Australian Government

Asia-Pacific Economic Cooperation

Current and future value of earth and marine observing to the Asia-Pacific region

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Foreword

The Asia-Pacific Economic Cooperation (APEC) Forum economies are home to 38 per cent of the world's population. Collectively, they contribute 47 per cent of global trade and 60 per cent of global gross domestic product.[1] Since the establishment of APEC 30 years ago, the region has experienced considerable change, including economic growth and significant reductions in poverty. It is anticipated that the Asia-Pacific region will continue to experience dynamic change over the coming years. However, economic growth is expected to slow, while socioeconomic inequality is expected to grow. In addition, at a global level, we face complex environmental problems, trade challenges, policy uncertainty and digital disruption.[2]

Advancements in digital technologies, data analytics and artificial intelligence provide opportunities for collaboration to help address some of these challenges at a regional as well as at a national level. Earth and marine observing (EMO)—the collection, analysis and interpretation of information on the earth's natural systems—is already helping us understand and respond to these challenges. Across the APEC region, there has been significant growth in the technologies that support EMO and the products and services derived from this information.

This report, for the first time, calculates the current economic value of earth and marine observing to APEC economies, and estimates the potential value of EMO by 2030, including from additional collaboration. The economic contribution of EMO is derived from its application to industry (for example to transport, utilities or agriculture), to disaster management, and to broader society. Across the region, EMO data are used to inform better decisions by public entities, private businesses and by individuals.

Each APEC economy is positioned to realise greater value from EMO by 2030. However, not all economies are currently able to take full advantage of all opportunities presented by EMO. Collaboration is essential if all economies—and the region as a whole—are able to achieve the greatest possible benefits from EMO.

This project was developed under the APEC Policy Partnership on Science, Technology and Innovation (PPSTI). Following a workshop hosted by Australia in Canberra in September 2016, government, research and industry representatives from 15 of the 21 APEC economies developed a regional approach to earth observing to support international development. A collaborative framework, underpinned by a 10-year action plan, was endorsed by APEC PPSTI in Port Moresby in February 2018. On the recommendation of the APEC Chief Science Advisors and Equivalents, APEC Ministers agreed to encourage cooperation and promotion of earth and marine observing capabilities in the region.[3]

In March 2019, the Australian Government Department of Industry, Innovation and Science commissioned Nous Group to produce this report. The department would like to acknowledge the work of Dr Jenny Gordon, Dr Matthew McLaren, Ethan Barden and the wider Nous team in preparing this report, and to thank the experts and officials from APEC economies who provided advice and insights.

This report is intended to encourage further collaboration and coordination of EMO across APEC economies, working in partnership with the international earth observations community. It is fitting therefore that this report was launched during the intergovernmental Group on Earth Observations (GEO) Week in Canberra in November 2019, under the theme 'Earth observations: investments in the digital economy'. Collaboration is critical to realising the value of earth and marine observing investments. Partnerships such as APEC and GEO are complimentary in demonstrating the transformational benefits of new technologies to the lives of people in the region and around the world.

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[1] Asia-Pacific Economic Cooperation (APEC) Secretariat, 2019, *APEC at a glance 2019*, APEC Secretariat, Singapore, viewed 30 September 2019, <https://www.apec.org/Publications/2019/02/APEC-at-a-Glance-2019>.

[2] APEC Policy Support Unit, 2019, *APEC regional trends analysis— APEC at 30: a region in constant change*, 2019 *APEC at a glance 2019*, APEC Secretariat, Singapore, viewed 30 September 2019, <https://www.apec.org/Publications/2019/05/APEC-Regional-Trends-Analysis---APEC-at-30>.

[3] APEC Secretariat, 2018, *APEC Ministerial Chair's Statement, 15th November 2018, Port Moresby, Papua New Guinea*, APEC Secretariat, Singapore, viewed 30 September 2019, <https://www.apec.org/Meeting-Papers/Annual-Ministerial-Meetings/2018/2018_amm>.

Contents

Acknowledgements **i**

Foreword **ii**

Executive summary **1**

1 What is earth and marine observing? **4**

1.1 Who are the main players in EMO? 5

1.2 What are the main technologies and applications? 6

2 Measuring the value of EMO **7**

2.1 Challenges in measuring the value of EMO 7

2.2 How does EMO contribute to the economy? 8

2.3 The actual value added depends on absorption 11

2.4 Greater collaboration and targeted investment can enhance the value added by EMO 13

2.5 The economic model 14

3 The current value of EMO to APEC **15**

3.1 The current value of EMO for each APEC economy 16

3.2 The current industry value of EMO 18

3.3 The current value of EMO to disaster management 29

3.4 Current consumer 'willingness to pay' value of EMO 34

3.5 Technology pathways and value 36

4 The potential future value of EMO **39**

4.1 The potential future economic value of EMO 40

4.2 The potential future industry value of EMO in 2030 43

4.3 The future value of EMO to disaster management 47

4.4 Future consumer willingness to pay value of EMO 50

4.5 The future direction of EMO technology and applications 52

5 Opportunities for collaboration **54**

5.1 The value of EMO in 2030 through collaboration 55

5.2 The case for greater collaboration 58

6 Methodology and approach **60**

6.1 The value is estimated based on potential value at an industry level and absorption at an economy level 61

6.2 Estimating the value in 2030 is based on projected growth in EMO applications and on economic growth 62

6.3 Estimating the difference that better collaboration can make 63

6.4 Incorporating natural disaster data and disaggregation by technology 63

6.5 Data collection 64

6.6 Limitations 65

Reference list **66**

Appendix A Economy profiles **69**

Australia 70

Brunei Darussalam 72

Canada 74

Chile 76

Chinese Taipei 78

Hong Kong, China 80

Indonesia 82

Japan 84

Malaysia 86

Mexico 88

New Zealand 90

Papua New Guinea 92

People's Republic of China 94

Peru 96

Philippines 98

Republic of Korea 100

Russia 102

Singapore 104

Thailand 106

United States 108

Viet Nam 110

Appendix B Applications of EMO for each industry **112**

Appendix C Studies that informed the estimated value of EMO to each industry **117**

Appendix D Economic model **120**

Executive summary

The value of earth and marine observing (EMO) to Asia-Pacific Economic Cooperation (APEC) forum economies is conservatively estimated at US$372 billion. These estimates represent the value added by EMO:

- to GDP, through the cumulative effect of higher growth across a range of industries (US$300 billion)
- through improved disaster prediction and management (US$26 billion)
- in non-market services to consumers (US$46 billion).

These estimates are conservative, in part, because the estimated value of EMO to disaster management does not include the enormous value of services that reduce the mortality and injury rates of natural disasters. The estimate of the value to consumers is also a lower bound, as it includes only the value of freely available weather forecasts, and not of other free services, such as digital maps.

To date, the transport industry has benefited most from EMO technologies: services built on digital mapping, and on better weather and ocean information, have contributed to massive improvements in logistics and routing that have saved time and fuel. Across the APEC region, EMO-enabled technologies are estimated to have increased the value added to GDP by the transport industry by US$140 billion—47% of the overall value added to all industry.

Other industries that have benefited greatly from EMO include power utilities (US$37 billion), in part because they are a large industry, but also because EMO-enabled technologies have improved demand forecasting and asset management:

- Agriculture, fisheries and forestry are growing users of EMO-enabled applications, which play a critical role in precision agriculture—not just through GPS positioning, but also through the data needed to identify the management systems that can achieve greatest production (output per unit input). The value from this, and from the wide range of other services (from regulatory enforcement, to optimal harvest strategies for natural resources, to crop insurance) is estimated to be US$37 billion.
- The value to mining of EMO-enabled applications is estimated at US$35 billion. This comes from the use of satellite imagery in exploration, drone and other monitoring systems for asset maintenance and regulation adherence; and weather forecasts that can (for example) improve safety to staff and reduce the risk of environmental problems, through timely shut-down of offshore rigs in bad weather.
- Communication utilities also benefit from EMO applications, to around US$30 billion—much of this from reducing the costs of monitoring and maintaining assets, which in turn reduces network disruption.

The United States stands out as the largest of the beneficiaries of EMO technology. This is due to the size of its economy; its relatively high share of those industries that have greater returns on EMO applications; and its high rate of absorption of EMO technologies. Even though its absorption rates are lower, the People's Republic of China is the second highest beneficiary, because of the size scale of its economy and population. Small, less-developed economies still benefit, but there is scope for better absorption of EMO-enabled technologies, particularly for industries where EMO applications can make a major difference (such as in agriculture, fisheries and forestry). Many APEC economies also benefit substantially from the savings made possible through better disaster management. While the overall dollars saved might be small, this monetary amount can be a substantial share of the economy's GDP and result in lives saved—thus offering value beyond the dollar measure.

The potential of EMO to add more value to the economy and to people's lives is growing strongly, because of advances in the technologies that collect and apply EMO data and to an increasing ability to access and use the many and varied applications that EMO enables.

Under a business-as-usual scenario, the value of EMO is expected to rise to US$1.35 trillion by 2030, an increase of almost US$1 trillion, reflecting an annual growth in EMO-enabled benefits of 12% over the period. The projected additional value to the United States (US$345 billion) is only just ahead of the additional value to the People’s Republic of China (US$342 billion). This reflects a more rapid rise in the rate of absorption of EMO technologies in the People’s Republic of China, as well as their higher rate of GDP growth. All economies should benefit from the growth in the potential provided from EMO technologies, which is conservatively estimated at around 8% a year. Economies where the growth in absorption is slower will gain proportionally less from EMO than the high-absorption economies. Boosting the absorption of EMO applications in those APEC economies that lack the data, analytics, and technical capabilities to apply EMO technologies would thus do much to enhance the value of EMO to the APEC region as a whole.

The importance of collaboration

Greater cooperation could increase the value added to GDP by EMO-enabled technologies by an extra 11%, and in disaster management by an extra 7%, to give a value of EMO of US$1.48 trillion in 2030.

There are many free data-sharing arrangements within APEC that support the development of suites of data products and services. However, greater collaboration is required to encourage investment; to bolster the baseline level of capability across APEC; and to enable innovation that can expand the boundaries of EMO technologies. From consultations undertaken for this study it was clear that many APEC economies would benefit from greater sharing of infrastructure, data and data products that could improve the reliability and accuracy of their predictions. To do this, several economies would require support to build their capabilities to share their own data.

However, access to open data is not a game-changer for economies if they also lack the analytical capabilities to convert data into information that can inform decision-making. These economies will therefore benefit most from data products and EMO insights that are ‘ready to use’. Ideally, such collaboration would not be limited to APEC economies but would include all economies in building a stronger EMO ecosystem.

The benefits from additional collaboration—including cooperative efforts to maintain assets and to develop capabilities—point to the importance of EMO development across the value chain. APEC economies working together can greatly enhance the value of EMO technologies for industry, disaster management and for society. As this study suggests, the value of such collaboration is profound.

The extensive consultations undertaken for this study also identified a need, in several economies, to develop processes to transfer EMO-based knowledge to the wider community. The leaders of EMO in APEC are well placed to support these efforts.

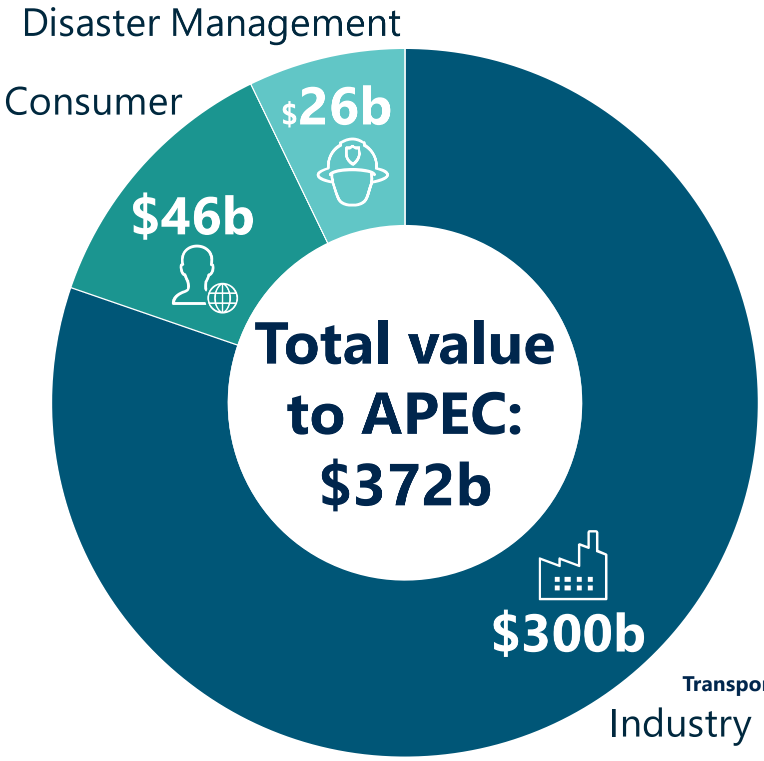
There is a growing concern that the technical and analytical capabilties of some economies are not keeping up with the expanding use of EMO. A further concern raised is that governments will fail to maintain the baseline technologies that support so much EMO data, even while investing in new sources of data. These fundamental EMO data sources are invaluable and need to be protected through sustainable funding arrangements.

The estimates used in this report have drawn on an extensive review of the literature, looking at the impact of EMO applications for specific industry segments (a bottom-up approach) and at the few studies that have sought to take a more top-down approach. This report has also benefitted from the collective knowledge of experts in many APEC economies, who have generously provided their insights into the differences that EMO applications have made to their economies, and who have shared their thoughts on where cooperation could most enhance the value of EMO across APEC.

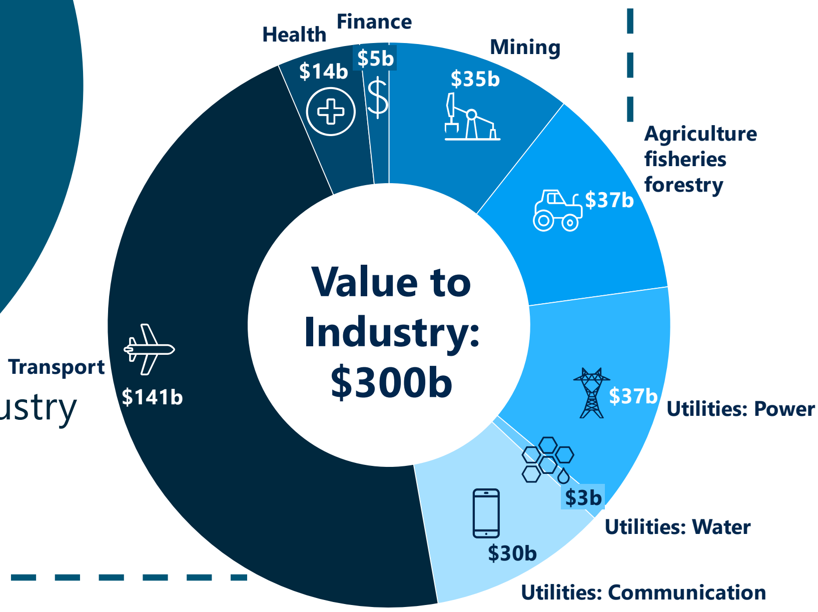
Undoubtedly, some of the estimates will be overstated at an industry and economy level, while others will be understated—but there is no denying the very considerable value that EMO-enabled applications have brought, and will continue to bring, to APEC economies.

VALUE OF EMO TO APEC from 2019 to 2030 (in US$)

2019



"EMO requires a significant number of people working who understand the potential."



2030

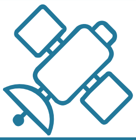
Potential future value of $1.35 trillion

Collaboration across APEC can generate an additional $126 billion

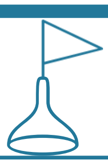
"We need to encourage data exchanges between different economies to inform awareness of the maximum benefit from joint action, research, and application."

1 What is earth and marine observing?

EMO is defined as the collection, analysis and interpretation of information on the earth's natural systems. This study has focused on EMO data collected through two forms of observatory infrastructure across APEC:



Remote sensing techniques: observational satellites, Radar/LIDAR, hyperspectral imaging, drones, etc.



In-situ techniques: ocean buoys, fixed cameras, radiosondes, atmospheric laser, seismographs, etc.

Figure 1 | Landsat satellite imagery of floodplains in Australia, and deep-ocean assessment and buoys for early reporting of tsunamis[4, 5]

EMO is a process that starts with infrastructure recording raw observational data and ends with data products that can inform economic policies, government programs, public and private sector investment, and a host of other applications (Figure 2). These even include archaeology, as satellites can scan below the current surface level to uncover layers of history.

A single collection method can produce extensive amounts of raw data that require storage, cleaning, analytics, and transformation before they deliver value as a data product. To provide perspective, NASA's earth observation data alone is currently estimated at nine petabytes (PB) of data, which is equivalent to 180 million four-drawer filing cabinets filled with text[6], or 35,156 of the most powerful iPhones currently available.

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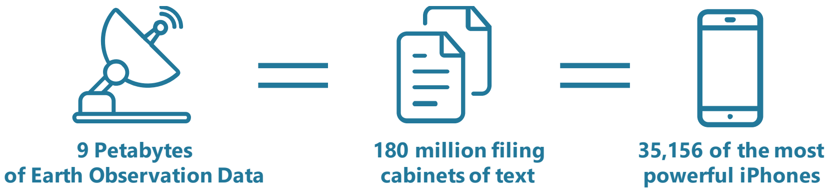
[4] Geoscience Australia, 2019, *Water observations from space*, Geoscience Australia, Canberra, viewed 26 March 2019, <https://www.ga.gov.au/scientific-topics/community-safety/flood/wofs>.

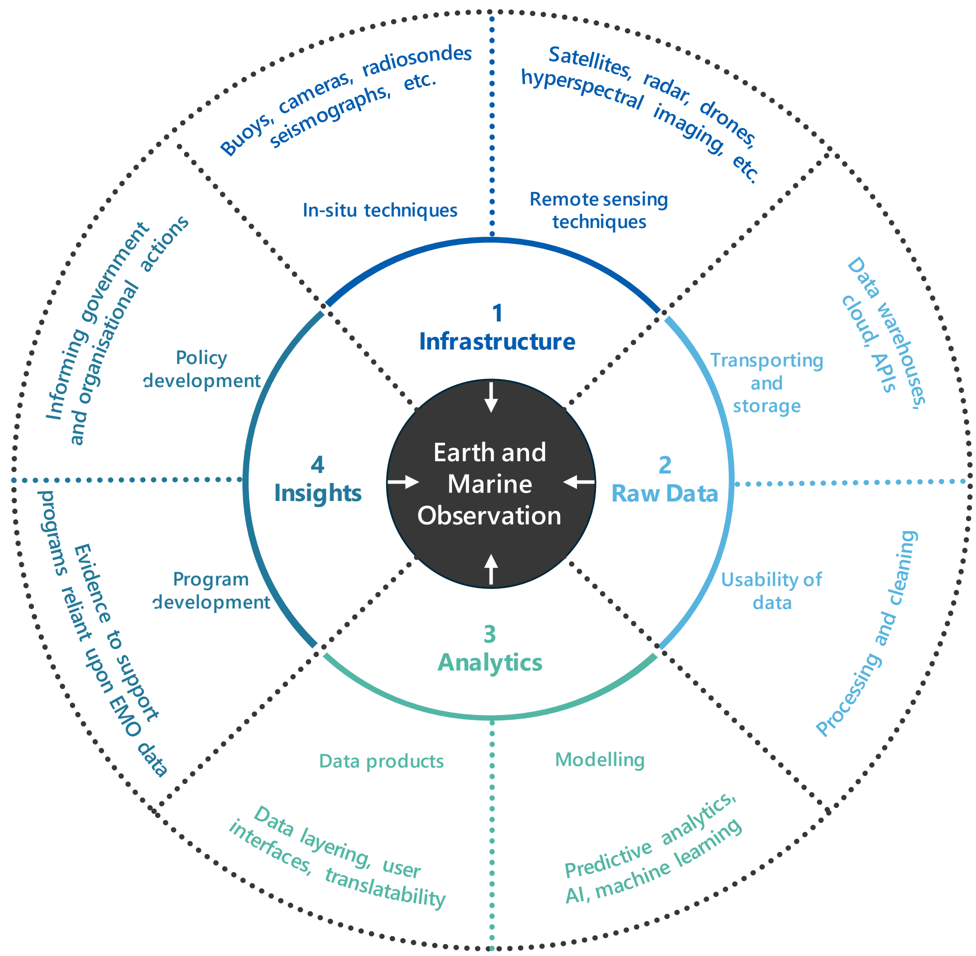
[5] NOAA Technology Partnerships Office, 2019, *Pacific tsunami warning center and deep-ocean assessment and reporting of tsunamis buoys*. NOAA, Silver Spring, MD, viewed 26 March 2019, <https://techpartnerships.noaa.gov/News-Successes/ArtMID/7817/ArticleID/623/Pacific-Tsunami-Warning-Center-and-Deep-ocean-Assessment-and-Reporting-of-Tsunamis-DART174-Buoys>.

[6] J Blumenfeld, 2019, *Getting petabytes to people: how EOSDIS facilitates Earth observing data discover and use,* NASA Earth Science Data Systems (ESDS), Washington DC, viewed 25 March 2019, <https://earthdata.nasa.gov/learn/articles/getting-petabytes-to-people-how-the-eosdis-facilitates-earth-observing-data-discovery-and-use>.



Although some single sources of data collection are valuable in isolation, many of the insights provided from EMO rely on the layering of multiple data sources to help us understand a phenomenon or model a scenario.

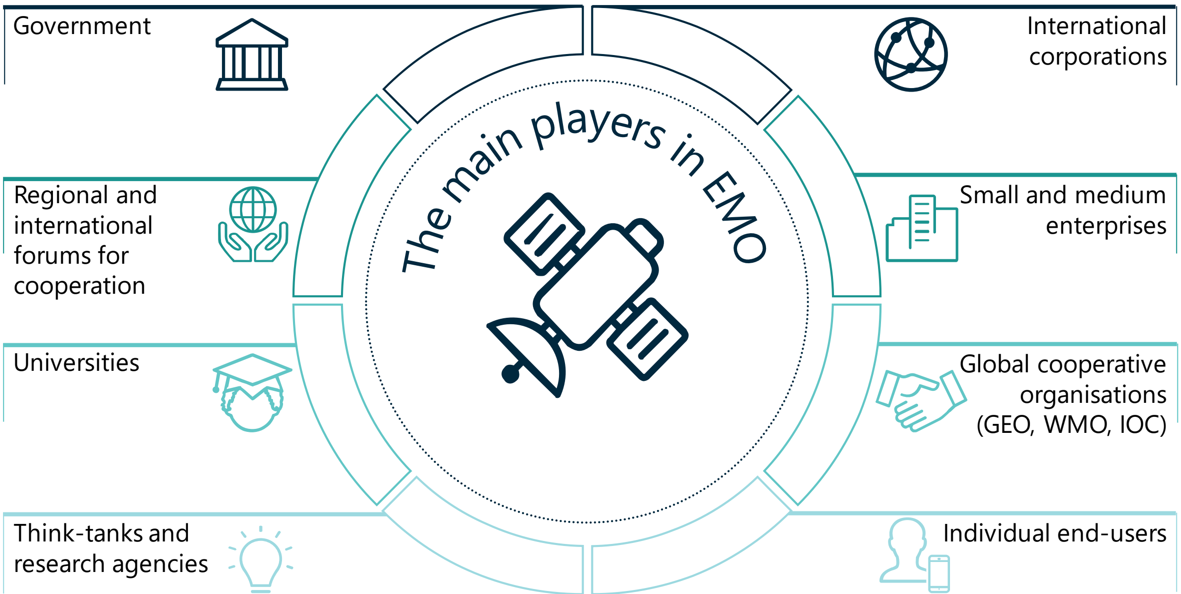
Figure 2 | What comprises earth and marine observing?



1.1 Who are the main players in EMO?

There are many organisations involved in collecting, analysing, and applying EMO data (Figure 3). These include government-funded organisations; international organisations; non-government agencies including universities and research agencies; and large, medium and small enterprises. APEC economies also participate in international collaborative efforts including the World Meteorological Organization (WMO), the Intergovernmental Group on Earth Observations (GEO), the Intergovernmental Oceanographic Commission (IOC), and other open-data associations and platforms. GEO, for example, has 108 member economies, and is working to coordinate earth observations systems and to facilitate data and information sharing at a global level. Similarly, cooperation across APEC is occurring not only at a macro level, but also through processes such as training in analytics or sharing of data products and insights between individual economies and institutions.

Figure 3 | The main players in EMO



1.2 What are the main technologies and applications?

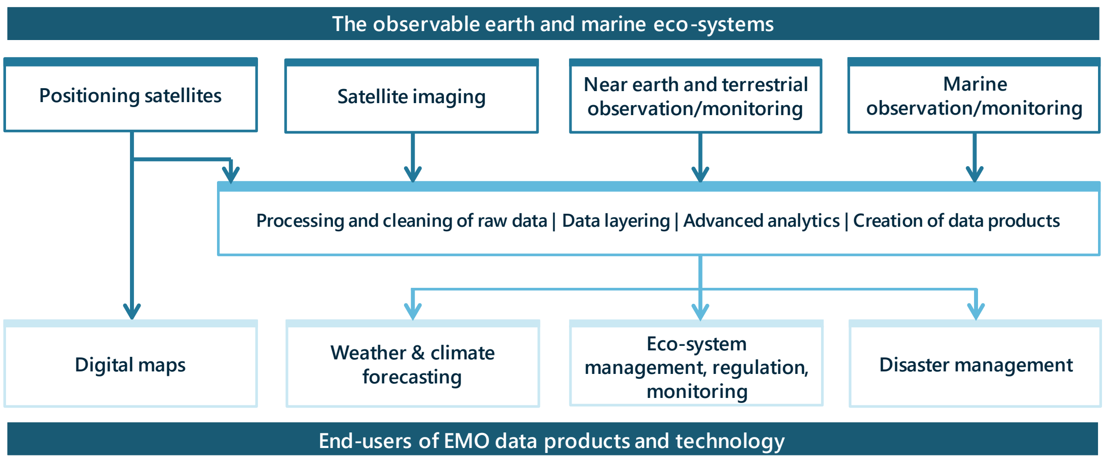
The breadth of technology involved in earth and marine observing is extensive and continually evolving. EMO infrastructure can provide:

- accurate positioning data to within a few centimetres
- visual images, including highly detailed data from low-flight drone technology and increasingly from satellites
- sensor information—including through terrestrial probes, ocean buoys and submerged systems, which monitor a range of earth and marine changes from movement to temperature.

Given this wide array of specific and often complementary data, the applications from EMO are already vast. They continue to grow, due to the development of better technology (such as nano-satellites), the falling price of processing and storing data, greater computational power, better analytics and a broader network of industries emerging as new prospective customers for EMO data products.

For the purpose of assessing impact, four broad categories of technology are mapped into four broad areas of applications (Figure 4). It is these applications that add value to industries and to people's lives through services such as better weather forecasts and improved disaster management.

Figure 4 | An overview of the main EMO technologies and applications



2 Measuring the value of EMO

EMO has delivered substantial value across the Asia Pacific by providing information to people, industry and governments. This information has become indispensable, spanning weather and climate; digital maps; assessments of the state of the environment; and disaster warnings, all at increasingly finer scales. Stimulated by growing global digitisation, industries using EMO data and information continue to develop new and better products, often at a lower cost, bringing better insights and greater value for researchers, businesses, consumers and governments.

While the myriad benefits of EMO appear obvious, mapping the connections between EMO technology and infrastructure to the value that EMO data adds to each economy is a complex task. Data must be turned into easily understood information that, when combined with other evidence, can empower the decisions made by governments, business and individuals.

These decisions can include:

- farmers deciding what to plant, where, and when to optimise their resource and input use
- governments and business deciding how best to harvest natural resources (fisheries and forestry) so that they are sustainable—including certification for market access
- transport firms mapping out optimal logistics, and shipping companies and airlines avoiding storms
- governments planning and zoning (including setting standards to withstand the effects of extreme weather and climate change), and developers deciding where and what to build.
- governments putting in place plans for disaster response and how to improve resilience against high-risk hazards.
- providing information and up-to-date weather forecasts to help individuals make decisions about the coming day, including when to travel, and how.

The following section outlines the challenges associated with measuring the value of EMO, and the three components used in this study to determine the economic value of EMO to APEC:

- understanding how EMO contributes to an economy, through productive and non-market economic value
- the importance of an economy's absorption rate to realise value from EMO
- how collaboration can impact realisable value.

2.1 Challenges in measuring the value of EMO

There are two primary challenges in measuring the value of EMO:

1. Estimating the change in value added that results from using EMO applications.

   Within this report, value added by EMO is the extent to which an industry's value is higher than it would otherwise have been due to the use of EMO. This is a cumulative effect, as over time, the use of EMO has increased the value of output and/or reduced costs in the industry.

2. Understanding how an economy's level of development impacts its use of EMO—and how close an industry is to this potential value added in each economy.

Challenge 1: Measuring the change in value due to EMO

The first challenge in measuring this value is that there are many applications affecting many different decisions. Very few have been measured in terms of the value that can be attributed to EMO-sourced information.

For example, there are estimates of the value that EMO delivers to farmers in terms of higher yields and/or lower inputs through precision agriculture, which apply in specific locations and for specific crops. But these need not apply to all of agriculture, or all of an economy: the challenge is using these specific applications of EMO to model the use of EMO more generally. This study is an attempt to address this challenge, drawing on specific research and collective knowledge of experts across APEC economies to conservatively extrapolate what has been measured to get an estimate of the value added.

Challenge 2: Understanding how development affects the benefit to be gained from EMO

The second challenge in measuring the impact of EMO is that not all economies are equally positioned to capitalise on the economic opportunities EMO presents. In part, this is because they do not have the industries, natural resources, or landscapes where EMO applications can make a large contribution to adding value.

But it is also because the economies are at different stages of development and may lack the private sector or government capabilities to make full use of the opportunities that EMO can provide. (For example, 'willingness to pay' studies have been used to estimate the value of weather forecasts to individuals—but these have been estimated for a high-income economy, and in lower income economies, while the value might be greater, the capacity to pay (even figuratively) is lower.)

Not all APEC economies are currently able to realise the full value added that is available from EMO applications. This analysis considers the stage of development of APEC economies, while recognising that, for a variety of reasons, some may be well ahead or behind, in some industries, in their application of EMO.

Looking forward, the role of EMO data products and services in meeting a range of domestic and international goals and priorities is expanding. International collaboration—to better coordinate investment in EMO technologies, data sharing, data analytics capabilities, and to facilitate the growth in applications of EMO data—remains paramount to support sustainable, inclusive growth across APEC.

2.2 How does EMO contribute to the economy?

The economic contribution of EMO comes from its application to industry, disaster management, and broader society as EMO data are used to inform better decisions by public entities, private businesses, and members of the community. EMO data supports some activities that might otherwise not be possible, such as early warning systems for tsunamis; tracking illegal fishing and deforestation; and hazard mapping for communities at risk from flooding. In some cases, this is because the data are time-critical, so speed is of essence to value; in other cases, it is far too expensive to get the data required from other sources.

EMO data also enhances many activities by lowering costs, improving outcomes or both. Precision farming is an example of how multiple EMO data provide geospatial location and imaging which is combined with technologies that measure the productivity of specific square metres of land to optimise the inputs and maximise yield.

Delivering value from the raw data produced by EMO infrastructure depends on the following critical processes—the EMO value chain (Figure 5):

Figure 5 | EMO value chain

It is useful to break out the different stages needed for government and industry to generate value from EMO infrastructure, as the scope for additionality from investment and collaboration will vary across the value chain.

Table 1 provides a description of each stage of the EMO value chain outlined in Figure 5 and its role in realising economic value.

Table 1 | Explanation of each stage of the EMO value chain

Stage of the value chain	Description
1. EMO infrastructure	EMO infrastructure includes observatory infrastructure, such as remote-sensing and in-situ techniques. EMO infrastructure also includes the supporting infrastructure necessary for calibration, management and maintenance of EMO assets.
2. Available data in a suitable form	The actual observation data produced by EMO infrastructure. This includes, for example, recorded raw data output from instrumentation, signals data, and live feeds for recording and processing.
3. Technical capacity	Specific technical requirements to realise value from the data include: • infrastructure for downloading the data from EMO infrastructure (for example, satellite earth stations to receive the information from orbiting satellites) • infrastructure for data transfers (for example, fibre optics) • data warehouses (or equivalent) to store the raw data • computing capabilities to process the data and run analytics • additional storage capacity to store the analysed data (which can be up to three to four times the amount of storage required for the raw EMO data).
4. Analytical capacity	EMO raw data needs to be cleaned, processed, layered with complimentary data, and transformed into actual data products and services that can be used by end users to produce economic value. 'Analytical capacity' includes professionals such as data scientists, statisticians and programmers who can transform raw EMO data into valuable insights that inform policies, programs and industry processes. Examples of these data products include: • usable time-series data sets • published statistics • official forecasts • live feeds of data for application program interface (API) access • camera feeds of particular conditions (road accessibility, snow cover, etc.) • mobile apps • predictive algorithms and end-user tools.
5. Available funding and an impetus to implement insights	The economic value of EMO is dependent on funding to action insights produced through analytics and being available to support all stages of the value chain. Many economies are not in a position to use valuable EMO insights that could help with decision-making, or to enhance their EMO capabilities, because there is limited funding available. Examples include: • the inability to intercept illegal fishing or logging due to the costs of redirecting naval forces or tracking perpetrators

Stage of the value chain	Description
Available funding and an impetus to implement insights (continued)	• not being able to buy private or enriched data that can be combined with free EMO data to produce or develop predictive algorithms used in data products • not having access to high-powered analytical (super) computers or only being able to purchase limited amounts of time to clean data or run complex analytics. Funding (from government or the private sector) needs to be available for the value of EMO to be realised as a return on investment. Even if funding is available, it is important that the entire EMO value chain is understood by decision-makers—including the complex steps involved in producing an EMO data product or recognising its end-uses (which could create an impetus for further investment). The scientific and research community also need to make the insights from EMO understandable and applicable to their end users, to help them make viable investment decisions. (For example, researchers should not only make raw data available, but also develop end-user tools and interfaces that translate this data into usable insights that are easily digestible and applied.)

2.2.1 The potential value generated by EMO varies across industries

By considering each stage of the value chain, this report has focused on the economic value that can be realised through two sources: productive economic value and non-market economic value.

Productive economic value

Productive economic value is defined as the value added by industries that makes up an economy's GDP. Those most able to use EMO applications have been identified as:

- **Mining** – used mainly in environmental compliance, exploration, remote operations, and in managing weather-related risks.
- **Agriculture** – used intensively in precision agriculture and production planning and in monitoring pasture condition to improve production. Weather forecasts are used extensively by all in agriculture.
- **Fisheries** – used mainly in assessing population dynamics; locating algal blooms and fish stocks; monitoring harvest activity; and in managing weather- and climate-related risks.
- **Forestry** – used mainly in assessing forest condition; preventing illegal logging; assessing growth rates (climate and weather-related); and in verifying sustainable harvest levels.
- **Utilities** (including power, water and communications) – used mainly in projecting supply and demand variations related to weather and climate; asset maintenance of networks; and risk assessment for investment in infrastructure.
- **Transport** – used mainly in optimising logistics; tracking fleet movements; and in assessing weather and climate-related risks.
- **Health** – used mainly in mapping disease outbreaks; monitoring changing risk patterns associated with changes in climate and vector adaptation; and in issuing health warnings related to extreme weather events.
- **Finance** – used mainly in (re)insurance and in assessing resource condition, and agricultural yields in determining the financial viability of enterprises.

Non-market economic value

Two areas enabled through EMO have been identified as unique sources of non-market value (but do not contribute directly to GDP):

- **People** – where EMO input into preparedness and response saves lives, property, and livelihoods that would otherwise have been lost due to natural disasters. People also use of EMO applications for daily convenience, with weather forecasts and digital maps being the main sources of value.
- **Infrastructure planning** – where EMO applications can improve urban resilience to natural disasters, through better infrastructure and planning.

The potential for EMO applications to add value in each of these areas is considerable. An assessment of this potential forms the first part of the analysis—which is to estimate how much higher an industry's value added could be, due to the use of EMO applications in that industry. The best-case use of EMO within each aforementioned industry and area of non-market economic value sets an upper limit for the potential value added by EMO applications.

2.2.2 The structure of the economy determines the potential value added for the economy

Given the variety of possible applications and differing relevance across and within industries, the rate of uptake of EMO applications within each industry varies widely. Some industries can readily realise value from more general-purpose technologies (such as the use of positioning data within a transport network). Other industries require specific technologies that—while enabled by EMO data—need additional non-EMO investment to realise value (for example, pasture management systems). Some of these specific purpose applications will have a large market, but most will need additional investment to tailor the application to the specific needs of the industry in a particular economy.

Pasture management systems need extensive additional effort regarding ground proofing to test predictive analytics and integrate these into the complex management systems.

If the required level of investment is made and EMO technology is applied, the potential value added by EMO applications will depend mainly on the make-up of industries and the different share of industries in each economy. This means the structural differences across economies will determine the potential value added by EMO in that economy. The actual value, however, depends on the local industries' ability to fully make use of the potential value.

2.3 The actual value added depends on absorption

The actual economic value of EMO for any economy depends not just on potential, but also on absorption (or adoption), which reflects the ability of an economy's industries to apply EMO to production, planning and other decision-making. This is the second part of the assessment required to estimate the value added to APEC economies by EMO. The value that EMO currently provides to each APEC economy depends on both the general level of development and the advancement of the industries in the economy.

Absorption is maximised where an economy has capability across all stages of the EMO value chain. Even without capabilities across the value chain, EMO can still deliver value as there are applications that can be bought 'off the shelf' and used by firms in an industry (such as digital maps and logistics software), as well as by individuals (such as weather forecasts); even if the EMO capabilities are relatively undeveloped in the economy. The absorption of EMO will still be highest where businesses and governments have capabilities to draw on the EMO data, combine it with other data, and apply it to their specific needs.

2.3.1 Absorption is affected by the overall level of development in each economy

Overall, the absorption of EMO applications in each APEC economy will vary due to factors such as:

- the level of development of the industries
- the income of the population
- different financial priorities for government
- varying degrees of analytical and technical expertise
- the degree of access to EMO infrastructure
- government, industry and business research and development imperatives.

Consequently, each APEC economy has a different rate of absorption of EMO. As a general rule, the level of absorption of EMO applications is likely to be proportional to their level of economic development. There will be exceptions to this general rule, as some industries in an economy will be close to using the full potential of EMO applications. For example, mining in Papua New Guinea (PNG) is large-scale and undertaken mainly by multinational firms, which have the resources to use EMO-enabled technologies. Many PNG farmers, however, would not have the resources to use EMO applications, and in any case, technologies have yet to be tailored that would add considerable value to PNG's largely subsistence agricultural systems.

In assessing the value of EMO to APEC economies, we must assess each economy's capacity to develop and use EMO applications in order to estimate how close they are to reaching their full potential.

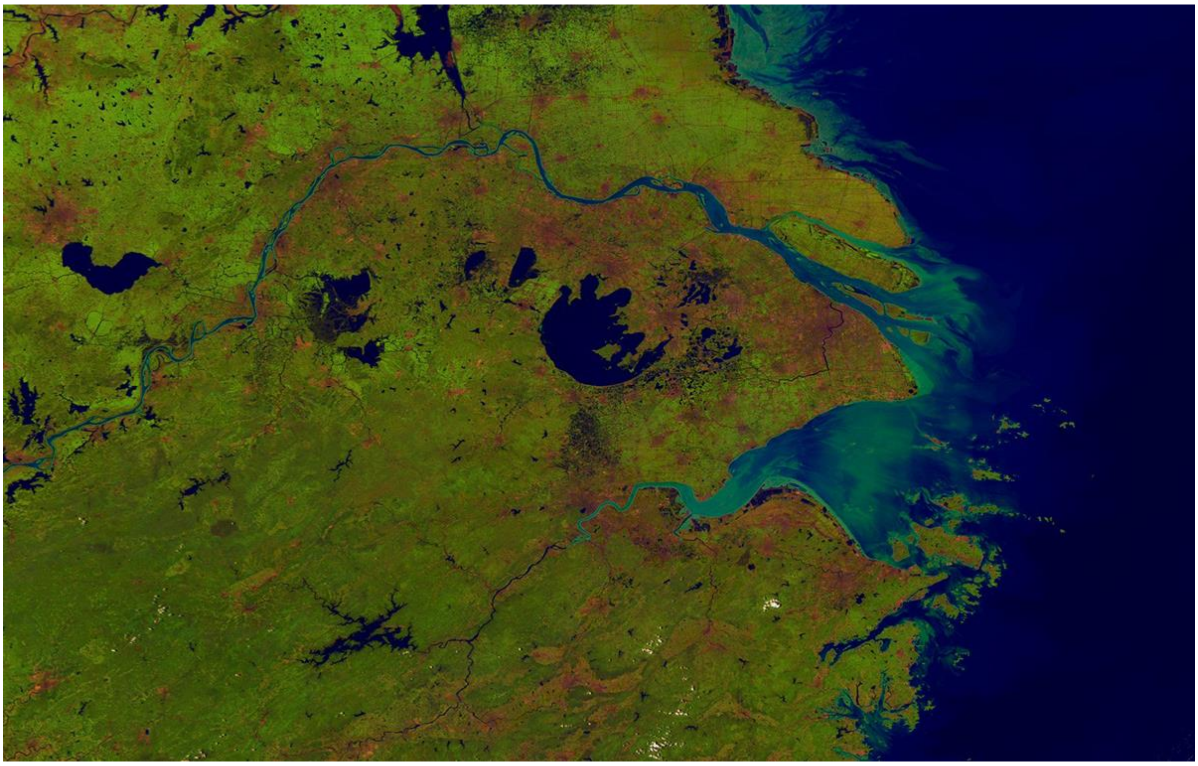
2.3.2 Absorption is also affected by the level of industry specific investment in each economy

Specific industry adoption rates may be a function of the local industry's level of investment in EMO. That is, industry adoption rates vary because certain industries have invested in using EMO data to solve specific problems and because they were able to identify greater cost-savings and increases in revenue. In some cases, it could be that a small investment to adapt an EMO application to the economy's specific needs would deliver value, but that there are barriers in access to the data, or lack of local capabilities to undertake the research needed to adapt the application for local conditions. For example, while Malaysia has low to moderate levels of infrastructure and analytics, they have a supercomputer that enables complex analytics to be coded and run for their economy. They can provide an analytical service to their own industries and to neighbouring economies, but need the data input and capabilities to do so.

Adjusting to this level of granularity is not possible in a study of this nature, but it matters for attracting local support for accessing EMO data and for investing in the capabilities to combine and analyse EMO and other data to inform local level decisions.

There are also multiple APEC-wide regional challenges and priorities that are central to the uptake of EMO, such as emergency management (preparedness, mitigation, response, and recovery); natural hazards; and agriculture and land use planning (water and food security). Areas of commonality offer an opportunity for greater adoption rates at both an economy and industry level, as well as across the whole of APEC.

Figure 6 | EMO can help protect natural waterways, like the Yangtze River, by showing changes in temperature, flow, quality and topography. ***Source: earth.esa.int***



2.4 Greater collaboration and targeted investment can enhance the value added by EMO

This study has estimated the current value of EMO to APEC economies (2019) and looks forward to 2030 to estimate what that value could be. Even without additional collective efforts, the value of EMO will rise as economies and industries grow and are better able to make the investments needed to use EMO applications. The EMO industry is not standing still, with considerable progress being provided by advances in sensors, computing power, artificial intelligence and machine learning, and the growing digitisation of economies. Given these advances, the value of EMO will be considerably higher in 2030 than it is today. However, with greater cooperation, this value could be even higher. Section 6 of this report looks at how much the value of EMO to APEC economies could be enhanced with improvements in collaboration and targeted investments.

2.4.1 Collaboration can improve the use of EMO applications in an economy

Collaboration remains critical to improving the absorption rates of EMO for each economy within APEC. For economic gains to be realised, not every economy needs to be expert in all stages of the EMO value chain. Rather, collaboration brings greater efficiencies and cost savings through:

- Sharing of data and analytics—such as through the World Meteorological Organization (WMO), the Intergovernmental Group on Earth Observations (GEO), the Intergovernmental Oceanographic Commission (IOC), and other open-data associations and platforms.
- Government frameworks—which provide a coordinated approach to areas of global concern, such as the APEC framework for EMO and the priority areas of emergency management, coastal health and hazards, and food and water security.
- Multi-economy data products—such as the Global Risk Map, or The Global Ocean Observing System.

- Financial investments to bolster capabilities—through global co-operations such as APEC, The World Bank, and United Nations, as well as investments by private and commercial entities for specific industry gains.
- Training and sharing lessons learned—by capability development programs and international exchanging of expertise (for example, Australia cooperating with New Zealand on a satellite-based augmentation system, or Malaysia receiving analytics training from Japan and the United States).

It is important to recognise that greater collaboration does not simply benefit lower-developed economies. Rather, richer data sources and insights are of economic value to all economies.

There are many free data-sharing arrangements within APEC that support the development of suites of data products and services. However, greater collaboration is required to help encourage investment, bolster the baseline level of capability across APEC, and enable innovation to continue to expand the boundaries of EMO technologies.

2.4.2 Targeted investment

Targeted investments present an opportunity to enhance specific sections of the EMO value chain that have been identified as being able to provide the greatest return on investment. An investment in infrastructure, for example, could deliver less value than an investment in building capability to use existing data products. Furthermore, the amount of free data that already exists across APEC economies presents an ideal opportunity for targeted investment—to harness what already exists and what remains to be fully utilised.

Through considered planning and collaboration, economy-specific targeted investments are one method by which to bolster the absorption rates for an economy; catalysing in greater value being realised from EMO.

2.5 The economic model

The economic model (outlined in detail in Section 6: Methodology and approach, and Appendix D) used to determine the value of EMO to APEC was built around the three components:

- the potential value added delivered by EMO for each industry and in two non-market applications (weather forecast value to consumers, and disaster management cost savings)
- an economy's absorption rate—which depends on their level of development and the advancement of their industries
- the structure of their economy—as some industries benefit more from EMO technologies than others.

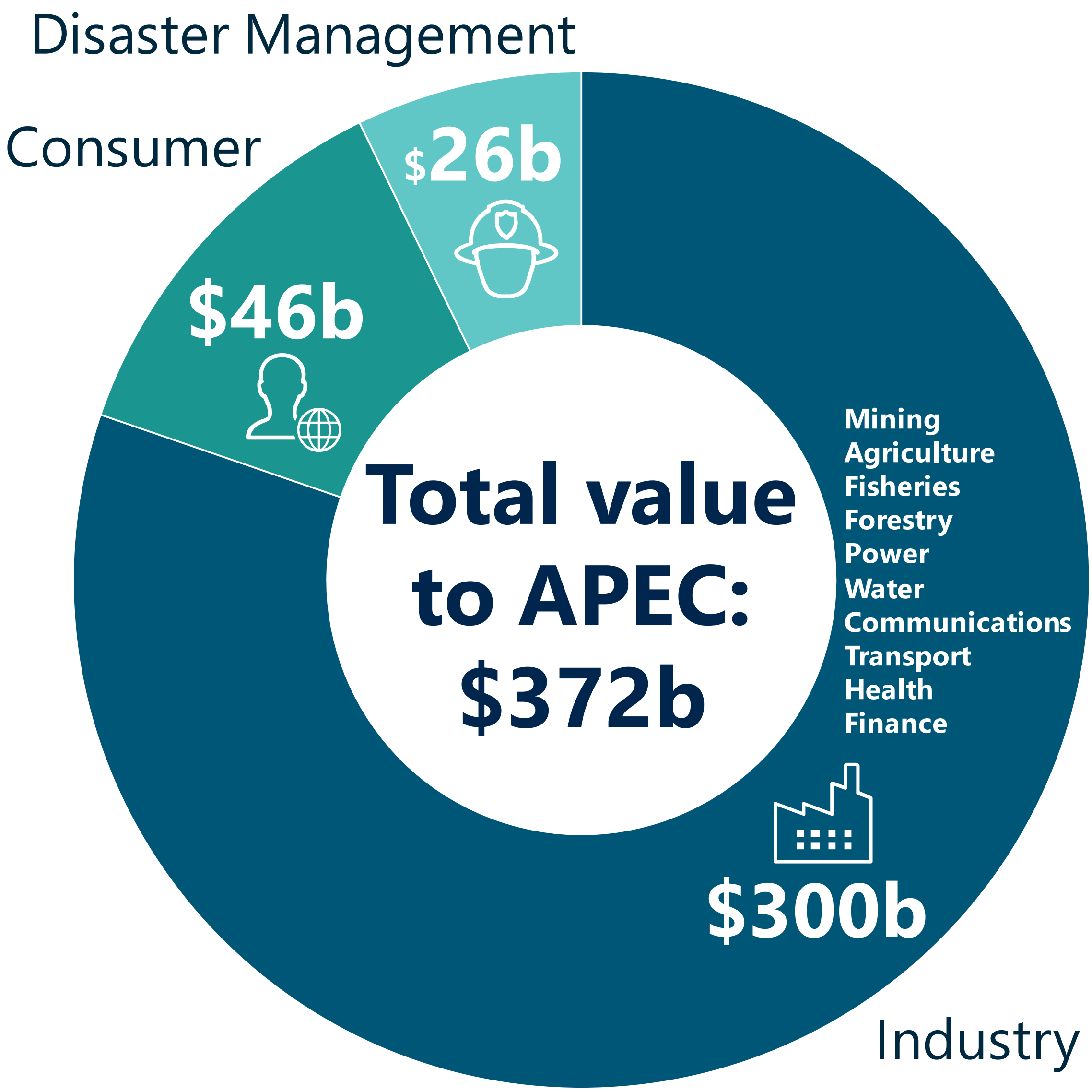
The following three sections respectively outline the results from the model for the present value of EMO to APEC, the potential future value in 2030 and the potential 2030 value through greater collaboration across APEC.

3 The current value of EMO to APEC

The current value of EMO to APEC is estimated at US$372 billion (Figure 7). The value added to industry contributes the largest proportion of this value at US$300 billion, followed by consumer willingness to pay at US$46 billion, and then disaster management at US$26 billion. Although disaster management had the lowest economic contribution, the estimates do not include the impact on people from injury and loss, and particularly the value of lives saved, through EMO. While there is data available on lives lost due to natural disasters, it is not complete and highly variable in scale, frequency, and location of natural disasters. It is also impossible to put a dollar figure on the value of saving lives. The estimate of the value of EMO in disaster management therefore understates the true value.

The following sections describe the disaggregation of the current economic value of EMO to APEC by economy, industry (relative to each economy), disaster management and consumer value.

Figure 7 | The current economic value of EMO to APEC (in US$)



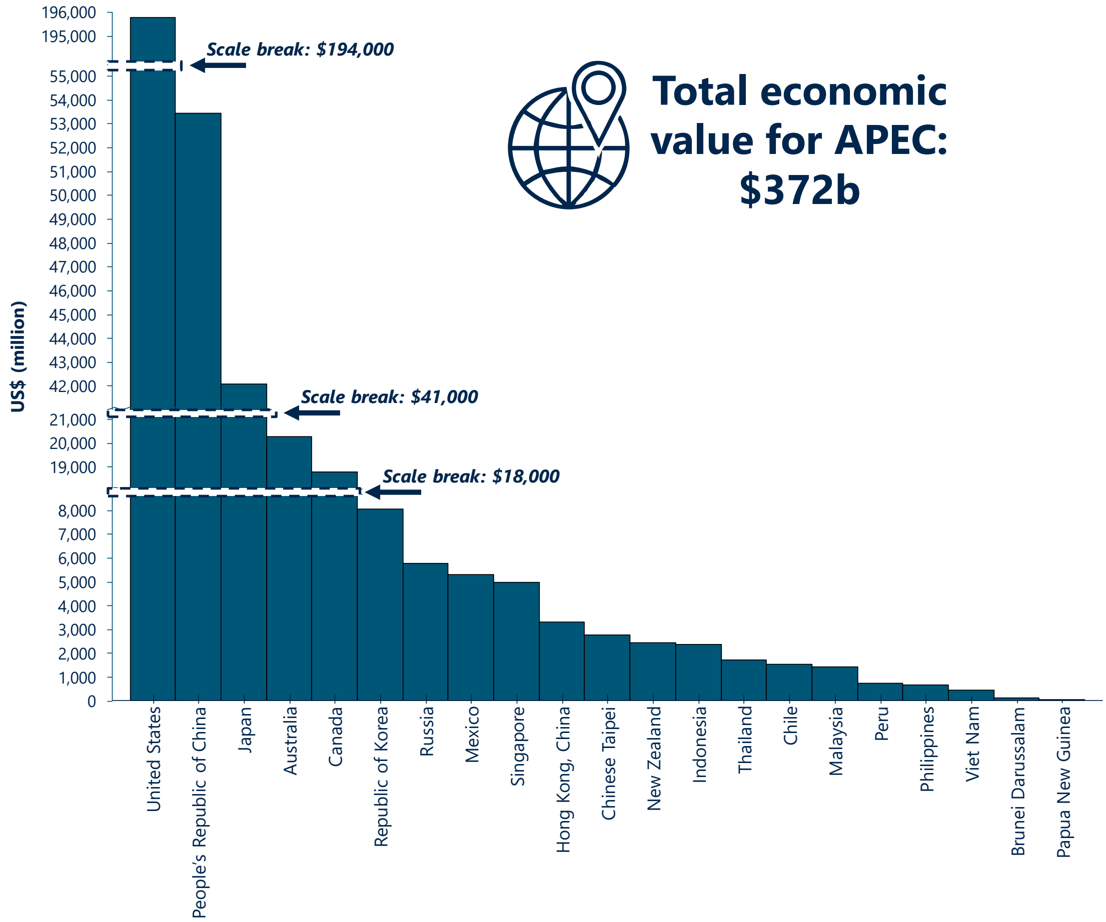
3.1 The current value of EMO for each APEC economy

The value of EMO for each APEC economy varies widely—in part due to the relative sizes of the economies, their economic structure and exposure to natural disasters, and their level of development (Figure 8). This number is made up of estimates of the value to industry, to consumers and disaster management (Table 2).

The United States, as one of the largest and most developed economies in APEC, currently realises the most value from EMO within APEC at US$196 billion. The People's Republic of China and Japan gain an estimated US$53 billion and US$42 billion, respectively, from EMO. For the People's Republic of China, the scale of their economy drives much of this value, as they have yet to fully realise the potential of EMO in most industries. Japan is much closer to potential use, but has a smaller economic base than the People's Republic of China. Australia and Canada benefit by an estimated US$20 billion each, reflecting similar economic composition, realisation of potential and scale.

Economies benefiting from US$8 billion to US$1.4 billion include (in descending order): the Republic of Korea; Russia; Singapore; Mexico; Hong Kong, China; Chinese Taipei; New Zealand; Indonesia; Chile; Thailand; and Malaysia. Economies that have yet to get close to the full potential value of EMO are the Philippines, Peru, Viet Nam, Brunei Darussalam, and Papua New Guinea, with a combined value of US$2 billion. This is due, in some cases, to the small size of these economies, but for many they have yet to release much of the potential value that EMO could provide.

Figure 8 | The total current value of EMO for each APEC economy (in US$)



It is important to recognise that the disparity between APEC economies in the value of EMO is a function of the overall size (GDP) of an economy; of its structure; and of the economy's level of development.

Table 2 | Current economic value of earth and marine observing for each APEC economy

Economy	Industry value	Consumer willingness to pay value	Disaster management value	Total current value	Proportion of the total current value
	US$ million	US$ million	US$ million	US$ million	%
United States	159,636	18,182	17,936	195,754	52.6
People's Republic of China	39,952	12,093	1,382	53,426	14.4
Japan	33,073	4,447	4,544	42,063	11.3
Australia	18,298	1,259	686	20,242	5.4
Canada	16,980	1,505	276	18,760	5.0
Republic of Korea	6,471	1,441	136	8,048	2.2
Russia	4,261	1,456	37	5,754	1.6
Mexico	4,082	1,334	159	5,575	1.5
Singapore	4,656	324	0	4,979	1.3
Hong Kong, China	2,948	321	12	3,281	0.9
Chinese Taipei	2,078	513	153	2,744	0.7
New Zealand	1,851	180	406	2,437	0.7
Indonesia	1,420	920	28	2,368	0.6
Thailand	1,150	449	112	1,711	0.5
Chile	1,081	263	183	1,526	0.4
Malaysia	1,100	312	7	1,419	0.4
Peru	516	234	11	761	0.2
Philippines	345	291	21	657	0.2
Viet Nam	210	217	16	443	0.1
Brunei Darussalam	107	12	0	119	<0.1
Papua New Guinea	15	21	0	36	<0.1
Total	**300,230**	**45,774**	**26,105**	**372,103**	**100**

3.2 The current industry value of EMO

The total value of US$300 billion added to GDP by EMO-enabled applications was estimated through adding together the contribution of EMO to each of the industries where EMO has made a major difference (Figure 9). It is estimated that EMO has enabled the value added to GDP by transport to be higher by US$141 billion than it would have been without EMO. This is equivalent to almost 7% of the current value of transport. At 47%, transport makes up the major share of overall industry value added by EMO.

The use of EMO data in a wide range of applications in mining; agriculture, fisheries and forestry; utilities: power; and utilities: communication increased the value these industries add to GDP by between US$35 to 40 billion, ranging between 1.8% and 4.3% of each industry's total value. The health, finance and utilities: water industries also benefited from EMO. Some industries have not been included, because the impact that EMO has on the productivity of the industry is currently small. For example, manufacturing is not included, as applications of EMO data have yet to have a significant impact on the industry productivity —although there would be some value to the industry in terms of producing EMO technologies.

The analysis of impact focuses on the extent to which EMO data and applications can reduce costs, enable new and more efficient business models, and improve outputs.

Figure 9 | Current industry value of EMO (in US$)

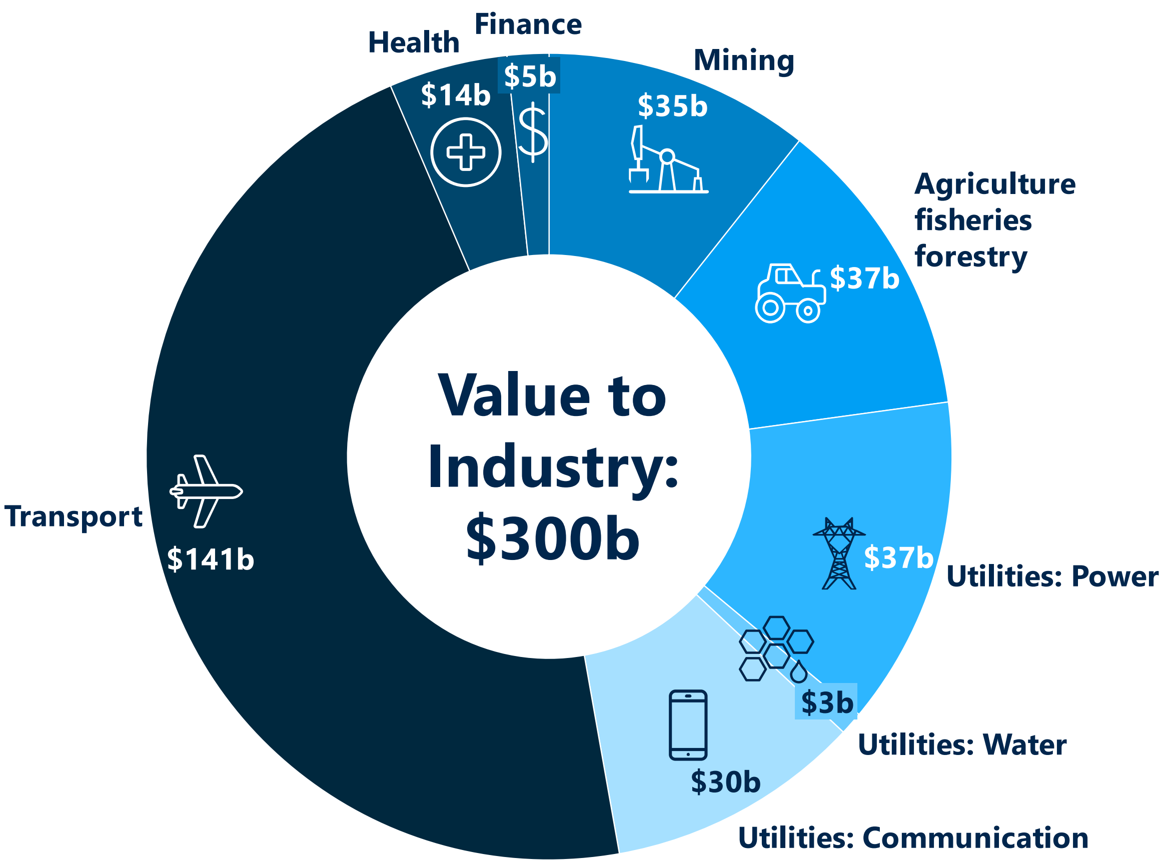


Table 3 provides a detailed breakdown of the contribution of each industry to the overall current industry value of EMO to APEC. It also outlines the value of EMO relative to the total value of each industry over all economies.

Table 3 | Current industry value of EMO for APEC

Industry	Current economic value of EMO for each industry US$ million	Share of total value of EMO to industries %	Value of EMO relative to the total value of each industry over all economies %
Transport	140,868	47	6.7
Utilities: Power	36,788	12	4.8
Agriculture, fisheries and forestry	36,542	12	2.1
Mining	34,511	11	1.4
Utilities: Communication	30,295	10	4.3
Health	13,711	5	0.7
Finance	4,692	2	1.1
Utilities: Water	2,822	1	2.7
Total	**300,230**	**100**	

The estimated value to each industry is based on:

- the size of the industries in each APEC economy
- the potential EMO could make to this value, under best-use applications, based on the current leading user economy
- the extent to which each economy can utilise the full potential for their industries.

The dominant factors driving value are both how well economies can use EMO to its full potential, and the relative size of these industry sectors in an economy. Transport extracts the highest value, not because it is the largest sector, but because it is where EMO has added the greatest value.

Value also comes through enabling new business models and the delivery of new products as much as it does cost savings for existing business models and products.

The use of Land Remote-Sensing Satellite (Landsat) data is reducing costs for citizens

As an indicator, a 2010 survey of Landsat users found that around 50% of respondents felt that their costs for identified projects using Landsat data would increase if they did not have access to the data, while 41% responded that they did not know. For those who felt their costs would increase, the average was by 30%. The same survey canvassed willingness to pay to avoid a break in continuity of the Landsat imagery, which was estimated to range between a mean of US$1,000 per image for federal government institutions and US$700 for private sector users.

3.2.1 Transport

The transport industry is the clear leader in the current value that is derived from EMO applications, with an estimated 47% of the total value of EMO to APEC value added by industry. This is driven by the cumulative value added that EMO has provided to the industry, which, when used to its full potential, is conservatively estimated to be between 12% and 15% of the total value of the transport industry.[7] The study estimates that the value added for transport is currently 6.7% higher than it would have been without EMO, reflecting the fact that only some economies are close to fully achieving this potential value.

One of the largest clients for Malaysia's EMO data products is the aviation and shipping industries.

Transport has been transformed over the past 50 years through the introduction of containers and improvements in ports, ships and aeroplanes (less so in rail and road transport, although this is progressing). In the last few decades, the unit cost of transportation for developed economies has fallen from 7.4% of the value of goods in the 1980s to 6.4% in the 2000s.[8] This has been driven largely by the improvement in logistics made possible by digital maps, GPS positioning systems and digital communications. GPS services are provided by EMO technologies. EMO also improves the productivity in transport through better information for route planning, avoiding bad weather, optimising fuel use by knowledge of ocean currents, and infrastructure design.

For example, the value of digital maps to the transport industry through efficiencies in a reduction of travel time has been estimated to be US$264 billion, although a substantial proportion of this is not included in market value.[9] Another estimate is that GPS contributed US$38.1 billion to the United States 2013 economy in transport, or 0.23% of the US GDP.[10]

Data on currents, winds and sea ice is used to determine shipping routes and improve safety and efficiency.[11] For example, satellite imagery is used to improve winter navigation through ice in the Baltic Sea. Finnish and Swedish icebreakers use satellite radar images (which replaced aerial surveys conducted by helicopters) to find the best route through ice, allowing them to save costs of time, fuel, and uncertainty. The estimated economic benefit to Finland and Sweden of just this application is between €24 and €116 million annually. While icebreaking may be less relevant to most APEC economies, it does give an indication of how EMO delivers value to the transport industry beyond the GPS and digital maps.

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[7] Where ranges are cited for the potential value added by EMO the mid-point was used in the model.

[8] R Asariotis, H Benamara, H Finkenbrin, J Hoffman, J Lavelle, M Misovicova, V Valentine, & F Youssef, 2011, *Review of maritime transport*, United Nations Conference on Trade and Development (UNCTAD), Geneva.

[9] AlphaBeta, 2017, *The economic impact of geospatial services: how consumers, businesses and society benefit from location-based information*, AlphaBeta, Sydney, viewed 25 March 2019, <https://www.alphabeta.com/wp-content/uploads/2017/09/GeoSpatial-Report_Sept-2017.pdf>.

[10] Cooperative Research Centre for Spatial Information (CRC–SI), 2017, *Earth observation: data, processing and applications: volume 1B: Data—image interpretation*, CRC–SI, Carlton, Vic., viewed 20 March 2019, <https://www.crcsi.com.au/assets/Consultancy-Reports-and-Case-Studies/Earth-Observation-reports-updated-Feb-2019/Vol1B-high-res-75MBpdf.pdf>.

[11] Copernicus Marine Environment Monitoring Service (CMEMS), 2016, *Marine Environment Monitoring Service*, [Copernicus, European Commission, Europe], viewed 19 March 2019, <https://www.copernicus.eu/sites/default/files/documents/Copernicus_MarineMonitoring_Feb2017.pdf>.

3.2.2 Utilities: power

Power utilities are in the next set of three industries where EMO is delivering considerable value, making up 12% of the industry value added. This high share of value is due, in part, to the fact that power is a major sector in most APEC economies and there is a potential for EMO to improve performance by an estimated 8% to 10%.

Power utilities benefit from EMO through its contribution to demand-forecasting: allowing suppliers to optimise production to stabilise the system and to meet demand. With the growing use of renewables, that are more dependent on weather, this value add will only increase over time. EMO is also useful in monitoring conditions for energy system assets, including shutdown to avoid damage.
Satellite imagery—and, increasingly, drones—are used to reduce maintenance costs on power grids and pipelines, and to optimise the location of new assets.

Mexico is using EMO to support alternative energy exploration through wind, solar and biomass energy.

There has been little quantitative analysis of the value of EMO to the energy sector. In the EU, improved weather forecasts using the ESA's Copernicus technology were estimated to have resulted in a 2% increase in revenues from solar PV, even though only 10% of firms in the sector were using the technology.[12] This was expected to increase by 7% per year from 2015 to 2020.

3.2.3 Agriculture, fisheries and forestry

The impact of EMO on agriculture, fisheries and forestry makes up 12% of the industry-derived value. This reflects, in part, the relatively small share of agriculture, fisheries and forestry in the overall APEC GDP. However, it also reflects the relatively low uptake of EMO applications in many of the developing APEC economies, where these industries make up a larger share of their economic activity. The gain for economies using more of the potential is significant, with EMO estimated to be able to raise the value added in agriculture by between 7% and 8%. The potential value added in forestry is slightly less, at 5%, while in fisheries the estimate is between 2% and 3%. Some economies are generating these levels of benefit, with Singapore and the United States attributing 7.2% and 7.0%, respectively, of their agriculture, fisheries and forestry value to EMO. Similarly, Australia, Hong Kong China, and Canada all attributed over 5% of their industry value to EMO. The importance of EMO for their agriculture, fishery and forestry industries was emphasised in the interviews with representatives from the People's Republic of China, Mexico, Republic of Korea, and New Zealand.

'Weather forecasting, ocean monitoring, agriculture, fisheries, forestry, land management, environment industries have relatively higher EMO capabilities [in our economy].'
(Republic of Korea)

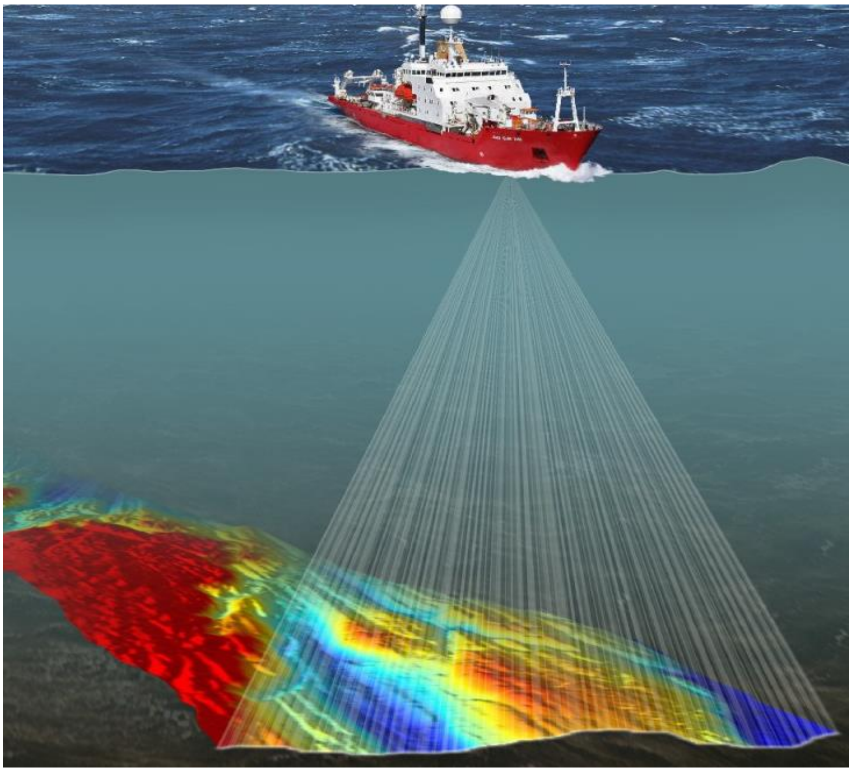
[12] PwC, 2016, *Study to examine the socio-economic impact of Copernicus in the EU: report on the Copernicus downstream sector and user benefits*, European Commission, Luxembourg, viewed 27 March 2019, <http://www.nereus-regions.ovh/wp-content/uploads/2017/10/Copernicus_Report_Downstream_Sector_October_2016.pdf>.

The uses of EMO vary considerably in their sophistication. For example, the value of EMO in weather forecasting for broad acre agriculture in Australia was estimated at AU$25 million in 2015, and with more accurate forecasts this is estimated to rise to AU$135.8 million in 2025 (assuming newer, recently installed satellites improve the accuracy and frequency of remote sensing and improve dynamic meteorological modelling).[13] Even what seem to be simple applications can have major benefits in agriculture.

For example, in India, EMO has been used to understand and improve decision-making around optimal sowing dates. It was estimated that the decision to sow wheat one week earlier on average led to an overall yield gain of 5% nationally.[14]

The potential of EMO to improve outcomes in agriculture, fisheries and forestry goes well beyond better weather information. The benefits to agricultural production systems from sophisticated applications of EMO are probably the best documented of all EMO applications. In part, this is due to the long tradition of research to improve agricultural productivity and to the interest of economists in designing optimal production systems.

Figure 10 | Ocean floor mapping is supported by a shipping volunteer program to provide supplementary data.[16]



EMO has allowed analysts to take their predictive models to a new level by providing the field level information needed to optimise inputs and improve yield. For example, one academic report found an increase in the return for corn production of between US$25 and US$200 per acre, and between US$19 and US$38 an acre for wheat in the US Heartlands and Northern Great Plains.[16] In Australia, a 2007 study on precision farming estimated that it delivered 10–15% savings in operating costs and 10–30% increase in yields.[17] In 2015, Copernicus services, used by 13% of the EU agriculture sector, generated between

[13] ACIL Allen Consulting, 2015, *The value of Earth observations from space to Australia: report to the CRC for Spatial Information December 2015*, Cooperative Research Centre for Spatial Information (CRCSI), Carlton, VIC., viewed 29 March 2019, <https://www.crcsi.com.au/assets/Resources/CRCSI-The-Value-of-Earth-Observations-from-Space-to-Australia-Final-web.pdf>.

[14] DB Lobell, JI Ortiz-Monasterio, AM Sibley & VS Sohu, 2013, 'Satellite detection of earlier wheat sowing in India and implications for yield trends', *Agricultural Systems,* vol. 115, viewed 11 July 2019, <https://www.sciencedirect.com/science/article/pii/S0308521X12001400>, (text copied from <https://www.spacefordevelopment.org/wp-content/uploads/2018/10/6.4502_UKSA_SPACEUK_Solutions-for-Agriculture_web.pdf>).

[15] British Antarctic Survey Press Office, 2009, *Press Release: Sonar images reveal seabed*, British Antarctic Survey: Natural Environment Research Council, Cambridge, UK., viewed 29 March 2019, <https://www.bas.ac.uk/media-post/new-antarctic-seabed-sonar-images-reveal-clues-to-sea-level-rise/>.

[16] CR Leslie, LO Serbina & HM Miller, 2017, *Landsat and agriculture–case studies on the uses and benefits of Landsat imagery in agricultural monitoring and production*, Open File Report 2017–1034, USGS science for a changing world, US Geological Survey, Fort Collins CO.

[17] N Schofield, P Chudleigh, S Simpson & S Pearson, 2007, *Land & Water Australia's portfolio return on investment & evaluation case studies*, Land & Water Australia, Canberra.

€9.2 and €13.7 million in benefit, with over 90% of this coming from precision farming techniques. These benefits are expected to increase by 38% per year between 2015 and 2020.
The annual value of EMO to the UK Government in agriculture in 2017 was estimated to be £45.1 million and this is expected to rise to £75.4 million in 2020.[18]

EMO is increasingly being used in estimating crop values well before they are harvested and even before they are planted. To get a sense of the potential value of EMO in these types of applications, consider the example of Weatherbill. This company, founded in 2006—which uses EMO data to provide applications for farmers to help them determine potentially yield-limiting factors in their fields—sold for US$1 billion in 2014. A major value of this service is in helping farmers to manage (and insure against) variability due to weather.

EMO plays a major role in reducing the cost of improving environmental outcomes

Maximising the value of EMO to agriculture and to the natural resource base that it relies on (and consequent cost savings due to improvements in environmental services such as clean water for other parts of the economy) needs investment that goes beyond the provision of the EMO data. It needs in-depth understanding of the production systems and how they interact with the natural resource base. In addition, it needs economic analysis, as there can be trade-offs between production outcomes and environmental outcomes.

Nevertheless, even without this level of investment, simple inference from land imagery guides producer decision-making and makes it more likely that farmers will implement regulation. Ultimately, this benefits both farmers and the environment.

As early as 1974, the benefit of Landsat in improving production forecasts was estimated to improve the value of agriculture by between US$3.8 and US$25.8 billion in the United States.[19] Similarly, there is growing emphasis on the importance of the ocean economy and the use of EMO to battle, "rising water temperatures, loss of biodiversity, rising sea levels, growing acidification and other impacts associated with climate change…[to encourage] a durable balance between increasing ocean uses and marine ecosystems' integrity".[20]

Tracking and forecasting of algal blooms is also growing in importance for a wide range of users (Figure 11). The cost of algal blooms in Australia was estimated at between AU$180m and $240m per year in 2000.[21] In 2000, monitoring for algal blooms alone cost AU$8.7 million; doing this using EMO substantially reduces this cost.

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18 G Sadlier, R Flytkjaer, F Sabri & N Robin, 2018, *Value of satellite-derived Earth Observation capabilities to the UK Government today and by 2020*, London Economics, London, viewed 28 March 2019, <https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf>.

19 GA Hazelrigg Jr & KP Heiss 1974, *The economic value of remote sensing of earth resources from space: an ERTS overview and the value of continuity of service*, ECON, Inc., Princeton, NJ.

20 OECD, 2019, *Rethinking innovation for a sustainable ocean economy*, OECD, Paris, viewed 18 March 2019, <https://www.oecd-ilibrary.org/sites/35309746-en/index.html?itemId=/content/component/35309746-en>.

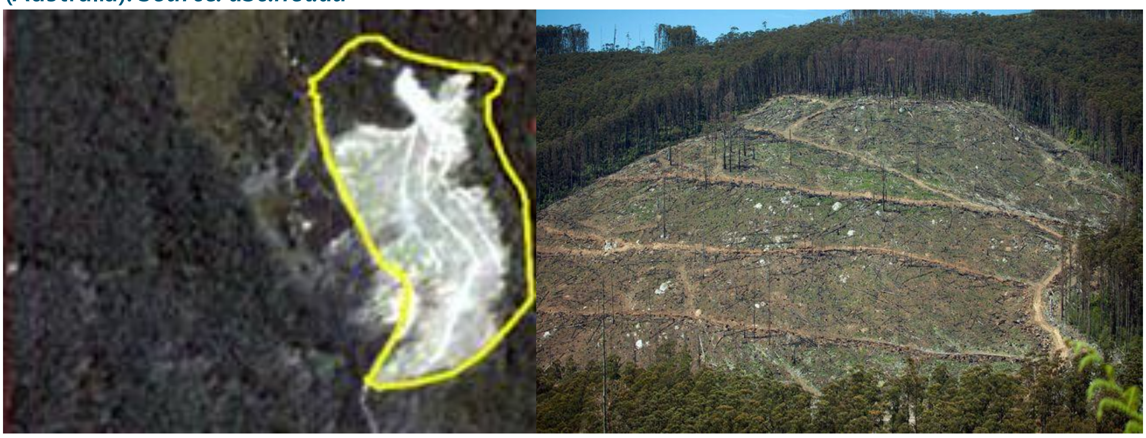
21 DA Steffensen, 2008, 'Economic cost of cyanobacterial blooms', in HK Hudnell (ed.), *Cyanobacterial harmful algal blooms: state of the science and research needs,* Springer-Verlag, New York, viewed 22 March 2019, <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.363.8727&rep=rep1&type=pdf>.

Figure 11 | Algal blooms can have devastating impacts on the ocean economy (Lake Erie, the United States). ***Source: NASA***

An example of how EMO applications can improve both agricultural productivity and environmental outcomes is its use in managing irrigation and fertiliser applications. The use of moderate-resolution land imagery led to improvements in crop management, which raised yields relative to what they would otherwise have been. This led to a reduction in the overuse of fertiliser, contributing to improvements in the quality of groundwater.

The value of these changes for 35 counties in north-eastern Iowa in 2010 has been estimated to be as much as US$858 million.[22] The mechanism for delivering improvement was through improved regulatory enforcement that was able to be focused on managing real risks rather than taking a more blanket, and hence costly, approach. The estimates illustrate the importance of local conditions for impact—the value for Iowa is likely to be greater than in many other locations, as 80% of its water supply comes from groundwater. But in every location, there is likely to be some application that can add value to both farmers through cost savings and/or higher yields, and to the environment through better management of the resource base.

Figure 12 | EMO can be used to monitor and enforce regulations regarding illegal deforestation (Australia). ***Source: abc.net.au***



[22] R Bernknopf & C Shapiro, 2015, 'Economic assessment of the use value of geospatial information', *ISPRS International Journal of Geo-Information*, vol. 4, pp. 1142–65.

Production based research has also been important for fisheries and forestry, but here the interest has been even more in the monitoring of the sustainable harvest as well as the development of optimal harvest strategies. For example, in commercial fisheries in north-eastern United States, the value of EMO from the information on biological community structure alone was estimated to be around US$4 million in 2007, while forecasts of algal blooms saved shellfish farmers around US$1 million.[23] Using EMO to monitor water quality of the Great Barrier Reef Marine Park was estimated to contribute AU$160 million in value to commercial fisheries in 2011–12. [24] An economic evaluation of the NSW Native Vegetation Monitoring Program (NVMP), which used earth observation satellites to monitor vegetation change and compliance, estimated the annual benefit of the NVMP, in terms of avoiding illegal clearing, reducing compliance costs, and improving efficiency of natural resource management to be AU$20.7 million in 2015 rising to AU$39.2 million by 2025. While EMO is not the sole source of this value added, without EMO, enforcement of regulations would be very difficult.

3.2.4 Mining

Mining accounted for 11% of the value of EMO to industry in 2018. At its best, EMO was estimated to contribute between 2% and 5% of value added in mining. This low share reflects the smaller share of mining activity where EMO applications have considerable use. The current main uses of EMO are in mineral exploration, managing weather-related risks and in monitoring for emerging problems. Applications in automated mining are not considered here because—while GPS can be used—local area systems are also used.

In exploration, EMO is used to generate topographical maps that can help confirm sub-surface structure derived from seismic data. It is also used to detect oil seeps from deep-water petroleum reservoirs. The costs of mineral exploration can be substantially reduced through use of EMO data. For example, Bernknopf et al. estimated that an updated, coarser resolution bedrock map enabled improved mineral exploration efficiency, productivity, and effectiveness by locating 60% more targets and supporting an exploration campaign that was 44% more efficient in a case study of the Flin Flon Belt area in Canada. Further gains of an additional 17% reduction in search effort across all favourable domains, and a 55% reduction in search effort in the most favourable domain, could arise with a finer map resolution. A similar study of the south Baffin Island case estimated a 40% increase in expected targets and a 27% reduction in search effort from using an updated finer resolution map, worth CAN$2.28 million to CAN$15.21 million, (a multiplier effect of up to eight on the cost of producing the map).[25] Additionally, the value of EMO to exploration for Australian mining was conservatively estimated at AU$5 million in 2015.[26]

> The People's Republic of China, Mexico and Malaysia all have highlighted the importance of EMO for their mining industry, including for oil and natural gas rigs.

[23] HL Kite-Powell, 2009, 'Economic considerations in the design of ocean observing systems', *Oceanography*, vol. 22, no. 2.

[24] ACIL Allen Consulting, 2015, *The value of Earth observations from space to Australia: report to the CRC for Spatial Information December 2015*, Cooperative Research Centre for Spatial Information (CRCSI), Carlton, VIC., viewed 29 March 2019, <https://www.crcsi.com.au/assets/Resources/CRCSI-The-Value-of-Earth-Observations-from-Space-to-Australia-Final-web.pdf>.

[25] RL Bernknopf, AM Wein, MR St-Onge & SB Luca, 2007, *Analysis of improved government geological map information for mineral exploration: incorporating efficiency, productivity, effectiveness, and risk considerations*, Geological Survey of Canada Bulletin 593, US Geological Survey Professional Paper 1721, US Geological Survey, Reston VA.

[26] ACIL Allen Consulting, 2015, *The value of Earth observations from space to Australia: report to the CRC for Spatial Information December 2015*, Cooperative Research Centre for Spatial Information (CRCSI), Carlton, VIC., viewed 29 March 2019, <https://www.crcsi.com.au/assets/Resources/CRCSI-The-Value-of-Earth-Observations-from-Space-to-Australia-Final-web.pdf>.

EMO is also used for monitoring for problems such as detecting spills or leaks during operations, malfunctioning infrastructure, and hazards to workers on remote rigs. It is used to identify adverse weather events and dangerous sub-surface currents, which influence timing on construction and when to withdraw staff from offshore rigs. This saves mining companies money as well as reducing risk, for example, EMO-enabled weather observation is predicted to be able to save 10% of extreme weather losses for off shore oil mining rigs.[27] It is also used to monitor compliance with environmental requirements, for example preventing illegal mining in India using a mining surveillance system. [28]

In the EU, 8% of the oil and gas industry use Copernicus services, which were estimated to benefit the industry by €2.4 to €13.6 million in 2015. Benefits were expected to grow by 11% per year from 2015 to 2020.[29]

3.2.5 Utilities: communication and water, sewerage and sanitation

Communication utilities make up 10% of the industry value of EMO, while water utilities, reflecting their smaller share in most economies, make up 1% of this value added. Both industries have a potential benefit from EMO in the range of 6% to 8%. Like power utilities, EMO data plays an important role in assisting these utilities to forecast demand and supply. EMO data are also used to monitor assets and to optimise the location of assets. Communication technologies are themselves sources of EMO data and share some technologies.

To the extent that EMO data enable the systems to be more robust and to find problems faster, they deliver value in fewer disruptions to these essential services. The cost of disruption is high, so even a small reduction in disruption events can be valuable to energy dependent industries, with a greater (non-market) value to their customers, who often bear the brunt of disruptions.

The value to water utilities of EMO arises in part through weather forecasts that assist in the modelling of demand and supply (rainfall, surface flows, and ground water recharge and evaporation) improving the efficiency of system management. This is particularly important for irrigation water provision, where EMO monitoring also plays a role in wider system management including identifying illegal water diversion. For example, Water NSW uses EMO data to measure and report on land cover changes in Sydney's drinking water catchment every four years. With EMO, data measurement costs AU$30,000, but without it, it would cost up to AU$150,000 as extensive fieldwork is needed to deliver the same information.[30] More broadly, Water NSW estimates that the value of EMO in meeting operating license, legislative, regulatory and service standard requirements is AU$885,000 per year in 2015.

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[27] *Ibid.*

[28] K Campbell, 2017, 'Earth observation satellites starting to bring benefits to mining sector', *Mining Weekly,* 2 June. Available from: <https://www.miningweekly.com/> - *Mining Weekly,* 2 June, Creamer Media, Johannesburg, viewed 22 March 2019, <https://www.miningweekly.com/article/earth-observation-satellites-starting-to-bring-benefits-to-mining-sector-2017-06-02/rep_id:3650>.

[29] PwC, 2016, *Study to examine the socio-economic impact of Copernicus in the EU: report on the Copernicus downstream sector and user benefits,* European Commission, Luxembourg, viewed 27 March 2019, <http://www.nereus-regions.ovh/wp-content/uploads/2017/10/Copernicus_Report_Downstream_Sector_October_2016.pdf>.

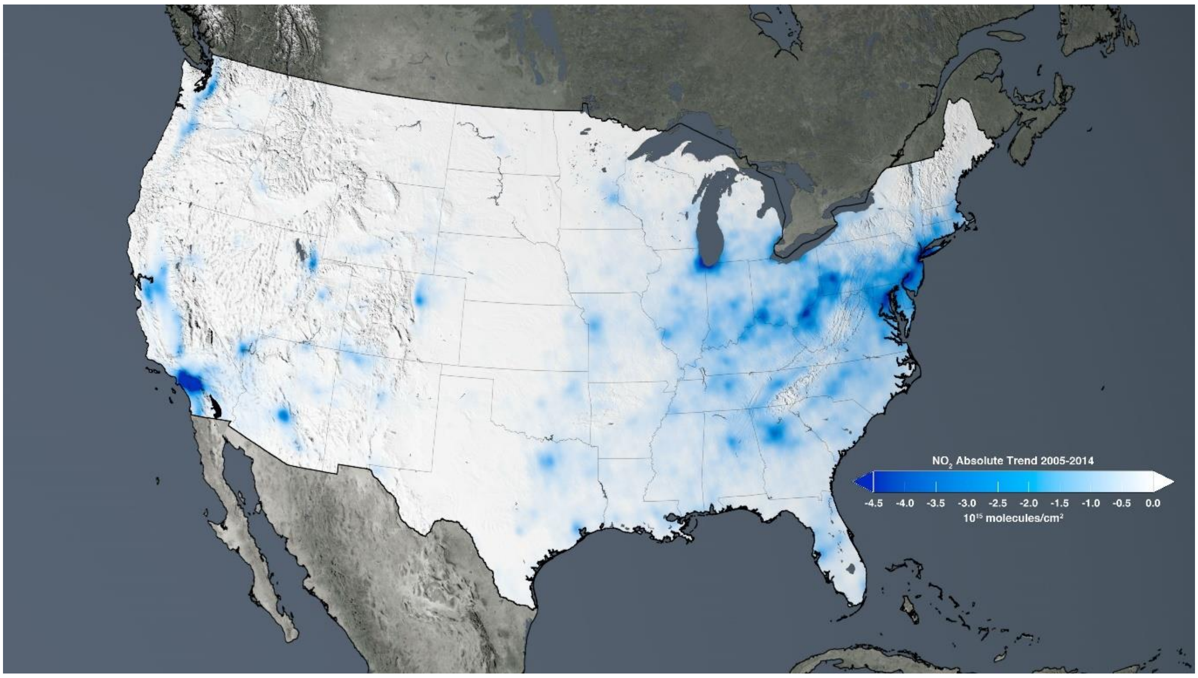
[30] ACIL Allen Consulting, 2015, *The value of earth observations from space to Australia: report to the CRC for Spatial Information December 2015*, Cooperative Research Centre for Spatial Information (CRCSI), Carlton, VIC., viewed 29 March 2019, <https://www.crcsi.com.au/assets/Resources/CRCSI-The-Value-of-Earth-Observations-from-Space-to-Australia-Final-web.pdf>.

3.2.6 Health

Health is a major industry in many APEC economies and accounts for a substantial share of public expenditure. Taking just private health services, the health industry contributes over 6% of GDP in Hong Kong, China; 4% in Australia; but 1.4% in the Philippines.

Many of the benefits that flow from the EMO contribution to the health industry are reaped by the consumers of health services (or by avoiding the need to consume health services). For example, a World Bank analysis of the benefits of upgrading hydro-meteorological information production for early warning systems in all developing economies estimated that it could save up to 23,000 lives a year (as well as saving approximately US$4 billion per annum in preventable asset losses).[31] The health industry also benefits, as early warning systems help to manage costs, and early intervention can reduce the cost of treatment. For example, EMO is used to monitor aeroallergens, air quality, and infectious diseases, and provide early warning for public health risks such as heat waves and epidemic pre-conditions.[32] Mapping weather, land and ocean variables is used to predict/anticipate the spread of contagious disease/epidemics (cholera, dengue, malaria).[33] Because these currently have more value in improving public health outcomes than in improving the productivity of health services, the industry estimates understate the real value to communities.

Figure 13 | EMO is being used to understand the impact of humans on global air quality (through measuring nitrogen dioxide levels). *Source: NASA*

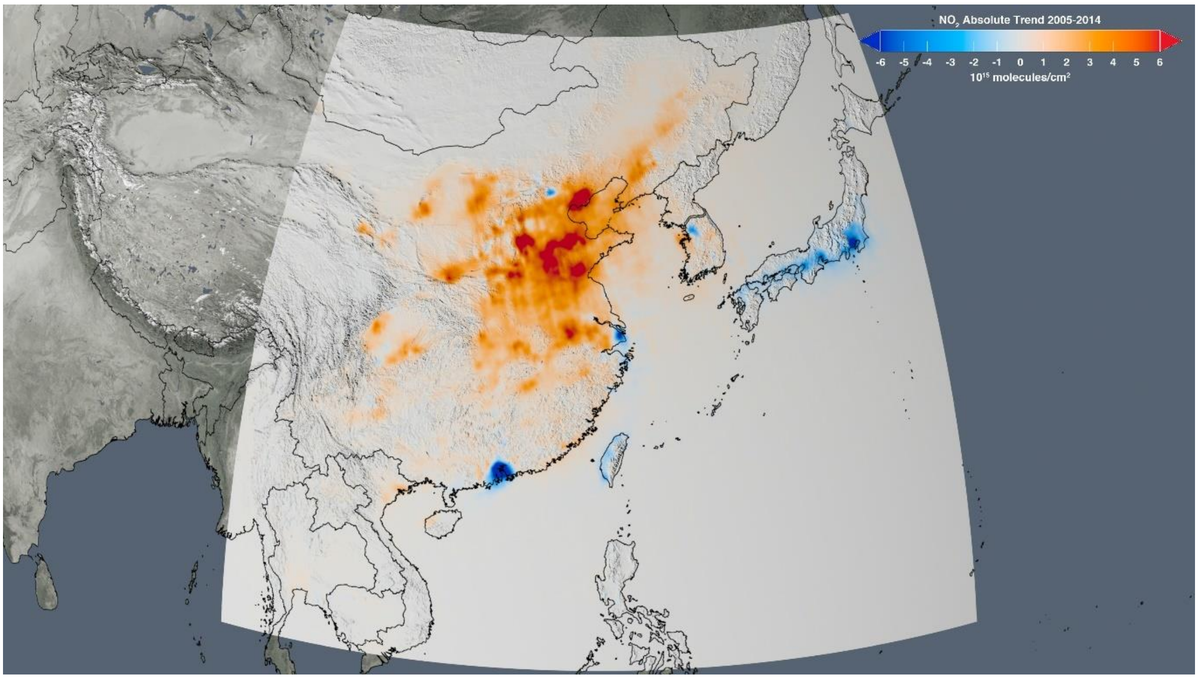


[31] UK Space Agency, 2018, *UK Space Agency International Partnership Programme: space for agriculture in developing countries*, UK Space Agency, Swinden, Wiltshire, viewed 3 April 2019, <https://www.spacefordevelopment.org/wp-content/uploads/2018/10/6.4502_UKSA_SPACEUK_Solutions-for-Agriculture_web.pdf>.

[32] CRCSI, 2016, *Earth observation: data, processing and applications: volume 1A: Data—basics and acquisition*, CRC–SI, Carlton, Vic., viewed 20 March 2019, <https://www.crcsi.com.au/assets/Consultancy-Reports-and-Case-Studies/Earth-Observation-reports-updated-Feb-2019/Vol1A-high-res-112MB.pdf>.

[33] Group on Earth Observations, Earth Observations for Health (EO4HEALTH), viewed 19 March 2019, <https://www.earthobservations.org/activity.php?id=143>.

Figure 14 | Trend maps for air quality (nitrogen dioxide concentrations) across the People's Republic of China, Republic of Korea, and Japan. ***Source: NASA***



3.2.7 Finance

Finance is another major industry sector, hovering around 10% of GDP in most developed economies. The finance sector's relatively low share of EMO industry value added comes from the sector's relatively low use of EMO applications — with estimates of EMO impact at around 1%.

The value of EMO to the finance industry comes in the improvements in real-time information across a wide range of areas. This is of particular value in futures markets: helping to model future supply and demand more accurately, and in insurance markets, through improved assessment of risk, including identification of fraud. For example, a review of the use of Landsat by the United States Department of Agriculture (USDA) Risk Management Agency (RMA), which is responsible for monitoring compliance with the terms of the federal crop insurance program, estimated the RMA return-on-investment in 2005 was 458 times the cost, based upon US$34.4 million in restitution and forfeiture and a US$75,000 USDA Image Archive subscription fee.[34]

[34] GC Nelson, DE Schimmelpfennig & DA Sumner, 2007, *Can satellite-based land imaging data be made more valuable for agriculture?*, Report to the US Department of Agriculture, Cooperative Agreement 58-6000-6-0047, US Department of Agriculture, Washington DC.

3.3 The current value of EMO to disaster management

Over the past 20 years, 2,968 recorded natural disasters have inflicted over US$2 trillion in damages across APEC, with 460,000 fatalities and an additional 2.6 billion people affected.[35] Storms, floods, earthquakes, landslides and wildfires accounted for approximately 90% of disasters during this period.

Within this context, it is estimated that the current value of EMO in terms of reducing the costs and improving the outcomes of disaster management is US$26 billion. This estimate is a lower bound as it does not include the cost savings of fewer lives lost and lower rates of injury. While there is data available on lives lost due to natural disasters, it is not complete and highly variable in scale, frequency, and location of natural disasters. There is also a further problem in putting a value on lives lost, with actuarial approaches using local wages as a proxy for value and discounting non-economic costs. For these reasons, a value was not assigned to these very important, but hard to quantify, impacts of EMO.

The value added by applications of EMO varies across each economy depending on their adoption of the available technologies and their exposure to natural disasters. More specifically, realisation of value is dependent upon the:

- **Stage of disaster management**: EMO technology, for example, can be used for early warning systems or flood map planning during preparedness and mitigation stages to inform zoning and prevent economic damages prior to a natural disaster. It can also be used to map damages and track the location of deployed resources during the response and on-going recovery.
- **Type of disaster**: the uses of EMO vary based on the type of disaster. Slow onset disasters, such as drought, cyclones and floods, can be tracked and impacted areas forecast based on current behaviour. Similarly, early warning systems are essential for saving lives during rapid-onset natural disasters such as tsunamis.
- **Level of development**: developing economies are more exposed to natural disasters, in part due to their location and in part the nature of their economies, which tend to be more agriculture and natural resource dependent.[36] They also have much higher mortality rates from natural disasters compared to developed economies due to generally insufficient and less advanced infrastructure and disaster management capabilities.[37] Conversely, the economic losses in developed economies are generally much higher due to the complex interconnected nature of these economies' GDP and the extent of infrastructure at risk.

Reflecting these three variables, the United States realised 69% of the current value of EMO to disaster management across APEC, valued at approximately US$18 billion. Similarly, Japan, the People's Republic of China, Australia and New Zealand each realised a substantial amount of value (Figure 15; refer to

[35] All natural disaster information was obtained from the leading international disaster database, EM-DAT, from the Centre for Research on the Epidemiology of Disasters, viewed 27 March 2019, <https://www.emdat.be/>.

[36] C Benson & E Clay 2004, *Understanding the economic and financial impacts of natural disasters,* Disaster Risk Management series, no. 4, World Bank, Washington DC.

[37] MK Lindell, 2013, 'Disaster studies', *Current Sociology*, vol. 61, no. 5-6, pp. 797–825.

Table 4 for specific values). The remainder of APEC economies account for only 4% of the current value in disaster management. (Note: there were no recorded losses from natural disasters in Singapore in the past 20 years, resulting in their realisable value being zero for the purposes of modelling.)

Figure 15 | Current value of EMO to disaster management by economy (in US$)

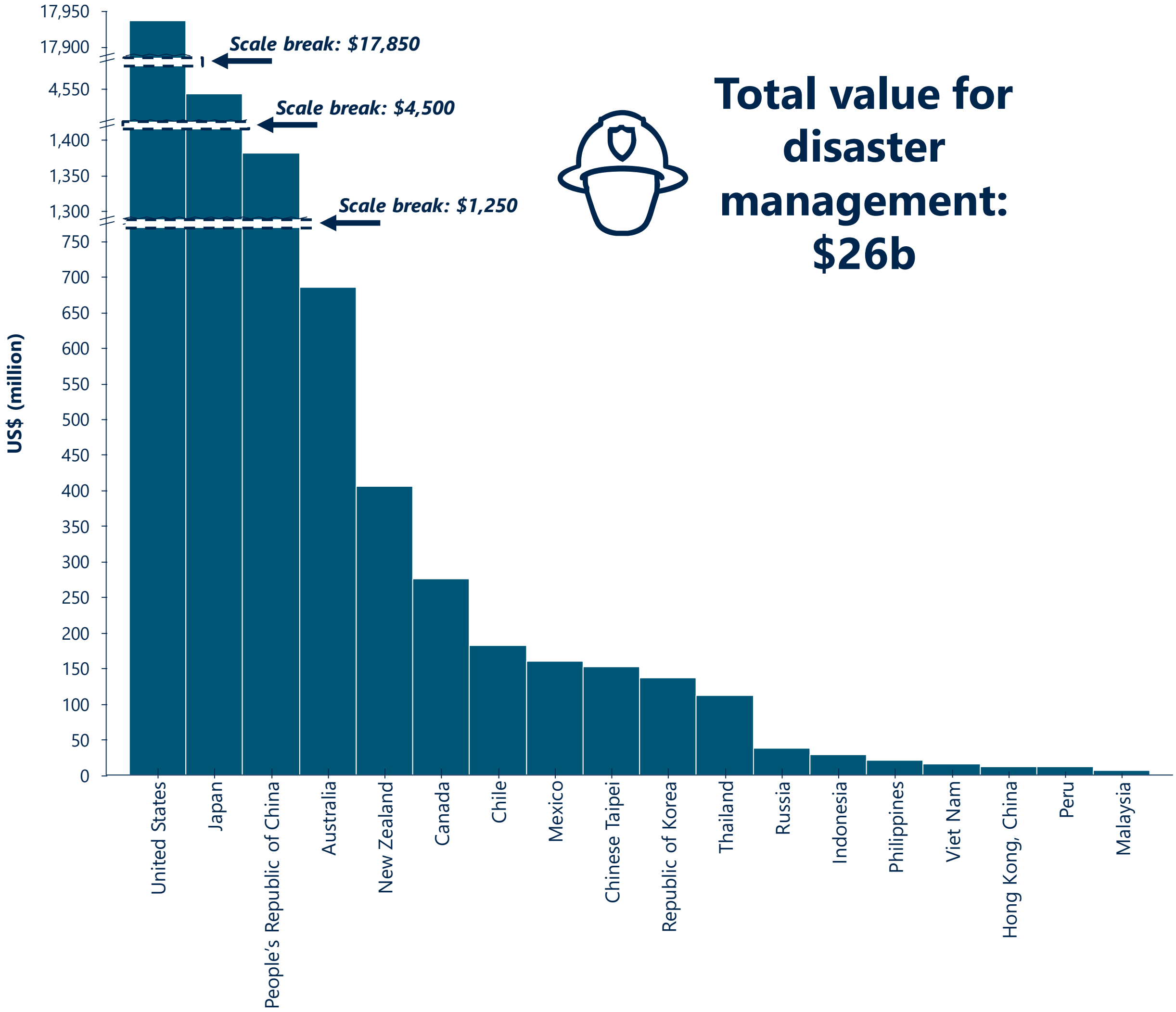


Table 4 | Current value of EMO for disaster management

Economy	Current economic value of EMO for disaster management US$ million
United States	17,936
Japan	4,544
People's Republic of China	1,382
Australia	686
New Zealand	406
Canada	276
Chile	183
Mexico	159
Chinese Taipei	153
Republic of Korea	136
Thailand	112
Russia	37
Indonesia	28
Philippines	21
Viet Nam	16
Hong Kong, China	12
Peru	11
Malaysia	7
Papua New Guinea	<1
Brunei Darussalam	<1
Singapore	0
Total	**26,104**

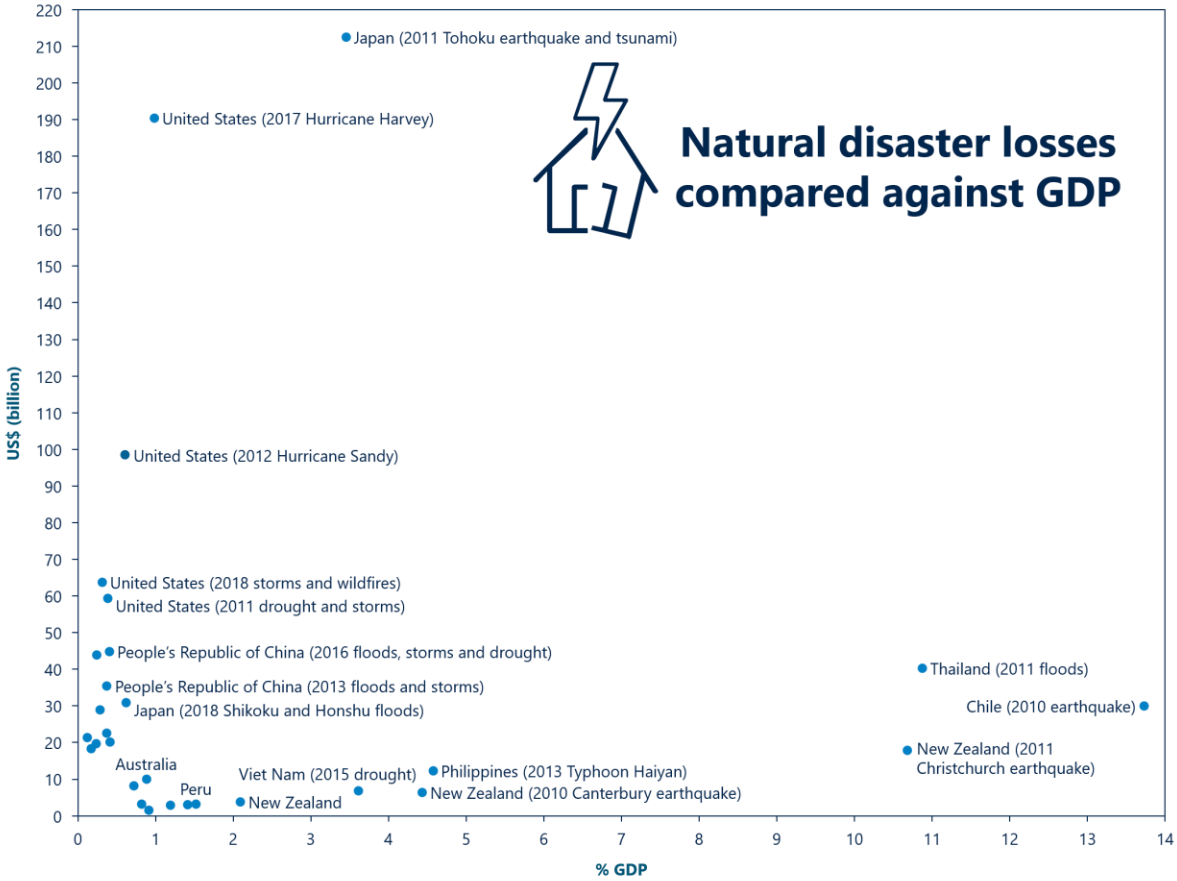
The more developed economies realised the most value added from EMO in disaster management, but these estimates focus on the cost to infrastructure and disruption to economic activity. It is important to recognise that the contribution of EMO to improved disaster management is not purely monetary.
As discussed above, the loss of human life is not included in the model due to the difficulty in assigning the reduction in loss due to EMO and concerns about putting a value on human life. There is also a direct impact on an economy of injury and death from natural disasters through the forfeiture of productivity and national capability that is not included in the estimates, which suggests that the estimates understate the value of EMO in reducing the costs of natural disasters.

Figure 16 | Super Typhoon Haiyan caused US$12 billion of damages to the Philippines in 2013.
Source: Earthsky.org

As developing economies are more exposed to natural disasters and suffer greater rates of mortality due to insufficient and less-advanced infrastructure and to the greater concentration of citizens, where it is applied EMO technology makes a major contribution to reducing economic losses. Many APEC economies are subject to natural disasters, which means that, although small relative to larger, more developed economies, the losses are significant when compared against the affected economy's GDP.[38] This is illustrated when the cumulative costs of natural disasters for each economy in a given year are plotted against the share of GDP that was lost for that year (from 2010 to 2019) (see Figure 17, which also notes the most significant natural disaster). The purpose of this analysis is to outline the important role that EMO plays in helping all economies reduce the losses from natural disasters, particularly those economies that are at risk of crippling effects on long-term economic development.

[38] C Charvériat, 2000, *Natural disasters in Latin America and the Caribbean: an overview of risk*, Inter-American Development Bank (IDB), Washington DC, viewed 1 April 2019, < https://www.preventionweb.net/files/2544_ENVNatDisastLACeline.pdf >.

Figure 17 | Annual losses from natural disasters compared against GDP for highly impacted economies (considered between 2010 and 2019)



A prime example of just how much is at risk from natural disasters is to compare the cumulative losses suffered by Chile in 2010 (primarily due to the Chile earthquake) against those for Japan in 2011 (mainly due to the Japanese Tohoku earthquake and tsunami). Although Japan suffered economic losses of US$213 billion compared to US$30 billion for Chile, Chile's losses equated to 13.7% of their GDP while for Japan they were 3.5% of GDP.

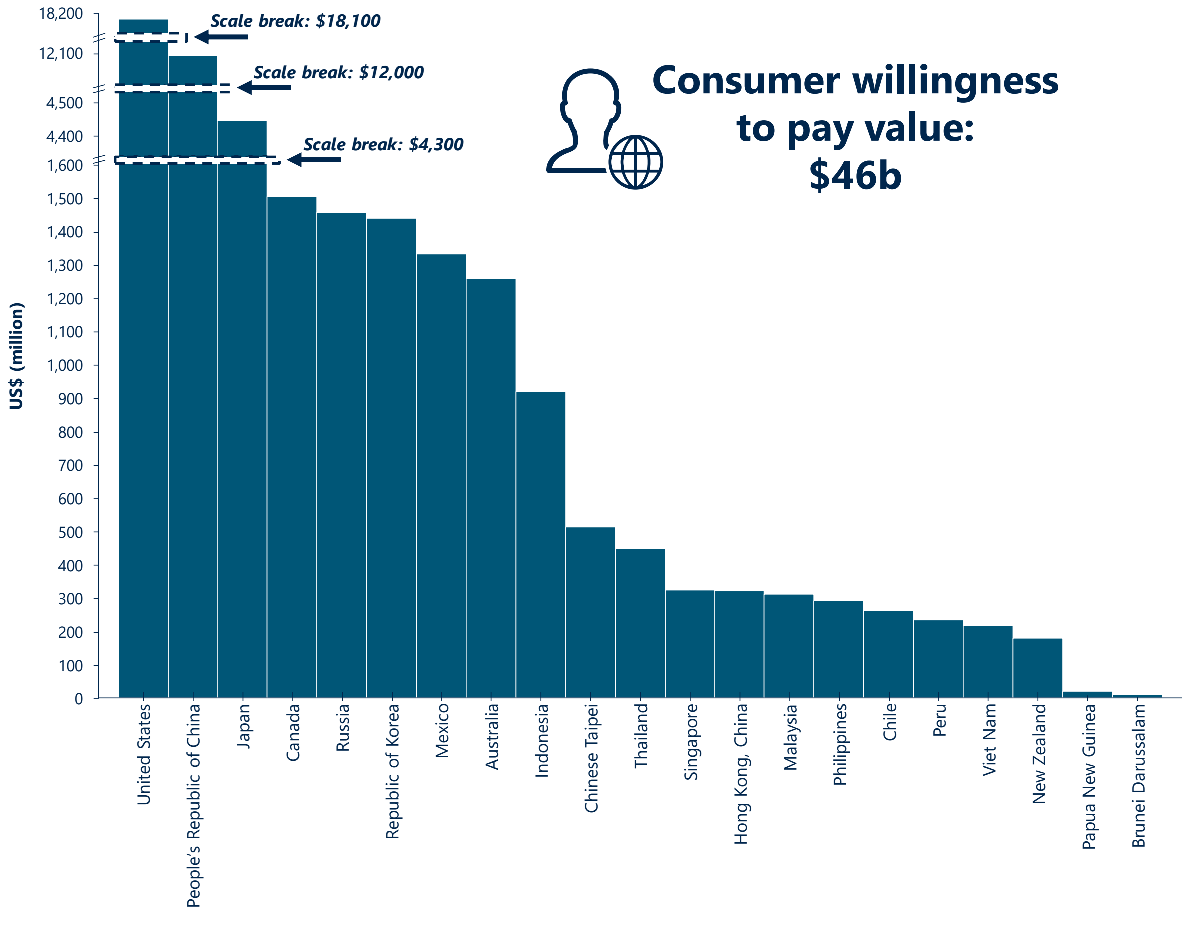
EMO can play an important role in empowering all economies to be more resilient to the impacts of natural disasters—particularly as urban growth and climate change are increasing the consequences and likelihood of catastrophic events. As explained through consultation with the United States representative, EMO can be used to inform incentives for reconstruction; insurance schemes; grants programs; and contingent liabilities. Furthermore, EMO can be used in all economies to improve mitigation and preparedness against the impacts of natural hazards (such as informing the construction of grey/green infrastructure for protection); enabling sufficient early warning systems; and undertaking predictive mapping of the path of a disaster.

3.4 Current consumer 'willingness to pay' value of EMO

There are a wide range of benefits from EMO that flow directly through to the population, with consumers willingly paying for these services. It is difficult, however, to disaggregate this value from the larger economic value to industry, because many of these consumer benefits interact with components of GDP. Examples of consumer willingness to pay include the use of phone apps for transportation (such as Uber and Go-Viet) or to determine the optimal route to work based on current traffic. Uses can be as specific as for recreational fishing—with EMO information being used to both locate fish and to keep anglers safe. In the north-eastern United States, this was estimated to be worth US$11 million in 2008, while the value to recreational boating was US$1 million.[39] The value of the additional fish caught by recreational fishers through use of EMO in Florida in 2007 was estimated at US$91million.[40] At a global scale, the value of digital maps alone to consumers has been estimated at US$347 billion per annum.[41]

Given the difficultly in applying these types of non-market use values to the different economies, this model has only included the value attributable to a consumer's willingness to pay for weather-related services, which ae widely available to most members of most economies. The estimates are based on willingness-to-pay studies in North America and scaled to account for each economy's population and level of development (hence, capacity to pay).

Figure 18 | Current consumer 'willingness to pay' value of EMO, by economy (in US$)



[39] H Kite-Powell, 2009, 'Economic considerations in the design of ocean observing systems', *Oceanography,* vol. 22, no. 2, pp. 44–49.

[40] K Wieand, 2008, 'A Bayesian methodology for estimating the impacts of improved coastal ocean information on the marine recreational fishing industry', *Coastal Management*, vol. 36, issue 2, pp. 208–23.

[41] AlphaBeta, 2017, *The economic impact of geospatial services: how consumers, businesses and society benefit from location-based information*, AlphaBeta, Sydney, viewed 25 March 2019, <https://www.alphabeta.com/wp-content/uploads/2017/09/GeoSpatial-Report Sept-2017.pdf>.

Table 5 | Current 'willingness to pay' value of EMO to consumers

Economy	Current 'willingness to pay' value of EMO to consumers US$ million
United States	18,182
People's Republic of China	12,093
Japan	4,447
Canada	1,505
Russia	1,456
Republic of Korea	1,441
Mexico	1,334
Australia	1,259
Indonesia	920
Chinese Taipei	513
Thailand	449
Singapore	324
Hong Kong, China	321
Malaysia	312
Philippines	291
Chile	263
Peru	234
Viet Nam	217
New Zealand	180
Papua New Guinea	21
Brunei Darussalam	12
Total	**45,772**

As expected, the economies with the greatest populations had the highest realisable value from consumer willingness to pay, with the United States' and the People's Republic of China's non-market value estimated as US$18 billion and US$12 billion, respectively. Six other economies realised over US$1 billion of value, with Japan measuring US$4.4 billion. Overall, the estimate of value of a consumer's willingness to pay for weather services was almost twice that of disaster management, illustrating how small gains to individuals every day adds up to considerable benefit—often of similar magnitude to the benefits from big gains from less common events.

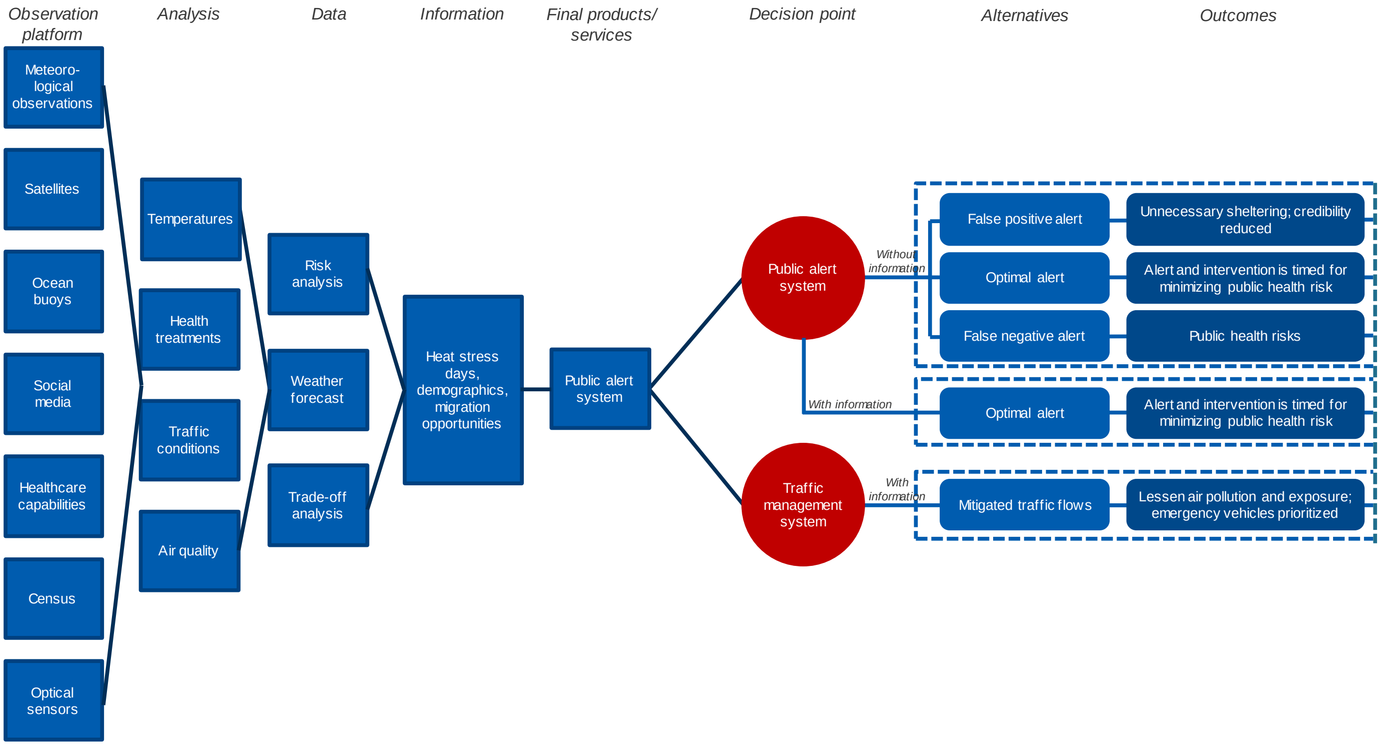
3.5 Technology pathways and value

This report does not attempt to trace the value from EMO applications in the various industries back to specific types of EMO infrastructure (such as satellites, drones and ocean-bottom sensors). This is because, for most applications, there are many technologies needed to provide the required information for making production and other investment decisions; to make predictions (such as weather forecasting); and to deliver a service (such as precision agriculture). The two following examples illustrate this well.

3.5.1 Public health alert systems rely on the interconnected nature of EMO technology

The first example is the decision tree for delivering value in relation to responses to increasing temperature on human health. This example is taken from a 2017 workshop of EMO experts where activities involved developing a number of these value chain/decision tree diagrams.[42] These are very useful in illustrating the range of data that goes into decisions, and the need for additional investments to turn the data into information and products—and then to act on that information (Figure 19).

Figure 19 | A decision tree outlining the impacts of increasing temperatures on human health highlights the integrated and cumulative nature of EMO technology in providing actionable insights.

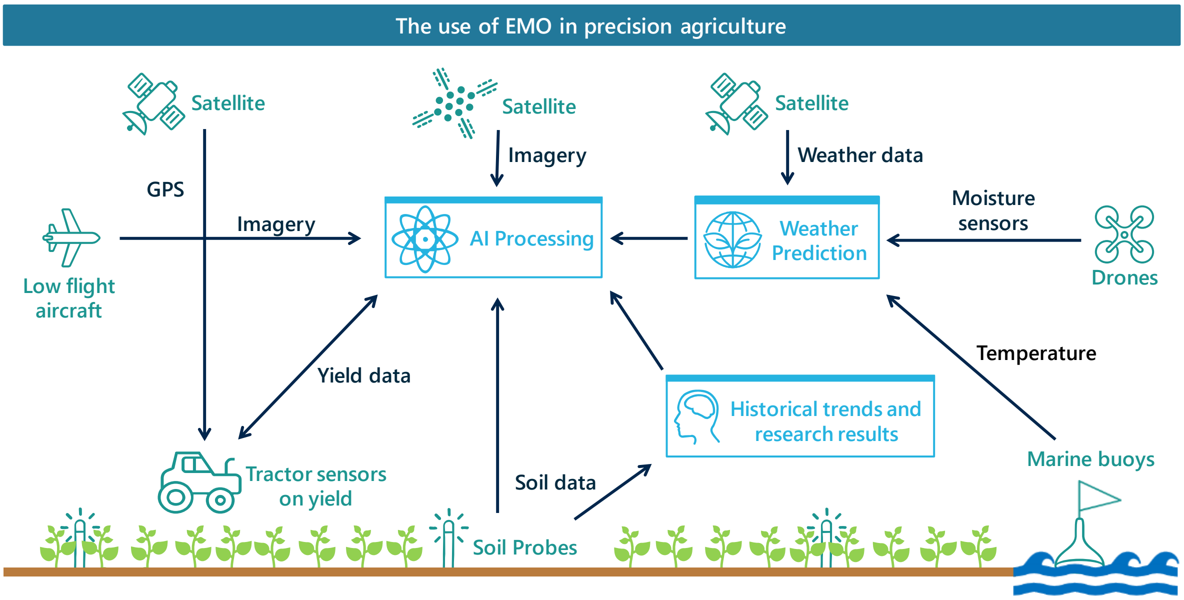


[42] F Pearlman et al., 2017, *Demonstrating the value of Earth observations—methods, practical applications, and solutions—Group on Earth Observations Side Event Proceedings*, US Geological Survey Open-File Report 2019–1033, US Geological Survey, Reston, VA..

3.5.2 Precision agriculture uses many types of EMO infrastructure

The second example is the range of data and technologies used in precision agriculture. Making accurate predictions about crop yield, soil conditions, biomass levels, moisture content, and other factors, requires the integration of a range of EMO sources. Not only that, this information also requires technical and analytical processing, and translation into data products that can be interpreted and acted on by farmers.

Figure 20 | The interconnectivity of EMO technology as part of precision agriculture



These examples also illustrate the importance of 'translatability', which was highlighted by multiple economies during the study's consultations. Translatability acknowledges that having the technology is not enough: the capabilities and uses of the technology (including analytics) need to be able to be understood by the decision-makers who have the authority and resources to put decisions into action. If governments and the private sector do not understand or appreciate the capability of EMO technology, or lack the resources to act on the information, then they will not invest in either the technologies to generate data or the analytics to turn data into information that informs the decisions they take.

As discussed in Section 5, this lack of ability to act on information is an issue in many APEC economies, in at least some areas of their economy (both in industries and in areas of non-market value). Governments need to recognise the value of EMO to their decisions, to ensure there is a consistent investment in baseline observation capability.

Views from APEC regarding translatability and raising awareness of the uses of EMO

The United States – 'Regardless of economy, there are significant issues…with the sustaining of baseline observing capability…these funds…have to be argued for consistently.'

Japan – have started to introduce policies that aim to raise the profile of mechanisms to implement EMO insights; however, some economies are still constrained by their economic standing. '[There needs to be a] mechanism to facilitate collaboration between industry, government, and academia…[including] promotion of public awareness.'

Malaysia – 'When the economy is bad, there is not much money for development projects. Also, awareness impacts investment by the Government. There is low awareness in Malaysia by policy personnel…To comply with regulations, there needs to be investment.'

New Zealand – there is a growing need for 'technical translators' to emphasise the relevance of EMO technology, not only locally, but globally—which will encourage private sector investment. '[It is important to get] the information into the hands of those making the decisions. There is a gap between the great ideas and the sensing people. There is a need for technical translators between developers and the scientists.'

The interviews conducted during this study showed that technology is only one part of the realisation of value. Having government and private sector impetus to invest and support the growth of EMO is just as significant, if not more, in realising economic value. These issues point to the areas where collaboration can add considerable value, which is taken up in Section 5.

4 The potential future value of EMO

The potential future value of EMO to APEC in 2030 is estimated at US$1.35 trillion (Figure 21). As with the current value, the value added to industry contributes the largest proportion of value at US$1.07 trillion, followed by consumer willingness to pay value at US$195 billion and then disaster management at US$81 billion.

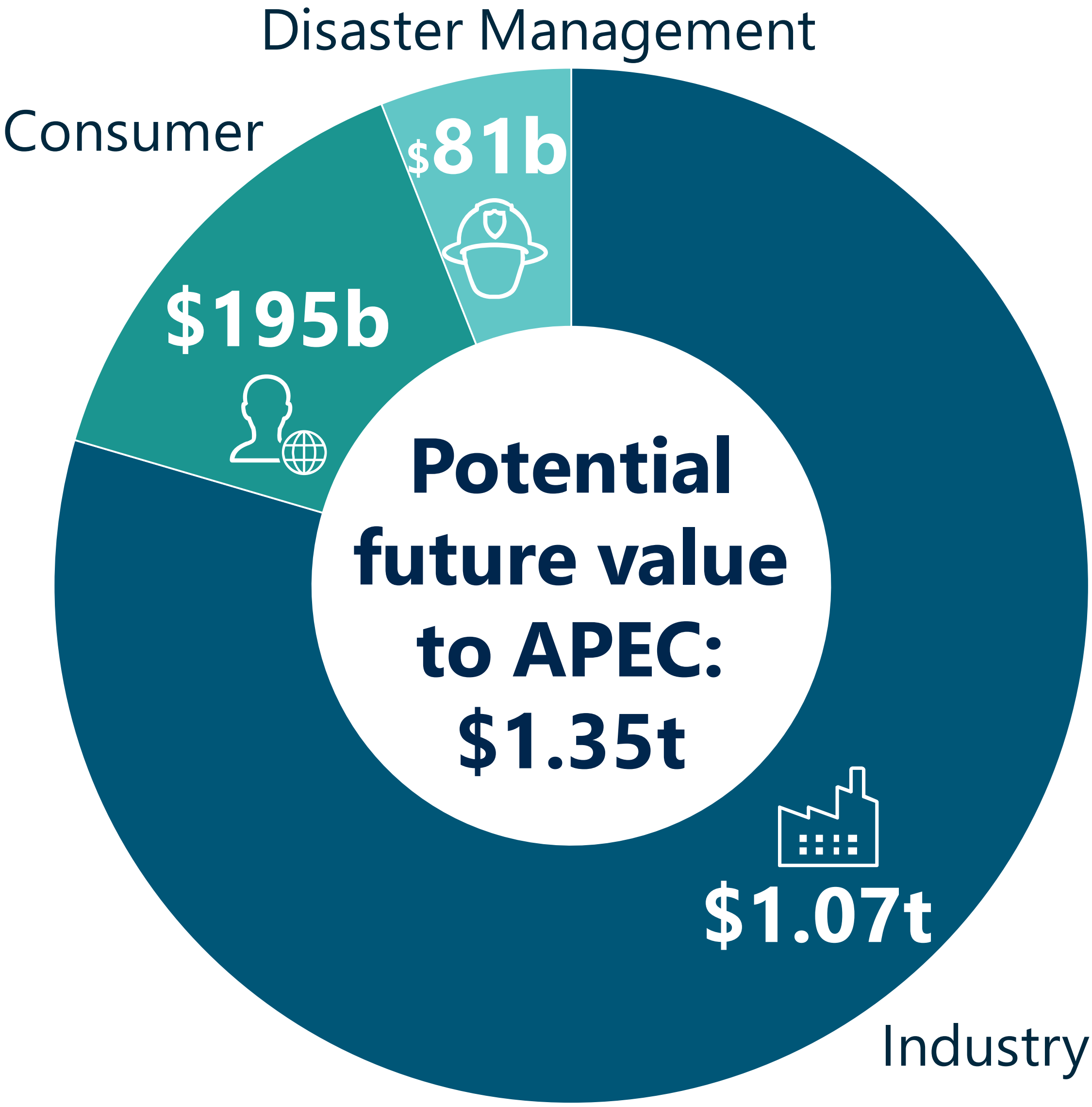
Forecasting the potential economic value of EMO to APEC until 2030 relies on a number of assumptions about the future that are inherently uncertain. Far more change is likely to arise in some areas, such as the industry breakdown of each economy in 10 years' time, but predicting this type of change is fraught—so we have assumed that the industry shares will not change significantly. Similarly, history tells us that there will be new advances in technology that will fundamentally alter the current growth rates of EMO adoption—but what applications these will be and which sectors of the economy they will affect is impossible to predict. For this reason, to model the 2030 value of EMO to APEC economies we have applied the following assumptions:

- Every industry in each economy will grow at the same rate as the projected growth of the whole economy.
- The industry composition for an economy will remain constant until 2030.
- The rate of absorption for an economy increases proportionally to the projected GDP per capita growth until 2030. (Refer to Section 6.1 for a detailed explanation of absorption).
- The projected growth rate of EMO as its own sector and the subsequent uptake of EMO applications varies globally. North America has estimated growth rates of 8.1%, while the Asia-Pacific region has estimated EMO growth of 18.5%.[43] Similarly, Republic of Korea estimated that the number of industries which use EMO applications is growing at 17% per annum.[44] Part of these projections relate to economies that are developing more rapidly, which will be captured by the GDP per capita growth. However, other parts of the projections reflect the development of particular technologies and new applications. The estimates use a conservative value of 8% per annum growth in the value added from improved applications of EMO (this increases the potential value added). This may result in an underestimate of the future value of EMO to APEC, and for each economy—particularly those economies within Asia that are on the cusp of realising much more benefit from EMO.
- The change in disaster management is driven by growing GDP per capita, representing an economy's ability to use EMO to increase their resilience to natural disasters.
- The rise in consumer willingness to pay is driven by population growth and growing GDP per capita.

[43] G Sadlier, R Flytkjaer, F Sabri & N Robin, 2018, *Value of satellite-derived Earth observation capabilities to the UK Government today and by 2020*, London Economics, London, viewed 28 March 2019, <https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf>.

[44] The Republic of Korea Government, 'Survey of the State of the Korean Space Industry', document provided to authors by representatives from the Republic of Korea.

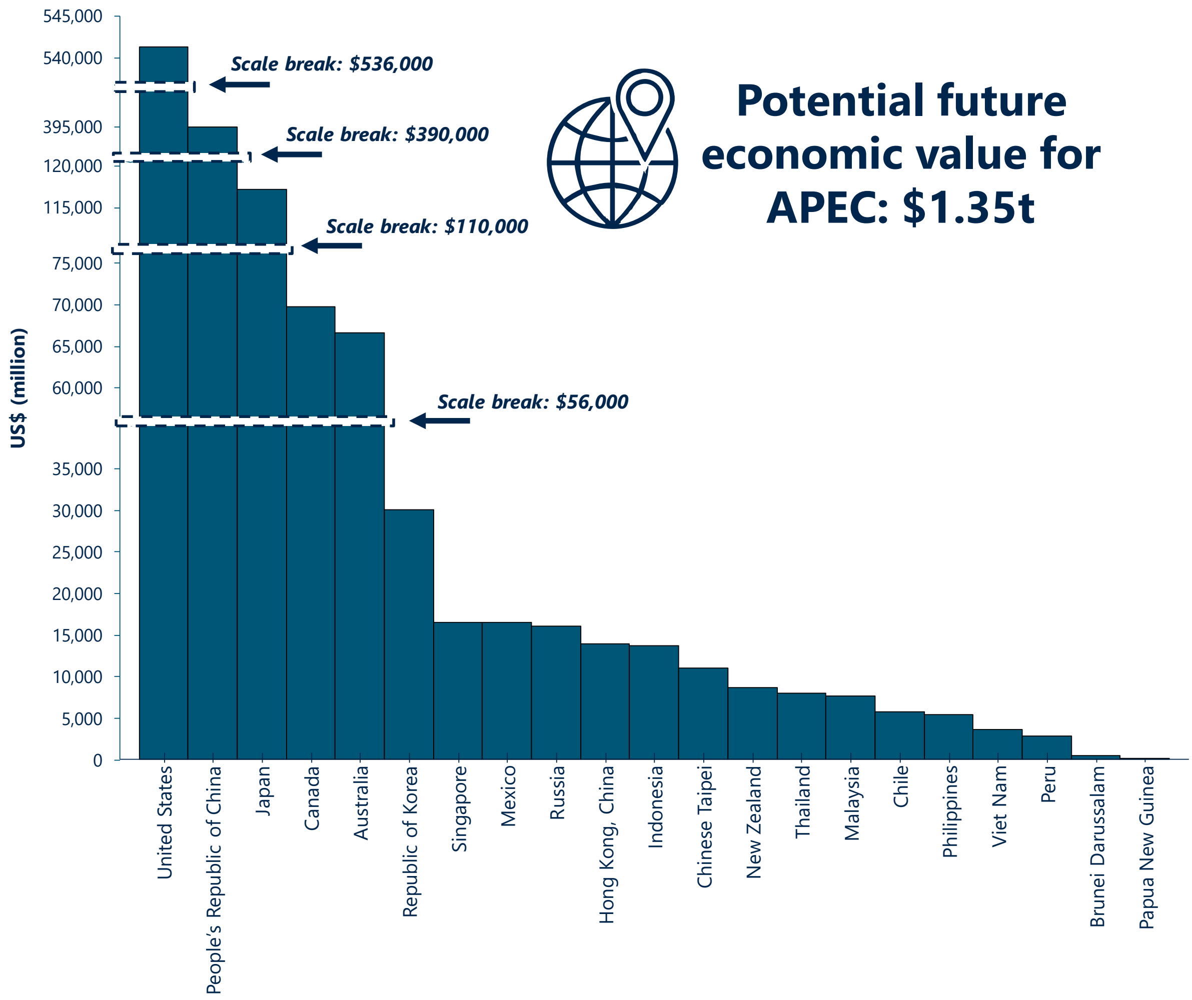
Figure 21 | Potential future economic value of EMO to APEC in 2030 (in US$)



4.1 The potential future economic value of EMO

Based on the assumptions set out above, in 2030 the United States will remain the biggest beneficiary of EMO making up 40% of its potential future value to APEC with US$541 billion (Figure 22). The value of EMO to the People's Republic of China is estimated to rise more rapidly to US$395 billion (29%). As with the current value, it is important to recognise disparity in the future value of EMO across APEC economies is a function of the overall size (GDP) of an economy; its structure (as some industries gain more from EMO than others); and an economy's level of development. Twenty one per cent of the projected future value is realised by Japan, Canada, Australia and Republic of Korea, with each economy gaining their greatest added value from transport. The remaining US$130 billion (9.6%) is distributed across the other APEC economies.

Figure 22 | The total potential future value of EMO for each APEC economy in 2030 (in US$)



With different relative rates of growth in GDP and in population, the distribution of the potential future value of EMO across APEC is expected to change (Table 6). The relative contribution of the United States to the overall value of EMO to APEC is estimated to fall by 12.5%, even while the value to the United States rises by US$346 billion. The People's Republic of China contribution rises by 14.9% and their value added by EMO is estimated to be US$342 billion higher than in 2019. Similarly, Japan, Canada, and Australia are also expected to make up a lower overall share of the benefits, while economies such as the Republic of Korea, Hong Kong China, and Indonesia are expected to make up a greater share of the overall value of EMO in the near future. These changes are attributable mainly to the different projected growth rates of each economy until 2030, which raise both the base on which EMO value is delivered and their rates of adoption of EMO applications.

Given the growth trajectories of the People's Republic of China, and other Asian nations of a similar development index, it is safe to assume that these economies will continue to contribute larger proportions of the overall value realised from EMO beyond 2030.

Table 6 | Potential future economic value of EMO for each APEC economy in 2030

Economy	Industry value US$ million	Consumer 'willingness to pay' value US$ million	Disaster management value US$ million	Total value 2030 US$ million	Proportion of the total potential value 2030 %
United States	2441,410	50,276	49,595	541,280	40.1
People's Republic of China	295,367	89,404	10,216	394,986	29.3
Japan	92,068	12,378	12,649	117,096	8.7
Canada	63,076	5,589	1,023	69,689	5.2
Australia	60,152	4,137	2,253	66,542	4.9
Republic of Korea	24,177	5,383	509	30,069	2.2
Singapore	15,442	1,073	0	16,515	1.2
Mexico	12,028	3,929	469	16,427	1.2
Russia	11,867	4,055	103	16,026	1.2
Hong Kong, China	12,470	1,360	50	13,879	1.0
Indonesia	8,184	5,300	161	13,646	1.0
Chinese Taipei	8,351	2,062	613	11,026	0.8
New Zealand	6,595	640	1,448	8,683	0.6
Thailand	5,318	2,078	517	7,914	0.6
Malaysia	5,928	1,681	37	7,647	0.6
Chile	4,068	988	687	5,743	0.4
Philippines	2,828	2,387	171	5,387	0.4
Viet Nam	1,718	1,771	131	3,621	0.3
Peru	1,877	853	41	2,771	0.2
Brunei Darussalam	378	42	<1	420	<0.1
Papua New Guinea	46	62	<1	108	<0.1
Total	**1,073,348**	**195,451**	**80,676**	**1,349,476**	**100**

4.2 The potential future industry value of EMO in 2030

The total potential future value of EMO technology and applications to APEC economies in 2030 is estimated at US$1.07 trillion (Figure 23). As with the current value, transport contributes the largest proportion of this value at US$490 billion, equivalent to 46% of the industry value (

Table 7).
Agriculture, fisheries and forestry (US$159 billion); mining (US$135 billion); utilities: power (US$125 billion); and utilities: communication (US$98 billion), respectively, contribute the next greatest values. Finance, health, and utilities: water provide US$66 billion of combined value, which is 6% of the overall industry value.

Figure 23 | Potential future industry value of EMO (in US$)

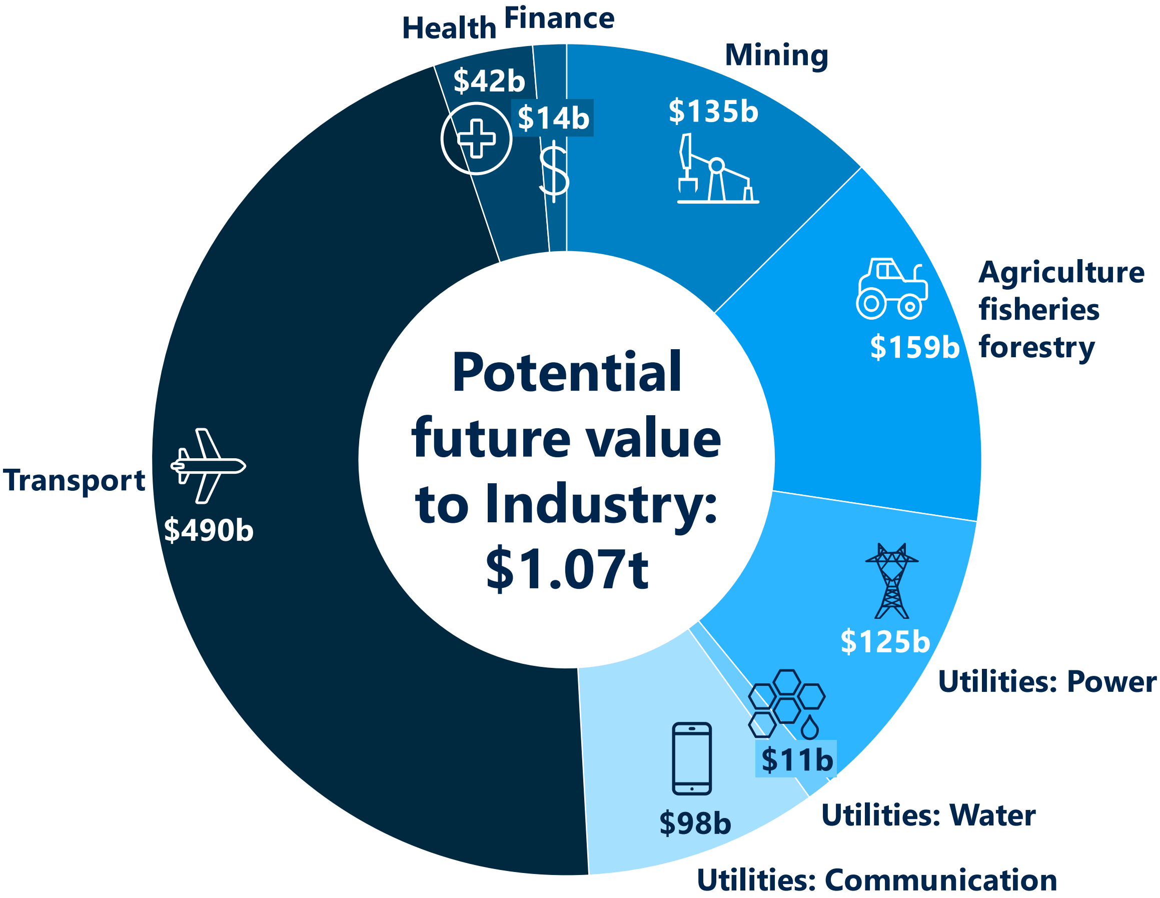


Table 7 | Potential future industry value of EMO across all APEC economies in 2030

Industry	Potential future economic value of EMO for each industry	Share of total future value of EMO to industries	Value of EMO relative to the total value of each industry over all economies
	US$ million	%	%
Transport	490,165	46	15.9
Agriculture, fisheries and forestry	158,833	15	5.5
Mining	135,025	13	3.4
Utilities: Power	125,486	12	11.3
Utilities: Communication	97,510	9	9.9
Health	41,640	4	1.7
Finance	14,058	1	2.7
Utilities: Water	10,632	1	7.0
Total	**1,073,000**	**100**	

The future value of EMO to industry depends in part on the growth rate in value added achieved through the constantly developing applications. The growth rate of 8% for EMO adoption and advancement has the largest, and most consistent, impact on this value.

The interviews and literature that informed this study (outlined in Section 6) highlighted five key areas of focus, which underlie the assumption of an annual growth of 8% in the value added by EMO applications through higher rates of adoption and improved uses of EMO within industry:

1. A greater effort to improve translatability of EMO data and insights

To increase government investment, and encourage private sector funding, there needs to be a greater effort to effectively communicate the technical components of EMO into realisable benefits that can be understood by investors and decision-makers. As emphasised by a representative of the People's Republic of China, there is a need for targeted investment to enhance data processing capabilities to support the Government and users through data products. Economies should leverage both government and private sector funding—recognising the needs of both markets—with governments pushing the boundaries of technology into segments of the spectrum other than visual and infrared; and the private sector generally focussing on the more traditional visual spectrum and data product development.

2. Greater analytical and technical capability

Many economies (the People's Republic of China, Mexico, Malaysia, New Zealand and Peru) stated that the future value of EMO for their economy would rely on both their technical and analytical capability. That is, capability maturity should happen at a rate equivalent to both EMO technology advancement and industry uptake, so that internal expertise remains relevant. Increasing capability across APEC will rely on collaboration between economies.

3. Maintaining baseline capability

If the use of EMO in industry, by consumers, and in disaster management is expected to increase, then each economy needs to maintain at least a baseline capability. This is not just in terms of new infrastructure or computational abilities to analyse data, but also funding committed for maintaining infrastructure (or the data that it provides; capability development; and data products that can encourage further private investment. 'There may be hesitance to invest in [EMO] if [the industry] don't see plans for sustained investment…' (United States).

4. Targeted investment

Each APEC economy, and particularly developing economies, should consider where the greatest return on investment is expected through the use of EMO in industry. This will be a function of:

- the respective size of each industry
- the growth of that industry until 2030
- the current data available (including time-series data)
- the current and potential data applications
- the degree of awareness by government and private sector decision-makers about EMO
- the funding available
- the technical and analytical capability required to realise the benefit.

5. Encouraging innovation

Economies that have advanced EMO capabilities should continue to strive for innovative solutions to industry problems and to share their insights. '[EMO] is maturing as an industry and finding its way into a lot more areas' (New Zealand). There are many applications of EMO that are in their infancy, but likely to develop if data and analytical insights are freely shared. (An example includes the use of EMO for radon mapping to identify sub-surface risks).

Additionally, the value of EMO to each industry is a function of both the size of that industry within each economy and of the level of absorption enabling that economy to utilise EMO. Therefore, each economy's growth rate and industry composition will have an impact on changes in realisable future value from EMO. As such, economies that are growing quickly (the People's Republic of China; the Republic of Korea; and Hong Kong, China) are where the biggest potential increases in value of EMO to industry will occur.

Finally (and not reflected in the model) economies that are able to get 'quick wins' from adopting baseline EMO technology and data products (such as Indonesia, Thailand, Malaysia, the Philippines) are likely to realise more value from EMO in the future than is currently reflected in the estimates. This will occur if they are able to accelerate adoption and attain a higher level of use of EMO-enabled technologies than their level of GDP per capita would suggest. If these economies are able to increase their absorption rate, the potential future value will be greater than that reported here.

4.3 The future value of EMO to disaster management

The potential future value of EMO to disaster management in APEC economies in 2030 is estimated at US$81 billion (Figure 24 and Table 8). The United States, Japan, and the People's Republic of China make up 61%, 16%, and 13% of this value, respectively. Australia, New Zealand, and Canada are estimated to all benefit by more than US$1 billion each from EMO in 2030 while the remaining economies cumulatively account for 4.3% (or US$3.5 billion) of the total potential future value from EMO in disaster management,.

Figure 24 | Potential future value of EMO to disaster management by economy in 2030 (in US$)

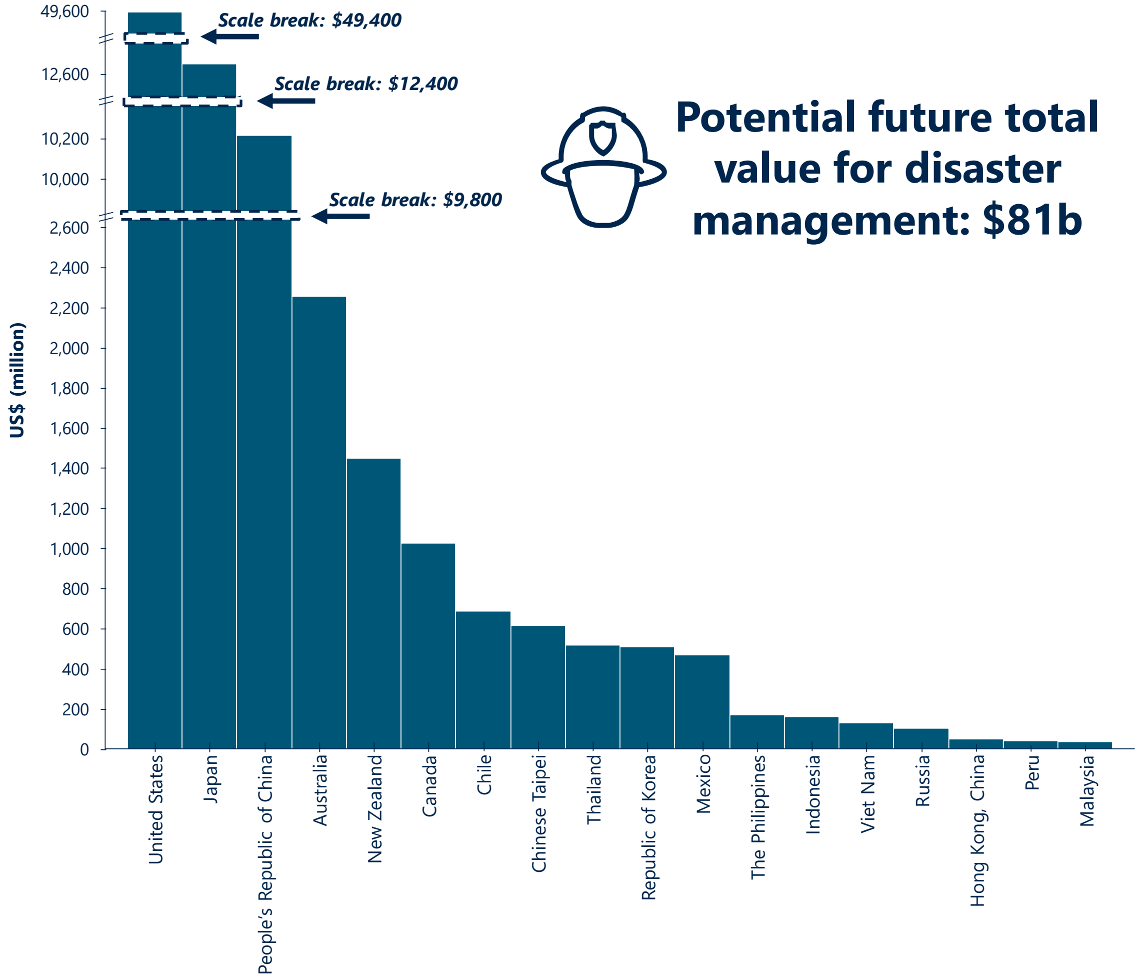


Table 8 | Potential future value of EMO for disaster management in 2030

Economy	Potential future economic value of EMO for disaster management US$ million
United States	49,595
Japan	12,649
People's Republic of China	10,216
Australia	2,253
New Zealand	1,448
Canada	1,023
Chile	687
Chinese Taipei	613
Thailand	517
Republic of Korea	509
Mexico	469
Philippines	171
Indonesia	161
Viet Nam	131
Russia	103
Hong Kong, China	50
Peru	41
Malaysia	37
Papua New Guinea	<1
Brunei Darussalam	<1
Singapore	0
Total	**80,676**

The continued use of EMO for natural disaster management should remain a priority for APEC. There were an annual average of 348 natural disasters globally over the past decade, with several APEC economies suffering major losses. In 2018, 'Indonesia recorded nearly half the total deaths (47%)' from natural disasters recorded globally.[45] Furthermore, '[for economies that] are not as diversified in their productive capacity and financial markets and are thus less able to successfully insure against the external shocks of a natural disaster'[46], EMO can play an important role in helping protect these crucial industries.

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[45] CRED, 2019, *Natural disasters 2018*. Available from: <https://www.emdat.be/publications>.

[46] D Kellenberg & AM Mobarak, 2011, 'The economics of natural disasters', Annual Review of Resource Economics, vol. 3, no. 1, pp. 297–312.

Whether by mapping floodplains, forecasting drought, planning response equipment locations, or providing early warning of tsunamis, EMO can empower APEC economies to better prepare for, and respond to, natural disasters.

The benefits from better disaster preparedness and management increase with the size and density of urban areas in economies affected by natural disasters. Urban areas are expected to absorb all the population growth over the next four decades. 'The population living in urban areas is projected to gain 2.6 billion, passing from 3.6 billion in 2011 to 6.3 billion by 2050.'[47] Subsequently, the role of EMO in city and infrastructure planning is only going to become more significant—with EMO data and data products being used to inform, for example:

- building standards
- the pervious-to-impervious ratio of cities and their drainage rates
- natural and constructed topography
- the change in natural protection and storm-surge buffering due to environmental degradation
- the (re)insurance industry
- disaster impact mapping
- response logistics
- planning for urban sprawl.

The increased concentration of people living in cities within APEC economies will present a growing challenge for many economies needing to have adequate disaster management processes in place. The integration of EMO in disaster management should only increase leading up to 2030, particularly due to the compounding impacts of climate change. Meeting this challenge will rely on a collective effort across APEC to ensure that the economic and human impacts of natural disasters are buffered by the whole of APEC—not borne wholly by those most vulnerable.

> 'Disasters in urban areas are exponentially more harmful, owing to the high population densities and economic importance of cities. Urban disasters yield enormous mortality and injury rates, tear apart the layered fabric of densely-settled neighbourhoods, destroy complex economies and interdependent social systems, and wreak havoc with costly infrastructure.'[46]

This report shows that there is a significant gap between the most and least developed economies within APEC in how much they can realise the value in disaster management from EMO. As previously argued, this value goes beyond dollars, to people's survival: their lives and their livelihoods. This raises the value—beyond those estimated here—of APEC efforts to empower the economies most at risk from natural disasters to be able to use EMO to make informed decisions and bolster their overall resilience.

[47] United Nations 2012. *World urbanization prospects: the 2011 revision* (highlights), Department of Economic and Social Affairs Population Division, United Nations, New York, p. 50.

[48] EJ Blakely, EL Birch & RV Anglin, 2011, 'Introduction', in EJ Blakely, EL Birch, RV Anglin & H Hayashi (eds), *Managing urban disaster recovery: policy, planning, concepts and cases*, Crisis Response Publications, Crowthorne UK.

4.4 Future consumer willingness to pay value of EMO

The consumer 'willingness to pay' value of EMO in 2030 is estimated at US$195 billion (Figure 25 and Table 9). As with the current consumer 'willingness to pay' value, this amount is dependent upon the population and on EMO absorption levels of an economy. As expected, economies such as the People's Republic of China and the United States gain the highest benefit from consumer 'willingness to pay', at US$89 billion and US$50 billion, respectively—equivalent to 71% of this projected 2030 potential future value.

'[Economies] that have strong capabilities ... are able to develop products and a commercial sector that are directly available to the public and so this promotes people-centric applications across a unified framework.'
(The People's Republic of China)

It is difficult to predict what consumers would be willing to pay in the future for access to EMO technology. EMO-based technologies that provide value to people in the community through improved convenience and timesaving are likely to become more pervasive and to grow in value. Given this, we have assumed that consumer future value will grow by the same rate as industry. (This reflects expected growth in public uses beyond weather forecasts, which form the base value.) Given the importance of growth in GDP per capita for the growth in adoption of EMO applications, economies that are expected to have the biggest increase in uptake of EMO use in industry by 2030 are also expected to be able to realise the greatest increase in consumer 'willingness to pay' value over this same period.

Figure 25 | Potential future consumer 'willingness to pay' value of EMO by economy in 2030 (in US$)

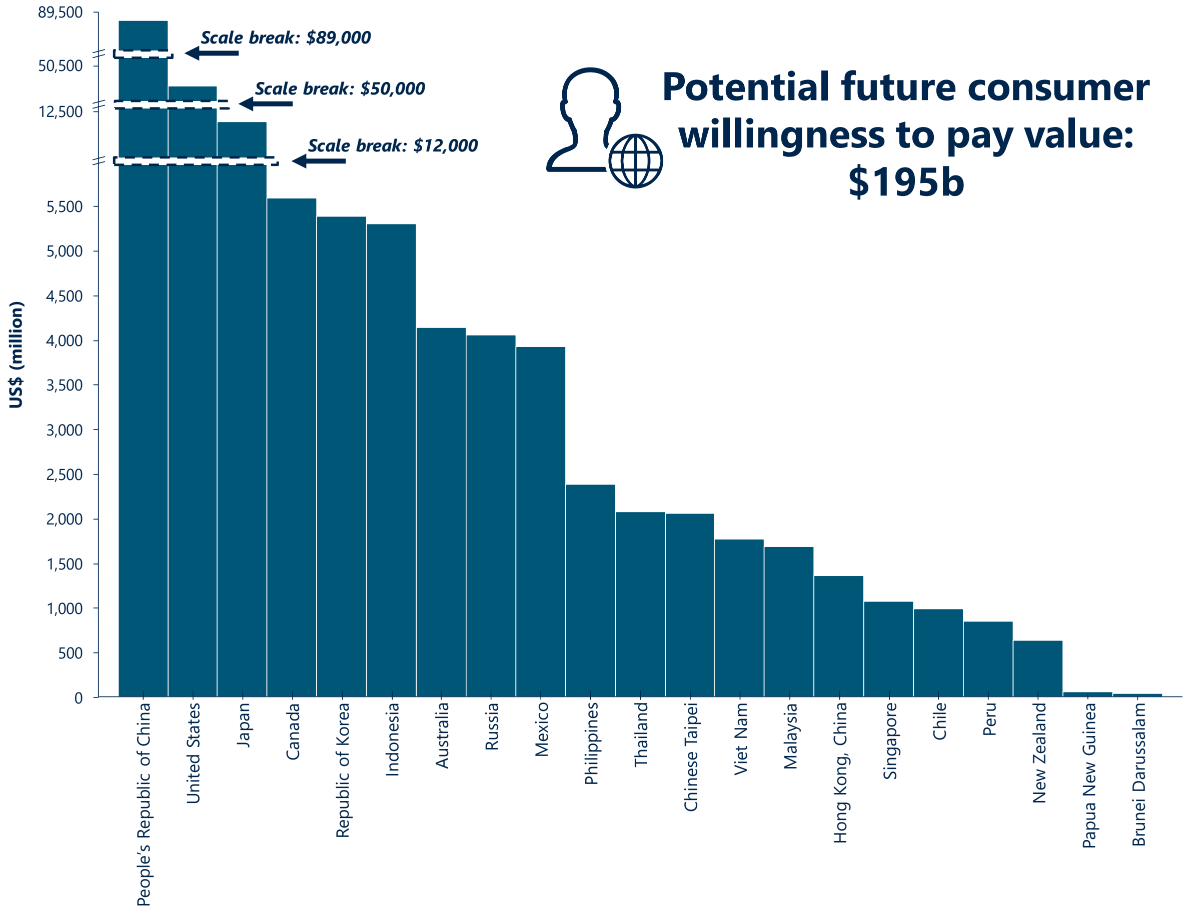


Table 9 | Potential future 'willingness to pay' value of EMO to consumers in 2030

Economy	Potential future 'willingness to pay' value of EMO to consumers, 2030 US$ million
People's Republic of China	89,404
United States	50,276
Japan	12,378
Canada	5,589
Republic of Korea	5,383
Indonesia	5,300
Australia	4,137
Russia	4,055
Mexico	3,929
Philippines	2,387
Thailand	2,078
Chinese Taipei	2,062
Viet Nam	1,771
Malaysia	1,681
Hong Kong, China	1,360
Singapore	1,073
Chile	988
Peru	853
New Zealand	640
Papua New Guinea	62
Brunei Darussalam	42
Total	**195,451**

4.5 The future direction of EMO technology and applications

Improvements in EMO technology will play an integral role in delivering this growth in the future value of EMO across all APEC economies. The following four areas where development is occurring were identified by economies during the consultation process. They highlight the importance of developments in EMO technology across all stages of the EMO value chain:

1. New infrastructure

EMO infrastructure goes well beyond the data collection technology of devices such as the geostationary satellite in space, or remote tidal sensors. There is substantial supporting infrastructure that is required to enable the use of recorded data: for example, through calibration, transporting data, data storage and processing and the creation of data products. Investment in this supporting infrastructure is essential to get the best value out of the data generating devices.

'Capabilities of ground systems are insufficient ... There is a network of calibration and supporting products that still need to be developed.'
(The People's Republic of China).

As the People's Republic of China stated, there is a need to develop supporting infrastructure, particularly for satellite technology. (For example, although Malaysia has the largest supercomputer within the ASEAN region, they still rely on calibration through infrastructure from other economies.)

For EMO to increase its influence within APEC, new and innovative infrastructure needs to continue to be designed, built, and maintained; driven by the need to address inter and intra economy problems.

2. Additional data sources

Several economies stated that there are large gaps in the data that is available, particularly regarding ocean observation. There have been advancements in this space (for example, the United States consultations noted that the People's Republic of China, the Republic of Korea and Japan have been expanding their ocean-observing capabilities through the development of deep submersibles).

However, for economies such as Peru and Malaysia, the costs for real-time oceanographic technology solutions can be an inhibitor. Peru reported a 'lack [of] real-time platforms to monitor oceanographic conditions in the water column... [which makes] forecasting changes in water conditions [difficult]'. While infrastructure like ocean-bottom mounted sensors and ship volunteer scanning programs provide part of the solution, innovative technologies are required to fill gaps in available data.

The OECD has noted that EMO can provide solutions to challenging economic measurement problems—such as the value of the ocean economy

'Ocean economy satellite accounts could offer a way forward. Building up on existing data collection efforts, satellite accounts offer a robust framework for monitoring aspects of an ... economy not shown in detail in the core national accounts, while allowing for greater flexibility for those industries not covered by industrial classifications. Satellite accounts for the ocean economy would provide a highly organised method for collecting consistent ocean economy data. Should a critical mass of [economies] develop such accounts then international comparability would be enhanced.'

3. Technical capability

There is a need for improvements in both the core technology to support analytics, and in developing and retaining technically capable personnel to develop such products in the first place.

EMO is increasingly being used to address very challenging questions that are incredibly complex to model. As an example, tropical economies like Malaysia are subject to very unpredictable weather, especially compared to mid-latitude economies. This makes forecasting weather accurately very difficult. Forecasts that are more accurate would stimulate a range of investments in the production of industry applications.

> 'If you are near the equator, you have light winds
> [and] plenty of sunshine, and therefore forecasting is very difficult…
> for the severe weather events…it is not possible to delineate areas impacted,
> just broad areas which may have a part impacted.'
> (Malaysia)

Building this capability (as people upskill in other economies with more predictable weather) would enable these investments. The future value of EMO will be partly dependent upon both the power of any core technology and upon the technical aptitude of personnel to develop data products that synthesise large amounts of complex data into understandable solutions.

4. Relevance of technology

The importance of 'translatability' of technology to the needs of the industries and governments in each APEC economy has already been raised (Section 3.5). The experts consulted emphasised the need to articulate the value of new technology to governments and decision-makers in each APEC economy, to ensure new or ongoing funding can be secured. As with current collaboration between New Zealand and Australia, new EMO technology should also strive to address contemporary issues—such as climate change, disaster management, and water and food security—that are already priorities across the region.

5 Opportunities for collaboration

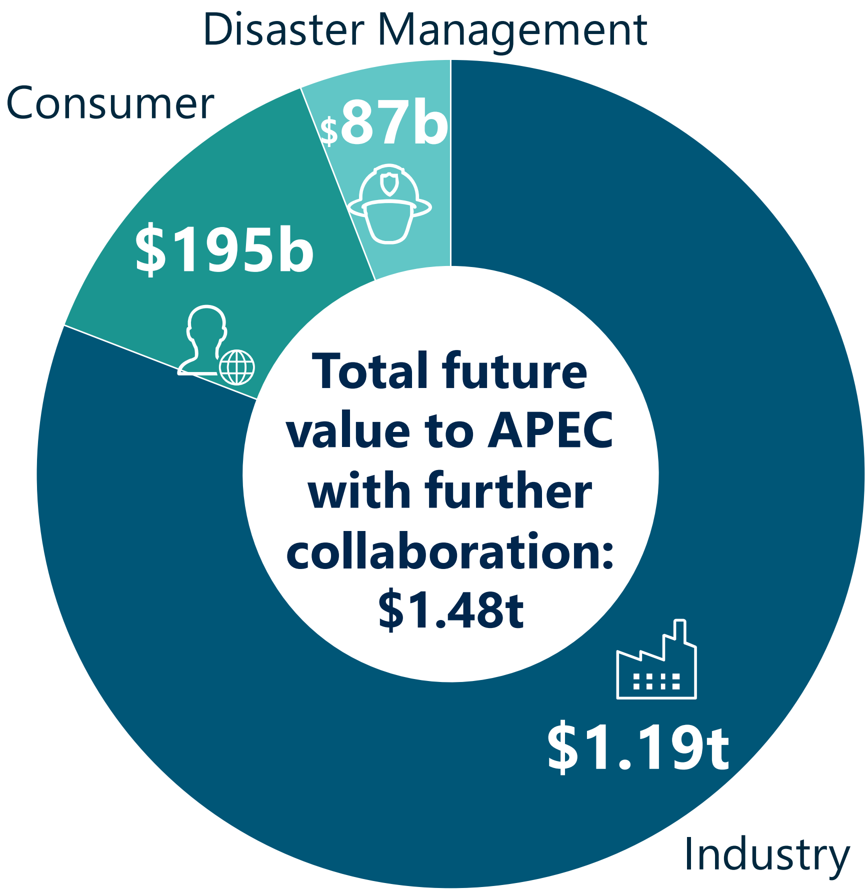
The potential future value of EMO to APEC in 2030 through collaboration is estimated at US$1.47 trillion (Figure 26). This presents an increase in value of US$120 billion through greater collaboration across all aspects of the EMO value chain. Forecasting the potential economic value through collaboration is inherently difficult and has not been done before. The present examples of collaboration that exis t across APEC do not outline the quantitative benefit attributable to this cooperation, whether through increases in capability or greater use of EMO across industries. Furthermore, accurately modelling the benefit of collaboration would also need to take into consideration shared costs through asset, infrastructure, and human-resource division—which is beyond the scope of this project.

'[More] collaboration …is better for us.' (Mexico)

What became very clear in consultations is that the economies with lower absorption rates have the greatest potential to make the largest gains relative to their current EMO value trajectory. This report aims to provide a starting point for this conversation concerning the importance of collaboration and how it increases the value of EMO to APEC. To get an idea of the potential value of increased collaboration, we developed the following 'what if' scenario, based on the premise that those furthest from the frontier of potential applications had the greatest to gain from improved collaboration. This 'what if' scenario assumes:

- Economies with a rate of absorption less than 20% have a collaborative multiplier of 40% - that is an increase in capability and applications of EMO to the economy through greater collaboration would raise the absorption rate by 40% in 2030 relative to that economy having no additional collaboration. For example, this means an economy with an absorption rate of 20% would increase to 28% - so this is a modest effect. This multiplier was applied to the application of EMO to industry.
- Economies with an absorption rate between 20% and 70% have a collaborative multiplier of 20%.
- Economies with an absorption rate greater than 70% have a collaborative multiplier of 5%.
- Given that disaster management was determined using an economy's absorption rate, the same collaborative multipliers were also applied to assess the potential for collaboration to improve the future value realised in disaster management.
- Provided the consumer 'willingness to pay' value is fundamentally based upon an economy's population and per capita GDP, the impact of collaboration on this value was not included.

Figure 26 | Potential future value of EMO to APEC with further collaboration in 2030 (in US$)



5.1 The value of EMO in 2030 through collaboration

Through collaboration across EMO, it is estimated that APEC can realise an additional US$126 billion of value, to bring the total future economic value of EMO in 2030 to US$1.48 trillion (Figure 27). The majority of this value would be realised by the People's Republic of China (48.4%), followed by the United States (19.5%). Although not respectively large values compared to these two economies, the Philippines, Viet Nam, Peru, Brunei Darussalam and Papua New Guinea all had significant gains in value proportional to their future value without collaboration. Economies such as Australia, Canada, Japan, the Republic of Korea, Mexico and Russia made up between 2.5% to 4.2% of the additional collaborative value, a total of US$26 billion (Table 10)

Figure 27 | The potential future value of EMO for each APEC economy with further collaboration in 2030 (in $US)

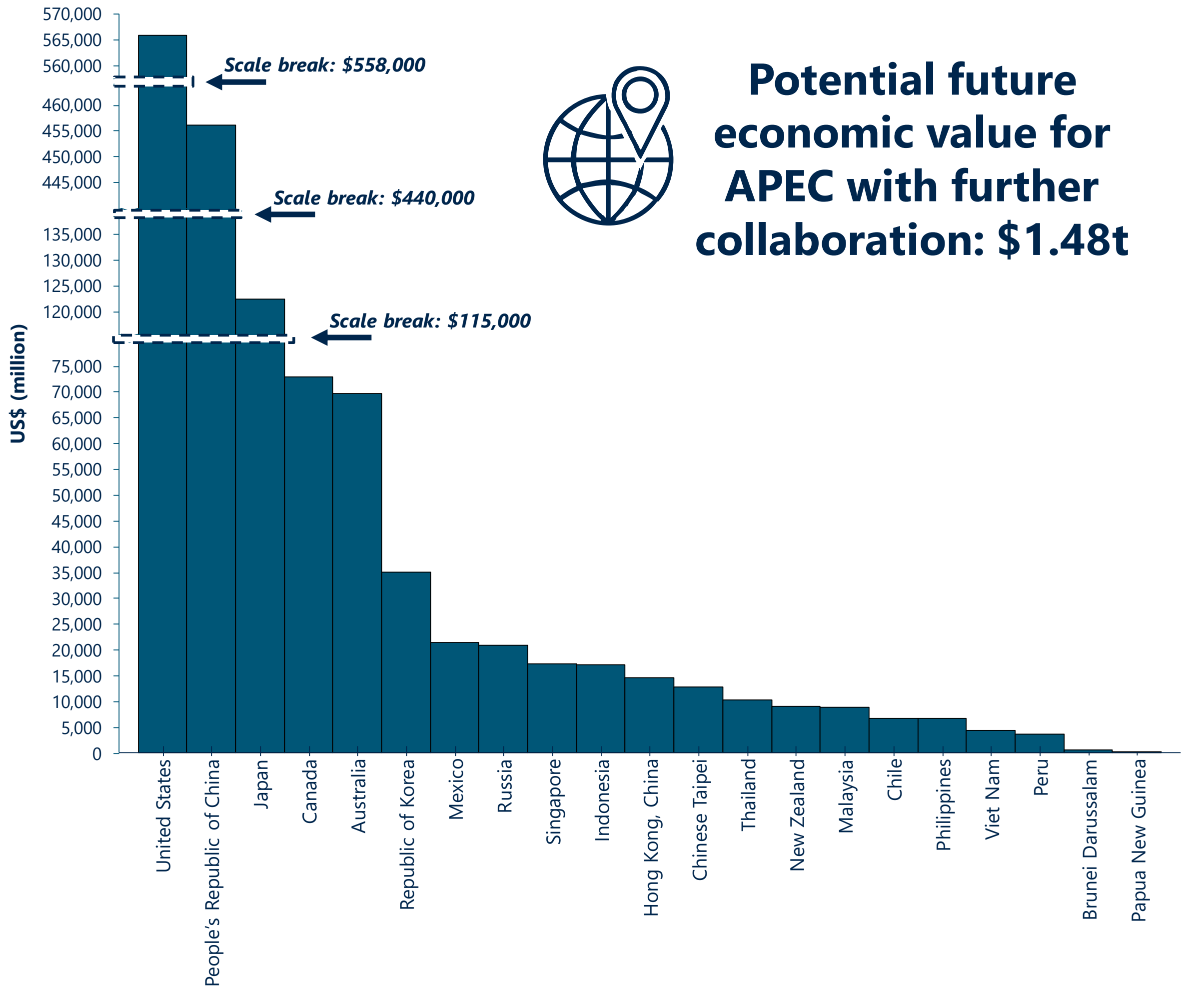


Table 10 | Potential future economic value of EMO for each APEC economy with further collaboration in 2030

Economy	Industry value US$ million	Consumer 'willingness to pay' value US$ million	Disaster management value US$ million	Total collaboration value 2030 US$ million	Additional value due to collaboration US$ million
United States	463,480	50,276	52,075	565,831	24,550
People's Republic of China	354,440	89,404	12,259	456,103	61,117
Japan	96,672	12,378	13,282	122,332	5,236
Canada	66,230	5,589	1,075	72,894	3,205
Australia	63,159	4,137	2,366	69,663	3,120
Republic of Korea	29,012	5,383	611	35,006	4,937
Mexico	16,840	3,929	657	21,426	4,911
Russia	16,613	4,055	145	20,814	4,386
Singapore	16,214	1,073	0	17,287	1,262
Indonesia	11,458	5,300	226	16,984	3,105
Hong Kong, China	13,093	1,360	52	14,505	859
Chinese Taipei	10,021	2,062	736	12,819	1,793
Thailand	7,445	2,078	724	10,248	1,565
New Zealand	6,925	640	1,520	9,085	1,171
Malaysia	7,114	1,681	45	8,840	1,193
Chile	4,881	988	825	6,694	951
Philippines	3,960	2,387	239	6,586	1,200
Viet Nam	2,406	1,771	184	4,361	740
Peru	2,628	853	57	3,538	767
Brunei Darussalam	453	42	<1	495	76
Papua New Guinea	64	62	<1	127	19
Total	**1,193,045**	**195,451**	**87,077**	**1,475,638**	**126,163**

5.2 The case for greater collaboration

Collaboration in EMO across APEC is central to optimising the value realised by all economies. Although there are large fixed costs for producing data (through infrastructure and the supporting technical capability that is required), the costs for sharing data and data products are low. However, collaboration should extend beyond simply making data open—although this is critical—and there should also be a focus on how APEC economies can support one another through all aspects of the value chain.

Australia and Mexico are currently working together on using data cubes for EMO applications.

This includes, for example, collaboration on:

- designing, testing, and creating infrastructure
- transporting and storing data
- improving technical and analytical capabilities of economies to use data
- developing ready-to-use data products
- coordinating international efforts to secure funding for multi-economy development programs (such as obtaining disaster management funding from multilateral banks).

Currently, there are examples of excellent collaboration already occurring, both inter-economy and through global organisations (such as the Intergovernmental Group on Earth Observations (GEO), the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization (WMO)— each of which have significant outreach and capability development programs).

Malaysia used the WMO and IOC for geophysical, seismological and tide-gauge data.

Similarly, collaboration is essential for managing global risks from natural disasters. However, throughout the consultations, two key areas were identified where there could be improved collaboration.

1. Further sharing of infrastructure, data and data products

Many economies across APEC would benefit from greater sharing of infrastructure, data and data products. As an example, Peru stated that they would benefit from more data around the South American coast (in addition to what they use from the Tropical Assistance System). Similarly, the Republic of Korea would benefit from increased satellite information for natural disaster management. From consultations, it was clear that many economies would benefit greatly from additional data to improve the reliability and accuracy of their predictions. However, to do this, several economies would also need support to help share their own data.

Economies like the United States and Japan have open data policies, which are essential to other economies (for example, for calibration of infrastructure and boundary condition inputs into their analytical models). As shown in the United States, economies that are able to adopt a collaborative open-data approach also benefit from the development of strong data centres to enable open data sharing.

'The data approach, open and free, drove the need for really strong data centres to enable this…[T]he data systems are critical.' (The United States)

However, some economies have less ability to use the data provided—so just having access to open data is not a game changer. Rather, these economies will benefit most from collaboration, through data products and EMO insights that are 'ready to use'. Ideally, collaboration is not limited to APEC economies but extends to partnering with all economies that can contribute to building a stronger EMO ecosystem. (For example, Europe—as a leader in EMO data products and technology—is a valuable additional source to supplement APEC collaboration.)

2. Capability development

The consultations helped identify a need in several economies to develop processes to transfer EMO-based knowledge to the wider community. The leaders of EMO in APEC are well placed to support these efforts.

Because of the high standards set by international collaborative bodies (such as the IOC, GEO and WMO), there is a growing concern that the technical and analytical capabilties of some economies are not keeping up with the expanding use of EMO. This presents two pressing concerns for these economies. Firstly, developing economies are unable to make full use of the EMO data collected to produce reliable and accurate insights. Secondly, they are less able to develop compelling business cases about the benefits of EMO to their economy, to present to central authorities and decision-makers.

> 'Developing [economies]...are experiencing fast development (they have funding, professionals and understanding of EMO technology), and so they can lead the way in transferring technology and analytics to the other economies.'
> (The People's Republic of China)

Some economies also stated that it is difficult to retain expertise, with experts moving to other economies where EMO technology is more advanced. This loss of knowledge has flow-on effects, including the costs of hiring and training replacement staff, and the loss of time and momentum within the broader EMO sector. However, as argued by Malaysia, the upskilling and retention of personnel can accelerate the provision of high-quality services.

Significantly, consultations revealed that many economies still do not have a complete picture of their own EMO capabilities. New Zealand, for example, is currently rolling out a national campaign to coordinate all their EMO datasets, because it is difficult to track all their EMO inputs.

> '...there are some resources for data processing and modelling and prediction, but the main limitation is the scarcity of human resources who can make use of these types of assets in the EMO.'
> (Peru)

Economies should also be considering collaboration between government; the private sector; small and medium enterprises; and the research sector as avenues to maximise the value realised from EMO.

For example, agriculture insights are needed from agricultural scientists who know the local production systems, and from economists who have the tools to use this knowledge. This can be combined with EMO-based knowledge to develop models to guide planting and production decisions. This cross-disciplinary approach requires involvement across the agricultural value chain from the agronomists who advise farmers, to the suppliers of machinery and fertiliser, through to the crop financiers and insurers.

Developing these cutting-edge approaches for the local economy is something that universities and research organisations can do well. An internal collaborative approach not only raises the profile of the value of EMO within an economy (encouraging and supporting further investment), but it also positions economies to be able to share their insights across APEC.

Peru would benefit from collaboration to improve their technical and analytical capability

Peru has a strong relationship with the United States and is looking to develop this further with their EMO program. The value of EMO to Peru's economy would greatly increase through a collaborative effort—across APEC—to develop its analysts and strengthen its technical capability, using real-time observation platforms (especially for marine systems) and state-of-the-art data processing and monitoring resources.

6 Methodology and approach

This section describes the methodology adopted to measure the economic value of EMO for each APEC economy and their respective industries, including research limitations and the data collection process.

Estimating the value of EMO to APEC economies would ideally be done through a detailed study of all the different applications in all their different uses in each economy. This task would be massive, ending up with a n*m*a matrix (economy n * industry segment m * application a)—with hundreds of thousands of variables needing to be estimated. What is already available includes several dozen studies of the return on a particular application for an industry segment in a particular economy (see Appendix C). These studies provide a glimpse of the potential value of EMO applications for different industries, and for disaster preparedness and response. They form an incredibly valuable starting point for this analysis. As more studies on the returns of specific EMO-related applications are undertaken, the evidence base to support this type of overarching value estimate will improve. As it is currently, it is only a well-informed estimate of the value of EMO to APEC economies.

To be able to scale up the insights provided from these studies, we have relied on expert opinion on what the potential value of EMO applications would be for the industries and areas identified in Section 2.2.1. We are very grateful to the experts across the APEC economies who engaged with us on this difficult task, and for sharing their knowledge and insights—not only regarding the returns that can be generated by EMO, but also in relation to factors affecting the uptake and application of EMO in specific economies.

This study seeks to answer a number of questions (Table 11). Most hinge on measuring the value of EMO applications to industries across economies. Our approach to answering these questions is set out below.

Table 11 | Research questions and key lines of enquiry

Research question	Key lines of enquiry
1. How does EMO contribute to current and future economic value across key areas (for example, those identified in the collaborative framework)?	• What are the key industries impacted by application of EMO information products? • What is the present economic value of EMO activity, considering more than a fiscal return on investment? • What is the future economic value of EMO activity, considering changes in the impacted industries; national capabilities; sharing of data products; and infrastructure?
2. Is there a difference in the value between EMO data collected through different EMO systems, including data collected remotely and collection of in-situ EMO data?	• When considering the many different infrastructure types involved, is it possible to attribute economic value and impact back to the unique data collections?
3. What is, and what will be, the economic contribution of EMO at different scales and for economies at different stages of economic development?	• What is the present, and future, relationship between economic development and the economic benefits of EMO? • Who has the most to gain, and is this impacted by levels of investment, collaboration, sharing of data products and services, and so forth? • How are these benefits expected to change over time; considering the future priorities of EMO?
4. What is the value of EMO and EMO data to APEC with regard to technology?	• What potential impact does the advancement of EMO technology have on the realisable value of EMO for APEC economies?
5. How could adopting a coordinated approach to EMO across the Asia Pacific improve the economic value EMO generates?	• What additional value and information could be generated by a more coordinated approach; as opposed to an individualistic model? • What are the current opportunities for collaboration and what are the barriers to collaboration? What enablers would be necessary to overcome these barriers?

6.1 The value is estimated based on potential value at an industry level and absorption at an economy level

Answering the questions set out in Table 11 requires that the estimates can be analysed both by industry and by individual APEC economies. The basis of the model is a simple matrix of estimates allowing the value to be added up either by industry across economies or by economy across all industries.
The estimates of value for an industry (*i*) in economy (*j*) are estimated as follows:

- The first set of core parameters for the model is the **potential value of EMO-enabled applications for each industry (G_i)**. An initial estimate of the potential value of EMO applications for industry ***(i)*** was made by drawing on the available studies. (As described earlier, these studies usually applied only to a segment of the industry. For example, the value of storm warnings to offshore oilrigs has been estimated in dollars saved from avoiding clean-up costs and asset maintenance. This gives a very small saving for offshore oil production, which in turn is a very small share of the oil industry, which makes up differing shares of all mining across the various APEC economies.)

  What this and the other studies do provide is a general indication of where the value in EMO applications lies. Building on other studies that have attempted to add up the impacts for Australia and for a few other economies, we developed a preliminary set of estimates of the potential value that is supported by EMO data at an industry level. It is important to note that this is the value enabled by EMO and includes considerable other required investments. We have not attempted to separate out these investments, on the basis that (like a good cake), all ingredients are important in delivering the value.

  The initial estimates of the potential value of EMO to the different industries **(G_i)** were tested with experts across APEC. Our estimates were then adjusted, based on the information provided. These estimates form the first set of core parameters in the model. We used the mid-point in the range to provide the headline value estimates and we used the ranges to demonstrate the sensitivity of the estimates to this parameter. (Refer to Appendix D for the values of G_i for each industry.)

- The second set of core parameters is the **value of industry *i* in each APEC economy *j* (I_{ij})**. As discussed above, the potential applications of EMO in an economy depend on the structure of the economy. Where data on the value of an industry (converted to current USD) was available at the one-digit industry level, this information was used to fill in the data layer for the economy. If the information on the structure of the economy was only available in a more aggregated form (for some economies, the most recent data distinguished only agriculture, mining, manufacturing and services), a disaggregation was applied using the structure of similar economy(ies) to get the industry shares, and these were then used to estimate the industry value added.

- The third core set of parameters is the **level of absorption for each economy *j* (A_j)**. The starting point for estimating this parameter is the level of development of the economy, which is estimated by comparing Gross Domestic Product (GDP) or Gross National Income (GNI) per capita, relative to the highest GDP per capita APEC economy. This assumption on the overall capacity to absorb EMO-enabled technologies was tested with experts from each economy and was agreed as an appropriate starting point. The parameter was adjusted up where economies were using EMO applications more than their relative per capita income indicated would be the case. We also adjusted the absorption parameter at an industry level where an industry in the economy was more advanced in its application of EMO than would be indicated by their level of income per capita. For example, if an economy had an absorption parameter of 15%, however were relatively advanced in using EMO in agriculture, then their absorption parameter would be appropriately increased when determining the value added from EMO for that economy in agriculture. Hence, we estimated the level of absorption by industry *i* in economy *j* **(A_{ij})**, but on the basis of exception. (Refer to Appendix D for the indicative relative values of A_{ij}.)

These three sets of parameters were used to estimate the **realised value of EMO applications to industry *i* in economy *j* (V_{ij})**. These were added up for an industry across all APEC economies to give the value of EMO applications to industry *i* (Equation 1) and across all industries in economy *j* to give the value of EMO to that economy (Equation 2). This information answers the majority of the first question in Table 11. It also allows us to answer question three, on how the level of development affects the value enabled by EMO.

Equation 1 | Economic valuation of EMO for a specific industry

Total value for an industry type

$$V(t)_{ind} = G(t)_{ind(i)} \sum_{econ} \left(I(t)_{ind(i)} A(t)_{econ(j)}\right)$$

Equation 2 | Economic valuation of EMO for an APEC economy

Total value for an economy

$$V(t)_{econ(j)} = A(t)_{econ(j)} \sum_{ind} \left(I(t)_{ind(i)} G(t)_{ind(i)}\right)$$

6.2 Estimating the value in 2030 is based on projected growth in EMO applications and on economic growth

Estimating the value in 2030 required three additional adjustments to the base model:

- The first adjustment was to grow the value of industries in each economy (I_{ij}), because a growing base means that EMO applications add more value. The published projected growth rates for the economies[49] were used to make this projection. This gave us estimates of the values of each industry *i* in economy *j* (I_{ij}) in 2030.
- The second adjustment is related to the first, but through a different mechanism. As the level of development increases (A_j – proxied by GDP per capita), so does the economy's ability to absorb EMO applications[50].

[49] A ten-year average of GDP growth for each APEC economy was used to determine a unique value for the indicative growth of each industry within that economy. (The model assumes that the industry composition for the economy is unchanged till 2030.) Values were aggregated from the World Bank, viewed in 2019 at <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.zg?end=2017&start=1961&view=chart> .

[50] As with industry growth, a ten-year average of growth of GDP per capita for each APEC economy was used to determine a unique value for the indicative growth in absorption for each economy. This naturally assumes that the economic development of each economy in APEC remains constant. Values were aggregated from the World Bank, viewed in 2019 at <https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG?end=2017&start=1961&view=chart>.

- The third adjustment was to increase the value added by EMO-enabled applications for each industry (G_i). This was based on global growth rates of EMO as its own industry[51]. These indicative values were used to update the estimates of the potential value added by EMO applications to industry *i* (G_i) in 2030.

Applying these adjustments and re-running the model generated the estimated value of EMO to APEC economies and industries in 2030. This answers the second part of the first question in Table 11, and part of the third question.

6.3 Estimating the difference that better collaboration can make

Better collaboration and targeted investments can make a difference through two main channels. The most important channel is through raising the absorption rate for APEC economies. This is achieved by building an economy's technical and analytical capabilities (formal training programs, global forums and workshops, participating in global cooperatives, sharing infrastructure, etc.) enabling them to combine EMO data with other information that is most relevant to the situation for industries in their economy. This channel is likely to bring the greatest value to the APEC economies, as there is considerable scope for greater absorption. The value delivered by greater collaboration can be modelled by raising absorption (A_{ij}).

The second channel is through enhancing the applications of EMO, raising the value added they deliver and increasing the segments of industries where EMO-enabled applications can be applied. In this case, the additional value from greater collaboration is modelled by increasing the potential EMO value added at an industry level (G_i). (This parameter was not adjusted, however, as there was not enough information about which industries might benefit most from collaboration to improve technical development.)

These estimates address the fifth question in Table 11.

6.4 Incorporating natural disaster data and disaggregation by technology

There are several other questions in Table 11 that require incorporating additional data into the model and cutting it in different ways:

- It was imperative that the model incorporated natural disaster data. The losses from natural disasters are not homogenous, with developing economies generally suffering high losses of life and developed economies greater economic losses. However, it is important to consider economic losses as a proportion of the overall national GDP to appreciate the 'true' impact of a natural disaster on the local economy. Our model therefore incorporated economic loss data due to natural disasters.[52]
- Given the many elements that go into many of the EMO applications (including multiple sources of data), attributing value to specific data collection techniques (the second question in Table 11) proved to be an impossibly complex task. Given this, value is not attributed to specific technologies.

  There are also other investments that are needed to deliver the value, so the total value added is not attributable just to investments in EMO technologies, but also to the many supporting investments required to deliver this value. Hence it is better to refer to the estimates as 'EMO-enabled value added'.

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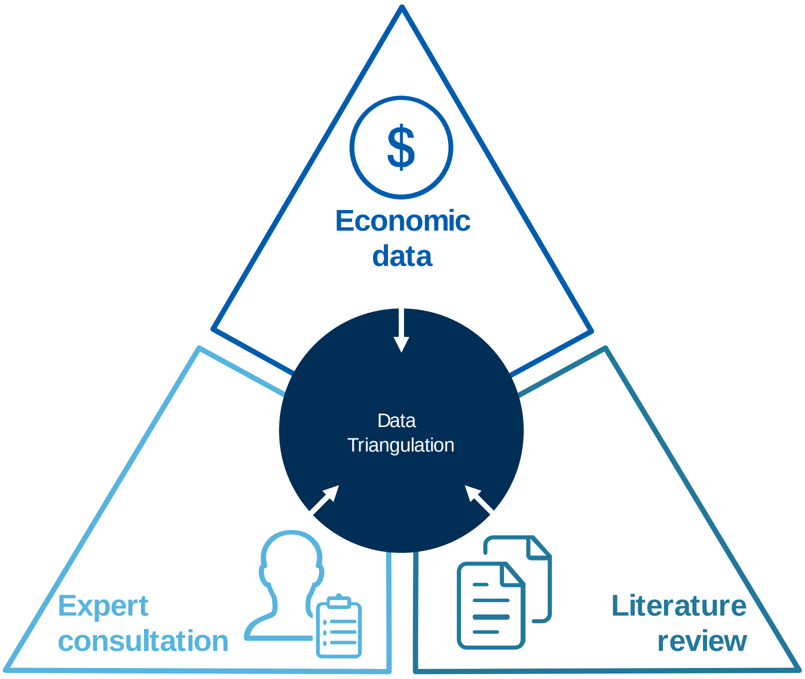
[51] The projected growth of the satellite-based market across the Asia-Pacific is 18.5%. (G Sadlier, R Flytkjaer, F Sabri & N Robin 2018, *Value of satellite-derived Earth observation capabilities to the UK Government today and by 2020*, London Economics, London, viewed 28 March 2019, <https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf>. This value is considered, in comparison with projected GDP growth, to estimate the forecast growth of EMO as its own industry in 2030.

[52] All natural disaster information was obtained from the leading international disaster database EM-DAT, from the Centre for Research on the Epidemiology of Disasters (CRED) 2019. *Natural disasters 2018*, CRED, Brussels, viewed 27 March 2019, <https://www.emdat.be/>.

6.5 Data collection

We recognise the complexity in accurately estimating the value of EMO for the whole of APEC, as well as for each industry and economy. Therefore, we combined multiple data collection techniques through triangulation, to strengthen and validate our results (Figure 28). Triangulation is beneficial because each data collection technique's weaknesses are offset by other techniques' strengths: such an approach helps increase the reliability and validity of any reported results and conclusions.

Figure 28 | Data triangulation to strengthen the reliability and validity of results



The economic model and subsequent analysis drew on many data sources, which formed the database required for the model. This includes all the parameter estimates so that the model can easily be updated as new data and evidence on the parameters become available.

The following list outlines the specific categories of data that were collected to inform the conclusions in this report:

- Industry breakdowns for each APEC economy: the economy's GDP and share of the industry were used to estimate the industry value added. Where industry shares were not obtainable, proxies were developed based on the shares for similarly structured economies and development indicators from the World Bank (GDP per capita).
- GDP per capita (which was the starting point for estimating absorption), which was tested through interviews.
- The international disaster database (EM-DAT) for emergency management and natural disaster data.
- Peer-reviewed studies and reports that estimated the impact of specific applications of EMO on an industry segment in a specific economy or region, or on the population of an economy.

It is also important to recognise that this study is a snapshot in time of the current and future value of EMO to APEC. As such, there are natural limitations to such a process, which are outlined in the next section.

6.6 Limitations

The estimates provided in this report are inherently approximate. There will be some areas where the impacts are overestimated and some where they are underestimated, and confidence in the estimates declines with greater disaggregation. The main sources of uncertainty are listed below:

- **The aggregate nature of the potential value parameter**. While this is based on estimates of the value added by specific applications for segments of an industry, the share that these segments make up within an industry will vary across economies. This is only partially corrected through the absorption parameter. The information on the value added by applications is also very limited, so as more studies are undertaken, the level of confidence in the potential value added estimates can be improved over time.
- **Estimates of industry shares**. In line with the relevance of applications only to segments of an industry, disaggregation of industries into these segments would improve the estimates. However, given the lack of detail in the industry divisions for some economies (where proxy economy shares were used to provide a disaggregation to the 1-digit level), this approach could only be applied for economies where this information was available.
- **Differences in the absorption of EMO technologies at industry level**. Our starting point is that there will be a common level of absorption across industries in each economy, based on the level of development. We recognise that the level of development of different industries varies between economies and we have adjusted these parameters where we have received advice.
- **Estimates are conservative**. The estimated value of EMO to disaster management does not include the enormous value of other services that reduce the mortality and injury rates of natural disasters. The consumer estimate includes the value to consumers only of the freely available weather forecasts, and not of other free services (such as digital maps).

The projections of value to 2030 are based, where possible, on published projections for economic growth, and expert advice on the foreseen developments in EMO applications. Most GDP growth projections go out only a few years and are not available at industry level—which introduces considerable uncertainty into the projections. The model is constructed so that different growth rates can be applied to see how much difference a change (for example, in absorption rates) can make to the broader outcomes.
The model developed to estimate the impact of EMO can easily be updated over time as better data becomes available.

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Appendix A Economy profiles

This appendix provides key information for the following Asia-Pacific Economic Cooperation (APEC) economies:

Australia....70
Brunei Darussalam....72
Canada....74
Chile....76
Chinese Taipei....78
Hong Kong, China....80
Indonesia....82
Japan....84
Malaysia....86
Mexico....88
New Zealand....90
Papua New Guinea....92
People's Republic of China....94
Peru....96
Philippines....98
Republic of Korea....100
Russia....102
Singapore....104
Thailand....106
United States....108
Viet Nam....110

Australia

Building awareness of the value of EMO will be important to enable infrastructure innovation.

Population: 25.2 million | GDP (per capita): US$57,305

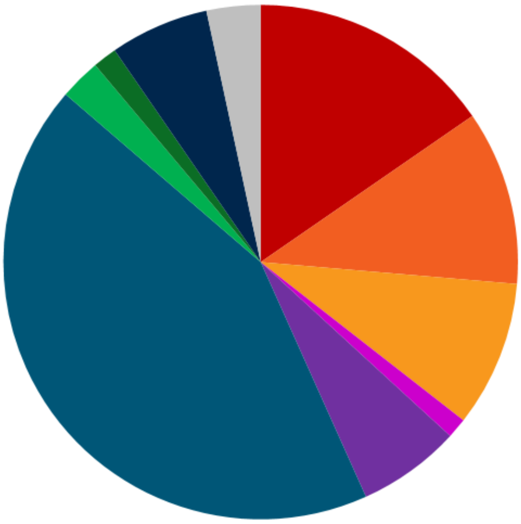
EMO value (US$ billion)

2019: $20.2

2030: $66.5

2030 (collaboration): $70

Total economic value

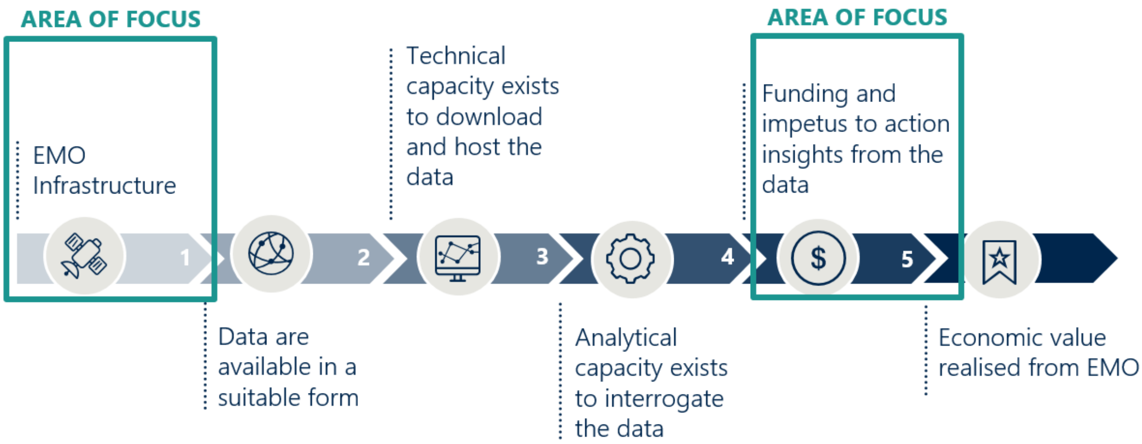


	US$ million
Mining	3,114
Agriculture, fisheries & forestry	2,221
Utilities: Power	1,861
Utilities: Water	256
Utilities: Communications	1,311
Transport	8,708
Health	521
Finance	307
Consumer	1,259
Disaster Management	686
Total	**20,242**

Key industry information

- The value of EMO to Australia is equivalent to 1.4% of GDP.
- US$8.7 billion (43%) of this value is realised through transport, which is equivalent to 12.4% of the value of the industry.
- Mining represents 15.4% of the total value of EMO, and is equivalent to 3.2% of the value of the industry.
- US$1.2 billion (3.4%) of total EMO value is realised through consumer willingness to pay.

Value chain

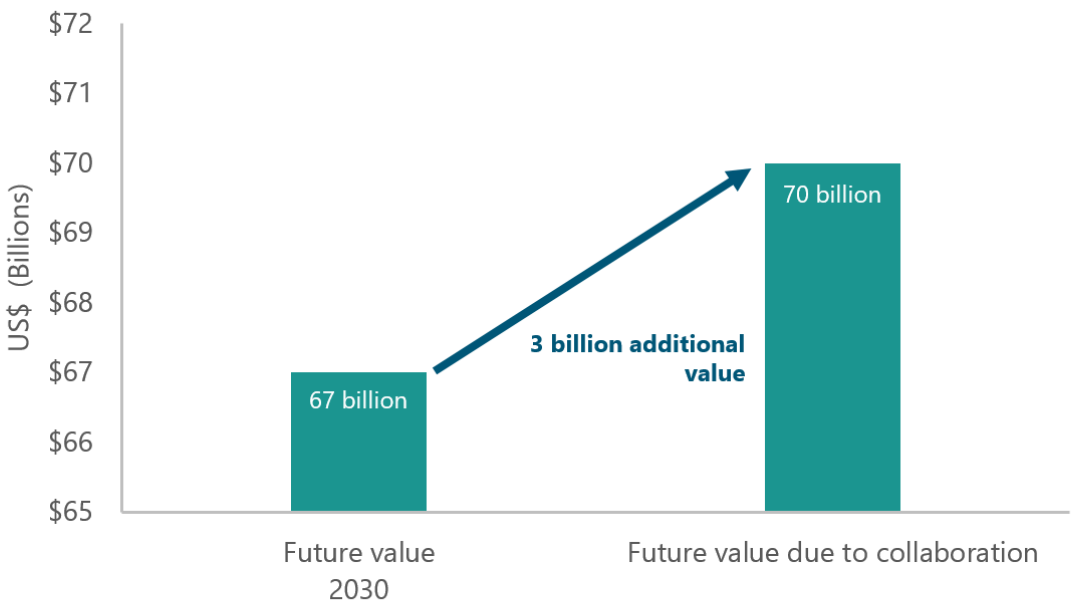


Areas of collaboration

Australia will benefit from continuing to strengthen its relationships across APEC, including building on current collaboration with the United States, New Zealand, and other economies.

Collaboration to develop innovative EMO infrastructure will be beneficial to Australia in maximising future potential value from EMO—given its unique geography and location within APEC.

Value from collaboration



Australia plays a critical role in EMO for APEC by offering technical and analytical expertise, as well as support to infrastructure (such as through calibration). There is an opportunity to leverage both its location and capability to realise further value and to develop new EMO infrastructure.

Brunei Darussalam

Industries, other than mining, have a lot to gain from greater use of EMO applications.

Population: 429 thousand | GDP (per capita) US$31,628

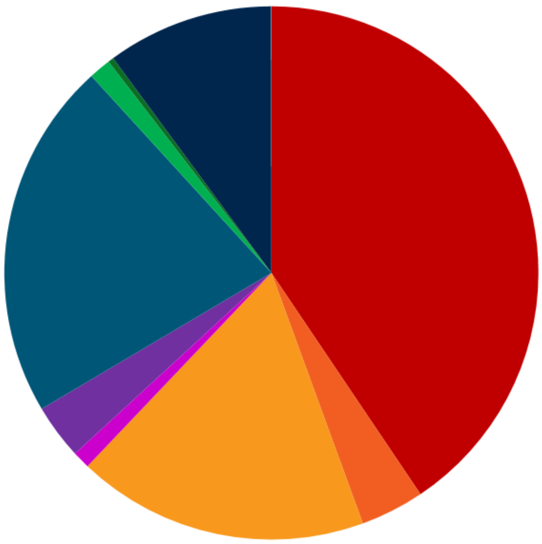
EMO value (US$ million)

2019: $119

2030: $420

2030 (collaboration): $495

Total economic value

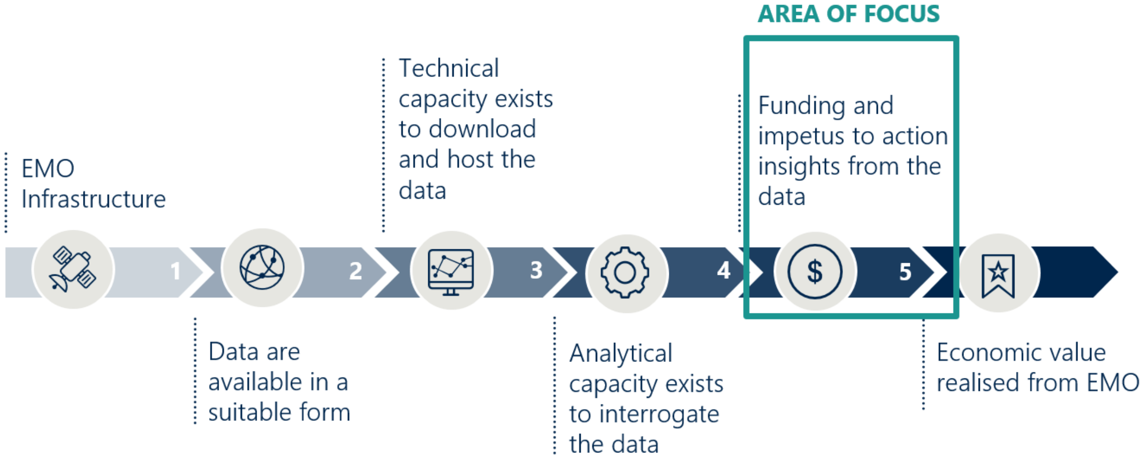


	US$ million
Mining	48
Agriculture, fisheries & forestry	5
Utilities: Power	21
Utilities: Water	1
Utilities: Communications	4
Transport	26
Health	2
Finance	<1
Consumer	12
Disaster Management	<1
Total	**119**

Key industry information

- The value of EMO to Brunei Darussalam is equivalent to 0.9% of GDP.
- Mining represents 41% of the value gained from EMO, at US$48 million.
- Unique to this economy, the EMO value added in the three utilities equals the value realised from transport. With transport, these account for 39% of value, at US$47 million.
- The value from utilities: water represents 3.5% of the total water industry's value.

Value chain

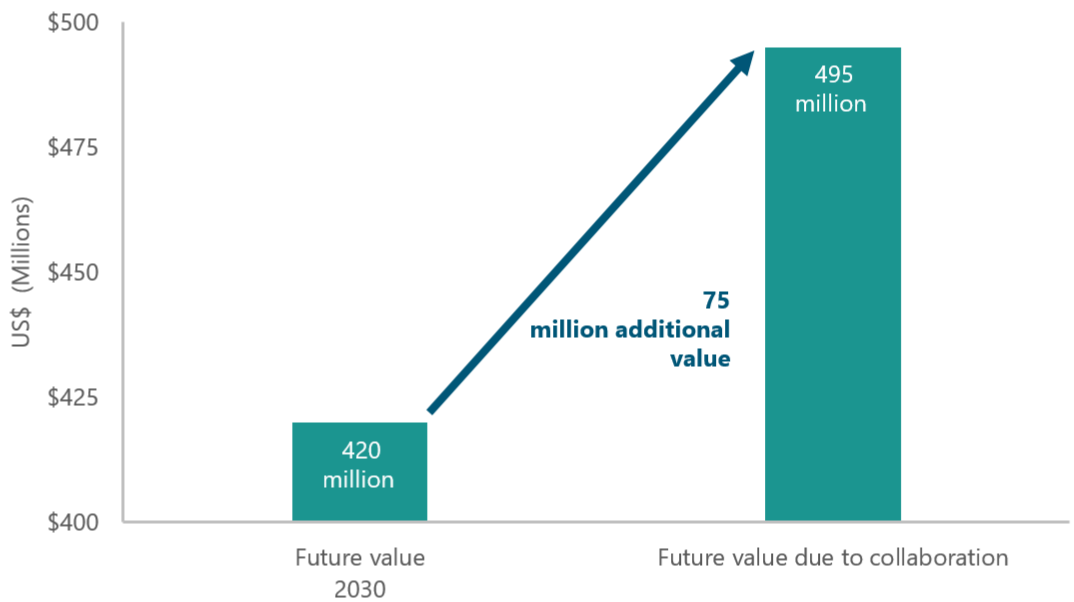


Areas of collaboration

Collaboration across APEC could be of great value to Brunei Darussalam, with capability development programs and increased data sharing focussing on the industries that can realise EMO value quickly.

Although mining is the largest contributor of value for the economy, value can also be realised by focussing funding and impetus on agriculture, fisheries and forestry, and communications.

Value from collaboration



Additional funding and investment from APEC-wide programs can bolster the uptake of EMO within Brunei Darussalam. Although mining is the primary industry to benefit from EMO to date, areas within other industries that are able to easily adopt EMO data applications could also be considered as future sources of value.

Canada

Infrastructure to link other sources of data to EMO data has great potential to raise the future value realised from EMO.

Population: 37.1 million | GDP (per capita): US$46,125

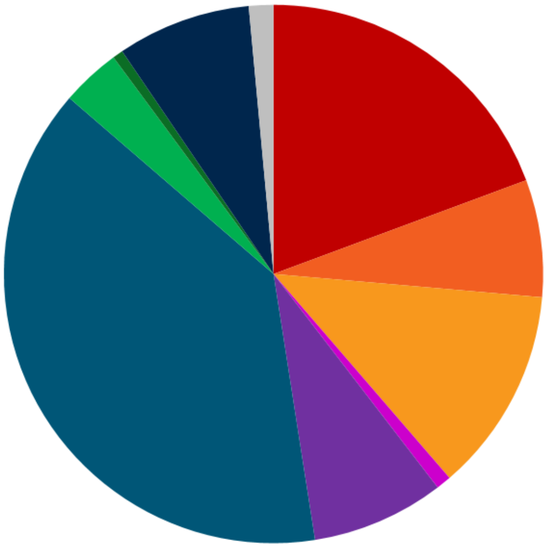
EMO value (US$ billion)

2019: $19

2030: $70

2030 (collaboration): $73

Total economic value

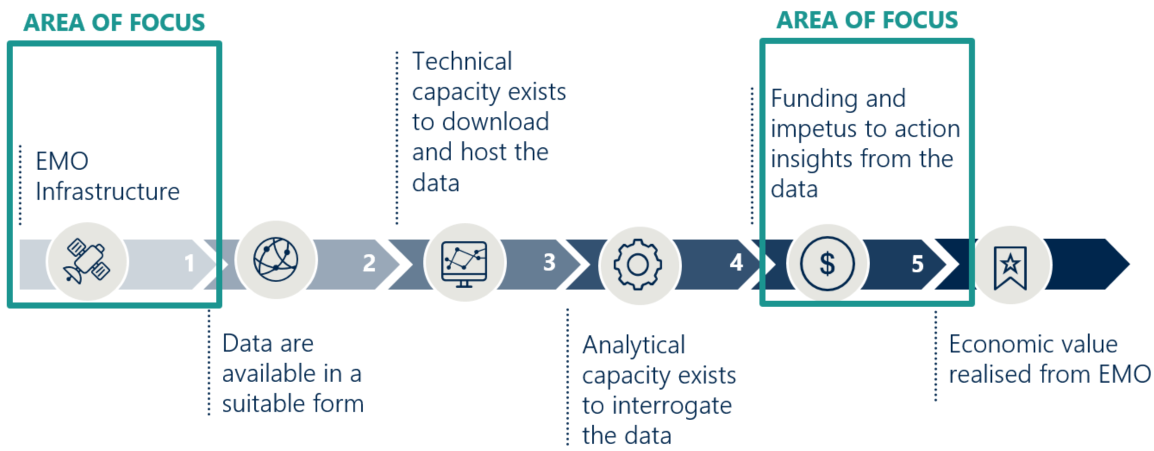


	US$ million
Mining	3,627
Agriculture, fisheries & forestry	1,321
Utilities: Power	2,308
Utilities: Water	168
Utilities: Communications	1,493
Transport	7,279
Health	666
Finance	117
Consumer	1,505
Disaster Management	276
Total	**18,760**

Key industry information

- The value of EMO to Canada is equivalent to 1.1% of GDP.
- US$3.6 billion (19.3%) of this value is realised through mining, which is equivalent to 2.6% of the value of the industry.
- Utilities: power represents 12.3% of EMO value, and is equivalent to 6.6% of the value of the industry.
- US$1.3 billion (7.0%) of EMO value is realised through agriculture, fisheries and forestry.

Value chain



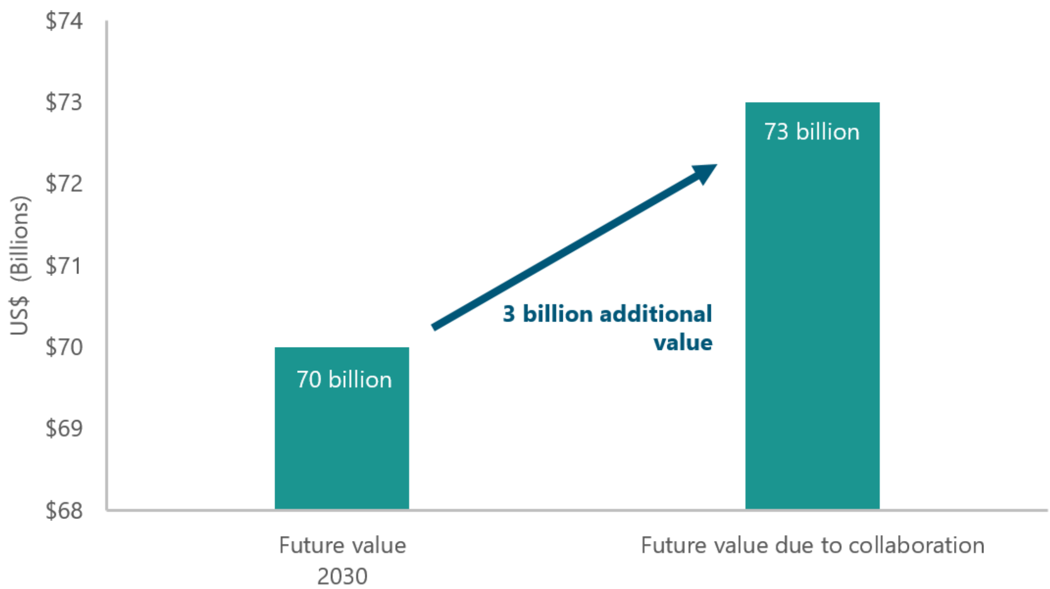
Areas of collaboration

Canada can continue to provide valuable insights to APEC through leveraging its strong EMO private sector.

Other economies would benefit from technical and analytical development from Canada, as it continues to be a leader in geospatial technologies.

Sharing of open geospatial data not only adds to Canada's GDP, but also assists other economies by providing access to additional data that can be used for their predictive models.

Value from collaboration



'Open geospatial data is also making a difference...The full potential of open data will be realised through combining foundational geomatics data with other government data holdings such as health, public safety, and climate information.' Source: Canadian Government

Chile

Disaster management applications present an opportunity to greatly increase the value of EMO.

Population: 18.7 million | GDP (per capita): US$15,923

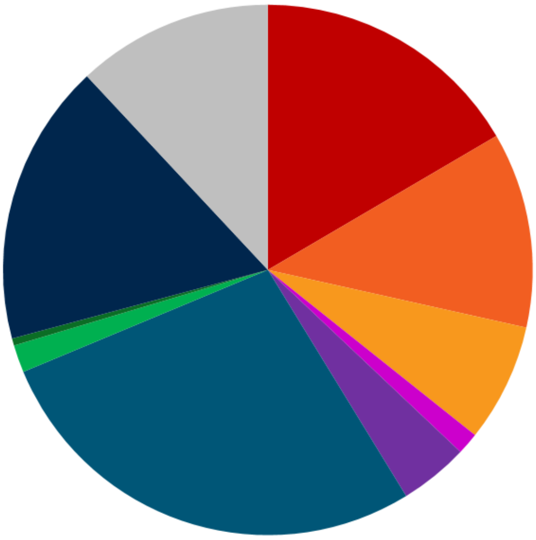
EMO value (US$ billion)

2019: $1.5

2030: $5.7

2030 (collaboration): $6.7

Total economic value

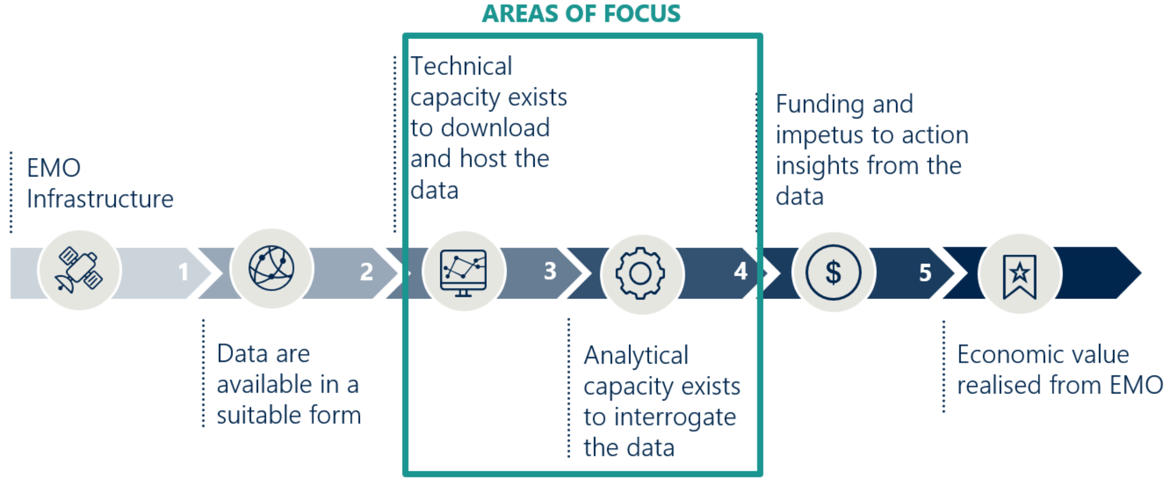


	US$ million
Mining	253
Agriculture, fisheries & forestry	182
Utilities: Power	110
Utilities: Water	20
Utilities: Communications	64
Transport	419
Health	26
Finance	7
Consumer	263
Disaster Management	183
Total	**1,526**

Key industry information

- The value of EMO to Chile is equivalent to 0.51% of GDP.
- Disaster management (12%) and consumer willingness to pay (17%) contribute a combined EMO value of US$445 million.
- Mining contributes US$253 million, which is equivalent to approximately 1% of the total value of the mining industry.
- Transport realises the most value from EMO, at $US419 million (28% of the total value of EMO).

Value chain

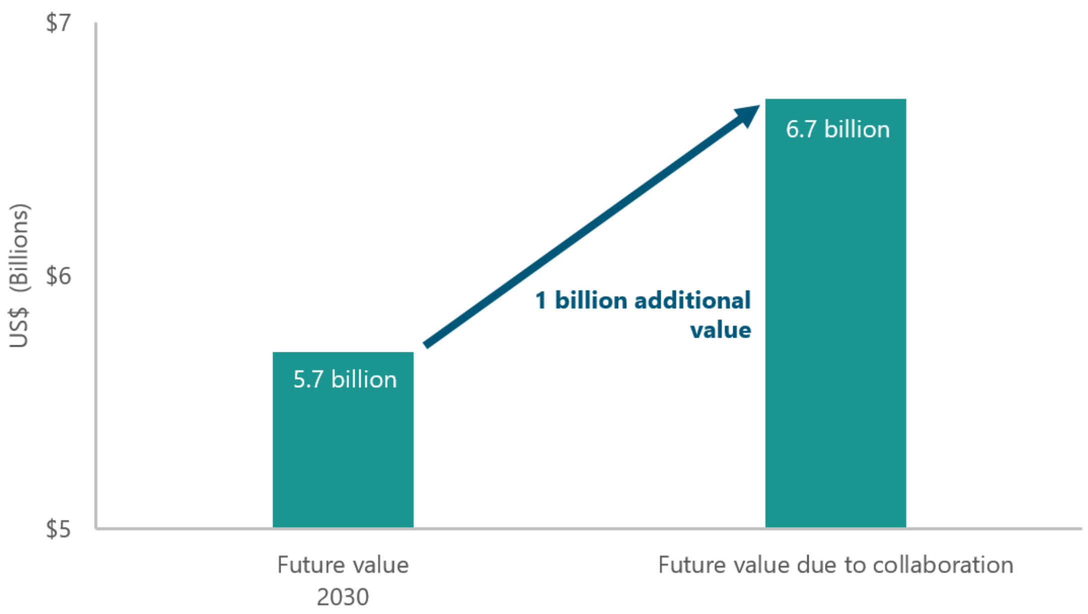


Areas of collaboration

Chile can leverage insights and data from other economies to strengthen its already growing EMO capabilities. Organisations such as the 'Asociación Chilena Del Espacio' (ACHIDE) are extending Chile's EMO capabilities and reach.

Targeted capability development across APEC could help realise this potential, including advancing Chile's current infrastructure programs.

Value from collaboration



Collaboration across APEC could help Chile realise even further value through its disaster management programs and consumer products. There are opportunities for targeted investment in capability programs to boost EMO uptake in other industries, such as utilities and health.

Chinese Taipei

Increased application of EMO to disaster management would further enhance value.

Population: 23.6 million | GDP (per capita): US$24,971

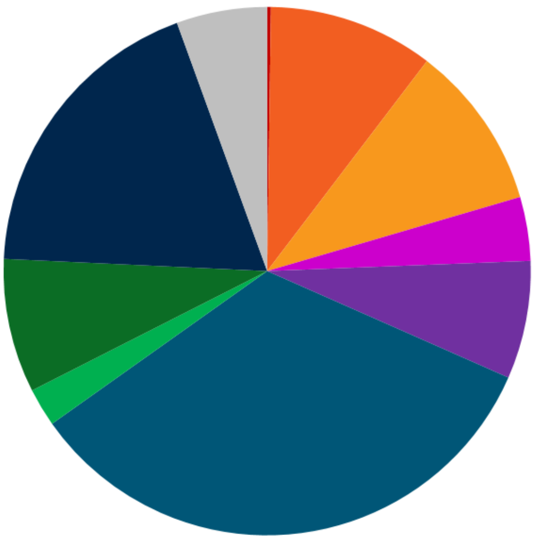
EMO value (US$ billion)

2019: $2.7

2030: $11.0

2030 (collaboration): $12.8

Total economic value

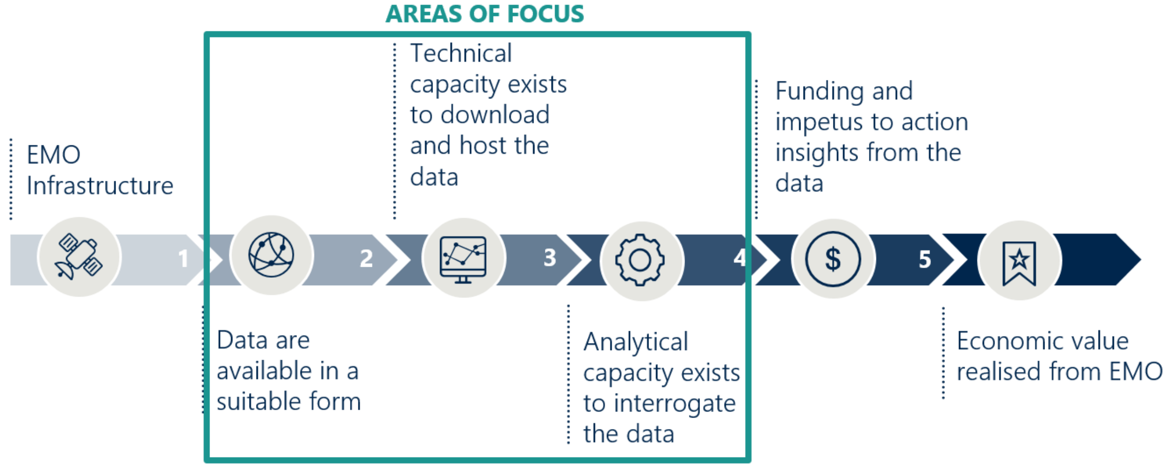


	US$ million
Mining	6
Agriculture, fisheries & forestry	278
Utilities: Power	277
Utilities: Water	107
Utilities: Communications	198
Transport	922
Health	64
Finance	225
Consumer	513
Disaster Management	153
Total	**2,744**

Key industry information

- The value of EMO to Chinese Taipei is equivalent to 0.5% of GDP.
- Agriculture, fisheries and forestry and utilities: power each gain 10.1% of value from EMO.
- Consumer willingness to pay is the second highest value from EMO, at US$513 million (18.7%).
- Although mining only represents 0.2% of value from EMO, this is equivalent to 1.4% of the total mining industry's value.

Value chain

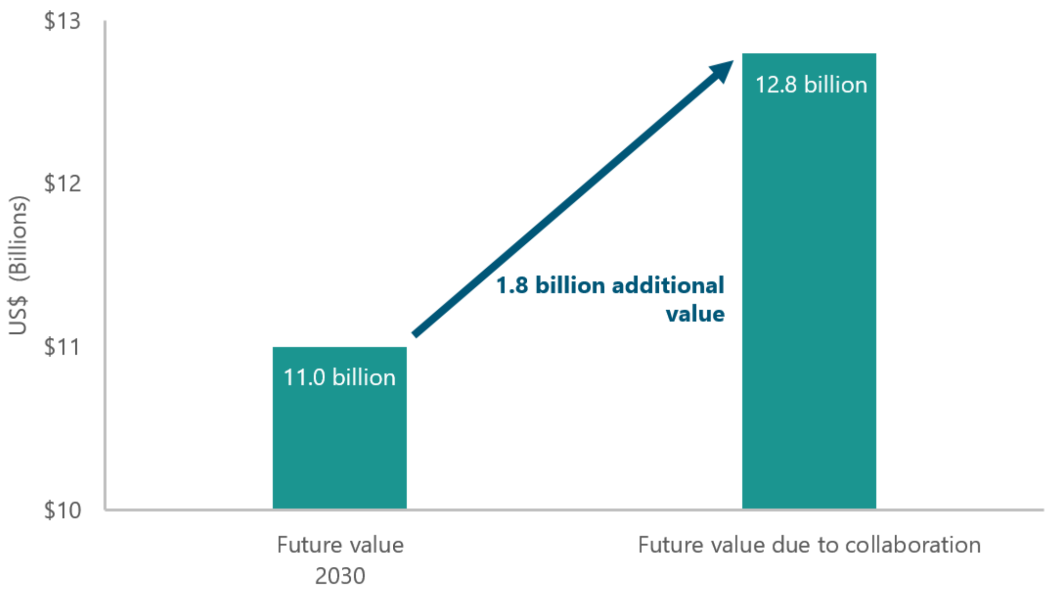


Areas of collaboration

Being located on the Huatung Longitudinal Valley (tectonic boundary), Chinese Taipei could benefit from greater data sharing and analytical and technical insights regarding disaster management—especially regarding earthquakes and pre and post disaster data.

Chinese Taipei can continue to benefit from collaboration across APEC through interdisciplinary cooperatives such as the 2019 Geosciences Assembly targeting environmental protection; disaster prevention; and sustainability of natural resources.

Value from collaboration



Chinese Taipei has multiple industries that have the potential to grow their use of EMO, particularly agriculture, fisheries, forestry; utilities: power; and utilities: communication. Collaboration across APEC would be beneficial in developing new insights and data products that can support this growth.

Hong Kong, China

Although realising the most value from transport, there is an opportunity to support EMO growth in other industries.

Population: 7.5 million | GDP (per capita): US$48,717

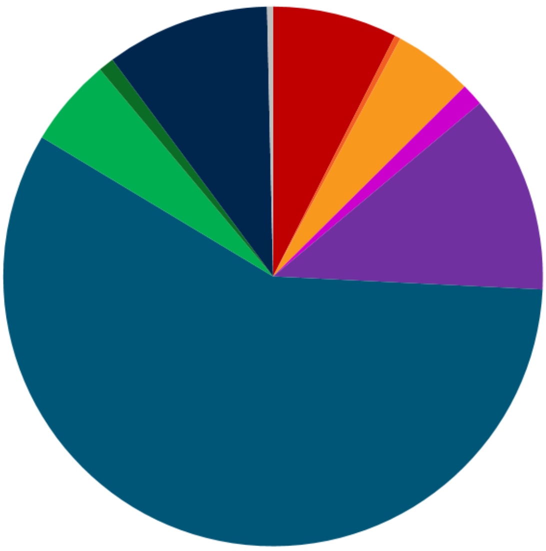
EMO value (US$ billion)

2019: $3.3

2030: $13.9

2030 (collaboration): $14.5

Total economic value

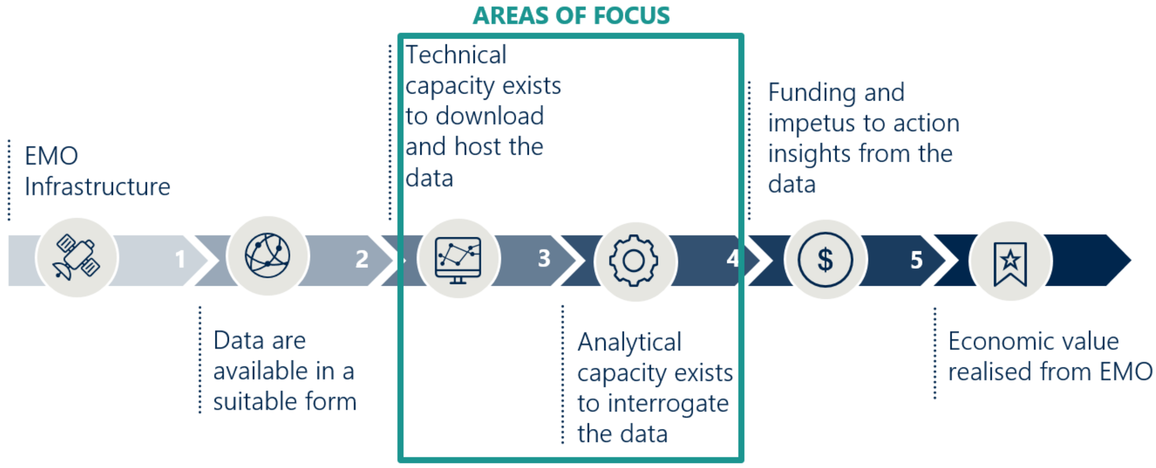


	US$ million
Mining	245
Agriculture, fisheries & forestry	12
Utilities: Power	156
Utilities: Water	44
Utilities: Communications	389
Transport	1,898
Health	174
Finance	31
Consumer	321
Disaster Management	12
Total	**3,281**

Key industry information

- The value of EMO to Hong Kong, China is equivalent to 0.9% of GDP.
- Although only 0.4% of EMO value, agriculture, fisheries and forestry is equivalent to 5.4% of the total agriculture, fisheries and forestry industry value.
- Transport accounts for 58% of value from EMO, or US$1.9 billion, followed by consumer willingness to pay at 10%.
- 5.3% of the total value of EMO is generated in the health industry.

Value chain

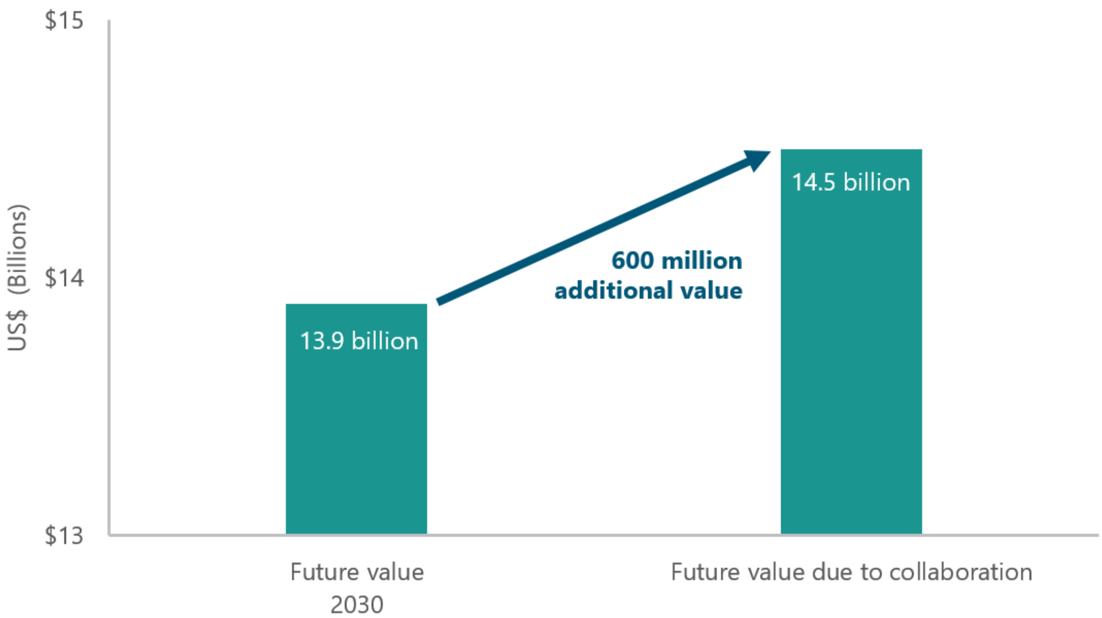


Areas of collaboration

Hong Kong, China would benefit from greater EMO collaboration, particularly in the health industry. As an industry, health is financially larger than transport, yet realises only 5.3% of the value from EMO, compared with transport at 57.9%.

This collaboration could focus on strengthening Hong Kong, China's analytical and technical capability through its research institutes, such as the Chinese University of Hong Kong and the Hong Kong Observatory.

Value from collaboration



Hong Kong, China can continue to support collaboration across APEC through its research into weather-related hazards and by providing meteorological and geophysical services. The economy would also benefit from targeted data applications that bolster other industries within the economy, such as transport.

Indonesia

With greater funding and impetus, Indonesia can substantially increase the value realised from EMO.

Population: 267.7 million | GDP (per capita): US$3,894

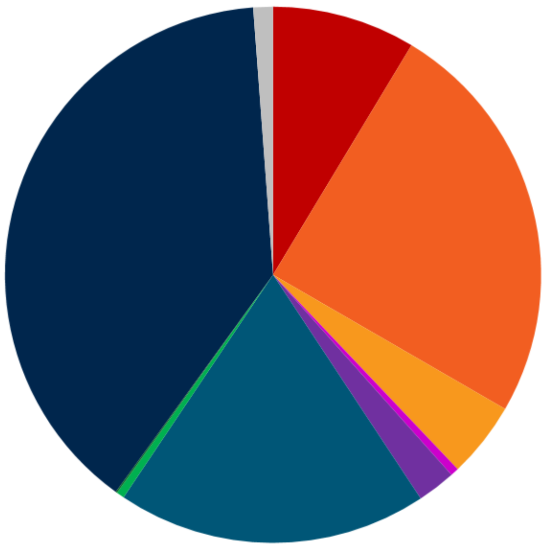
EMO value (US$ billion)

2019: $2.4

2030: $13.6

2030 (collaboration): $17.0

Total economic value

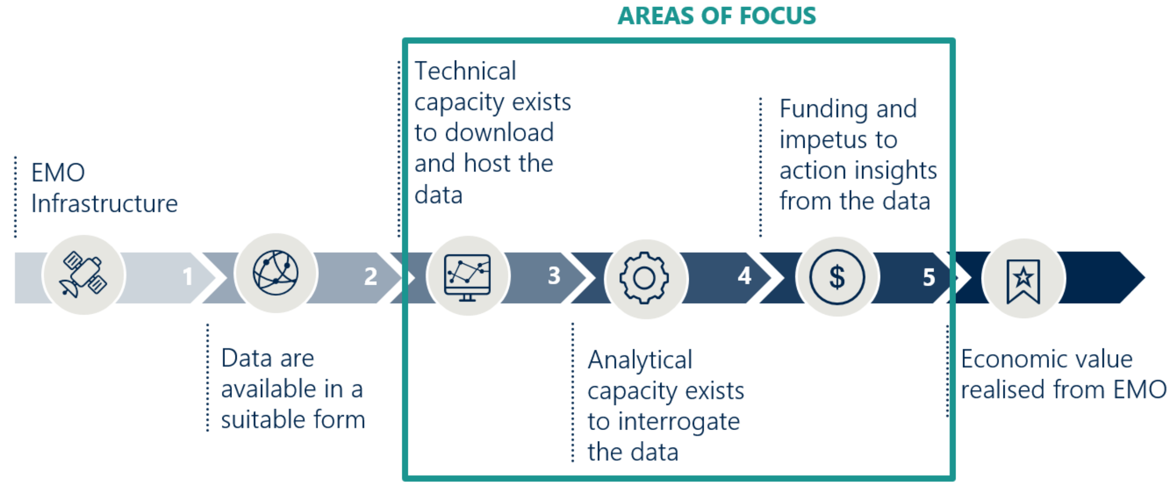


	US$ million
Mining	205
Agriculture, fisheries & forestry	585
Utilities: Power	108
Utilities: Water	12
Utilities: Communications	55
Transport	443
Health	11
Finance	2
Consumer	920
Disaster Management	28
Total	**2,368**

Key industry information

- The value of EMO to Indonesia is equivalent to 0.23% of GDP.
- Consumer willingness to pay contributes the largest value from EMO at US$920 million (39%).
- Interestingly, Indonesia realises more value from EMO in agriculture, fisheries and forestry (25%) than from transport (19%).
- Indonesia has the opportunity to realise more value from EMO for disaster management (1.2%).

Value chain

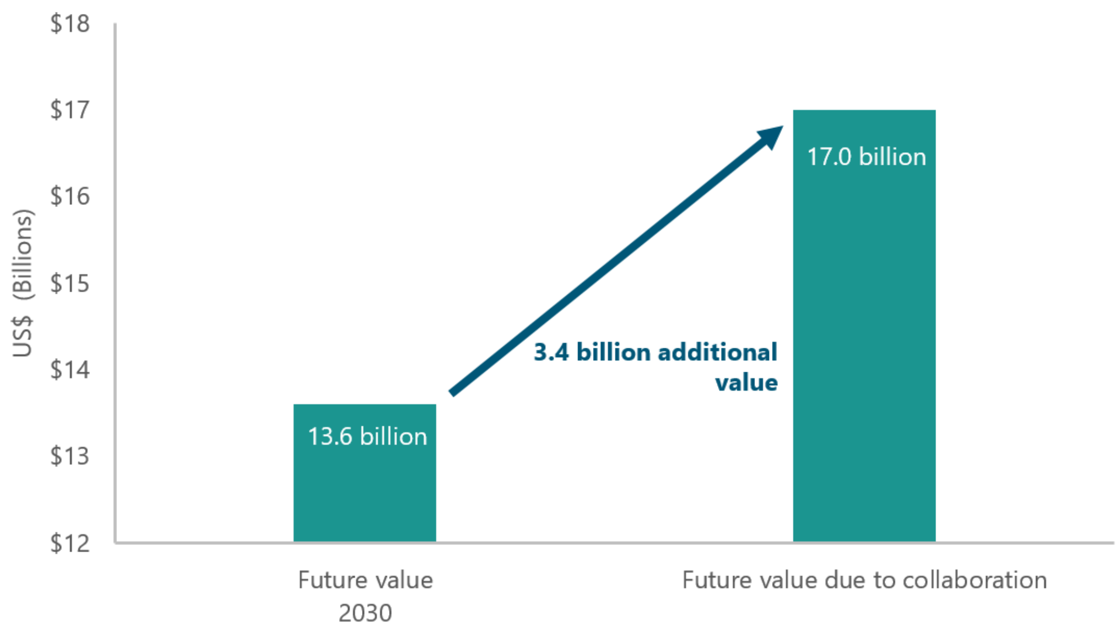


Areas of Collaboration

Current collaboration is strengthening Indonesia's EMO capabilities. Examples include the Indonesia Program Initiative on Maritime Observation and Analysis (Ina PRIMA); researching marine meteorology; climate; air quality; oceanography; and geophysics.

To continue growth of its EMO industry, including in disaster management, Indonesia could benefit from collaboration regarding technical and analytical capability, and leveraging APEC-wide programs.

Value from Collaboration



Through collaboration across APEC, Indonesia is well positioned to substantially increase the value realised from EMO. Collaboration should focus on the industries that are both growing and also able to incorporate EMO easily into their standard operations.

Japan

Sustained support for the development of EMO will be imperative for realising future value.

Population: 126.5 million | GDP (per capita): US$39,287

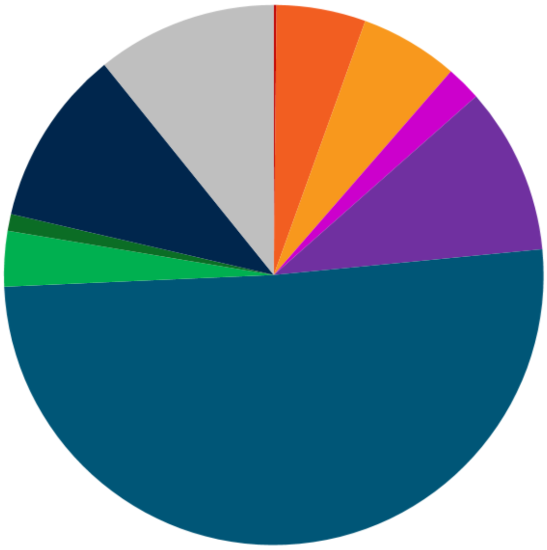
EMO value (US$ billion)

2019: $42

2030: $117

2030 (collaboration): $122

Total economic value

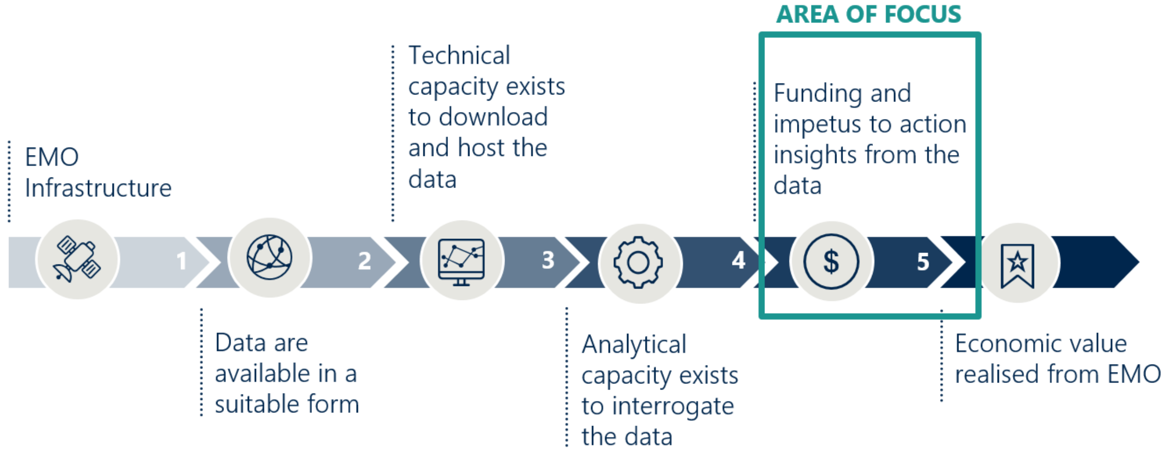


	US$ million
Mining	68
Agriculture, fisheries & forestry	2,249
Utilities: Power	2,478
Utilities: Water	881
Utilities: Communications	4,199
Transport	21,380
Health	1,395
Finance	422
Consumer	4,447
Disaster Management	4,544
Total	**42,063**

Key industry information

- The value of EMO to Japan is equivalent to 0.8% of GDP.
- Just over half of this value (51%) is realised through transport, at $US21 billion; which is equivalent to 8.5% of the value of the industry.
- The EMO value from agriculture, fisheries and forestry represents 4.4% of the value of the industry.
- All the utilities combine to 18% of the value of EMO.

Value chain



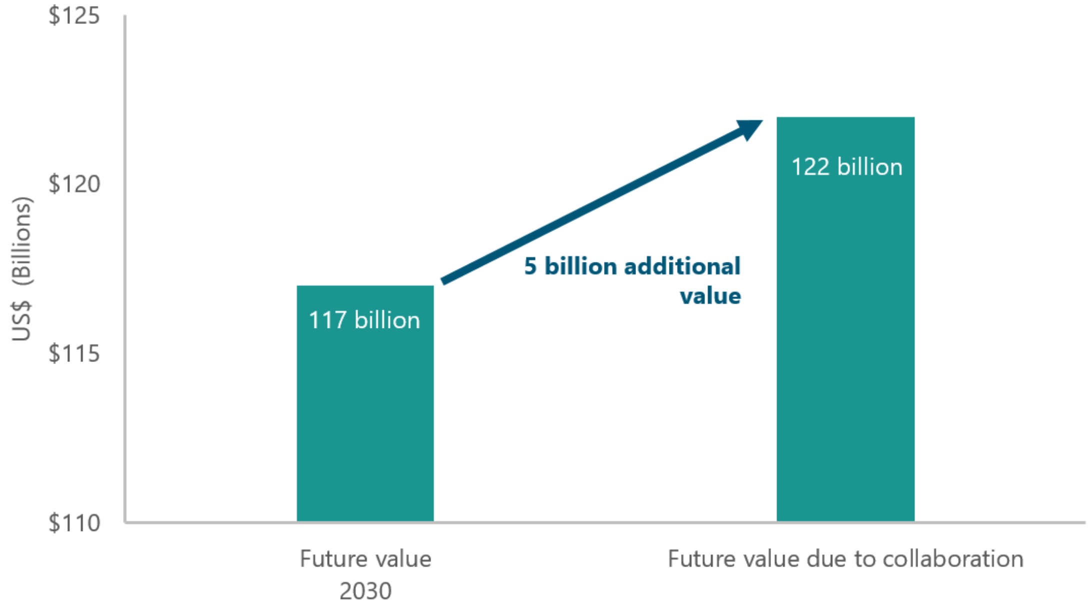
Areas of collaboration

Many economies in APEC would benefit from Japan's open data sharing, including through the Tellus program.

Japan can realise substantial value from collaborating not only across APEC, but also through internal collaboration with government, the private sector, and academia.

Japan can support APEC and lead the way in marine observation by continuing to progress technology for deep submersibles.

Value from collaboration



'[EMO is] not limited to the economic value. We expect that the EMO would continue providing...[through] its contribution to mitigation and adaptation to climate change, water management and the risk reduction of water disasters, improvements of agriculture, preservation of biodiversity, and health.' (Japan)

Malaysia

Raising awareness of EMO would add additional impetus to invest to increase the value of EMO.

Population: 31.5 million | GDP (per capita): US$11,239

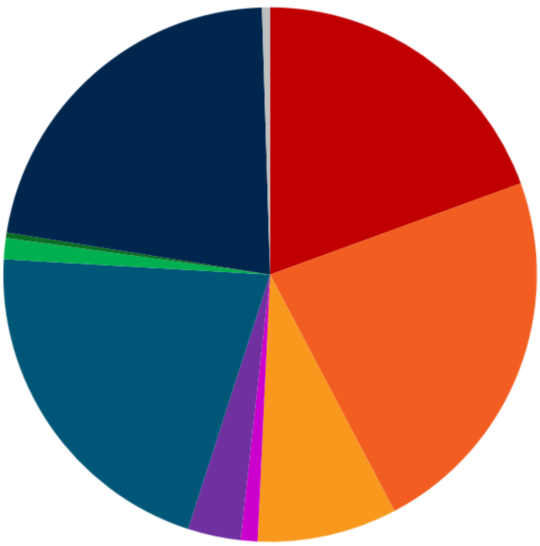
EMO value (US$ billion)

2019: $1.4

2030: $7.6

2030 (collaboration): $8.8

Total economic value

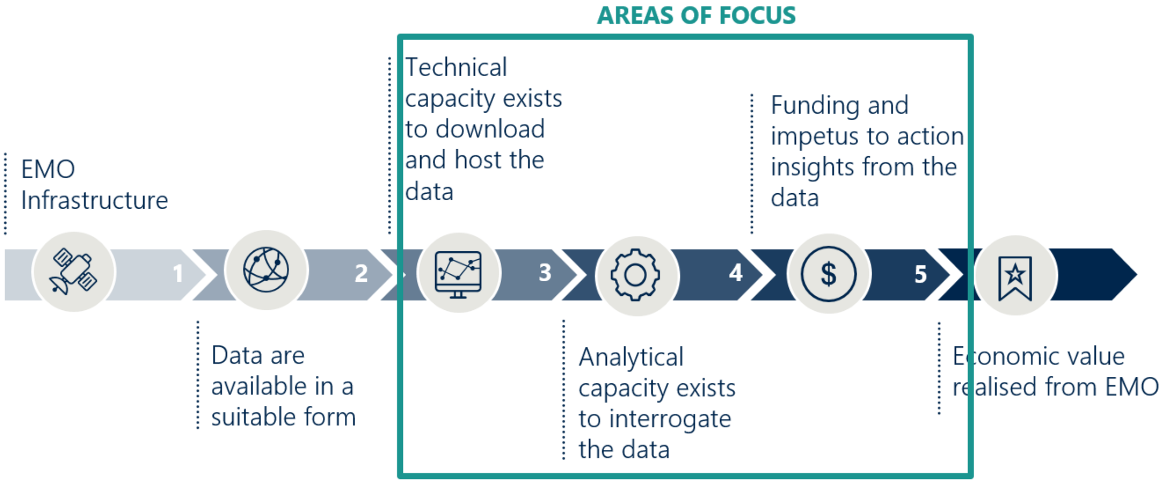


	US$ million
Mining	276
Agriculture, fisheries & forestry	324
Utilities: Power	120
Utilities: Water	14
Utilities: Communications	46
Transport	297
Health	18
Finance	5
Consumer	312
Disaster Management	7
Total	**1,419**

Key industry information

- The value of EMO to Malaysia is equivalent to 0.4% of GDP.
- Unlike most other economies, agriculture, fisheries and forestry (23%), and consumer willingness to pay (22%) both exceed transport (21%) in the value realised from EMO.
- Disaster management presents an opportunity to grow the value obtained from EMO by 2030, as it is currently only 0.5% of the overall value.

Value chain

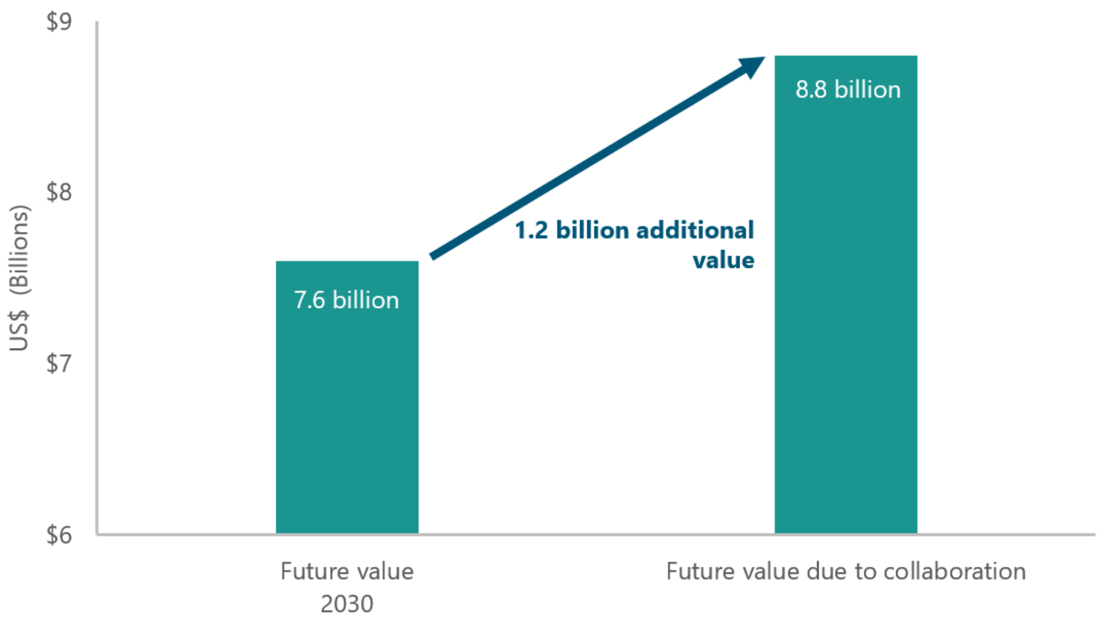


Areas of collaboration

Given Malaysia's tropical climate, collaboration would be beneficial in helping to develop analytical models that can accurately forecast weather (particularly extreme weather events).

Access to additional EMO infrastructure and data would help inform current modelling efforts and enable Malaysia to extend its current EMO program.

Value from collaboration



Collaboration to raise awareness of the importance of EMO is valuable to Malaysia. 'Awareness impacts investment by the government. There is low awareness in Malaysia by policy personnel.' (Malaysia)

Mexico

Greater access to infrastructure and additional data sources is important for realising future value.

Population: 126.2 million | GDP (per capita): US$9,698

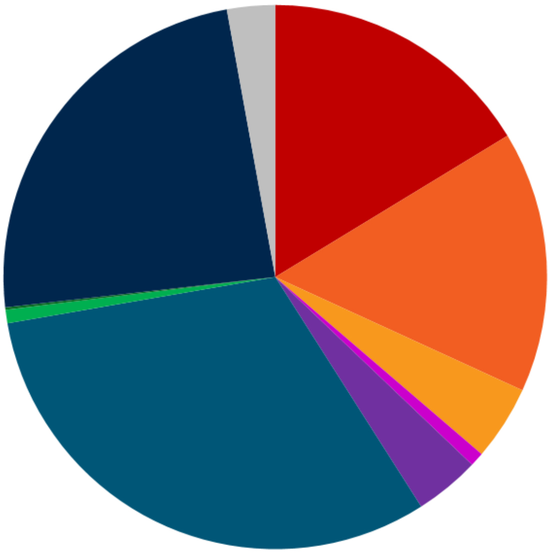
EMO value (US$ billion)

2019: $5.6

2030: $16.4

2030 (collaboration): $21.4

Total economic value

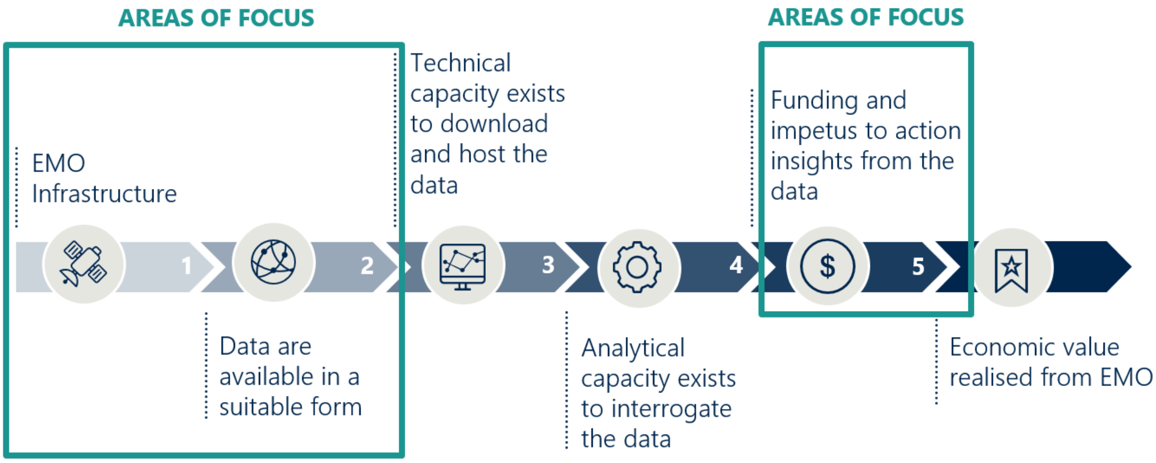


	US$ million
Mining	909
Agriculture, fisheries & forestry	865
Utilities: Power	248
Utilities: Water	47
Utilities: Communications	215
Transport	1,745
Health	44
Finance	8
Consumer	1,334
Disaster Management	159
Total	**5,575**

Key industry information

- The value of EMO to Mexico is equivalent to 0.5% of GDP.
- The values of agriculture, fisheries and forestry, and of transport both represent 2.1% of the total value of these industries.
- Consumer willingness to pay represents 23.9% of value at US$1.3 billion.
- Utilities: water and health both represent only 0.8% of the value from EMO.

Value chain



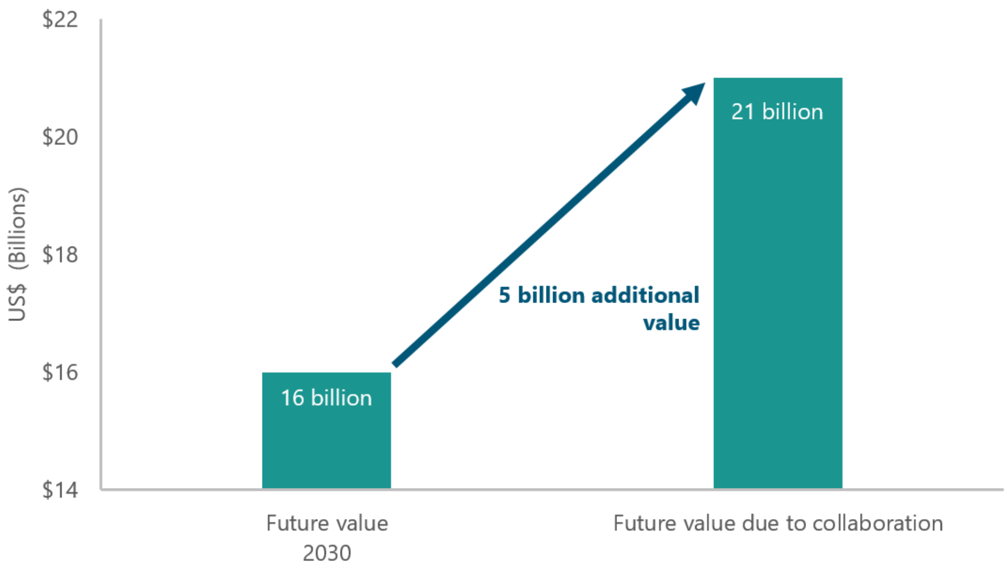
Areas of collaboration

Mexico can realise more value from EMO by working with the industries that currently lead the way in using EMO—being mining and agriculture, fisheries and forestry.

Mexico also has the opportunity to partner with other economies to develop EMO applications that help produce alternative energy sources, such as wind, solar, and biomass energy.

Greater access to infrastructure and data would benefit Mexico.

Value from collaboration



Mexico currently purchases data from the United States, the People's Republic of China, Europe, and commercial sources. Realising the potential future value from EMO will be dependent upon greater access to infrastructure, more data, and economic support.

New Zealand

Access to data and translatability were identified as the areas of focus for increasing EMO value.

Population: 4.9 million | GDP (per capita): US$41,966

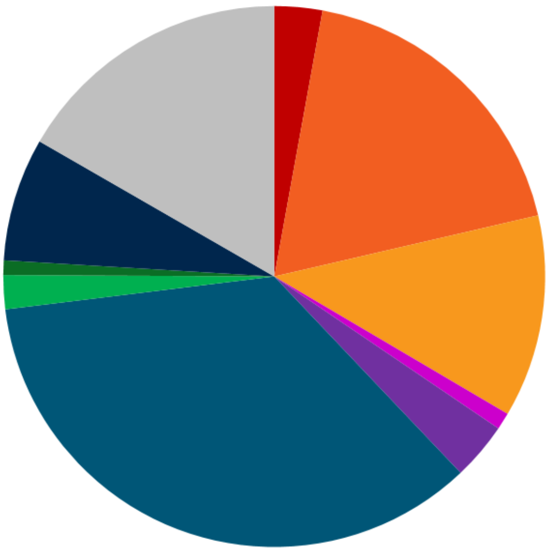
EMO value (US$ billion)

2019: $2.4

2030: $8.7

2030 (collaboration): $9.1

Total economic value

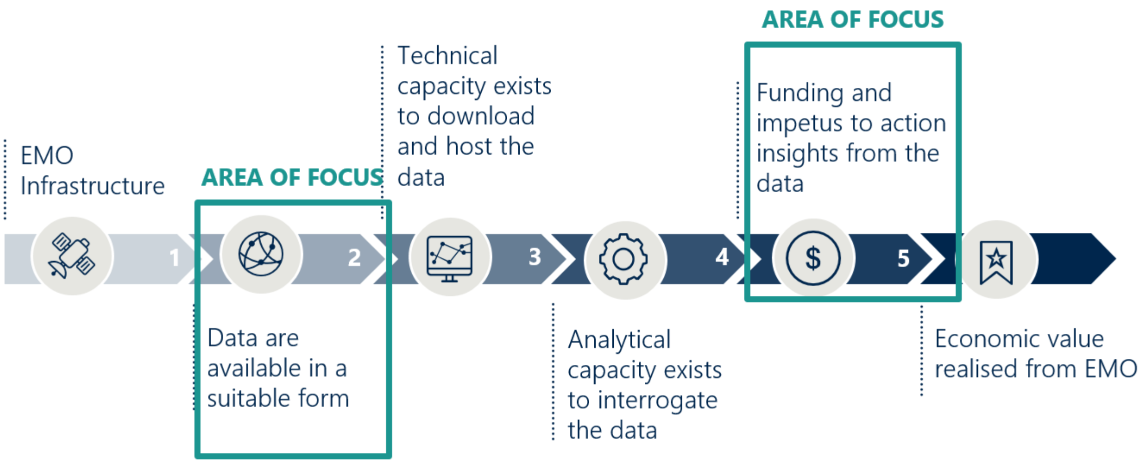


	US$ million
Mining	70
Agriculture, fisheries & forestry	451
Utilities: Power	295
Utilities: Water	25
Utilities: Communications	84
Transport	856
Health	49
Finance	21
Consumer	180
Disaster Management	406
Total	**2,437**

Key industry information

- The value of EMO to New Zealand is equivalent to 1.2% of GDP.
- Agriculture, fisheries and forestry contribute a significant portion of value from EMO, at $US451 million (18.5%)—which is equivalent to 4.7% of the industry's total value.
- Given New Zealand's history of natural disasters, disaster management represents 16.7% of the value attributable to EMO.

Value chain



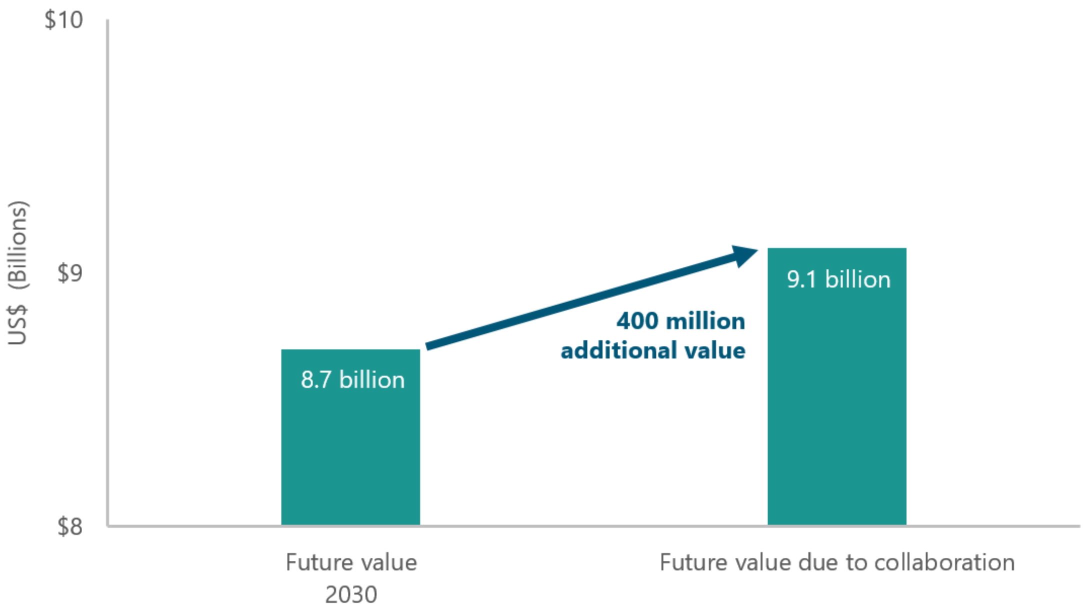
Areas of collaboration

New Zealand would benefit from greater data sharing to inform agriculture, fisheries and forestry policy, in particular, as well as disaster management and climate change policy.

New Zealand's national campaign to coordinate its EMO datasets presents an opportunity for greater collaboration across APEC to provide new data products to other member economies.

Current relationships with Australia, Japan, the United States and Canada offer a path for addressing the priority areas of EMO for APEC.

Value from collaboration



Collaboration can help New Zealand and other economies across APEC to access and understand the data available. 'It is important to release a better product to end users, rather than just the raw data equivalent that people may not understand. Re-usable data products need to be prioritised so that the average user can utilise EMO better.' (New Zealand)

Papua New Guinea

Access to ready-to-use data products can help Papua New Guinea realise more value from EMO.

Population: 8.6 million | GDP (per capita): US$2,723

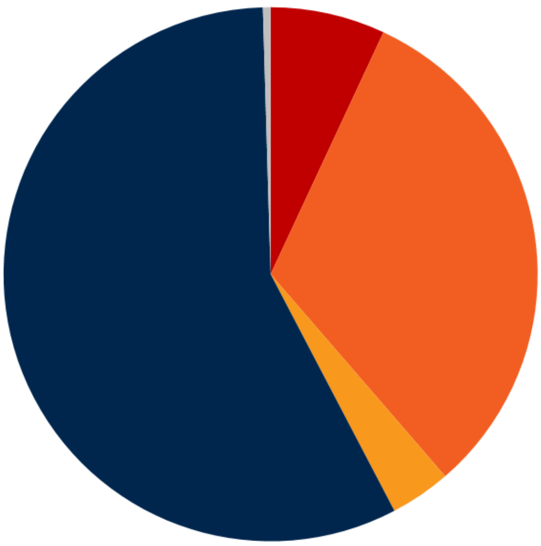
EMO value (US$ million)

2019: $36

2030: $108

2030 (collaboration): $127

Total economic value

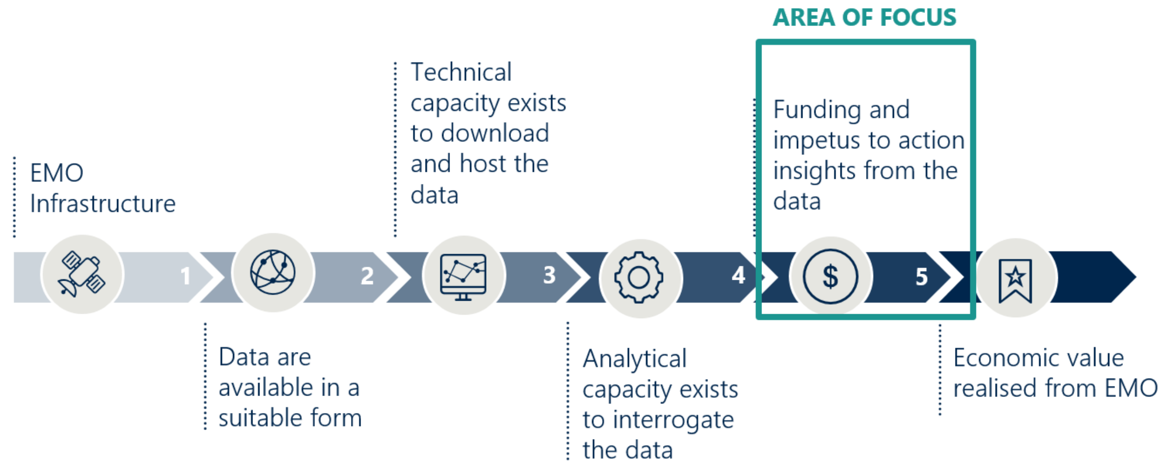


	US$ million
Mining	2
Agriculture, fisheries & forestry	11
Utilities: Power	1
Consumer	21
Disaster Management	<1
Total	**36**

Key industry information

- The value of EMO to Papua New Guinea is equivalent to 0.15% of GDP.
- Consumer willingness to pay is the largest share of value from EMO at 57%, equivalent to US$21 million.
- Agriculture, fisheries and forestry make up the majority of the remainder of value (32%).
- Although not recorded, EMO is expected to contribute also to transport.

Value chain

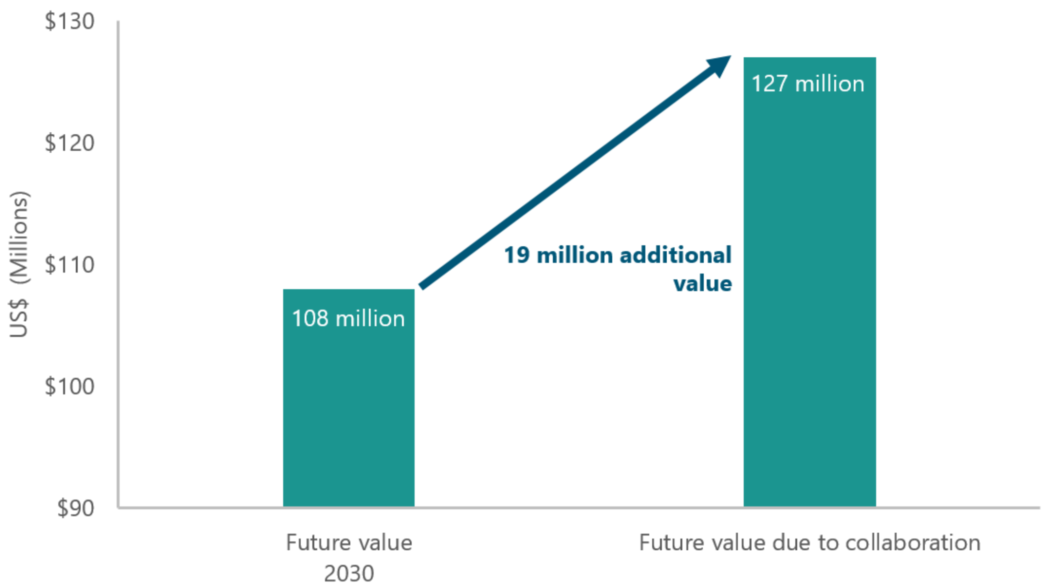


Areas of collaboration

Papua New Guinea's exposure to natural disasters presents an area for greater collaboration and the realisation of future value—such as with the Earth Observatory of Singapore and Rabaul caldera (volcano).

It is also anticipated that there is additional value to be realised from the other industries not included within the model. (For example, the Asian Development Bank has worked with Papua New Guinea to use EMO to undertake a transport infrastructure assessment.)

Value from collaboration



Papua New Guinea is positioned to increase the value realised from EMO over the coming decade. Natural disaster management and other industries (such as transport and agriculture, fisheries and forestry) present an opportunity for targeted investment: finding ways EMO can reduce industry costs and increase productivity.

People's Republic of China

Future value will be unlocked as analytical and technical capabilities continue to expand.

Population: 1.4 billion | GDP (per capita): US$9,771

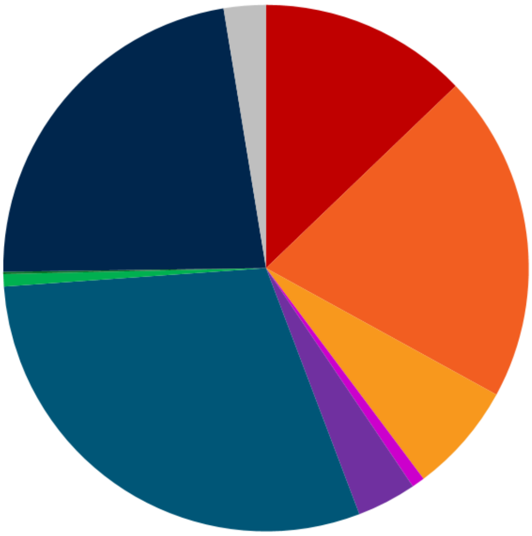
EMO value (US$ billion)

2019: $53

2030: $395

2030 (collaboration): $456

Total economic value

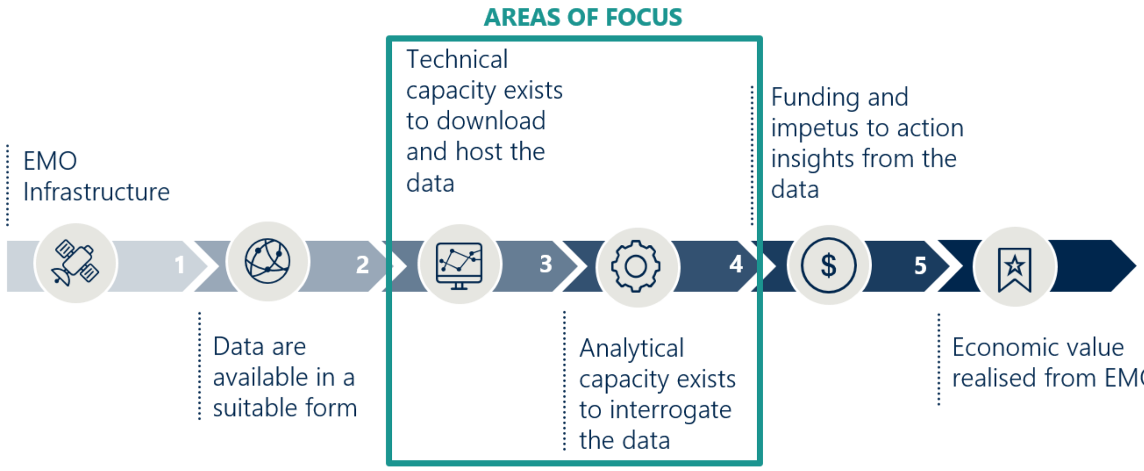


	US$ million
Mining	6,859
Agriculture, fisheries & forestry	10,761
Utilities: Power	3,625
Utilities: Water	423
Utilities: Communications	1,956
Transport	15,849
Health	402
Finance	76
Consumer	12,093
Disaster Management	1,382
Total	**53,426**

Key Industry Information

- The value of EMO to the People's Republic of China is equivalent to less than 0.01% of GDP (US$ 13.61 trillion).
- US$12 billion (23%) of this value is realised through consumer willingness to pay.
- Agriculture, fisheries and forestry contribute $US11 billion (20%) of EMO value, which is equivalent to 1.1% of the value of the industry.
- Transport and utilities: power, respectively, represent 2.1% and 1.4% of the industry's value.

Value chain

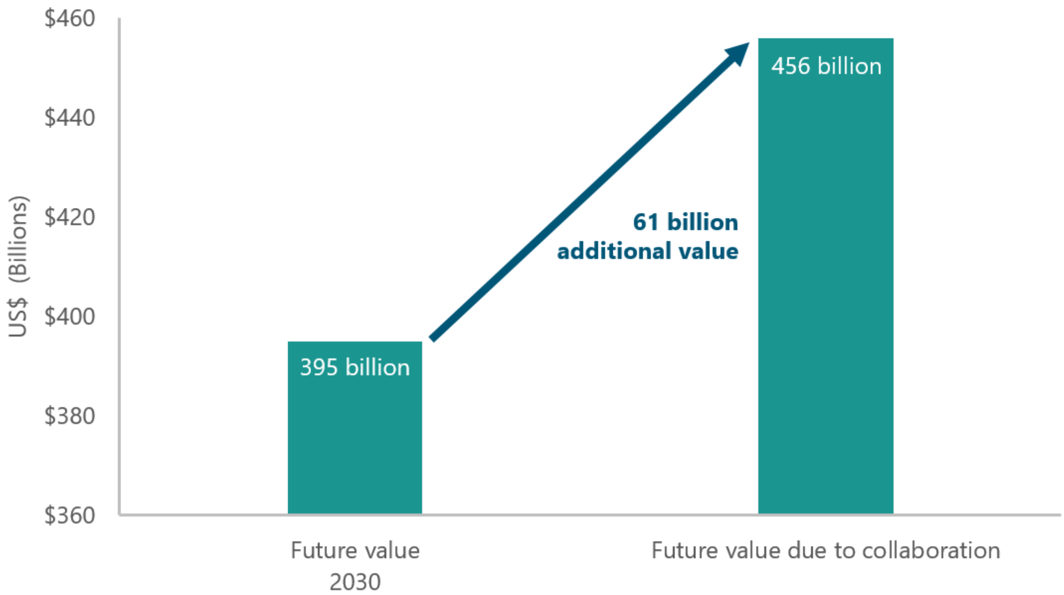


Areas of collaboration

The People's Republic of China can realise large gains in value from EMO through greater collaboration to develop its technical and analytical capabilities. Additionally, other economies within APEC have expressed their interest in collaborating with the People's Republic of China to upskill their own EMO specialists.

Value can be realised quickly by collaborating with the industries that have the greatest potential gain from EMO applications.

Value from collaboration



'We need to encourage data exchanges between different [economies] to inform awareness of the maximum benefit from joint action, research, and application...Collaboration is critical to try to use more data and technology to talk to the global issues such as disaster management and climate change.' (The People's Republic of China)

Peru

Developing technical and analytical capability could help Peru realise more value from EMO by 2030.

Population: 32 million | GDP (per capita): US$6,947

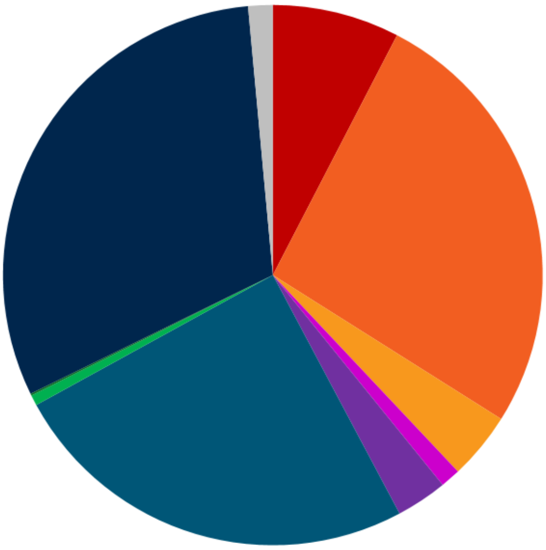
EMO value (US$ million)

2019: $761

2030: $2,771

2030 (collaboration): $3,538

Total economic value

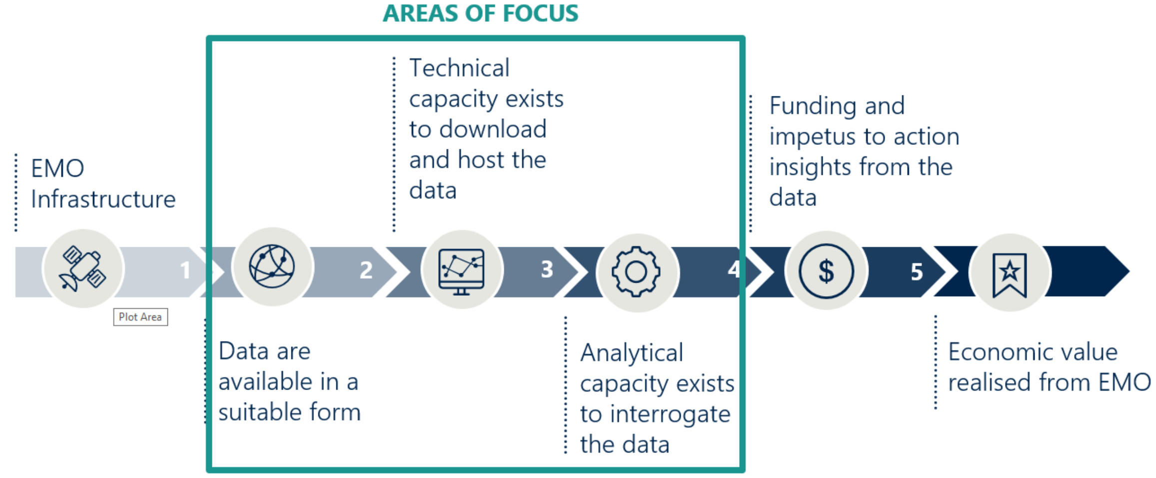


	US$ million
Mining	58
Agriculture, fisheries & forestry	200
Utilities: Power	31
Utilities: Water	9
Utilities: Communications	23
Transport	189
Health	5
Finance	1
Consumer	234
Disaster Management	11
Total	**761**

Key industry information

- The value of EMO to Peru is equivalent to 0.3% of GDP.
- Consumer willingness to pay contributes the largest value from EMO at US$234 million (31%).
- Transport and agriculture, fisheries and forestry together represent 51% of the value gained from EMO, at a combined total of US$389 million.
- Although only US$9 million, utilities: water represents 1.4% of the total value of the industry.

Value chain

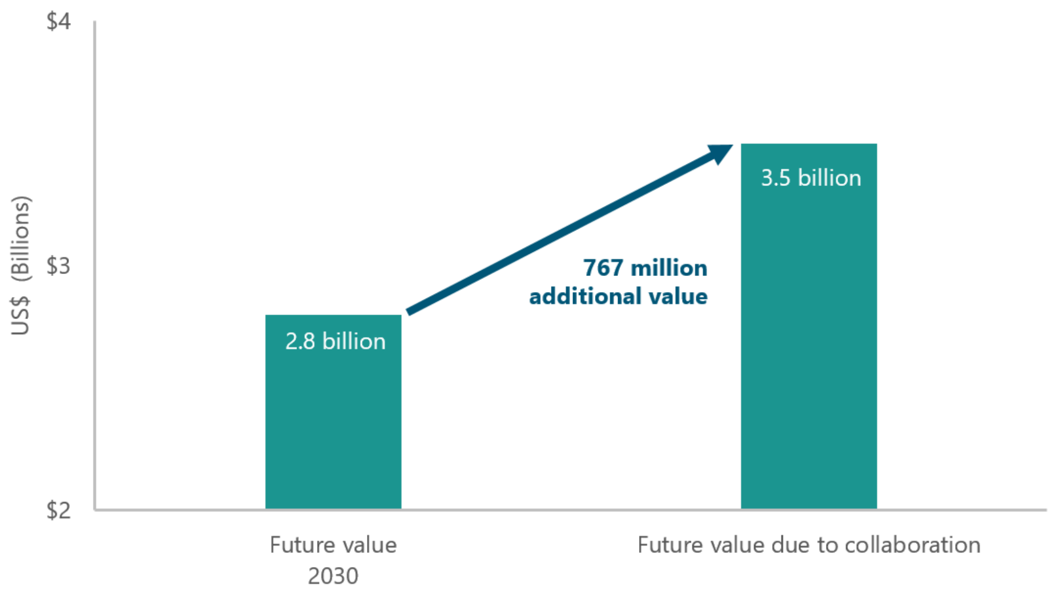


Areas of collaboration

Peru could benefit from data collaboration across APEC. There is a need for more data around the South American coast to support what is already used from the Tropical Assistance System. Additional data would help improve the reliability and accuracy of report results.

Partnerships with Chile, the United States, Japan and the Republic of Korea should continue to expand to improve Peru's oceanographic observation and monitoring, modelling, and its management of fisheries.

Value from collaboration



There has been a recent push in Peru to improve early warning capabilities for disaster management, including the dissemination of information to citizens. Collaboration with other APEC economies could help Peru improve its use of EMO within disaster management, as well as other developing sectors such as oceanographic observation and monitoring.

Philippines

Targeted investment into EMO and disaster management can increase its future value.

Population: 106.7 million | GDP (per capita): US$3,103

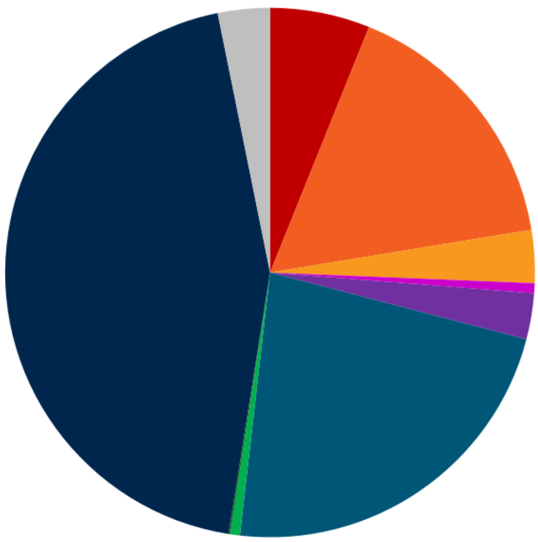
EMO value (US$ million)

2019: $657

2030: $5,387

2030 (collaboration): $6,586

Total economic value

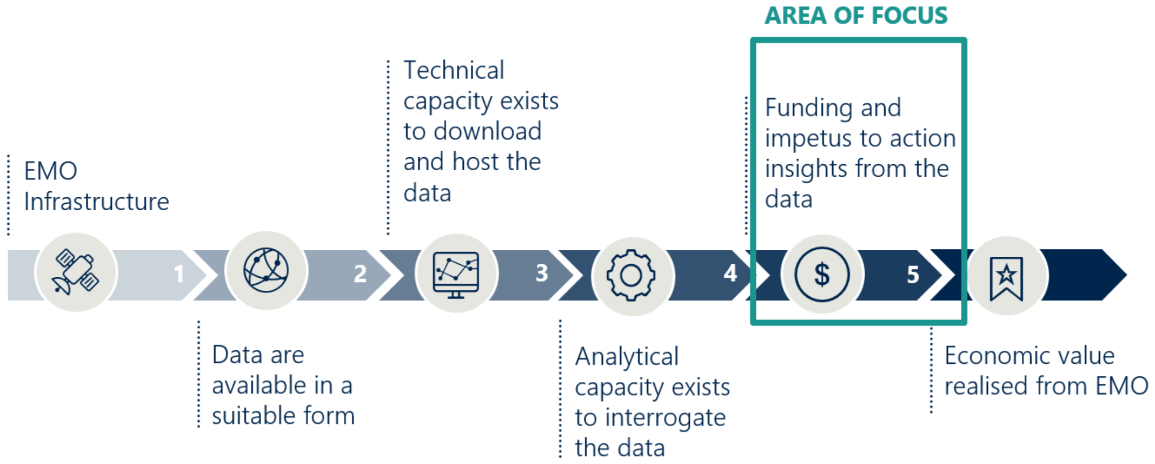


	US$ million
Mining	40
Agriculture, fisheries & forestry	107
Utilities: Power	21
Utilities: Water	4
Utilities: Communications	18
Transport	150
Health	4
Finance	1
Consumer	291
Disaster Management	21
Total	**657**

Key industry information

- The value of EMO to the Philippines is equivalent to 0.2% of GDP.
- Consumer willingness to pay contributes the largest value from EMO at US$291 million (44%).
- Utilities, combined, contribute 6.6% of value, at US$44 million.
- Mining and agriculture, fisheries and forestry together contribute just under a quarter of the value from EMO for this economy.

Value chain

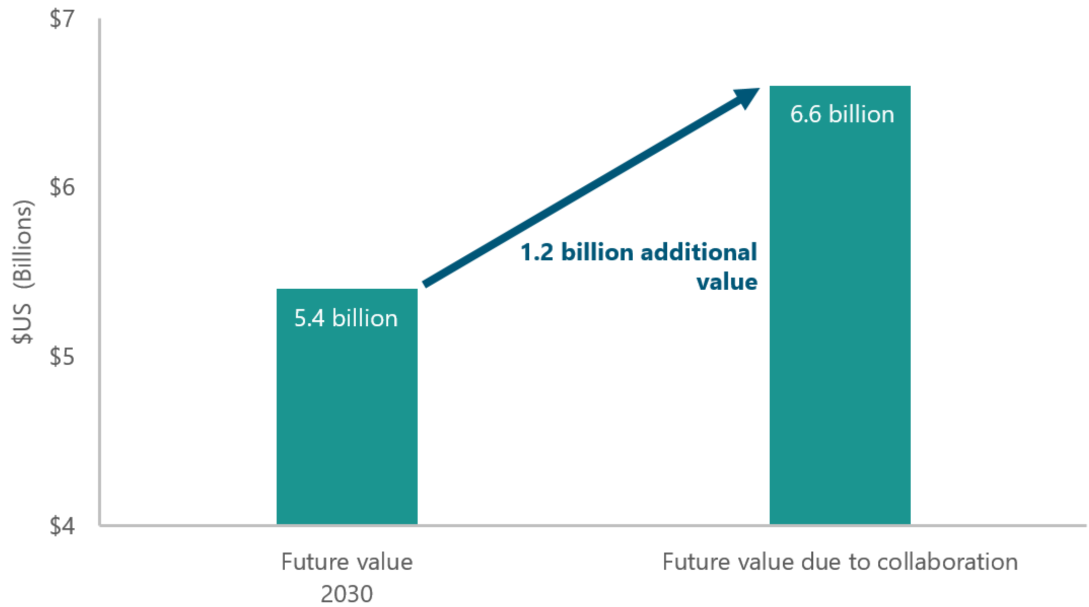


Areas of collaboration

Given the Philippines' vulnerability to natural disasters, the economy could benefit from greater collaboration to increase the use of EMO for resilience building.

Disaster management accounts for approximately 3% of value from EMO, and there is the opportunity to bolster this value. This will be dependent on funding and APEC-wide initiatives to improve resilience for the most at-risk economies in the Asia-Pacific region.

Value from collaboration



The Philippines have an opportunity to increase the value from EMO, particularly in disaster management. Collaboration across APEC could help target specific programs to grow the use of EMO for resilience building activities.

Republic of Korea

A new source of EMO data is expected to increase value added leading up to 2030.

Population: 51.6 million | GDP (per capita): US$31,363

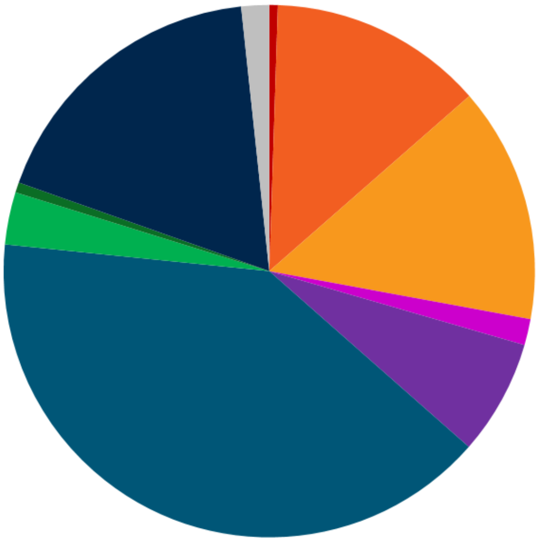
EMO value (US$ billion)

2019: $8

2030: $30

2030 (collaboration): $35

Total economic value

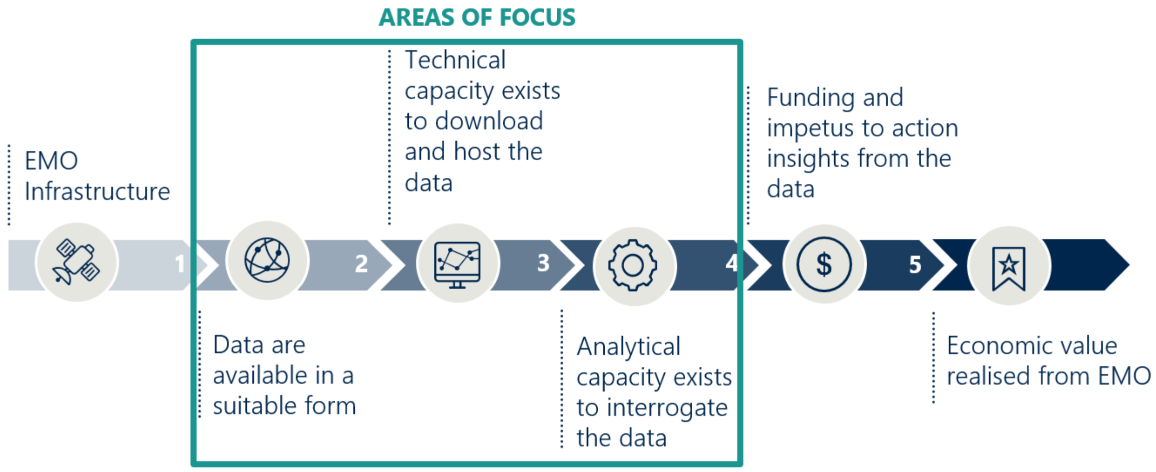


	US$ million
Mining	42
Agriculture, fisheries & forestry	1,050
Utilities: Power	1,152
Utilities: Water	128
Utilities: Communications	563
Transport	3,229
Health	256
Finance	50
Consumer	1,441
Disaster Management	136
Total	**8,048**

Key Industry Information

- The value of EMO to the Republic of Korea is equivalent to 0.5% of GDP.
- US$3.2 billion (40.1%) of this value is realised through transport, which is equivalent to 6.8% of the value of the industry.
- US$1.4 billion, the second highest share of EMO value for the Republic of Korea, is attributed to consumer willingness to pay.
- Agriculture, fisheries and forestry contribute 13.1% of value from EMO.

Value chain



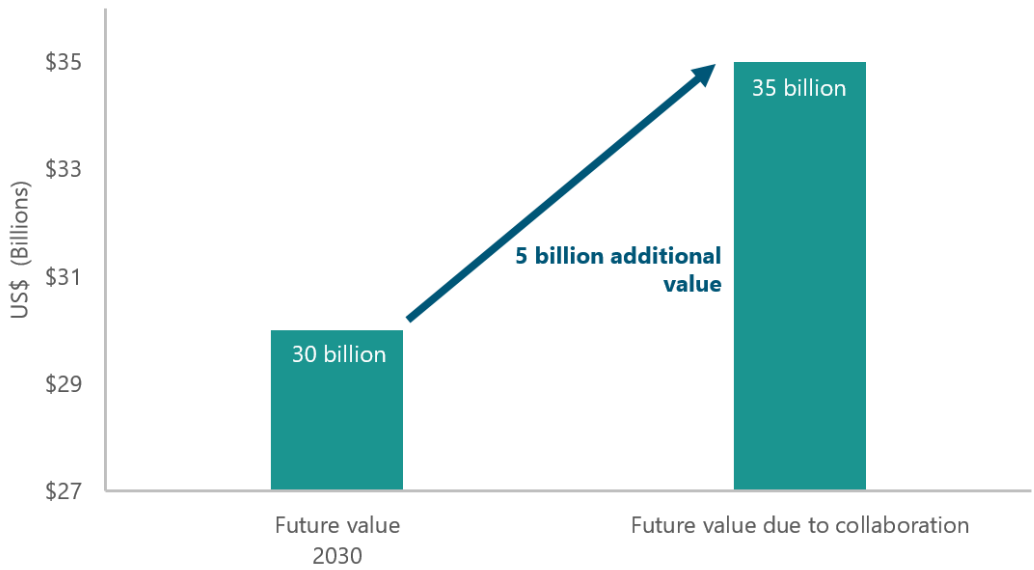
Areas of collaboration

The Republic of Korea would benefit from increased collaboration in disaster management, including data and analytical capability.

Data sharing is also important, as there is a shortage of satellite data for the Korean peninsula, which limits the use of EMO in industry.

The 'Second Satellite Information Utilisation Plan' can be leveraged to support EMO capabilities not only within the Republic of Korea, but also across the whole of APEC.

Value from collaboration



'The "Second Satellite Information Utilisation Plan"... [seeks] to improve EMO capability for disaster management, weather forecasting, environment monitoring, ocean and water resources monitoring, agriculture, land management, communication, and high precision satellite navigation in the future (2030 and beyond).' (The Republic of Korea)

Russia

Translatability will be imperative to realising the greatest future value from EMO.

Population: 144.5 million | GDP (per capita): US$11,289

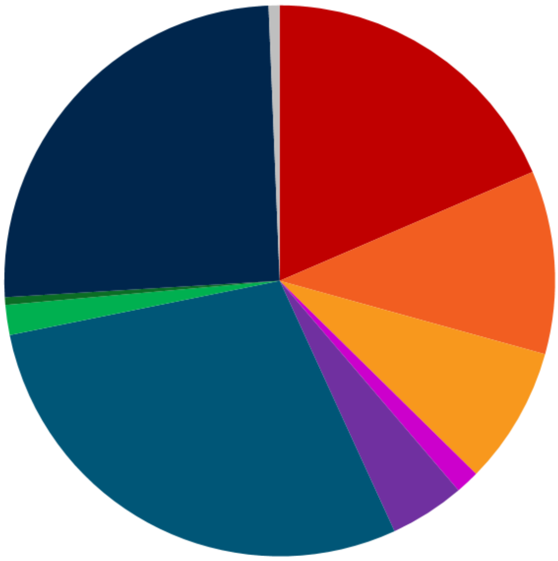
EMO value (US$ billion)

2019: $5.8

2030: $16.0

2030 (collaboration): $20.8

Total economic value

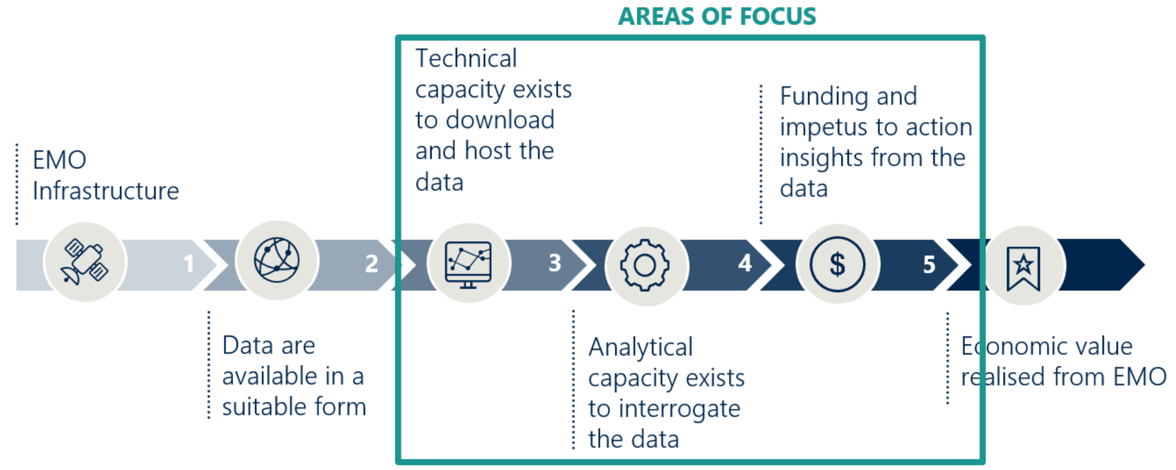


	US$ million
Mining	1,066
Agriculture, fisheries & forestry	619
Utilities: Power	464
Utilities: Water	80
Utilities: Communications	253
Transport	1,651
Health	101
Finance	26
Consumer	1,456
Disaster Management	37
Total	**5,754**

Key industry information

- The value of EMO to Russia is equivalent to 0.3% of GDP.
- Consumer willingness to pay and transport together contribute 54% of the value from EMO, at US$1.5 billion and US$1.7 billion, respectively.
- Although contributing over US$1 billion, the value of EMO to mining is only equivalent to 0.6% of the value of the industry.
- Utilities, combined, contribute approximately 14% of value from EMO.

Value chain



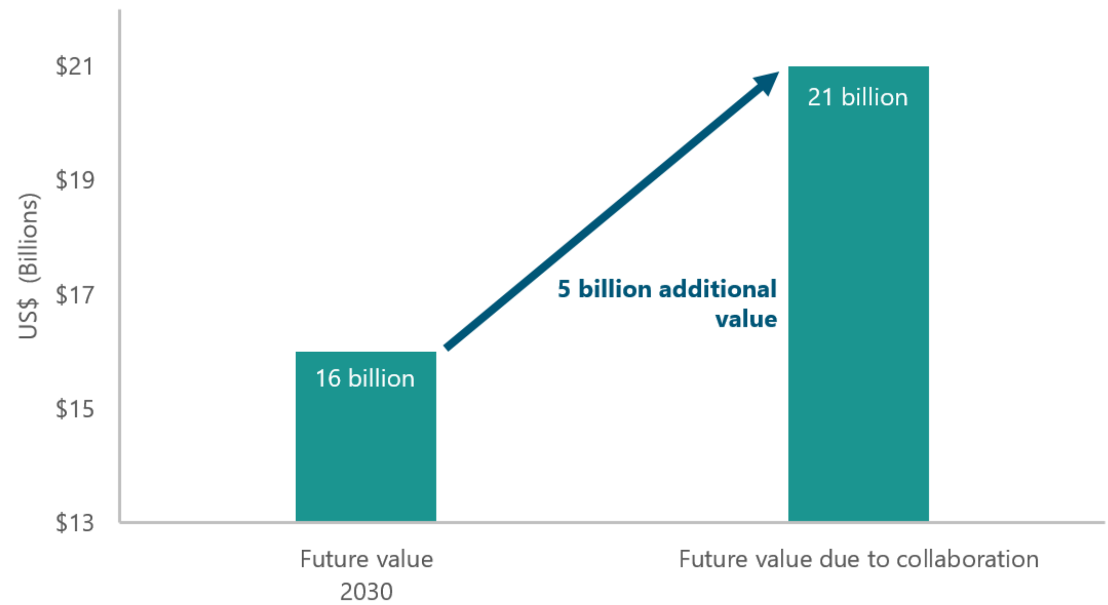
Areas of collaboration

With considerable earth and marine observation infrastructure, there is great value for Russia in collaborating with other APEC economies to enhance its technical and analytical capabilities.

Value can be realised quickly by collaborating with other economies in the power industry, as well as in disaster management.

Given Russia's size and unique geography, there is substantial value to be realised for APEC through data sharing and by raising awareness of Russia's EMO capabilities.

Value from collaboration



The benefits of EMO for Russia from future collaboration will be partly dependent upon sustained funding being provided by the government. Stronger analytical and technical capabilities can support the translatability of insights that can encourage further investment from both government and the private sector.

Singapore

The use of EMO can continue to expand, including supporting disaster management across APEC.

Population: 5.6 million | GDP (per capita): US$64,582

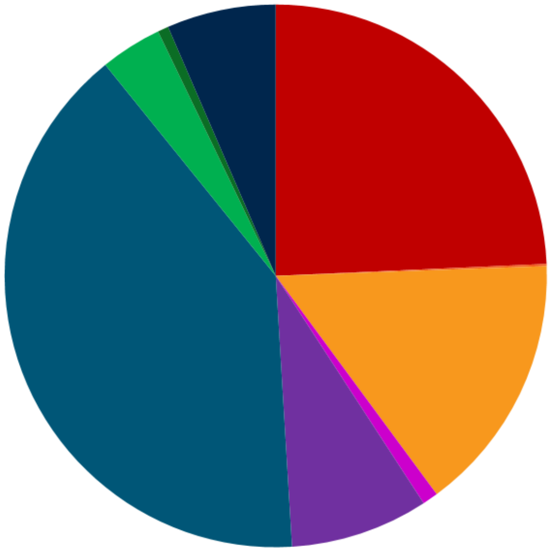
EMO value (US$ billion)

2019: $5.0

2030: $16.5

2030 (collaboration): $17.3

Total economic value

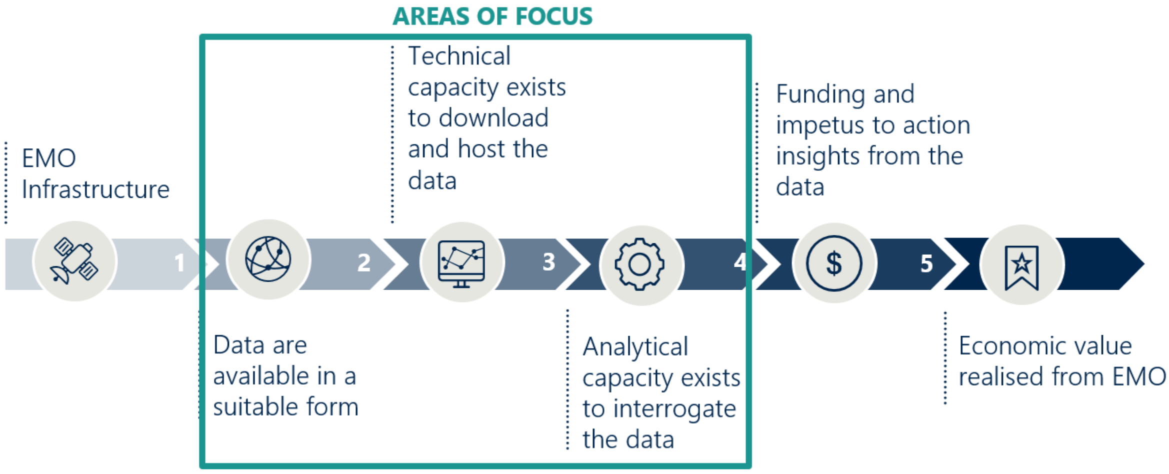


	US$ million
Mining	1,210
Agriculture, fisheries & forestry	6
Utilities: Power	770
Utilities: Water	46
Utilities: Communications	410
Transport	1,999
Health	183
Finance	32
Consumer	324
Disaster Management	0
Total	**4,979**

Key industry information

- The value of EMO to Singapore is equivalent to 1.4% of GDP.
- Although contributing only 0.1% of EMO value, agriculture, fisheries and forestry is equivalent to 7.2% of the total industry value.
- Consumer willingness to pay represents 6.5% of value, at US$324 million.
- Utilities: communications and utilities: power equate to 23.7% of the value from EMO.

Value chain

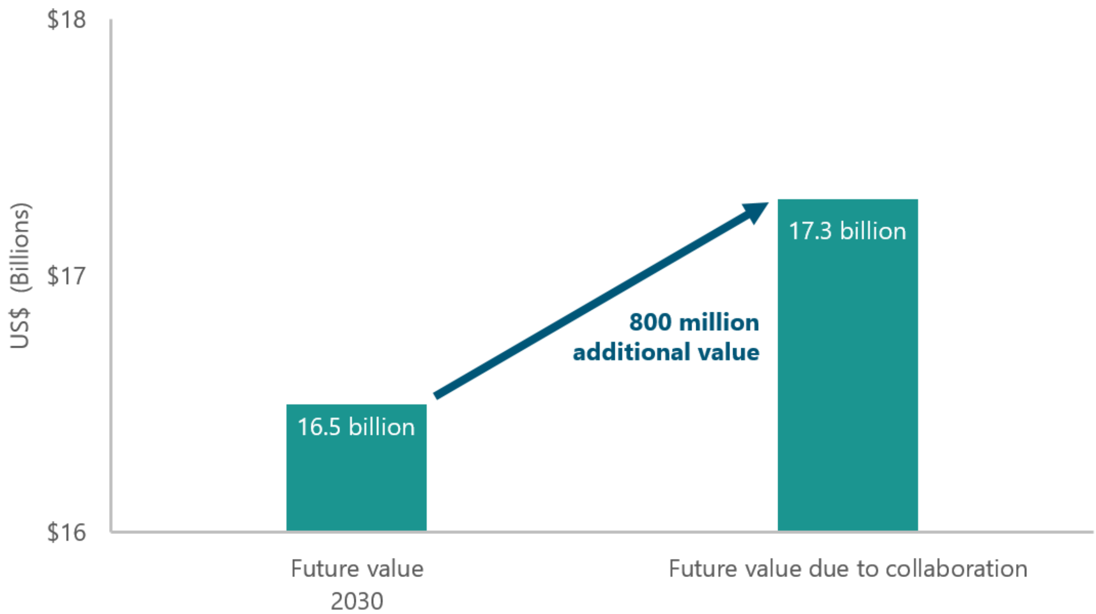


Areas of collaboration

Singapore can play a fundamental role in supporting natural disaster management for Asia and the APEC region through its EMO capabilities, such as the Earth Observatory of Singapore (EOS).

Through collaboration across APEC, Singapore can build on its already strong capability to provide richer insights to its own, and neighbouring, economies. This can be realised through greater data sharing and through technical and analytical capability development.

Value from collaboration



Although Singapore recorded no natural disasters during the period modelled, its economy undertakes substantial research in geo-hazards and other types of natural disasters across Asia. Through greater collaboration, this work can continue to thrive, contributing value to other economies as well as increasing the final value to Singapore above the forecast US$17.3 billion.

Thailand

Further value from EMO can be realised with more development of analytical and data capabilities.

Population: 69.4 million | GDP (per capita): US$7,274

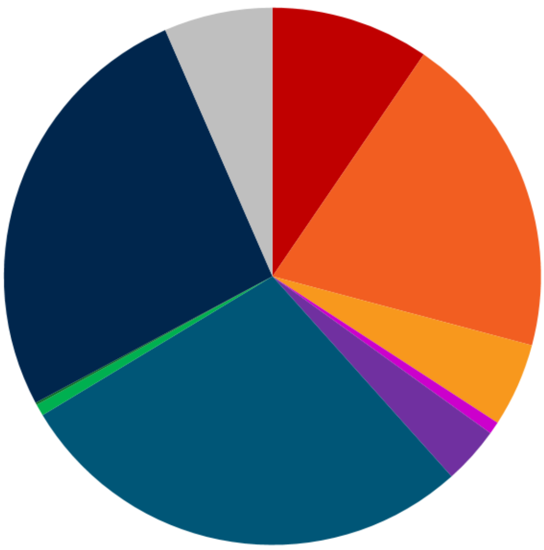
EMO value (US$ billion)

2019: $1.7

2030: $7.9

2030 (collaboration): $10.2

Total economic value

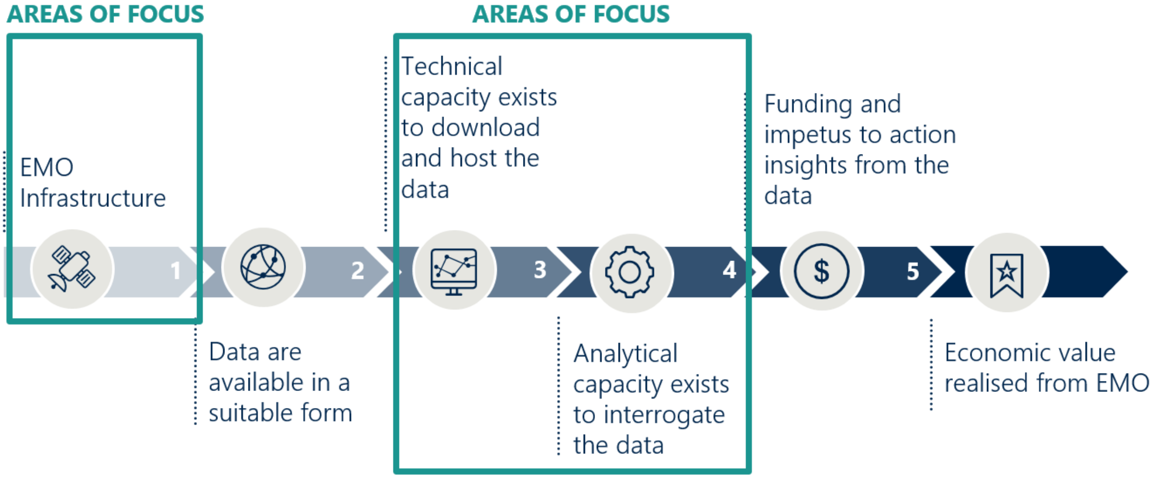


	US$ million
Mining	163
Agriculture, fisheries & forestry	336
Utilities: Power	86
Utilities: Water	13
Utilities: Communications	59
Transport	479
Health	12
Finance	2
Consumer	449
Disaster Management	112
Total	**1,711**

Key industry information

- The value of EMO to Thailand is equivalent to 0.34% of GDP.
- Consumer willingness to pay (26%) and transport (28%) contribute approximately the same value from EMO.
- Agriculture, fisheries and forestry together realise US$336 million from EMO (20%).
- All utilities represent 9% of value from EMO, at a combined total of US$158 million.

Value chain

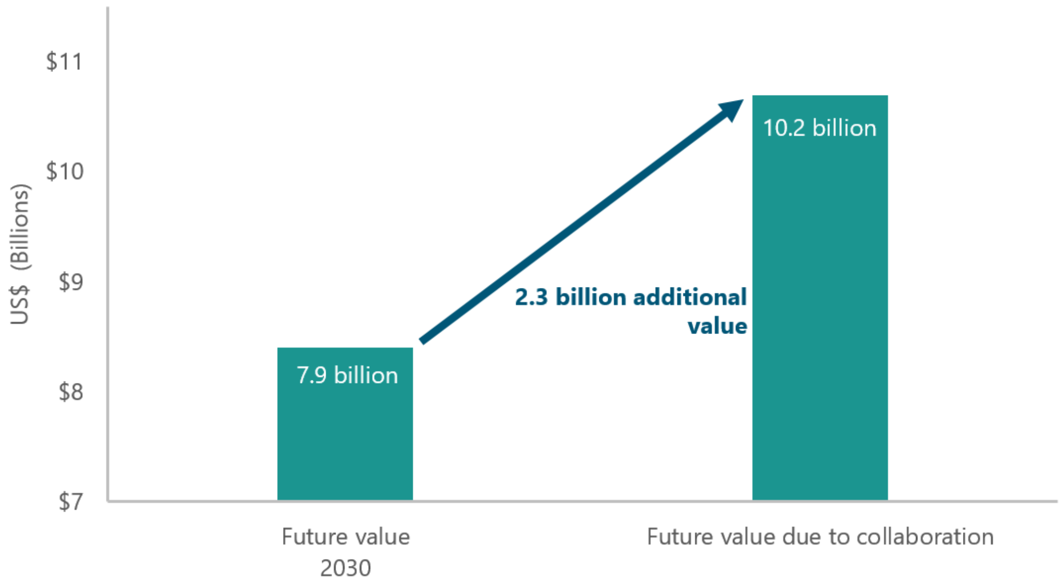


Areas of collaboration

Thailand is making large strides toward realising its EMO capabilities through developing infrastructure, such as the Thailand Earth Observation System (THEOS).

Collaboration across APEC could focus on developing additional infrastructure and the technical and analytical capabilities needed for the creation of data products for agricultural monitoring, coastal zone monitoring and flood risk management.

Value from collaboration



Collaboration across APEC can support Thailand to continue to grow its data capabilities and data products to inform cartography, land use, agriculture, forestry, coastal zone monitoring, and disaster-mitigation efforts. Given Thailand's geographical location, its valuable data can also be shared across APEC and the region to inform other economies' programs.

United States

Although a global leader in EMO, maintaining baseline capability remains an imperative.

Population: 327.2 million | GDP (per capita): US$62,641

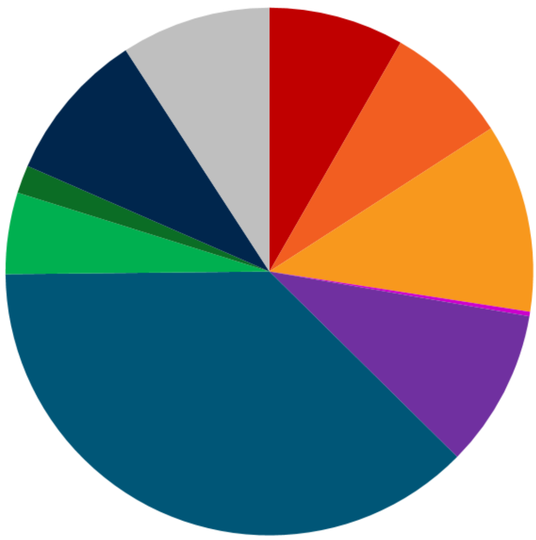
EMO value (US$ billion)

2019: $196

2030: $541

2030 (collaboration): $566

Total economic value

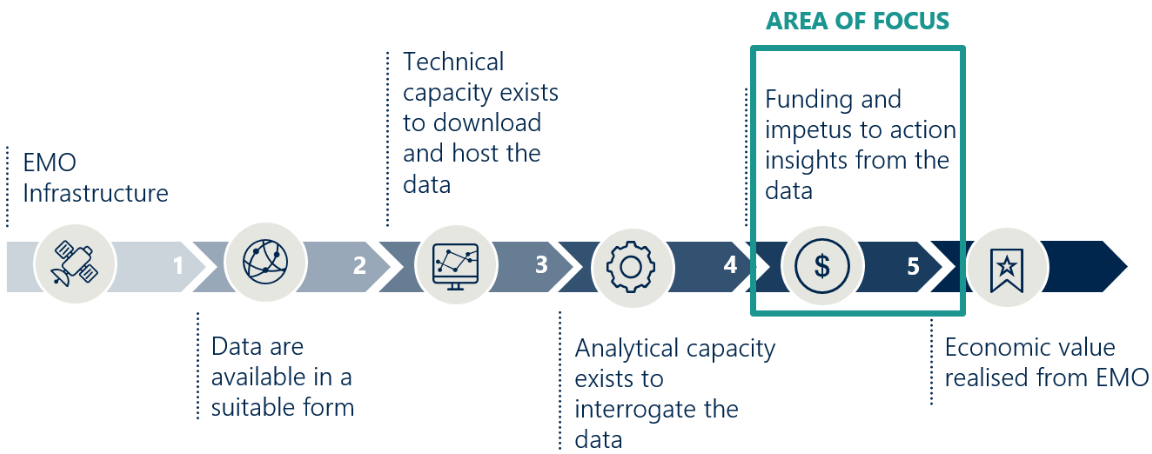


	US$ million
Mining	16,222
Agriculture, fisheries & forestry	14,854
Utilities: Power	22,639
Utilities: Water	542
Utilities: Communications	18,948
Transport	73,294
Health	9,778
Finance	3,359
Consumer	18,182
Disaster Management	17,936
Total	**196,000**

Key industry information

- The value of EMO to the United States is equivalent to 0.8% of GDP.
- US$73 billion (46%) of this value is realised through transport, which is equivalent to 14% of the transport industry's value.
- Mining; agriculture, fisheries and forestry; and utilities (power and communications combined) together contribute an additional 46% of EMO value, and are all relatively equal in terms of value realised from EMO.

Value chain



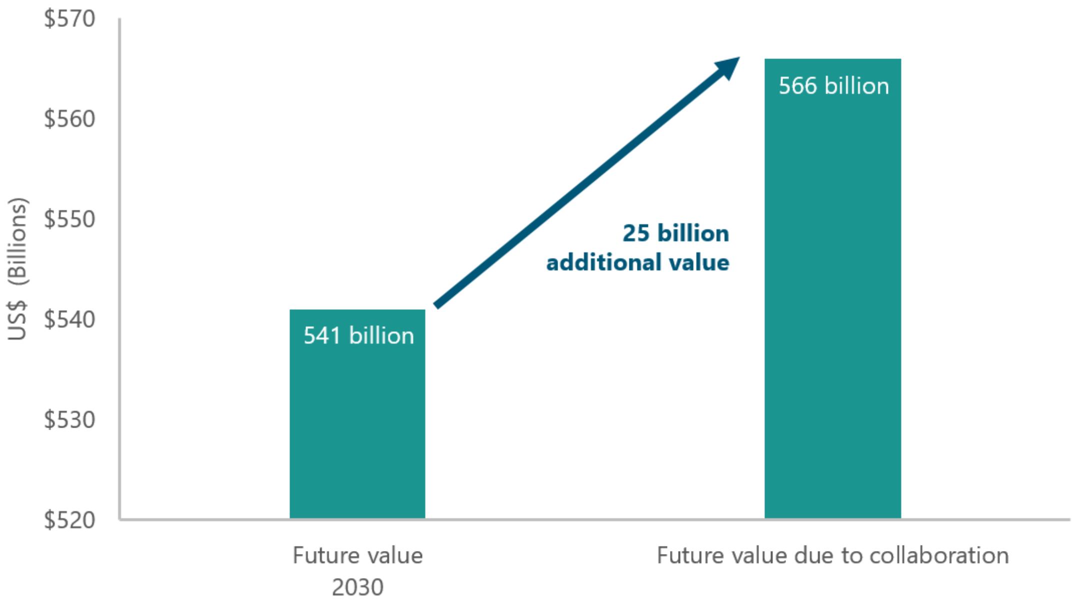
Areas of collaboration

The United States has a critical role to play in developing the analytical and technical capabilities of other economies within APEC.

As a global leader, the United States can continue to pursue opportunities to collaborate with other economies and to share Landsat and other associated data.

It can also play a significant role by continuing to educate decision-makers and by advocating for the wider use of EMO across industries.

Value from collaboration



The United States can realise a significant amount of additional value through collaboration, while also empowering other APEC economies to realise greater potential through data sharing and through technical and analytical capability development.

Viet Nam

Increased analytical and technical capabilities can propel the use of EMO in more industries.

Population: 95.5 million | GDP (per capita): US$2,564

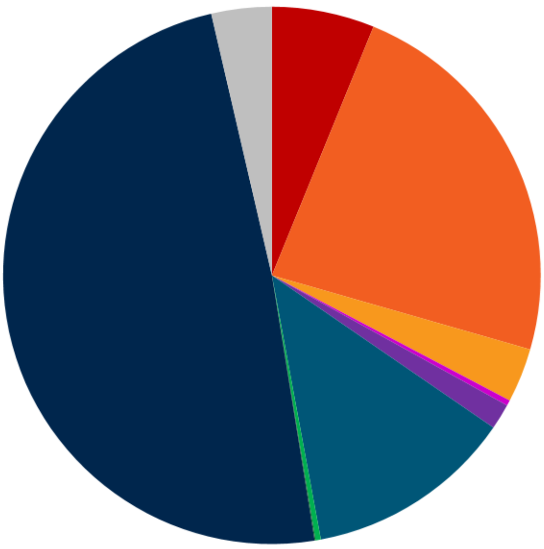
EMO value (US$ million)

2019: $443

2030: $3,621

2030 (collaboration): $4,361

Total economic value

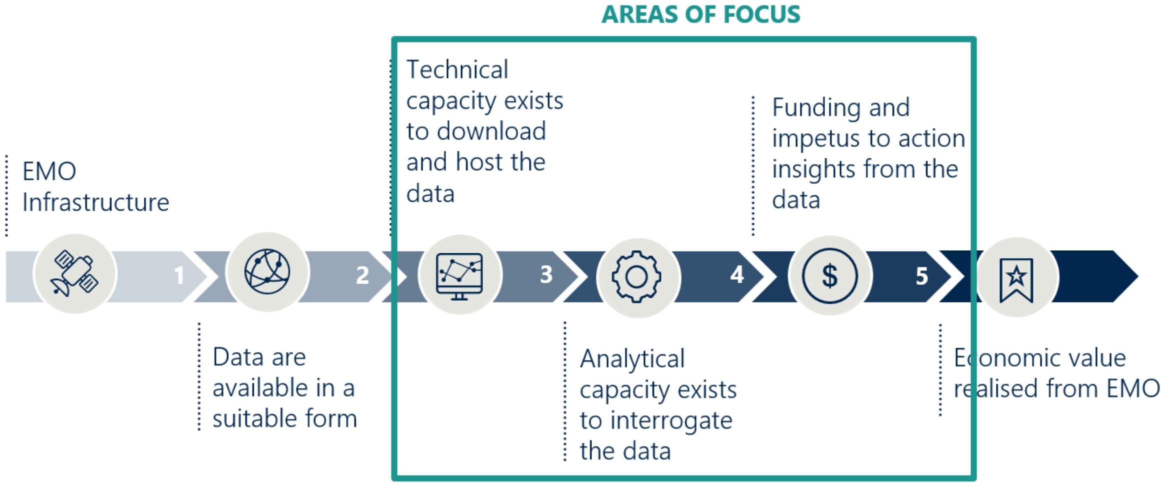


	US$ million
Mining	27
Agriculture, fisheries & forestry	103
Utilities: Power	14
Utilities: Water	1
Utilities: Communications	7
Transport	55
Health	1
Finance	<1
Consumer	217
Disaster Management	16
Total	**443**

Key industry information

- The value of EMO to Viet Nam is equivalent to 0.2% of GDP.
- At US$217 million (49%), consumer willingness to pay contributes the largest value from EMO.
- Agriculture, fisheries and forestry together realise 23% of the value from EMO.
- 3.6% of value is realised through the use of EMO for disaster management.

Value chain

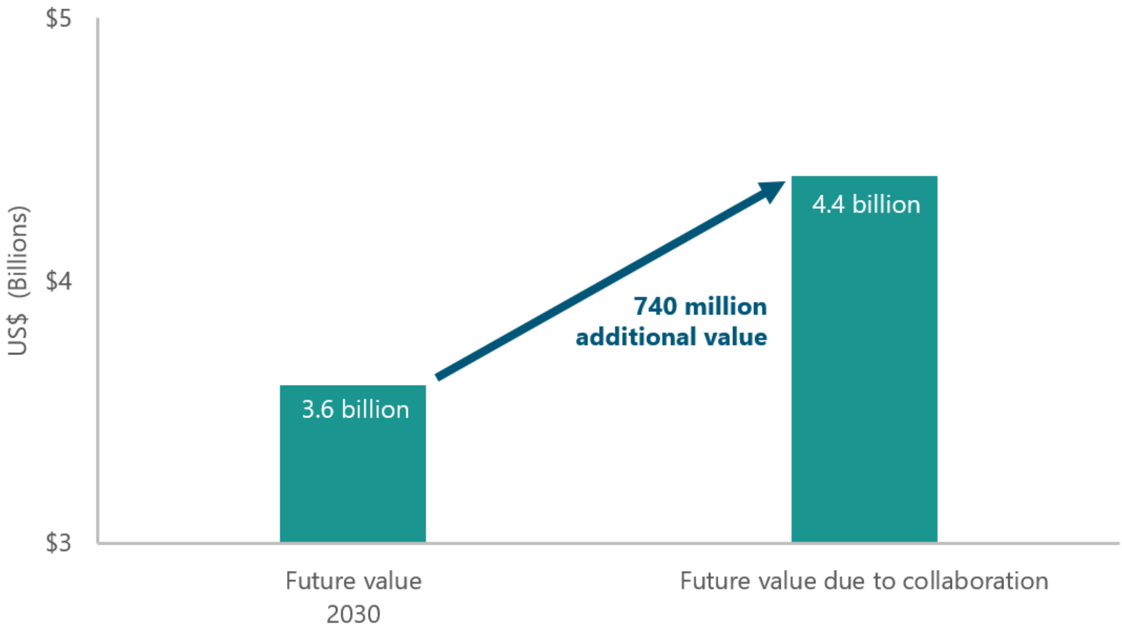


Areas of collaboration

Viet Nam's current collaboration is already realising value for the economy (for example, the Viet Nam National Space Centre is working with Japan to launch the MicroDragon Satellite). These projects provide substantial data to improve understanding of disaster and climate change response.

Collaboration could also strengthen Viet Nam's analytical and technical capabilities, through events such as the Viet Nam School of Earth Observation Atmospheric Remote Sensing and Molecular Spectroscopy workshops.

Value from collaboration



Since launching the Viet Nam Natural Resources, Environment and Disaster Monitoring Satellite (VNRED Sat-1A), Viet Nam continues to realise value from EMO. The future value for Viet Nam can further grow through greater collaboration to increase the analytical and technical capabilities of researchers.

Appendix B Applications of EMO for each industry

The primary groups of applications of EMO we have identified are:

- weather and climate forecasting
- resource mapping—identifying where resources can be found, and their state.
- ecosystem management—for monitoring change in ecosystems.
- natural disaster management—improving management decisions and action across the stages of preparedness, mitigation, response and recovery.

Table 12 below outlines our preliminary thinking about how important these applications of EMO are to each industry within APEC economies. The potential of EMO to add value to the industry through reducing costs or improving outputs is represented by ticks under each broad application group:

✓✓✓ Three ticks representing **high potential** to add value

✓✓ Two ticks representing **moderate potential** to add value

✓ One tick representing **low importance**

No ticks representing **not currently delivering significant additional value**.

As this table is not exhaustive, it is not practical to provide a complete list of the applications of EMO. However, we have included a brief explanation of how each included EMO application adds value within an industry.

Table 12 | The applications of EMO to the primary industries within APEC

Industry	Weather & Climate Forecasting	Resource Mapping	Ecosystem Management	Disaster Management
Mining (incl. oil and gas)	✓ Predicting extreme weather and oceanographic conditions.	✓✓✓ Prospecting and exploration. Meeting regulatory requirements. Monitoring remote infrastructure.	✓✓ Monitoring environmental impacts and minimising damages. Identifying and preventing illegal mining. Situation monitoring including oil spills, tailings dams, chemical leaching and so forth.	✓✓ Mitigation and preparedness against impacts of natural disasters, incl. hardening of structures to guard against natural disasters.
Agriculture	✓✓✓ Optimised decision-making for immediate and long-term planting, harvesting, application of fertiliser/pesticide, water distribution. Awareness and resilience building against slow-change climate effects. Conducting efficient measurements and creating longitudinal datasets.	✓✓✓ Adoption of precision agriculture. Water demand estimation. Crop inspection. Yield estimation/ forecasting to improve supply chains and market function. Identifying pests and disease.	✓✓✓ Monitoring environmental degradation (erosion, desertification, chemical pollution, water shortages, run-off). Soil monitoring. Obtaining carbon credits from sustainable farming practices.	✓✓ Mitigation and preparedness for impacts of slow- (for example, drought) or rapid-onset (for example, tsunamis) natural disasters. Biosecurity and protecting against disease. Asset valuation. Early warning.

Industry	Weather & Climate Forecasting	Resource Mapping	Ecosystem Management	Disaster Management
Fisheries	✓✓✓ Preparedness for extreme weather. Optimised decision-making (go/no-go) regarding stocking/harvest time, quota purchases, labour requirements, equipment purchases, feed management. Switching fishing gear due to regime shifts.	✓✓✓ Monitoring and preventing illegal fishing. Understanding bottom habitats to predict where fish populations may be concentrated. Fish farm site optimisation. Ship routes. Fish stock modelling. Carrying capacity for aquaculture. Climate change resources projections.	✓✓✓ Monitoring water quality. Enhanced decision-making for aquaculture management. Predicting, identifying and monitoring harmful algal blooms. Mapping marine protected areas. Predicting, identifying and monitoring anoxia, hypoxia, sulfidic events and heat waves. Ocean acidification (for example, impacts on the oyster industry) Assisting with credentialing of compliant resource use.	✓✓ A sortie, or additional precautions in port, to protect boats. Finding fishing boats for safety search and rescue. Habitat vulnerability (for example, coastal cyclone damage). Mitigation and preparedness against impacts of natural hazards, incl. the construction of grey/green infrastructure to protect against storms.
Forestry	✓ Ability to plan for optimal forest locations to account for weather and climate forecasting.	✓✓✓ Rapidly identifying illegal logging and providing information to enforcement agencies to intercept. Increasing supply chain transparency. Optimised decision-making for harvesting. Carbon offsets. Measuring forest coverage and creating forest inventories.	✓✓✓ Monitoring land use changes. Monitoring carbon stocks within forests. Monitoring forest and peatland health, preventing degradation and managing restoration. Land applications and habitat characterisation. Assisting with credentialing of compliant resource use.	✓✓ Predicting, monitoring and mapping forest fires. Restoration and rehabilitation due to fires. Response planning. Management and monitoring of a forest reserve.

Industry	Weather & Climate Forecasting	Resource Mapping	Ecosystem Management	Disaster Management
Utilities: Power	✓✓✓ Yield forecasting for renewable energy sources, using insolation, wind and rainfall information to predict solar, wind and hydropower output. Demand forecasting for grid management. Determining optimal locations for new renewable sites.	✓✓✓ Monitoring and compliance. Monitoring remote energy infrastructure (powerlines, pipelines, and so forth). Asset maintenance. Monitoring energy losses to improve energy efficiency. Monitoring biomass production.	✓✓ Monitoring emissions from energy production.	✓✓✓ Improved preparedness and mitigation for natural disasters, to prevent damage to infrastructure. Early warning systems to isolate power sources for deactivation. Pre-plan crews and placement of emergency response equipment in safe locations to minimise response time.
Utilities: Water	✓✓✓ Estimating precipitation for supply management. Immediate and long-term demand management. Predicting and monitoring drought.	✓✓✓ Hydrological mapping. Measuring and monitoring freshwater availability (including terrestrial water storage and snow water equivalence). Monitoring water demand for irrigation. Prospecting for groundwater and other unmapped water resources. Reducing monitoring and compliance costs. Asset maintenance. Improved infrastructure for provision of clean water and sanitation.	✓✓ Measuring evapotranspiration. Monitoring pollution in water resources (for example, from industrial effluent). Monitoring surface water conditions.	✓✓✓ Flood delineation mapping. Improved preparedness for natural disasters, to prevent damage to infrastructure. Real-time flood projection.
Utilities: Communications	✓✓ Outage expectations. Supply and demand usage forecasting.	✓✓✓ Infrastructure site selection. Remote infrastructure monitoring and asset maintenance.		✓✓✓ Improved preparedness for natural disasters, to prevent damage to infrastructure.

Industry	Weather & Climate Forecasting	Resource Mapping	Ecosystem Management	Disaster Management
Transport	✓✓✓ Optimisation of all forms of transport (road, rail, sea and air). Go/no-go decisions due to forecast weather. Safe and efficient routing.	✓✓✓ Logistics coordination for movement of supplies (agricultural products and so forth), using geodetic and navigation data. GPS services. Development, monitoring and maintaining assets/infrastructure (for example, bridges). Automated driving systems. Mapping for UAS traffic management.	✓ Mapping transport pollution (air, terrestrial, marine).	✓✓✓ Re-routing flights (for example, due to volcanic eruptions). Logistics coordination during a response operation.
Health	✓✓ Predicting and anticipating the spread of disease.		✓ Monitoring air quality, including transboundary air pollutants. Allergy monitoring (for example, pollen trend forecasting). Mapping ozone depletion.	✓✓✓ Emergency health costs. Epidemiology and natural disasters.
Finance (for example, insurance)	✓ Risk modelling.	✓ Resource monitoring (for example, crops) to influence premiums. Asset valuation.	✓ Assess risk of disease outbreaks.	✓✓✓ Mapping risk-prone areas to inform premiums. Faster and more efficient responses to disasters; reducing damages and subsequently insurance costs.
Areas of non-market value *(these are areas that do not directly contribute to GDP but have been identified as unique sources of value enabled through EMO).*				
People (for example, convenience)	✓✓✓ Value of convenience from knowing the weather forecast.	✓✓ Value of convenience through GPS and navigation.		✓✓✓ Lives lost, people injured, people affected by natural disasters.
Infrastructure planning	✓✓ Engineering standards. Existing infrastructure vulnerability to climate change, etc.— for example, mitigation strategies for low-lying areas.	✓✓ Informing urban planning due to access to water resources. Monitoring of large infrastructure developments.	✓ Mapping land use and cover and planning for future developments. Changes to inform zoning regulations, urban growth management, monitoring compliance, etc.	✓✓✓ Estimating costs of natural disasters. Asset valuation for buildings and infrastructure.

Appendix C Studies that informed the estimated value of EMO to each industry

Industry	Referenced literature
Mining	• The enabled revenues to the oil and gas from Copernicus data in 2018 was \$6.7–10 million for intermediate users and \$190–\$467 million for end users.[53] • Using accurate weather data can help to mitigate shutdown costs for offshore oil/LNG extractions, estimated to cost \$28.38 million per year in Australia.[54] • EMO technologies lowered monitoring and compliance costs in Australia by \$3.46 million in 2015. This is expected to rise to \$4.64 million in 2025.[55]
Agriculture, fisheries and forestry	• The total enabled revenue from Copernicus data for the agricultural sector was \$187–\$376 million in total in 2018—which includes \$12–\$21 million for intermediate users and \$174–\$356 million for end users.[56] • The annual value of satellite-derived EO to the UK Government in agriculture was \$56 million in 2018 and it is expected to reach \$94 million in 2020.[57] • The annual benefit of EMO to Australian broadacre agriculture through weather forecasting services was \$17 million in 2015 and is expected to grow to \$94 million by 2025. The annual benefit of EMO for precision agriculture in the same area was \$12.5 million in 2015 and is expected to rise to \$153 million in 2025.[58] • The enabled revenue from the Copernicus Program in the EU forestry sector was \$4.5–7.9 million for intermediate users and \$59–86 million for end users. This benefit is expected to grow at 18% per year to 2020.[59] • Copernicus data generated an estimated benefit of \$206–\$281 million in 2018 for marine observation exercises including mapping fish zones, forecasting algal blooms, fish stock monitoring and so forth. (This figure also includes navigation for shipping).[60]

53 PwC, 2019, *Copernicus Market Report – February 2019,* European Commission, Luxembourg, viewed 29 March 2019, <https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf>.

54 ACIL Allen Consulting, 2015, *The value of Earth observations from space to Australia: Report to the CRC for Spatial Information December 2015.* Cooperative Research Centre for Spatial Information (CRCSI), Carlton, VIC., viewed 29 March 2019, <https://www.crcsi.com.au/assets/Resources/CRCSI-The-Value-of-Earth-Observations-from-Space-to-Australia-Final-web.pdf>.

55 *Ibid.*

56 PwC, 2019, *Copernicus Market Report – February 2019.* European Commission, Luxembourg, viewed 29 March 2019, <https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf>.

57 G Sadlier, R Flytkjaer, F Sabri & N Robin, 2018, *Value of satellite-derived Earth observation capabilities to the UK Government today and by 2020*, London Economics, London, viewed 28 March 2019, <https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf>.

58 ACIL Allen Consulting, 2015, *The value of earth observations from space to Australia: report to the CRC for Spatial Information December 2015,* Carlton, VIC., viewed 29 March 2019, <https://www.crcsi.com.au/assets/Resources/CRCSI-The-Value-of-Earth-Observations-from-Space-to-Australia-Final-web.pdf>.

59 PwC, 2016, *Study to examine the socio-economic impact of Copernicus in the EU: report on the Copernicus downstream sector and user benefits,* European Commission, Luxembourg, viewed 27 March 2019, <http://www.nereus-regions.ovh/wp-content/uploads/2017/10/Copernicus_Report_Downstream_Sector_October_2016.pdf>.

60 PwC, 2019, *Copernicus Market Report – February 2019,* European Commission, Luxembourg, viewed 29 March 2019, <https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf>.

Industry	Referenced literature
Utilities: Power	• Improved weather forecasting using Copernicus data resulted in a 2% increase in revenues from Solar PV in 2016. This rate is expected to increase by 7% annually to 2020.[61] • The enabled revenues for the renewables sector from Copernicus data in 2018 were $2.5–$5 million for intermediate users and $30–$170 million for end users.[62]
Utilities: Water	• Conservative estimates indicate that a 1% improvement in water-use efficiency enabled by EMO, including through improved modelling for irrigators, would create $27 billion in economic benefit in Australia.[63] • Using Landsat, Spot, Modis and other EMO products, Water NSW reduced their annual costs for monitoring Sydney's drinking water catchment by 80% (from $104,000 to $21,000).[64]
Transport	• Conservative estimates suggest that GPS contributed $68 billion to the US economy in 2013, of which 38% related to vehicle location services and 18% related to fleet vehicle telematics.[65] • Improved navigation techniques using satellite radar images generate $27–130 million in benefit to the Swedish and Finnish transportation sectors in the Baltic Sea, primarily through reduced operational costs.[66] • The estimated potential benefit of satellite-based solutions (such as EO-SCANS) for asset monitoring and maintenance, traffic monitoring and greenhouse gas emission calculations could generate $108 million per year for the UK Government (just in railway and road infrastructure), predominantly through reduced operational costs and avoided exceptional costs.[67]
Health	• The application of Copernicus data for air quality monitoring (air pollution monitoring and allergy monitoring) generated benefits valued at $0.1–$0.7 for intermediate users and $414–$602 million for end users.[68]

[61] PwC, 2016, *Study to examine the socio-economic impact of Copernicus in the EU: report on the Copernicus downstream sector and user benefits*, European Commission, Luxembourg, viewed 27 March 2019, <http://www.nereus-regions.ovh/wp-content/uploads/2017/10/Copernicus_Report_Downstream_Sector_October_2016.pdf>.

[62] PwC, 2019, *Copernicus Market Report – February 2019*, European Commission, Luxembourg, viewed 29 March 2019, <https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf>.

[63] ACIL Allen Consulting, 2015. *The value of earth observations from space to Australia: report to the CRC for Spatial Information December 2015, CRCSI*. Cooperative Research Centre for Spatial Information (CRCSI), Carlton, VIC., viewed 29 March 2019, <https://www.crcsi.com.au/assets/Resources/CRCSI-The-Value-of-Earth-Observations-from-Space-to-Australia-Final-web.pdf>.

[64] *ibid*

[65] Cooperative Research Centre for Spatial Information (CRC–SI), 2017, *Earth observation: data, processing and applications: volume 1B: Data—image interpretation*, CRC–SI, Carlton, Vic., viewed 20 March 2019, <https://www.crcsi.com.au/assets/Consultancy-Reports-and-Case-Studies/Earth-Observation-reports-updated-Feb-2019/Vol1B-high-res-75MBpdf.pdf>.

[66] European Association of Remote Sensing Companies, 2015, *Copernicus Sentinels' Products economic value: a case study of winter navigation* in *the Baltic*, EARSC, Brussels.

[67] G Sadlier, R Flytkjaer, F Sabri & N Robin, 2018, *Value of satellite-derived Earth observation capabilities to the UK Government today and by 2020*, London Economics, London, viewed 28 March 2019, <https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf>.

[68] PwC, 2019, *Copernicus Market Report: February 2019*, European Commission, Luxembourg, viewed 3 April 2019, <https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf>.

Industry	Referenced literature
Finance	• Copernicus data enabled a $15.6 million benefit to natural disaster insurance providers in 2018 through improved risk modelling and comprehensive mapping of affected areas.[69]
Disaster Management	• A survey of Namibian stakeholders by the United Nations Office for Outer Space Affairs, the International Council for Science-GeoUnions and the Joint Board of Geospatial Information Societies estimated that the savings enabled by geospatial information in this flood case study may have been in the order of 45% of the total damages and losses. The study also reported that early flood warnings can reduce the damage expected by 35–47%.[70] • Total benefits from EMO for floods in Ireland during 2015–16 were estimated at between €6.5m and €30.3m, with the majority of benefits being realised for the general public and businesses through the reduction of flood damage and wider impacts.[71]

[69] PwC, 2019, *Copernicus Market Report: February 2019,* European Commission, Luxembourg, viewed 3 April 2019, <https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf>.

[70] Joint Board of Geospatial Information Societies, 2013, *The value of geoinformation for disaster and risk management (VALID): benefit analysis and stakeholder assessment*. JB GIS, Copenhagen.

[71] European Association of Remote Sensing Companies, 1918, *A case study: flood management in Ireland*, EARSC, Brussels, viewed 17 July 2019, <http://earsc.org/Sebs/wp-content/uploads/2019/06/Flyer_Flood-Management-in-Ireland.pdf>.

Appendix D Economic model

The purpose of Appendix D is to explain the two equations used to estimate the value of EMO to APEC:

- Equation 3 determines the total value of EMO for an economy within APEC.
- Equation 4 determines the total value of EMO for an individual industry across APEC.

Each of these equations are discussed in more detail below.

Equation 3 | Economic valuation of EMO for an APEC economy

Total value for an economy

$$V(t)_{econ(j)} = A(t)_{econ(j)} \sum_{ind} \left(I(t)_{ind(i)} G(t)_{ind(i)}\right)$$

Equation 3 estimates the value of EMO for economy *j* at time *t*. This value depends on the size of the set of affected industries in economy *j*, the contribution that EMO could make (the best case) to the value added by that industry, and the ability of that economy to make best use of the EMO applications. The starting point is that A(t) is the same for each industry that could benefit from EMO within each economy.
This assumption can be relaxed if there is strong evidence that it varies significantly by industry within an economy. For example, agriculture in Papua New Guinea might not be able to apply EMO to its potential, due to its largely subsistence nature—but the mining industry would come closer to realising its EMO potential use.

Equation 4 | Economic valuation of EMO for a specific industry

Total value for an industry type

$$V(t)_{ind} = G(t)_{ind(i)} \sum_{econ} \left(I(t)_{ind(i)} A(t)_{econ(j)}\right)$$

Equation 4 takes the same information as in Equation 3, but sums across the industries rather than across the economies. The model will take account of industries that contribute to GDP, and the areas of non-market impact.

Table 13 outlines the economic model variables for the report from these two equations.

Table 13 | Economic model variables

Dependent variables	
$V(t)_{econ(j)}$	The total economic value of EMO for economy *j* within APEC at a specific time.
$V(t)_{ind(i)}$	The total economic value of EMO for industry *i* across APEC economies at a specific time.
Explanatory variables	
$A(t)_{econ(j)}$	The absorption multiplier for each APEC economy *j*. Three factors are considered in estimating absorption: an economy's access to EMO data products and services; its degree of collaboration; and the scale of impact of EMO to the economy. This variable is a function of time, as capability is expected to improve through collaboration and cooperation between now and 2030. It is expected to correlate with the level of development indicated by income per capita.
$I(t)_{ind(i)}$	The value of industry *i* for an economy as a function of time. For industries, this is the contribution to an economy's GDP. For areas of non-market value, other than industry, the value will consider factors such as: • the expected savings due to investments in emergency management preparation and mitigation • the forecast realisable costs from any national response and recovery efforts for a slow- or rapid-onset natural disaster (for example, a drought compared with a tsunami) • how much consumers would be willing to pay to access to EMO data products.
$G(t)_{ind(i)}$	A time-dependent coefficient that considers the maximum estimated benefits for a specific industry *i* due to EMO. (That is, with the use of EMO, how much the industry has to gain at time *t*.) This estimates the potential improvement from EMO, whereas actual improvement depends on the interaction with absorption.

Table 14 outlines our initial estimates of the potential value of EMO to the different industries (G(*t*)). These numbers were drawn from the literature and then refined through consultations with experts across APEC. The model uses the mid-point in any ranges to provide the headline value estimates and uses the ranges to demonstrate the sensitivity of the estimates to this parameter.

Table 14 | The potential value of EMO to each industry – $G(t)_{ind(i)}$

Industry	Total value of EMO as a percentage of that industry
	%
Mining	2–5
Agriculture	7–8
Fisheries	2–3
Forestry	5
Utilities: Power	8–10
Utilities: Water	6–8
Utilities: Communications	6–8
Transport	12–15
Health	1
Finance (for example, insurance)	1–2

Table 15 outlines the indicative values of absorption (A(t)), which were determined using GDP per capita relative to the highest GDP per capita in APEC. These values provided a starting point for the initial estimates of absorption for each APEC economy. The industry-level adjusted absorption values (which were identified through the interviews) are not included here, but rather remain part of the microdata within the model.

Table 15 | The indicative absorption values of each APEC economy – $A(t)_{econ(\mathrm{j})}$

Economy	Indicative absorption values (Percentage relative to the highest GDP per capita in APEC) %
Australia	93
Brunei Darussalam	47
Canada	75
Chile	25
People's Republic of China	15
Hong Kong, China	77
Indonesia	6
Japan	64
Republic of Korea	50
Malaysia	17
Mexico	15
New Zealand	71
Papua New Guinea	4
Peru	11
Philippines	5
Russia	18
Singapore	97
Chinese Taipei	41
Thailand	11
United States	100
Viet Nam	4