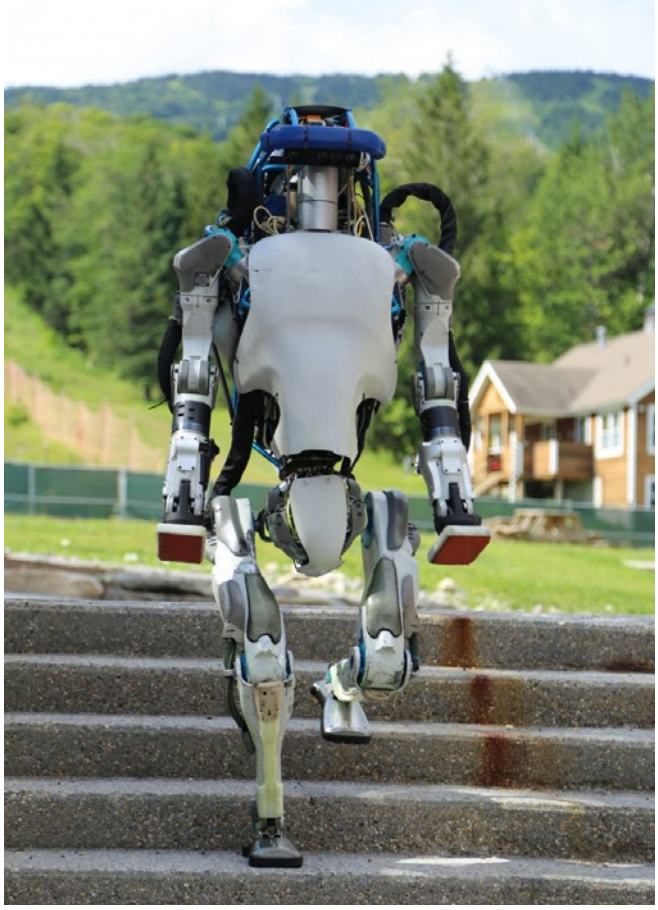
This end of the axis represents an incremental change from today's technologies. In this future, the main advances have been in asbestos detection and development of augmented reality systems that can present information to users about contamination in their work environment. However, the main constraining factor is that asbestos data platforms are either not open or fragmented across a mix of private and public sector agencies, and only subscribers can access information about the location of asbestos and other hazardous materials in the built environment. Furthermore, functionality for some technologies has fallen short of requirements, with many users experiencing false positives and negatives.

Today's technologies pointing to this future include:

- Hyperspectral imaging or spectroscopy – infra-red imaging sensors have been researched and developed in recent years.[98] Handheld devices (e.g. microPHAZIR and Asbestoprobe) are commercially available to cut costs related to lab-based detection techniques.
- Augmented reality visors used in construction for accessing building information modelling data and safety systems (e.g. Safety Compass, Daquri and Bridgit).
- Vacuum containment techniques for spot removal and servicing (e.g. MiniContainment).

4.1.2 TECHNOLOGIES TO ADDRESS ASBESTOS WORK CHALLENGES ARE SUBSTANTIAL

This is a future in which detection devices are refined and reliable, with capabilities to detect ACMs behind other materials and sheeting. Exciting breakthroughs have also been achieved in smart robotics, bringing down removal costs and improving safety. Open data issues are well resolved and GIS information has matured to the point where most people are able to assess the probable presence of asbestos through their smart device (likely an



Boston Dynamics' Atlas robot

augmented reality visor). Artificial intelligence assistants communicate with workers about safety hazards in their environment and provide advice about how to manage exposure risk and decide between options to remove or manage the material in-situ. The circular economy is booming, with breakthrough technologies in thermal destruction of asbestos, cost-effectively converting the harmful fibres to safe and useful products.

Today's technologies that point to this future include:

- 3D-imaging scanner Walabot has been developed for the DIY market to help renovators see through walls to identify studs, pipes, cabling and even vermin.
- Hazard mapping platforms are available today, such as Safecast.
- Humanoid robots are currently being developed for disaster recovery and military applications by leading robotics companies such as Boston Dynamics. Exoskeleton suits are also being commercialised for industrial use to help workers with lifting heavy objects, operating heavy tools and walking on uneven terrain
- Thermal destruction technologies that can convert asbestos fibres to an inert, non-toxic and reusable product are available today.[98] UK-based companies ARI Global Technologies and Tetronics are currently commercialising thermal treatment processes for recovery of ACM waste.

4.2 Vertical axis: Exposure risk stance (reactive to proactive)

The vertical axis describes contrasting attitudes and behaviours to managing exposure risk. A reactive stance reflects a future state in which many workers are less aware of the impact of exposure than today and tend to take higher risks. The proactive future is characterised by greater training across the industry and communication campaigns that target the general public, particularly homeowners: in this future, workers take the risk seriously and use the best available techniques to mitigate exposure.

4.2.1 EXPOSURE RISK IS MANAGED REACTIVELY

This is a future in which 'out of sight, out of mind' has shaped worker attitudes to risk. The general public and industry are less aware than today – people take higher risks with procuring products and working with older buildings. In this future, very few people know of anyone who has been impacted by asbestos-related diseases, and much of the stock of building materials managed in-situ has been concealed with various layers of sheeting and wet coatings. Popular online renovation/trade shows and publications do not discuss asbestos risks.

4.2.2 EXPOSURE RISK IS MANAGED PROACTIVELY

In this future, workers are more aware and better trained. Concerted effort and investment has been made by government, industry and worker bodies to communicate and educate trades professionals and DIYers. Popular online renovation/trade shows and publications demonstrate high safety awareness and run special segments on asbestos exposure risk and how to approach renovation work in older buildings. Educational websites and apps are mature and constantly updated, reflecting the changing and diverse information needs of workers in a growing gig economy. For example, educational resources are offered in foreign languages to assist workers who have newly arrived from other countries.

4.3 Scenario 1: What asbestos?

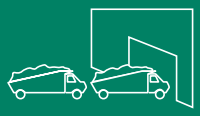
Combining limited technological progress and a reactive stance, this scenario is characterised by ad-hoc management of exposure risks, with new risks from non-conforming products passing through supply chains undetected. ACMs are hidden and too difficult to locate without active destruction of products and buildings. Workers do not yet have the technology to 'see through walls' in buildings to identify ACMs and many feel the risks are too small to worry about. Most people do not suspect asbestos in consumer goods, and assume the odd discovery of contamination in new products to be isolated incidents, rather than a potential systemic threat. In this scenario, the gig economy has grown incrementally over the past 10 years, enabling a diverse workforce which new Australians and young people can enter with minimal barriers.

What might trigger this scenario?

- Asbestos-related deaths peaking in 2020-2025. In 2028 deaths caused by asbestos exposure are at very low levels, causing the community to largely forget about the issue.
- Gig economy platforms rise to prominence for low-cost labour, especially for job types experiencing labour shortages.
- Health/injury risks associated with natural hazards increase dramatically with climate change, and crowd out concerns about asbestos exposure.
- Poor integration of data across government agencies and lack of investment in data infrastructure means that people have lost track of the location and extent of ACMs in the built environment.

Questions/risks for policy makers:

- How to maintain high public and industry awareness in a future where ACMs are concealed and the health impact is relatively small?
- What can be done to address legacy risks related to concealment of ACMs by previous generations of renovators?
- Investments in data infrastructure might not be seen as a priority for mitigating exposure risks if people perceive the issue to be relatively minor or well-managed with existing systems.



4.4 Scenario 2: Bursting at the seams

Combining limited technological progress with a proactive stance, this scenario sees detection and mapping technologies make the location of ACMs more visible. Most property buyers include checks for ACMs during building and pest inspections. Building inspection companies are highly skilled and knowledgeable about the strengths and limitations of their methods, but they cannot keep up with demand. Buildings where ACMs have been detected are old, and the ACMs are typically in a degraded state requiring removal. The removal market is booming, and so are the costs. The waste stream has not peaked but continues to climb, with waste management facilities and removal workers struggling to meet demand. Online labour hire platforms are enabling many untrained workers to enter the market, and illegal dumping practices are prevalent. Many workers and building occupants are being exposed due to poor removal practices by an untrained workforce.

What might trigger this scenario?

- Climate change-related issues such as more frequent and intense storms, bushfires and heatwaves degrade and reduce the life of ACMs.
- Population growth and densification of cities results in demolition of many post-war suburbs with high concentrations of ACMs.
- Lack of available landfill sites and/or high landfill levies near major population centres open a 'black market' for illegal dump sites.

Questions/risks for policy makers:

- How to cope with a delayed peak in the waste stream when landfill sites may be constrained and expensive?
- How to manage at-risk workers and communities who may expect awareness of the issue to result in lower risk of exposure?

4.5 Scenario 3: Unsure about the technofix

Renovators and workers who come into contact with ACMs have become relaxed about the risk of exposure in this scenario, which combines a reactive stance with substantial technological progress. The problem seems to have all but disappeared over the past decade of renovation and urban redevelopment. A few industry advocates and agencies maintain the safety message and are trying to promote promising technologies that have been developed internationally. However, workers and companies are not using them due to scepticism about their cost-effectiveness and reliability, when compared with the perceived risk of exposure. The benefits of assistive technologies are undervalued and the risks of exposure are downplayed. The asbestos removal market is immature and little work has been done to demonstrate and evaluate technologies for Australian applications; the industry simply does not have available funds or perceive the need to carry out local trials and develop usage guidelines for workers. High-end technology is used only for major projects, and viewed by many industry workers as an excessive risk mitigation measure. General complacency with ACMs and improper use of technology aids has increased the risk of a new wave of exposure among renovators.

What might trigger this scenario?

- There is an assumption that asbestos risk is a thing of the past – that all the hard work has been done.
- Waste stream volumes decline.
- The prevalence of asbestos-related illness is low.

Questions/risks for policy makers:

- How can the industry adopt and invest in advanced technology when the market is uncertain?
- How to develop and deploy promising technologies when exposure risks are perceived to be low?

4.6 Scenario 4: Informed and tech-enabled

Pro-safety attitudes pervade society in this scenario, with most Australians learning about asbestos and how to use technological aids to manage the risk. Heightened awareness about the health impacts of asbestos exposure is driving significant demand for workers in the removal, transport and disposal of ACMs. Large volumes are flowing into waste management facilities which use advanced low-cost thermal destruction methods to recycle asbestos waste into a non-hazardous material that can be used as an input into the manufacture of building products. Knowledge about available technologies and their strengths and weaknesses is shared through construction industry 'living lab' centres, where professionals can learn about, develop and evaluate technologies that improve safety and performance. As a result, trade professionals are technologically savvy and knowledgeable about all types of hazardous materials and chemicals. School students at primary and secondary levels undertake required course modules on environmental toxicology, including mitigation of exposure risk and protocols for handling chemicals and materials. Gig economy platforms provide online training courses on many aspects of occupational health, safety and environment, including hazardous materials.

What might trigger this scenario?

- A series of natural disasters in Australia and overseas causes severe exposures to asbestos and other hazardous substances, resulting in an elevated incidence of asbestos-related illnesses.
- Higher education attainment and longer life spans increase the importance of public/environmental health to support quality of life.
- Market shifts towards service providers with proven credentials in all aspects of OHSE.
- Deployment of technologies with an untrained workforce leads to high-profile cases of exposure.

Questions/risks for policy makers:

- Is this an aspirational (and preferred) scenario for Australia?
- What could be done to make this future a reality?

5 RESEARCH IMPLICATIONS AND FUTURE ACTIONS

The aim of developing megatrends and scenarios for asbestos-related work was to explore important drivers and plausible futures that could have implications for exposure risks and inform asbestos management policy, research and practice to ensure Australia is well-placed to prevent future asbestos-related diseases. Megatrends were identified through an assessment of relevant trends data, while scenarios were derived from two factors identified as having the most uncertainty and impact on asbestos-related work: technological solutions and exposure risk stance. The resulting scenarios did not offer predictions, but stories that capture what could happen at the extremes of these two axes.

The megatrends and scenarios outlined in this report are useful only if they support conversations and strategy development regarding long-term challenges and opportunities facing asbestos-related work and the workforce. To support this process, this section discusses three key policy implications. These are areas where targeted strategic actions can have the most impact on preparing the workforce and mitigating exposure risks.

IMPLICATION 1: Data infrastructure is underutilised and more investment can enable effective assessment and management of asbestos exposure risks, but this requires appetite to join up datasets and work across governments

In the context of climate change the ageing ACM stock will require removal in the coming decades, increasing demand for qualified workers and disposal sites. Complete and readily available data on ACM quantities and locations, both in the built environment and disposal sites, can support effective planning of workforce needs and mitigation of exposure risks. Similar mapping approaches have been carried out in South Korea to inform priority removal decisions.[99]

However, in Australia there is a shortage of asbestos-related data, limiting the capacity of policy makers to make informed decisions. Existing data about asbestos has been scraped together from collections provided by Queensland, New South Wales, Victoria and Western Australia. Data about contaminated soil and asbestos have also been gathered from landfill reports in which hazardous waste was not specifically tracked. Asbestos individually is tracked only in Victoria, Queensland and South Australia, but New South Wales has accepted landfill data as an appropriate source of asbestos-related information. The lack of asbestos-specific data in the case of New South Wales makes it difficult for decision makers to identify areas of highest risk. Queensland provides certificate-by-certificate datasets which helps for precision analysis and better informs policy decisions.[5]

Strategic actions for policymakers to consider:

- Collaborate across jurisdictions and levels to create an asbestos dataset and mapping application that integrates asbestos registers for both public and private properties. Geospatial mapping of ACMs with natural hazard overlays and urban development activity (i.e. densification, demolition, renovation) can highlight areas of higher risk where targeted investment in education, the workforce and waste management facilities may be required.

IMPLICATION 2: New and emerging hazmat technology could substantially shift/heighten risk awareness and support management and handling of ACMs, but will require vetting and training for their use

This report described new and emerging technologies in the areas of asbestos identification, management, handling and disposal. Breakthrough technologies appear necessary to address industry challenges. However, new technologies require assessment of effectiveness, technical limitations, usability and social impact in order to promote industry confidence and minimise the risk of misuse. Without such assessments, promising new technologies suffer low adoption and a slow path to maturity. Such assessments are unlikely to occur while the market for asbestos removal and removal companies remains relatively immature.

First generation and early version technologies are often expensive and full of 'teething issues', and may require public investment in situations where industry lacks certainty or the means to invest in technologies that could have potentially great public benefits. European governments have a long history of supporting structured technology assessment processes to inform adoption across a variety of domains, from clean energy technology to nanotechnology, artificial intelligence and the internet.[100]

Strategic actions for policy makers to consider:

- Explore options for independently examining the effectiveness of key emerging technologies that address major challenges facing asbestos safety and management.
- Consider the best way to disseminate information about hazmat technologies and raise awareness regarding their technical performance and limitations.

IMPLICATION 3: Asbestos removal market changes, workforce changes and new technologies could disrupt the balance between supply and demand for asbestos-related work – labour supply and demand should be monitored to minimise this risk and ensure the safe and efficient operation of the market and effectiveness of reducing future exposure risks

Demand for asbestos-related work could vary considerably in the coming decades. Climate change-related extreme weather and redevelopment and densification in cities, in combination with the ageing ACM stock, could trigger peaks in the waste stream and jobs market. It is very difficult to predict how labour markets will develop over the next 10-20 years. Automation could push more workers into knowledge-intensive and service sector jobs, and simultaneously relegate substantial portions of the workforce to an uncertain employment future.[2] Future research is needed to identify and track workers in the asbestos field and the available jobs that involve management and handling of ACMs. Monitoring and tracking the supply of workers and jobs can help flag workforce constraints or oversupply, either of which could adversely impact the asbestos-related industries: a constrained workforce could drive increases in illegal dumping, while oversupply could elevate unemployment levels and discourage industry investment.

Strategic actions for policymakers to consider:

- Examine the availability of employment monitoring systems to track the balance of jobs and available workforce and skills in asbestos-related industries.
- Explore strategies for addressing labour market challenges under varying scenarios.

6 CONCLUSION

This report used strategic foresight techniques to explore possible outcomes of key trends for the future of asbestos-related risks in the community. Predicting exactly how these trends will impact on how Australians live and work with asbestos is not possible. The intent of this report is not to offer predictions or firm recommendations, but provide decision-makers with insights about what could plausibly happen given the available evidence, and inform strategies that are robust across a range of futures.

Powerful trends are building that will reshape the nature of asbestos-related work and exposure risks over the coming decades. New and emerging tools and technologies can significantly assist all parties with mitigating exposure risk. In the future, machines may substitute for human workers for particularly dangerous jobs, such as post-disaster clean-up of asbestos-containing building debris. Such a prospect may become essential to worker safety as the climate changes and presents more frequent and intense natural disasters that damage vulnerable buildings and infrastructure. Globalisation also poses new and more complex risks as production of building materials and other products passes through different companies and national jurisdictions with different laws, policies and enforcement practices. Many countries that Australia trades with are not as advanced in eliminating asbestos from the built environment. In fact, some of our closest trading partners still mine asbestos or produce asbestos-containing products.

Megatrends and scenarios have been used by governments of leading economies to help navigate uncertainty and complexity in a rapidly changing world.[101] Much foresight work has been done on the future of work, in particular. Blue-collar jobs have been a specific area of focus due to the propensity for automation technologies to target dangerous, difficult and repetitive tasks. Recent studies suggest that many of these jobs are at higher risk of being automated over the next two to three decades.[102,103] But this labour market shift could erode important knowledge and skills in asbestos exposure risk management. Understanding labour market dynamics for asbestos-related industries will be critical to managing exposure risks for workers and the wider community.

Using advanced technologies will bring new risks if their strengths and limitations are not well understood, and the impact of technological change could be limited by data deficits. Industry and government stakeholders need to ensure that adoption of new technologies is met with investment in data infrastructure, and evaluation and training programmes are developed to ensure the workforce is able to capitalise on the opportunities and mitigate new risks. While technological breakthroughs are already happening and still more are imminent, users must be aware of technology's strengths and weaknesses, and make judgements about when such tools and devices can and cannot help.

The task of eradicating asbestos-related illness has hinged and will continue to hinge on coordination and collaboration between government and industry. Australia has made genuine strides forward in recent years towards this effort. This report provides insights that can support productive discussions among stakeholders and guide strategy development for the challenges ahead.

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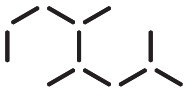

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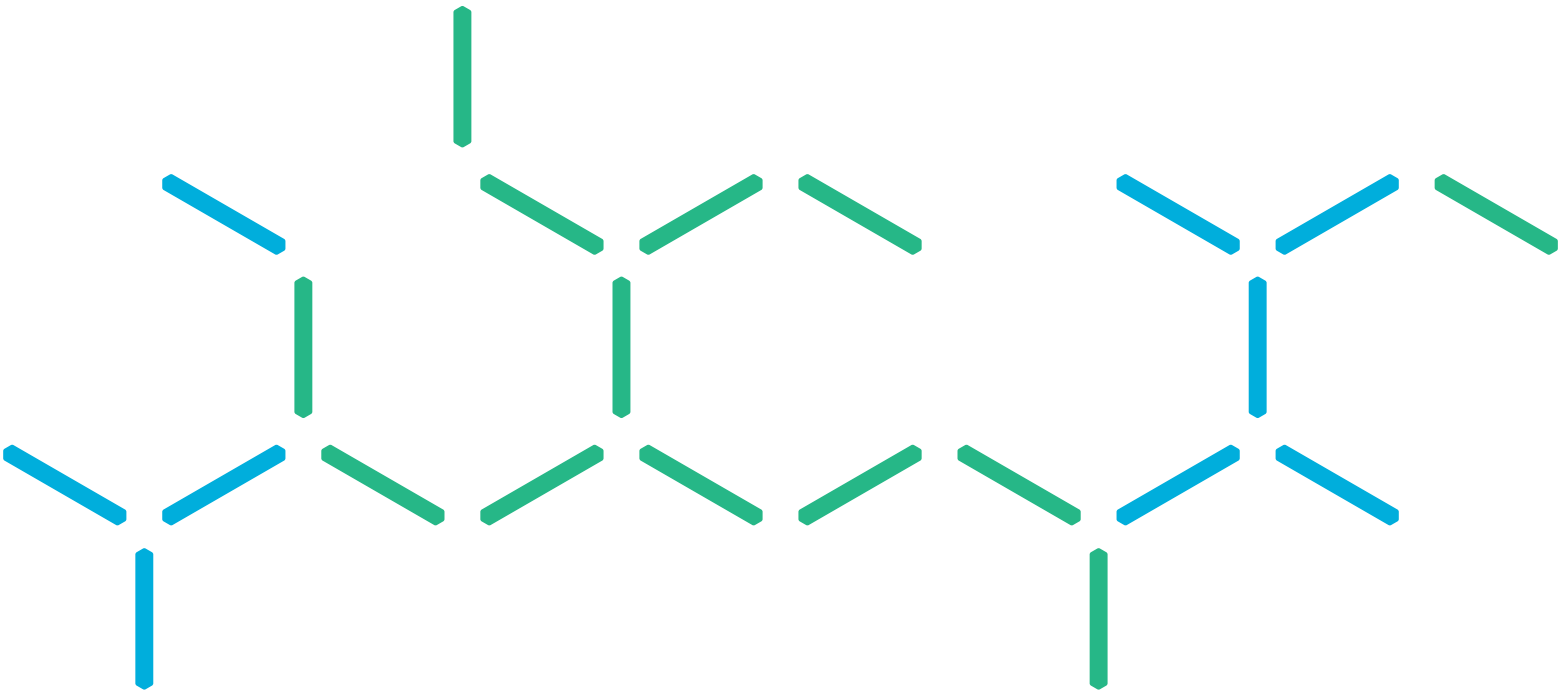

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