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THE AUSTRALIAN EXPERIENCE WITH RESOURCES, INFRASTRUCTURE CORRIDORS AND SUPPLY CHAINS

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FOREWORD

THE CANADIAN NORTHERN CORRIDOR RESEARCH PROGRAM PAPER SERIES

This paper is part of a special series in *The School of Public Policy Publications,* investigating a concept that would connect the nation's southern infrastructure to a new series of corridors across middle and northern Canada. This paper is an output of the Canadian Northern Corridor Research Program.

The Canadian Northern Corridor Research Program at The School of Public Policy, University of Calgary, is the leading platform for information and analysis on the feasibility, desirability, and acceptability of a connected series of infrastructure corridors throughout Canada. Endorsed by the Senate of Canada, this work responds to the Council of the Federation's July 2019 call for informed discussion of pan-Canadian economic corridors as a key input to strengthening growth across Canada and "a strong, sustainable and environmentally responsible economy." This Research Program will benefit all Canadians, providing recommendations to advance the infrastructure planning and development process in Canada.

This paper, "The Australian Experience with Resources, Infrastructure Corridors and Supply Chains", falls under theme *Economic Outcomes* of the program's eight research themes:

- Strategic and Trade Dimensions
- Funding and Financing Dimensions
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- Organization and Governance
- Geography and Engineering
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Dr. Kent Fellows
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THE AUSTRALIAN EXPERIENCE WITH RESOURCES, INFRASTRUCTURE CORRIDORS AND SUPPLY CHAINS

Ian Satchwell

ABSTRACT

The North of Canada and the North of Australia are both resource-rich, but have underdeveloped infrastructure, small, scattered populations and high proportions of inhabitants who are Indigenous. The experiences of developing Australia's North hold lessons for Canada. Experience from development of iron ore mining and gas production in the Pilbara region of Western Australia, and with coal and gas development in the Central Queensland coalfields region, can be applied usefully to development of resources and infrastructure in Canada's North, as well as in other resource-rich regions of the world.

Supply chains that provide efficient transport, handling and processing of mineral and energy products in the two Australian regions, and goods and services inputs to production, have been critical to their success in becoming world-leading resources exporters. Governments and industries in the Pilbara and Central Queensland have followed contrasting pathways to developing infrastructure and supply chains. Each initial pathway had advantages and disadvantages. Approaches by governments and project operators have changed over the 60 years of resources development, in light of experience, in response to big increases in scale of production, to the need to increase efficiency, experience of existing approaches and to accommodate new industries and entrants.

Governments have key roles to play in resources regions through their control of land allocation for development, and environmental and social protection. Governments also have responsibilities and unique abilities for co-ordination of development.

While discussion in this paper focuses primarily on supply chains for transport of outputs and inputs, another important consideration is infrastructure for people, without which resources projects cannot be developed and operated.

POLICY RECOMMENDATIONS

1. Infrastructure and supply chain planners should take an options-based approach to allow for uncertainties about the future scale and type of development, maximize and not limit future options and avoid locking in supply chain inadequacies and economic inefficiencies.

2. Governments and project developers should seek to achieve supply chain integration to maximize efficiency, while avoiding exclusion of new producers by implementing supply chain access regimes and avoiding inefficient duplication of infrastructure.

3. Governments, through their control of land, have critical roles to play in identifying, planning and creating infrastructure corridors and development precincts for private sector investment, and to conclude strategic land access agreements and environmental approvals to facilitate development of individual projects.

4. Governments need to implement effective cross- and inter-government mechanisms to co-ordinate and facilitate investment in resources development and infrastructure.

5. Infrastructure to support communities is essential for them to be able to attract and retain workers needed for resources projects and supply chains, to achieve scale for liveability and business capability and to enable resources regions and their people to derive sustained benefits from development.

SUMMARY

The North of Canada and the North of Australia are alike in many ways, except for climate. Both are resource-rich, but have underdeveloped infrastructure, small, scattered populations and high proportions of inhabitants who are Indigenous. The experiences of developing Australia's North hold lessons for Canada, and vice-versa. Lessons from development of iron ore mining and gas production in the Pilbara region of Western Australia, together with coal and gas development in the Central Queensland coalfields region, can be applied usefully to resources and infrastructure development in Canada's North and elsewhere.

This paper examines the development of supply chains to provide efficient transport and handling of mineral and energy products in the two Australian regions, as well as goods and services inputs to production. Approaches by governments and project developers and operators have changed over the 60 years of modern resources development in the two regions, in response to big increases in scale of production; the constant need to enhance efficiency; and opportunities to accommodate new industries and entrants.

A key conclusion is that had governments in the 1960s and 1970s understood the potential for the scales and patterns of activity to increase and change to what is experienced today, they likely would have made different decisions about policies for development and infrastructure. That said, the economies of both host states and the financial capacities of their governments were much smaller, limiting choices for government. Some decisions,

however, limited future options and locked in supply chain inadequacies or economic inefficiencies. The lesson, therefore, is to take an options-based approach to infrastructure planning to allow for uncertainties about the future and to maximize future options and flexibility.

Efficiency of supply chains is imperative for export-oriented resources industries. Supply chains in the Pilbara and Queensland are at, or close to, leading practices in efficiency, but with Central Queensland coal chains lagging iron ore chains. Part of the reason is the trade-off between open-access rail systems that allow multiple producers to enter the market, and the inefficiencies that arise from rail being only loosely integrated with other separately operated components of the supply chain. In the Pilbara, the four privately owned rail systems are fully integrated into "pit to ship" supply chains operated by the producers, but this has acted to exclude other, smaller producers from gaining easy access to the rail systems. The fact that more integrated supply chains are being introduced into coal production and transport in Central Queensland points to the benefits of closer control by producers of their supply chains. At the same time, new rail systems in the Pilbara operated by single producers are required to provide access to others, with government also requiring sharing of ship-loading terminals.

There is thus some convergence of the approaches to heavy-haul rail systems and terminals between the two regions.

Governments have key roles to play in resources regions through their control of land allocation and responsibilities and abilities for co-ordination. In both Central Queensland and the Pilbara, state governments have planned, created and expanded corridors and development areas to accommodate privately owned infrastructure such as railways, pipelines and handling and processing facilities such as product stockyards and LNG plants. In both states, governments have implemented different, but effective investment co-ordination and facilitation mechanisms.

While discussion in this paper focuses primarily on supply chains for transport of outputs and inputs for minerals and energy operations, another vital consideration is infrastructure for people, without which resources projects cannot be developed and operated. Considerations around social infrastructure can involve making policy and business decisions about whether operations are more feasibly serviced by local towns or by fly-in, fly-out workforces; ensuring towns in resources regions have adequate scale, infrastructure and services to attract and retain skilled people and their families to live there; and ensuring resources regions and their people can derive sustained benefits from development.

1. INTRODUCTION AND OVERVIEW

1.1 STUDY REGIONS

The Pilbara region of the state of Western Australia and the Central Queensland[1] coalfields have hosted continuous development and operation of resources projects since the 1960s. This has been driven principally by export demand for coal, iron ore and liquefied natural gas (LNG), mostly from Asian economies to the north. Figure 1 locates these two regions in Australia and relative to primary markets in Asia. Figure 2 is a summary comparison of key metrics for each region.

Successive waves of investment have resulted in the Pilbara becoming the world's leading iron ore production hub and one of the world's largest LNG-producing regions. Other major resources operations include copper, gold and salt production, with recent development of lithium mining and processing, and gas-based manufacturing, adding to output. Very large-scale renewable energy production (wind and solar) is proposed for the region's north, with the output to supply both the Pilbara's mines and new facilities to produce hydrogen, primarily for export.

The Central Queensland coalfields region has become a leading producer of thermal coal, the world's biggest exporter of metallurgical coal and a large-scale producer of coal seam gas and exporter of LNG. Central Queensland also hosts alumina refining and aluminum smelting operations, gas-based manufacturing and large-scale coal-fired electricity generation. Renewable energy precincts are planned or have been established to serve the electricity needs of current and future industries.

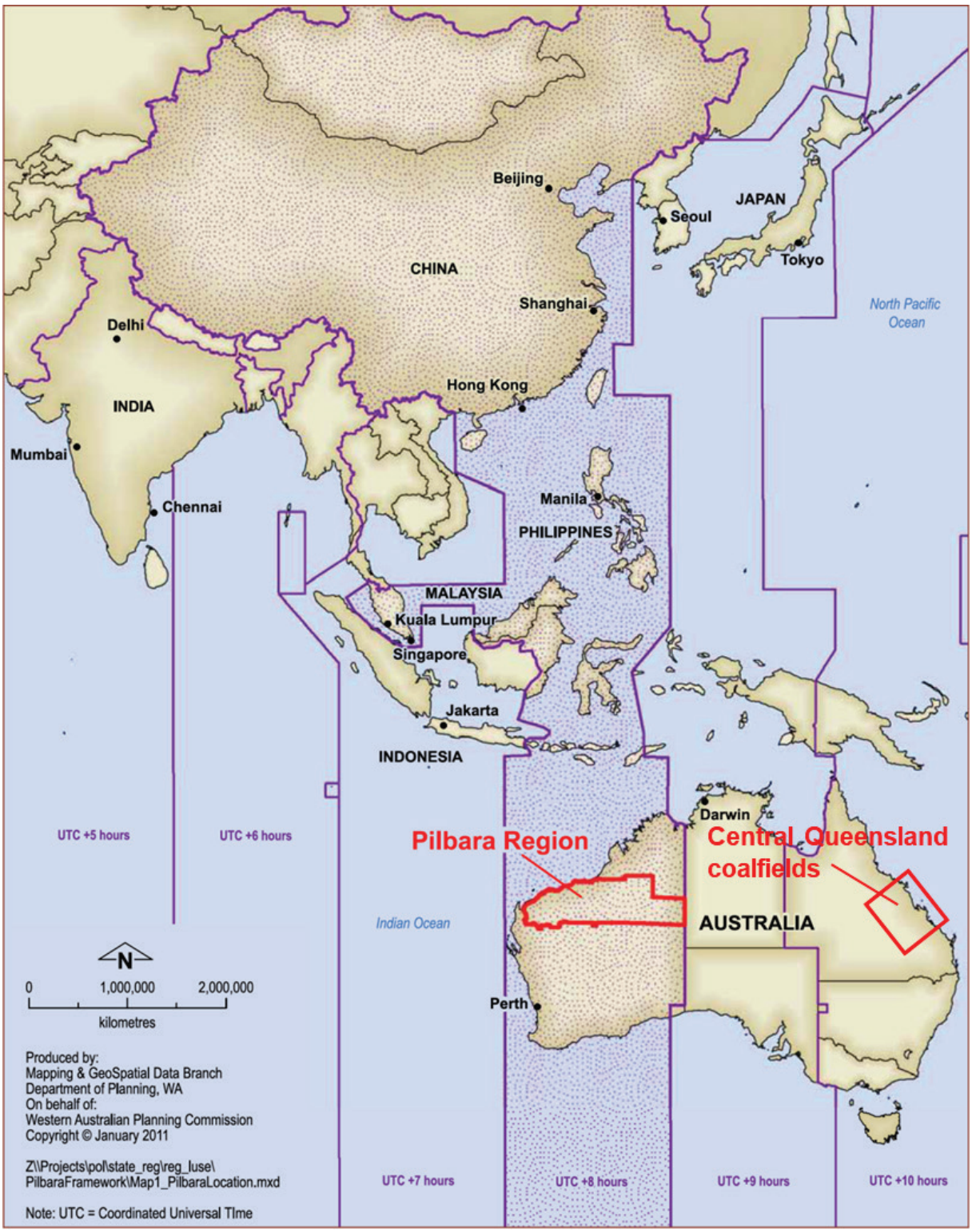
Both regions have other industries, but production of mineral and energy products has been the overwhelming driver of development and infrastructure provision for the past 50 years. Development has followed somewhat different pathways in each region, dictated by geographies and demographics, government policies, markets and resource companies' approaches. Principal demands for infrastructure have been driven by the needs for movement of bulk mineral and coal products from mines to ports and loading onto ships. More recently, pipelines to transport natural gas to LNG plants and domestic markets have become additional components of transport infrastructure. Secondary infrastructure demands, which have proved critical to development, centre on servicing resources production, other industries and communities, which are vital to providing skilled labour and local services to resources industries.

[1] The Central Queensland coalfields encompass the region of Central Queensland as defined by the Queensland government, plus the Mackay, Isaac and Whitsunday region to the north, which hosts part of the coalfields and associated railways and ports.

Resources investment and production in both regions has grown far beyond the scale governments and resources companies envisaged when development began. The approaches to infrastructure in the 1960s and 1970s assumed much more modest levels of activity. In several instances, decisions were made that by the 2000s were suboptimal for economic efficiency and locked out or made difficult retrofitted approaches. As a result, governments and companies have tended to adopt approaches to new infrastructure that are options-based in the face of ongoing uncertainties about future markets and patterns of development. The experiences of development in these regions hold lessons for others.

The short- and medium-term market outlooks remain strong for the mineral and energy resources produced in the Pilbara and Central Queensland, notwithstanding national and international responses to climate change and global economic shocks delivered by events such as the COVID-19 pandemic and war in Ukraine. The Australian government's forecaster expects that the value of national resources export earnings will rise in the 2022-23 year to a new record of AU$450 billion before declining in the following year, but still reaching the third highest earnings ever (Department of Industry, Science and Resources 2022b). Consensus estimates compiled by forecasters S&P Capital IQ have coking coal, thermal coal and natural gas trading higher in 2030 than in 2021, albeit lower than the expected peak in 2023 (S&P Capital IQ 2022). By 2030, iron ore is expected to trade at considerably lower than the current prices, but higher than the five-year average to 2020.

Figure 1: Location of the Pilbara and Central Queensland Coalfields in Australia, Showing Key Market Region



Source: Source: Base map from Department of Planning, Lands and Heritage (2012)

Figure 2: Summary Comparison of the Pilbara and Central Queensland Coalfields Regions

1.2 THE BRIEF

The terms of reference (ToR) for this paper from the School of Public Policy at the University of Calgary set out specific requirements. These are summarized as follows:

- The research topic is "The Australian Experience with Multi-focus vs Single-focus Infrastructure Corridors," focusing on the Pilbara and Central Queensland regions and how lessons could be best applied to corridor development in Canada.
- While specific content and analysis are left to the author's discretion, this review should result in a lay-language report that answers the following research questions:

  1. What are the strengths and weaknesses of the Pilbara region Transportation Infrastructure Corridor?

     a. What regulatory and governance framework was used?
     b. What key challenges arose during the corridor's development and operation?
     c. Have expected net benefits been realized?

2. What are the strengths and weaknesses of the Queensland Province Transportation Infrastructure Corridor?
    a. What regulatory and governance framework was used?
    b. What key challenges arose during the corridor's development and operation?
    c. Have expected net benefits been realized?
3. What lessons from these experiences are relevant for future corridor development in Canada (or other regions)?

The ToR noted that "Canada stands out as the only country/region without an overarching transport infrastructure framework in place at the time of the review." The ToR also noted that a revised approach to infrastructure planning could be informed by Australia's experience, which has a close parallel with Canada in several ways, and which has already formulated and partially or fully implemented transport infrastructure frameworks.

1.3 THE APPROACH

This paper covers the above ToR but expands the scope to examine not only development of transportation infrastructure corridors, but also supply chains related to resources industries in each region, of which transportation corridors are key components. The term "supply chains" is used to cover all transport and logistics associated with movement of outputs of resources industries and the inputs they require. The paper also briefly examines policy, planning and development of other classes of infrastructure, including social infrastructure and its relevance to regional development.

The paper also discusses:

- The histories of development in each region and how these influenced the decision-making by governments and investors over time;
- Similarities and differences of approach, and outcomes in each region over their 60-year history of export-oriented resources development; and
- Challenges experienced during development and operation of corridors, and responses of governments and developers.

The paper does not quantify expenditure on infrastructure by public and private sectors, as this is outside the scope of the brief. In any case, such an exercise would be very complex, requiring analysis of project-by project historical data over 60 years, where available, and calculations to establish comparable current-day valuations.

2. PREVIOUS STUDIES

A search of literature has revealed only a few historical studies of supply chains in each region, and even fewer comparative studies. This includes literature from academia, governments and think tanks, as well as trade and general media.

There have been more studies into, and documentation of, development of the Central Queensland coalfields than the Pilbara. This is most likely due to the much larger population and number and diversity of cities and towns, and to the proximity of tertiary institutions in the region and in Brisbane that have been motivated to conduct research.

Two histories of Pilbara development provide useful context. An unpublished paper (Limerick and Satchwell 2015) charts the phases and features of development in the Pilbara and these were summarized in a presentation on infrastructure and resources regions (Satchwell 2015). An excellent summary of early railway construction and operation in the Pilbara, with comparative references to Queensland coal railways (Walker 2015), documents development of the region through a railway lens.

For Central Queensland, the Gladstone Ports Corporation has published a detailed timeline of the development of the export coal trade since the 1940s and its port facilities (GPC 2022). Numerous Queensland government reports and policy documents have also provided information to build an understanding of the region's coal development. A technical paper on coal seam gas development in Queensland (Towler, Firouzi et al. 2016) provides useful background on regulatory initiatives by government for this new industry.

A 2009 report commissioned by the Minerals Council of Australia (ACIL Tasman 2009) examined infrastructure needs for 21 Australian resources regions, including the Pilbara and Central Queensland, focusing on current and future adequacy of supply chains and community infrastructure for production in 2009 and by 2020. The Pilbara Cities initiative (DPIRD, WA 2022) and Queensland's Strong and Sustainable Resource Communities legislation (Queensland Coordinator-General 2022b) are two responses by government to concerns about sustainability of towns and the communities they host.

The quest for access to existing Pilbara railways by aspiring new iron ore producers, including legal action up to Australia's High Court, was documented in Australian business media between 2004 and 2014, as well as by the statutory National Competition Council (NCC 2022). Access arrangements for the two most recently built railways are discussed in the *Review of the Western Australian Rail Access Regime* (Treasury, WA 2020).

Coal supply chain inefficiencies and solutions have been canvassed in several studies since 2005. These include a comparison of the Hunter Valley coal supply chain in the state of New South Wales with the less efficient Central Queensland ones (Affleck 2005), and a government-commissioned study (O'Donnell 2007) that made recommendations for improvements to the Goonyella Coal Chain in Central Queensland.

Current policy and planning documents together take the most comprehensive view yet of national, state and regional infrastructure needs and strategies. They include:

- State and regional infrastructure strategies (DSDILGP 2022); (Infrastructure Western Australia 2022); and (WAPC 2012);
- State freight and supply chain strategies (Department of Transport and Main Roads 2020);
- National strategies and assessments, including Australian Infrastructure Plan 2021 (Infrastructure Australia 2021), Infrastructure Priority List (Infrastructure Australia 2022b) and National Freight and Supply Chain Strategy (Transport and Infrastructure Council 2019); and
- Resources-specific plans like the Queensland Resources Industry Development Plan, 2022 (Department of Resources, Queensland 2022).

3. THE PILBARA

3.1 GEOGRAPHY AND ECONOMY

The Pilbara region of Western Australia is located approximately 1,300 kilometres north of the state capital, Perth. Like Central Queensland, it sits close to the Tropic of Capricorn. This delivers a hot and wet summer season and a warm, dry winter. The dominant vegetation is dry sclerophyll rangeland, interrupted by rugged, rocky landforms, some of which host large, high-grade iron ore deposits as well as other minerals. Offshore basins host petroleum resources, dominated by natural gas.

The Pilbara is endowed with an estimated 48 billion tonnes of iron ore resources, or almost 30 per cent of the world's identified iron ore resources. Mining and shipping these resources make the Pilbara the world's largest iron ore production centre. The region produces about 39 per cent of global supply (CMEWA 2022).

Iron ore resources in the Pilbara occur in two forms: hematite and magnetite. Hematite is the dominant form mined in the Pilbara. It is suitable for direct shipping, often after superficial beneficiation. Magnetite is concentrated and pelletized before shipping and hence is generally more costly to produce, though its higher grade and low impurities make it market attractive. The major ore producers of hematite are BHP, Rio Tinto, Fortescue Metals Group (FMG) and Hancock Prospecting through its subsidiary, Roy Hill Iron Ore. CITIC Pacific Mining and the FMG Iron Bridge project produce magnetite concentrate.

Other minerals produced in the Pilbara include gold, copper, lithium and tantalite. Offshore petroleum resources are large, with the region hosting four onshore liquefied natural gas (LNG) plants supplied by undersea pipelines. Project operators are Chevron and Woodside Petroleum on behalf of joint venture partners.

A large-scale ammonia-urea plant uses gas as a feedstock, with a second plant expected to commence construction soon. The region also produces export salt for industrial use and has a sizable cattle industry.

Future industries are expected to include very large-scale renewable energy (solar and wind) supplying green hydrogen production and other industries. The Pilbara will also become a uranium-producing province if a Canadian-owned mining project proceeds.

The gross regional product (GRP) of the Pilbara is estimated at AU$75 billion (Remplan 2022a), which is considerably higher than the gross state product of several states and territories of Australia and 50 per cent higher than the GRP of Central Queensland coalfields.

The population of the Pilbara is small, just 58,000, and shows little growth despite a massive increase in the region's output over the past decade. This contrasts with a high rate of population growth in Central Queensland, which is home to more than 400,000 people. The small Pilbara population reflects both the capital intensity of the export-oriented resources sector, the dominance of fly-in, fly-out (FIFO) workforces and development of Perth-based remote operations centres that control many of the resources operations across the vast region. There are 64,000 jobs in the Pilbara, notably more than the resident population. The Pilbara has two large towns, Karratha and Port Hedland, and eight smaller communities, of which five were established to service inland resources production centres and coastal ports.

Table 2 summarizes production of the major mineral and energy products from the Pilbara. Iron ore and LNG dominate by both tonnage and production value. Production value of other mineral products, while significant, is likely to remain relatively small, even with likely expansion of lithium production from the two current mines and associated processing plants, and potential new operations. Similarly, while processing of gas into ammonia and thence into products such as urea and ammonium nitrate has emerged as a growing industry sector in the Pilbara, it is expected to remain small relative to iron ore and LNG.

Table 1: Minerals and Energy Production from Pilbara Study Area in 2021-22

Type	Output Tonnes	Output Value (AUD)
Iron ore	838 million	$134.4 billion
Gold, silver, copper	N/A	$1.4 billion
Lithium in spodumene plus tantalum pentoxide	0.3 million (spodumene only)	$995 million
LNG and other petroleum	46 million (LNG only)	$51 billion
Salt	11.6 million	$557 million
Ammonia	0.84 million	NA

Source: Department of Mines, Industry Regulation and Safety (2022a) and author's calculations

3.2 DEVELOPMENT HISTORY

The first inhabitants of the Pilbara region, Australian Aboriginal people, have lived there for more than 45,000 years. European explorers arrived in the region in the 1860s. It was not until 1938, however, that the region's iron ore potential was identified, when government surveyors documented a large, high-grade (66 per cent Fe) deposit at Mount Goldsworthy. That same year, however, the Australian government put an iron ore export embargo in place with the Second World War looming and amid concerns that Australia did not have sufficient reserves to meet its own needs.

Iron ore development in the Pilbara region of Western Australia finally began in 1960 after the Australian government lifted its embargo. By the early 1980s, four major mining companies had established operations and were exporting up to 85 million tonnes per annum (Mtpa) of iron ore. Forty years later in 2022, exports total more than 825 Mtpa.

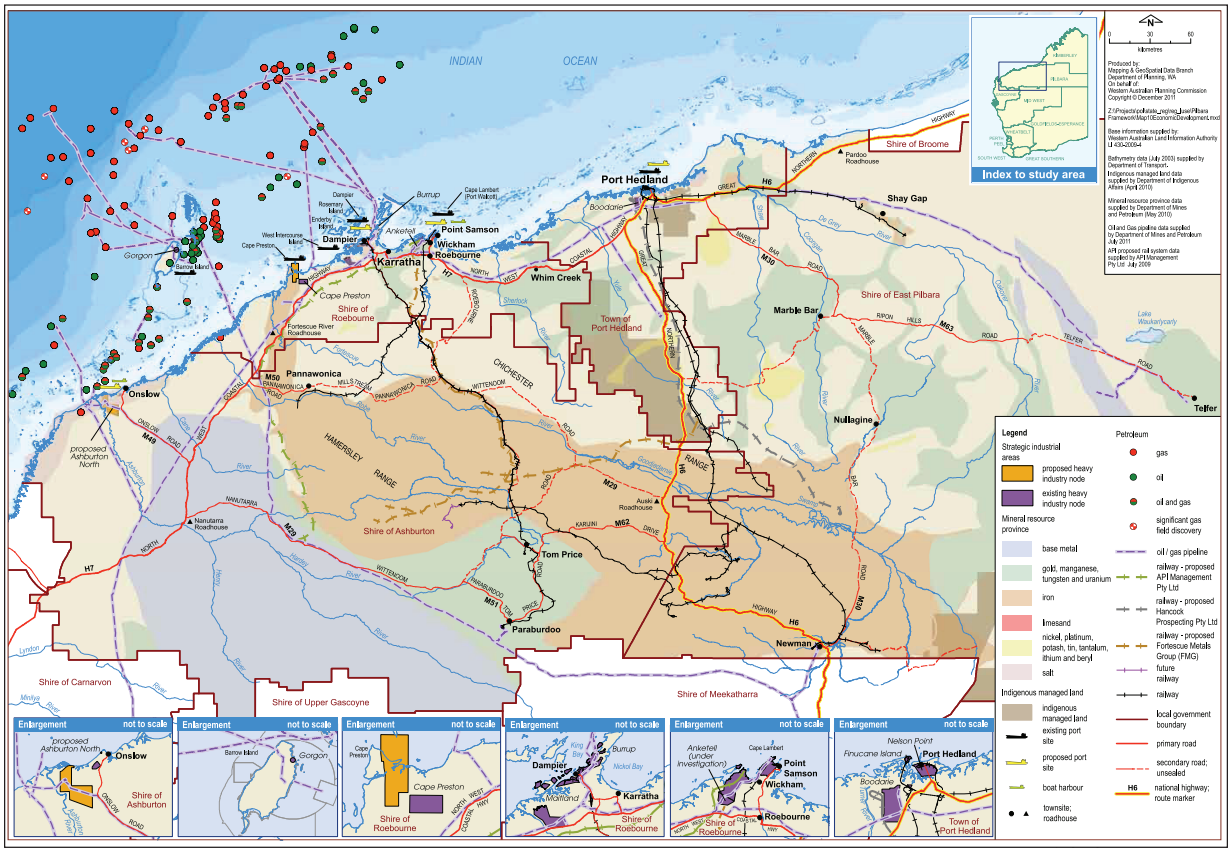
Some iron ore is also shipped around the Australian coast to a steel plant at Port Kembla in New South Wales.

Five new mines have opened in the Pilbara since 2020, while four new mines are scheduled to open during 2022 and 2023. These mines will replace some production from mines nearing the end of their lives and will also contribute to continued expansion of production.

The Pilbara has produced oil at small scale since the 1960s. Large deposits of natural gas were discovered in the Carnarvon Basin off the Pilbara coast in the 1970s. Production commenced in the early 1980s to provide natural gas both for the Western Australian market and for export as LNG. Since then, capital investment in the LNG industry has grown to more than AU$150 billion in four plants, offshore facilities and associated infrastructure. Pilbara LNG production of 46 Mtpa makes the region a major world producer.

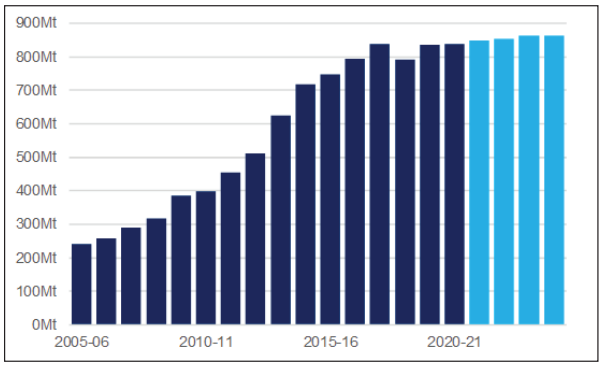
This paper identifies four phases of development in the Pilbara since the 1960s, each with a distinct approach to infrastructure. The current situation of development and infrastructure approaches has been influenced by the region's development history. Phases of development are identified in section 3.3 and their characteristics are discussed in the Appendix.

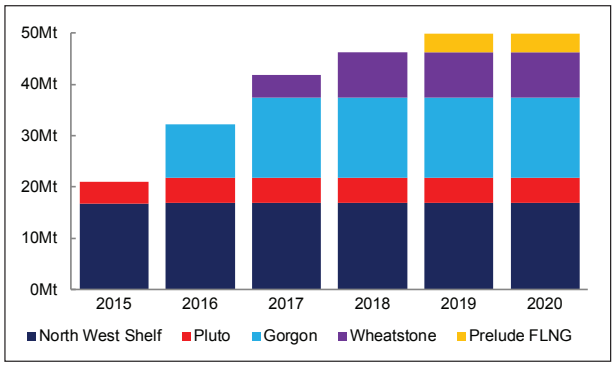
Figure 3: Map of the Western Half of the Pilbara Region



Source: Base map from Department of Planning, Lands and Heritage (2012)

Figure 4: Western Australia Volume of Iron Ore Sales Actual and Forecast: Million Tonnes (Mt), Financial Years; and Volume of LNG Sales: Mt Calendar Years





Notes: Pilbara iron ore production accounts for all but about 17 Mt per year of total state production; Prelude LNG is located offshore the Kimberley region, north of the Pilbara; Pluto has a second 5 Mtpa train under construction.

Source: Department of Planning, Lands and Heritage (2012)

Overview of Economic Infrastructure

Infrastructure in the Pilbara consists of railways, ports, gas pipelines and electricity and water supply facilities built since 1960 and funded largely by resource companies. Today, there is greater co-ordination of this infrastructure and associated services, including a strong role of government in policy and planning. Government-funded roads link the region's towns and mineral and energy operations, as well as linking the region with Perth, more than 1,200 kilometres to the south.

Most Pilbara towns were established by minerals and energy companies before later being "normalized" as open communities, overseen by local government. Unlike Central Queensland's established cities and towns, the Pilbara's existing small settlements could not provide the workforce and services needed to support development.

Provision and operation of infrastructure are summarized in this section and detailed in the Appendix. This infrastructure enables and supports supply chains. The six principal supply chains in the Pilbara are:

- Iron ore production and logistics
- Production and transport of other minerals
- Gas production, processing and transport
- Inputs to mineral and gas production
- Electricity and water supply
- People and services supply chains

Each of these supply chains is described in the Appendix. Characteristics of components of supply chains are summarized in the following sections and described in more detail in the Appendix.

3.2.1 Ports

The major ports are:

- Port Hedland (~650 Mtpa capacity iron ore, plus other minerals)
- Dampier (~150 Mtpa iron ore and 11 Mtpa LNG/LPG, plus other products such as salt and ammonia)
- Cape Lambert (~210 Mtpa iron ore)
- Cape Preston East (24 Mtpa iron pellets)
- Port of Ashburton (9 Mtpa LNG, with 30 Mtpa iron ore project under construction)
- Barrow Island (16 Mtpa LNG)

Several of these ports are also used for importing fuel for mining operations, businesses and communities.

3.2.2 Railways

Four privately owned railways deliver iron ore from mine to port, typically several hundred kilometres away. Pilbara Iron Pty Ltd., a subsidiary of Rio Tinto, operates more than 1,300 km of railway, hauling ore from Rio-related mines to Dampier or Cape Lambert. Trains can be more than 2.5 km long, carrying up to 35,000-tonne loads. BHPIO hauls ore over 400 km from its mines near Newman to Port Hedland, FMG some 280 km and Roy Hill about 350 km. Train control for most lines is now located in Perth within integrated remote operations centres for each iron ore supply chain. There is no rail connection between the Pilbara and Perth.

3.2.3 Gas Production, Processing and Transport

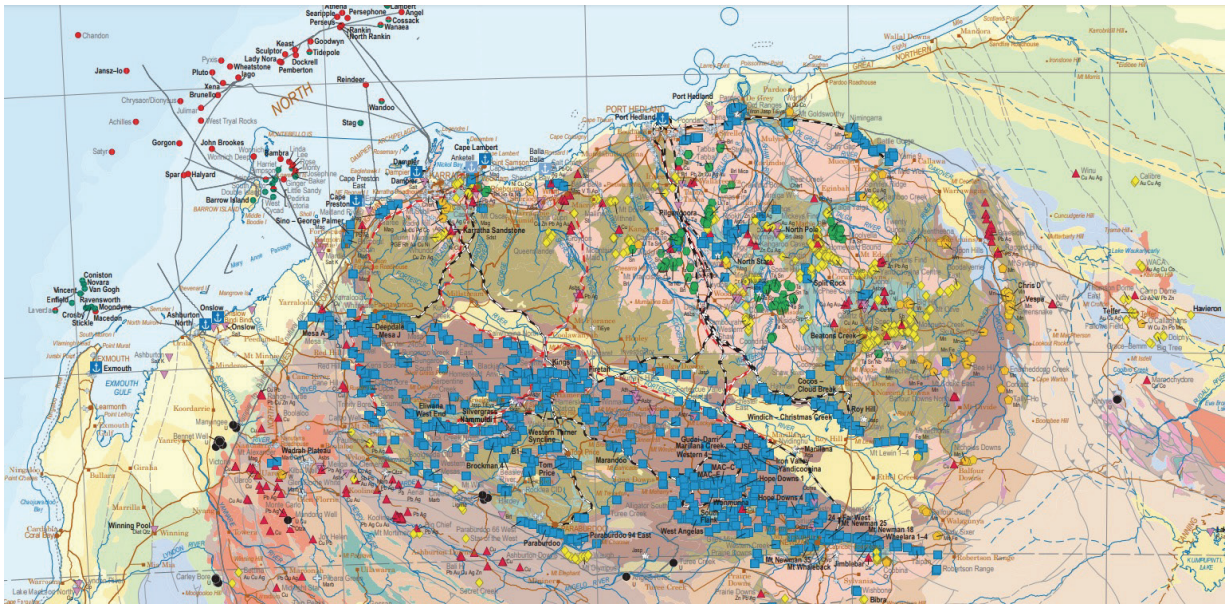
The Pilbara hosts four LNG plants, together with offshore infrastructure, comprising platforms, floating production and storage vessels and pipelines connecting offshore facilities to onshore LNG plants, an ammonia-urea plant and domestic gas supply. Total capacity of the four plants is 46 Mtpa, with an additional 5 Mtpa of capacity due to commence construction in 2023.

3.2.4 Roads

While railways and pipelines are the primary modes of transport for iron ore and gas, most other mineral outputs are transported by road, as are most inputs, the bulk of which are hauled 1,300 to 1,400 kilometres from Perth. The Pilbara is extraordinarily dependent on both the local road network and the highway from Perth.

Public main roads such as state highways are funded by state and federal governments and managed by the Western Australia government. Local government authorities build and maintain minor urban roads.

Figure 5: Mines and Transportation Networks in the Pilbara



Source: Geological Survey and Resource Strategy, Western Australia (2021)

3.2.5 Electricity Supply

Electricity infrastructure in the Pilbara is in the process of transition from a series of stand-alone systems operated by major mining companies to a more integrated system, overseen by an independent operator. Some systems supplying individual mining and processing sites remain stand-alone, however. The other major change is a shift to greater proportions of renewable generation from exclusively gas-fired generation. If the very large-scale Asian Renewable Energy Hub proceeds, it is expected to generate up to 26 gigawatts of electricity from combined wind and solar plants and produce 1.6 million tonnes of green hydrogen or nine million tonnes of green ammonia each year. It will also supply the Pilbara's existing industries.

3.2.6 People and Services Supply Chains

Pilbara communities require many and varied goods and services to sustain them. Most goods are transported by road from the Perth region. Services such as human services and retail are generally delivered locally, while in common with global trends, remote servicing is growing. Efficient telecommunications are particularly important in this remote region.

FIFO working dominates employment in the Pilbara's mines and gas operations, extending to elements of services provision such as in medical services. This contrasts with the dominant pattern of resident workforces in Central Queensland, although some workers drive in/drive out (DIDO) from communities near the coast to inland operations, as discussed in section 4.3.6.

3.3 INFRASTRUCTURE GOVERNANCE AND PLANNING

This paper identifies four phases of development in the Pilbara, detailed in the Appendix, with evolving approaches to infrastructure and its governance. The four phases can be characterized as:

- Iron foundations (1962-1982)
- Emerging energy (1982-2002)
- China growth (2002-2018)
- Market consolidation (2018-present)

The evolution has encompassed project-specific infrastructure built and operated by developers from the 1960s, to multi-user provisions for new railways, to public-private partnerships in ports and energy supply and to improved co-ordination between levels of government.

The key features of Pilbara infrastructure governance and planning in 2022 are summarized in the following sections.

3.3.1 Improved Access to Infrastructure

There is easier access to infrastructure than in the past through various mechanisms, including:

- Provisions for access to new iron ore railways legislated in state agreements, through above-rail access to third-party trains and/or haulage arrangements by current operators, with associated sharing of terminal facilities;
- Multi-user wharf, storage and loading facilities provided by the Pilbara Ports Authority for use by smaller iron ore miners and producers of other minerals such as copper and lithium;
- Planning and expansion of infrastructure corridors, including widening of the corridor for the Dampier to Bunbury natural gas pipeline (DBNGP) by government to accommodate future additional pipelines by multiple operators; and
- Progressive upgrades to road infrastructure, funded by state and national governments, to enhance access to ports and towns and to facilitate high tonnages of road freight from and to Perth.

3.3.2 Improved Planning Processes and Co-ordination

Infrastructure planning is more consistent, more rigorous and better co-ordinated than earlier in the Pilbara's history, through:

- More rigorous and co-operative approaches to infrastructure planning and prioritization through national and state infrastructure advisory agencies, including consistent prioritization and cost-benefit frameworks, and close consultation with large industries, small business and local government; and
- Greater use of public-private partnerships to improve infrastructure planning and delivery, including for road infrastructure, town infrastructure and electricity supply.

3.3.3 More Emphasis on Community Infrastructure and Connectivity

Both industry and government are focusing more closely on the needs of Pilbara communities to better attract and retain residential skilled staff and service workers, through:

- Enhanced city and town centres to provide focal points for activities;
- Improved neighbourhood planning to enhance amenity and liveability;
- Enhanced education, training, health, recreation and family facilities and services tailored to meet the needs of communities; and
- Improved connectivity through enhanced telecommunications and digital connections, new and improved roads to connect Pilbara towns to each other and the rest of the state, and air services subsidies to improve affordability of travel to and from Perth.

Despite improvements to liveability, populations of towns in the Pilbara have grown little. The preference of many workers and their employers for FIFO working, the costs of establishing and maintaining towns and remote locations of many resources operations, have led the government of Western Australia to take a pragmatic approach and support FIFO arrangements.

3.3.4 The Role of State Agreements in Pilbara Development

Institutional arrangements for facilitation of investment and protection of state interests have differed between the Pilbara and Central Queensland and continue to do so.

From the commencement of Pilbara development to the present day, legislated *State Agreement Acts* (SAA) have been used to provide long-term certainty to both developers of major projects and the state government. An initial additional driver was the inadequacy of existing legislation (e.g., the *Mining Act 1904*) when applied to very large-scale projects.

Early State Agreements required companies to submit comprehensive proposals for mining operations, railways, ports, towns and utilities. They then had to implement the proposals as approved within a timeframe and with at least the minimum capital expenditure set out in the SAA, and to commence export at a minimum specified rate. In implementing their proposals, companies were required to:

- Develop townsites and provide adequate and suitable housing, recreational and other facilities and services; and
- Construct and provide roads, housing, school, water and power supplies and other amenities and services.

Some later SAAs, notably for North West Shelf LNG project development, also used the proposals mechanism and in this case required the joint venture to provide housing for its resident workforce and to pay a contribution towards hospital, school and community leisure facilities, as well as all the industrial infrastructure (roads, port terminal, water and electricity) the project required.

State Agreements include rights to infrastructure corridors required by the project operator. These generally are single-user corridors for railways, and electricity, water and gas infrastructure, all of which historically have been constructed as part of the project.

Not all projects have been required to have SAAs applied, with government deeming the two most recent LNG and iron ore projects able to be managed without a SAA. Infrastructure corridors have been acquired under the *Mining Act* as "miscellaneous licences."

Institutional arrangements in Central Queensland are set out in section 4.4.

3.4 MEETING CHALLENGES AND TAKING OPPORTUNITIES

Through the Pilbara's modern history, there have been several consistent challenges and some that have changed over time. There have also been opportunities associated with these challenges. The major challenges, opportunities and approaches are summarized in this section.

3.4.1 Limited Government Resources Relative to Infrastructure Need

In the early days of Pilbara development, the government of Western Australia had very limited financial resources and many infrastructure priorities apart from those of the Pilbara. This was the key reason the government required initial iron ore developers, under SAAs, to fund and construct all infrastructure required for mining, energy transport and workforces. Consequently, operators had exclusive use of this infrastructure.

Another benefit to government of this arrangement was that it faced very little risk, while benefiting from a new, large royalties stream.

This approach contrasts with that of the Queensland government, which funded its own investment in railways and ports through refundable security deposits lodged by producers. In many cases, however, Central Queensland coal producers provided housing and key town infrastructure for their workers.

While Pilbara towns have since been normalized, and a multi-user electricity system implemented, iron ore logistics have remained the exclusive province of each producer operating under legacy state agreements, with new producers required to share infrastructure while still maintaining control of their supply chains (see section 3.4.2).

3.4.2 Enabling New Mineral Development

Exclusive use of iron ore supply chains by existing producers made it very difficult for other miners, particularly smaller operators, to enter production. The generally long distances between iron ore deposits and ports require railways to move iron ore efficiently.

For this reason, the government introduced requirements for more recent iron ore projects to negotiate access to their railways and terminal infrastructure by other producers. Several agreements have been reached for either above-rail access or haulage, enabling new producers to access viable supply chains. Agreements include access to terminal infrastructure at ports.

3.4.3 Gaining Access to Land and Seas for Development

Most of the Pilbara, except for freehold land (mostly in townsites), is subject to the *Australian Native Title Act 1993* (National Native Title Tribunal 2022), which confers on traditional owners a right to negotiate with governments and companies over the terms of a "future act" such as grants of mining tenements or other land titles (Department of Mines, Industry Regulation and Safety 2022).

Lease applicants are required to negotiate in good faith with each of the native title parties affected by the proposed grant of the tenement, with a view to reaching agreement. Agreements are approved and registered by a government authority as Indigenous land use agreements (ILUA).

Agreements typically include measures and protocols to protect Indigenous heritage and packages of benefits for the native title parties.

Infrastructure corridors are generally not subject to the right to negotiate provisions, but in practice companies and governments enter negotiations leading to agreements with native title parties. ILUAs are required in any case. In the case of widening of the Dampier to Bunbury Natural Gas Pipeline corridor, an agency of the government of Western Australia conducted consultation and negotiations with native title parties.

Approvals required by governments for mineral and energy extraction and process activities to take place are many, and encompass protection of Indigenous heritage, protection of the natural environment, land clearing and management of water resources (Department of Mines, Industry Regulation and Safety 2022b).

Recent court decisions in relation to resource company consultation of Indigenous people with traditional interests in seas near a gas project off the northern Australian coast are likely to result in more rigorous engagement processes with traditional owners around development in "sea country" off the Pilbara (*Santos NA Barossa Pty Ltd v Tipakalippa* 2022).

3.4.4 Enabling Gas Supply to Domestic Markets

Growth in global demand for LNG has led to increased exploration, the discovery of large offshore gas reserves and development of four LNG projects during the past 30 years. The capital costs of offshore gas and LNG projects can only be justified by the volumes and prices that export markets generate. Domestic markets are price sensitive, particularly when gas is used for process heat or feedstock in manufacturing. Without some market intervention, it would have been likely that the domestic gas market in Western Australia would be undersupplied and subject to export-parity costs.

For these reasons and a desire to expand manufacturing, the government of Western Australia implemented several initiatives:

- Underwriting construction of the DBNGP in the early 1980s to transport gas to the south of the state through capital contributions and take-or-pay gas contracts entered into by the then-state-owned energy utility, the Energy Commission of Western Australia;
- Introducing in 2006 a domestic gas reservation policy requiring exporters to supply 15 per cent of export volumes to the Western Australian market; and
- Widening the DBNGP corridor to accommodate future gas pipelines from the Pilbara to the south of the state.

The domestic gas reservation policy of Western Australia has not been replicated for export gas from elsewhere in Australia, including Central Queensland. Current global gas demand and consequent high spot LNG prices have driven up domestic gas prices in eastern and southern states. Domestic gas prices in Western Australia, which is not connected by pipeline to the rest of the country, remain moderate.

3.4.5 Resolving Skills Shortages

As development of the Pilbara moved into the emerging energy and later China growth phases, a larger Pilbara workforce with different skill sets was required. Government and companies became increasingly concerned about their ability to attract and retain skilled workers and those who provide services to them. High levels of turnover of skilled workers became a critical issue that potential investors wished to resolve.

This led to greater government investment, with private sector support, into facilities and services in Pilbara cities and towns that are required by workers and their predominantly young families. It also led to greater policy tolerance for much higher levels of FIFO working, which many workers and families prefer to living full time in the Pilbara's remote and challenging environment. Government also reformed its skills training institutions to better match supply with demand.

Technology has enabled resources producers to locate a greater proportion of workers in remote operations centres in Perth that oversee mining and logistics in the Pilbara, including use of autonomous machinery and trucks.

As noted in section 3.1, the number of people employed in the Pilbara now exceeds the population.

3.4.6 Facilitating Development of Resources Operations and Infrastructure

In the early stages of Pilbara development, the then-Department of Resources Development (DRD) had strong powers like those of Queensland's Coordinator-General. Over time, and as environmental legislation and the legal rights of Indigenous people became stronger, DRD's overarching powers were eroded. Approval timelines became extended and processes for proponents less certain. A review of the approvals process resulted in introduction of the Lead Agency Framework in the mid-2000s (Government of Western Australia 2022c) in a successful effort to improve process certainty and reduce timelines.

The Lead Agency Framework allows the designated lead agency (generally an economic development agency) to guide proponents through approvals processes and know what is expected to bring projects to development and operation. For major projects, the lead agency is responsible for:

- Facilitating provision of advice from state and national regulators to proponents on statutory and other requirements;
- Case-managing and facilitating approvals applications across government (including the Australian government) for proposals; and
- Assisting proponents to identify the potential social, environmental and heritage impacts of the proposal on relevant stakeholders and communities.

The Lead Agency Framework and enhanced infrastructure planning processes deliver outcomes like the Queensland Coordinator-General arrangements but through different institutional mechanisms.

Poor co-ordination or even clashes between state and national environmental assessment and approval processes historically led to duplication of requirements, uncertainty for proponents and delays in projects. In the past decade, however, agreements between the Australian and state governments have made processes less duplicative and more efficient.

3.4.7 Adapting to Changes in Market Dynamics

Aided by a world-class resource base, minerals and energy producers in the Pilbara have been able to pivot over the decades to realize new market opportunities and adapt to shifts in both demand and standards expected by customers, governments and host communities.

The 2020s provide both larger and changing market opportunities, and heightened standards of producer and supply chain performance. The major changes can be summarized as:

- Government responses to climate change, with increasingly rigorous licensing and regulatory requirements placed on developers and operators;
- Corporate responses to global climate change, with producers seeking to reduce scope 1 and 2[2] emissions towards goals of net zero over various timeframes, and engaging with shippers and customers in scope 3 emissions reduction;
- Corporate responses to environmental, social and governance (ESG) requirements, especially with respect to relationships with traditional owners and protection of Indigenous heritage;
- Uncertain demand scenarios for fossil fuels as the world transitions to renewable energy, but with a short-term shortage of oil and gas due to geopolitical perturbations;
- Rapidly increasing demand for battery, strategic and critical minerals[3] to enable energy transformation, supply demand for digital and defence technologies and diversify supply sources; and
- Increasing costs of inputs to development and production, in particular energy and labour, and competition from producers in other countries.

All producers have committed to carbon emissions reduction targets and adopted comprehensive ESG strategies.

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[2] Scope 1 emissions are those directly from production operations; Scope 2 emissions are indirect from purchased energy; Scope 3 emissions are indirect emissions that occur in the downstream product value chain.

[3] For the purpose of this discussion, battery minerals include lithium, nickel and cobalt. Strategic minerals include copper, iron ore and aluminium. Critical minerals are centred on rare earths. Each category overlaps with the others.

The other principal opportunities and challenges derive from changes in demand for products. As noted in section 1, commodity prices are expected to remain high in the short term, before falling below the current peak prices but still remaining strong to 2030 (Department of Industry, Science and Resources 2022b; S&P Capital IQ 2022).

For the Pilbara, iron ore output is expected to continue at or above the current world-leading rate due to demand for infrastructure and manufacturing. Gas demand as export LNG, and for domestic electricity generation and non-substitutable industrial supply, is expected to continue to rise as the world needs more gas to meet energy demand and to enable long-term transition to renewables. The Pilbara's copper, lithium and tantalum production is expected to increase, driven by global demand and enabled by a growing identified resource base. Globally, lithium supply shortfall relative to burgeoning demand is expected as early as 2024 (S&P Capital IQ 2022).

The resources investment outlook for the Pilbara is heavily influenced by government policies. The governments of Australia and Western Australia have policies that seek both to expand minerals and energy production and to reduce greenhouse gas emissions. These policies:

- Commit Australia to reducing greenhouse gas emissions by 43 per cent below 2005 levels by 2030, and net zero by 2050, with the commitment legislated in September 2022 (Department of Climate Change, Energy, the Environment and Water 2022);
- Set out how the government of Western Australia will implement its commitment to adapting to climate change and work with all sectors of the economy to achieve an aspirational target of net zero greenhouse gas emissions by 2050 (Government of Western Australia 2020);
- Seek to secure future energy supplies through exploration for, and development of new oil and gas resources (Australian Government 2022b, d; Government of Western Australia 2022b);
- Strongly support minerals and energy production and exports (Australian Government 2022c); (Government of Western Australia 2021); and
- Seek to expand research and investment in, and production and processing of battery and critical minerals, and to develop co-operative supply chains with nations including the U.S., Canada and India (Department of Industry, Science and Resources 2022a; Australian Government 2022a).

3.5 REALIZING BENEFITS

During the past 60 years, the Pilbara has transformed from being an outback cattle region to become one of the world's preeminent minerals and energy hubs, with a regional product exceeding the product of several Australian states and even the GDP of some nations.

For the people and economy of Australia, the Pilbara generates large export income, as well as big revenues for state and national governments in the form of royalties and corporate taxes. There are also flows of financial benefits to traditional owners of the land on which resources projects operate.

The bulk of flow-on economic activity, however, is not realized in the Pilbara region itself. Rather, Perth's role is as the principal residential and service centre, and corporate headquarters for resources production in the region.

The government of Western Australia's economic and development policies are pragmatic in this regard. They reflect the realization that the Pilbara's harsh environment and remoteness from the population centre in the southwest of the state mean it has limited capacity to host large communities and technology-intensive service industries, with many resources operations best served by FIFO workers and contractors.

Despite the Pilbara's enormous economic contribution to the state and nation, and large financial transfers and other benefits to traditional owners via Aboriginal corporations and through opportunities for training, employment and business, a large gap remains between the economic and social outcomes of the Indigenous and non-Indigenous peoples of the region. Indigenous people of the Pilbara remain highly disadvantaged on most metrics of the Closing the Gap strategy[4] (Productivity Commission 2022).

The Pilbara's economy is thus quite hollow, with weak connections between the resources economy, the local service economy and the regional Indigenous economy. The prospects of much change are slight, save for improved connections between the resources economy and Indigenous economy through employment, contracting and land access agreements.

The Pilbara contrasts markedly with Central Queensland in this regard. Central Queensland, with its large population, substantial cities, numerous regional towns and shorter travel distances, has been able to capture more of the benefits of resources development.

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[4] Disaggregated data for Closing the Gap performance in the Pilbara are not available, but Western Australia data are a proxy. The Pilbara's Indigenous population is nine per cent of the state's.

4. CENTRAL QUEENSLAND COALFIELDS

4.1 GEOGRAPHY AND ECONOMY

The state of Queensland hosts a large and diverse resources sector, of which coal and coal seam gas production is the largest component by production volume and value. Figure 6 illustrates the location and diversity of mineral, coal and petroleum operations and resources throughout the state.

The coal mining and coal seam gas province of Central Queensland (for this discussion, including the adjacent Mackay-Isaac-Whitsunday region) is one of the world's major coal production and export regions.

The Tropic of Capricorn bisects the region, which brings sub-tropical climates, delivering a range of vegetation ranging from rainforest areas on the coast to wet-dry sclerophyll rangelands further inland. The dominant landforms are flat to undulating.

The Central Queensland coal basin, as defined by the Department of Natural Resources and Mines of Queensland, includes six sub-basins, of which the Bowen and Callide basins are the only currently producing basins. Large-scale mines are proposed for the Galilee basin in the northwest of the region, facilitated by dedicated infrastructure.

Apart from coal-based resource production, other large-scale industries in the region are electricity generation; alumina and aluminum production; agribusiness in the form of broadacre cropping, sugar cane growing and raw sugar production, and cattle production and processing; equipment and services for mining and agriculture; and education and human services.

For a regional area of Australia, Central Queensland has a comparatively large population of 228,000, mostly located in coastal cities and towns. In addition, the Mackay-Isaac-Whitsunday region, which contains the northern parts of the coalfields and associated infrastructure, has a population of 181,000 (Australian Bureau of Statistics 2021). The total population of 409,000 contrasts with just 58,000 living in the Pilbara.

Central Queensland's 49 coal mines (out of a total of 54 for the whole of Queensland) produce thermal coal and metallurgical coal[5] (Geological Survey of Queensland 2019). Some 37,000 workers are employed directly in coal mining. Unlike in the Pilbara, most workers in Central Queensland resources operations are residents of the region.

Thermal coal is used to generate electricity and process heat for industry in Australia and Asian nations. Metallurgical coal is used to manufacture coke, an essential component of the dominant blast furnace technology for iron production or is pulverized for direct injection into blast furnaces.

Three coal seam gas fields produce gas for domestic and export markets. Most of the gas produced is transformed by refrigeration into LNG for export in specialized ships. LNG occupies 1/600th of the volume of natural gas. Regasified LNG is used in customer nations for electricity generation and reticulated gas supply.

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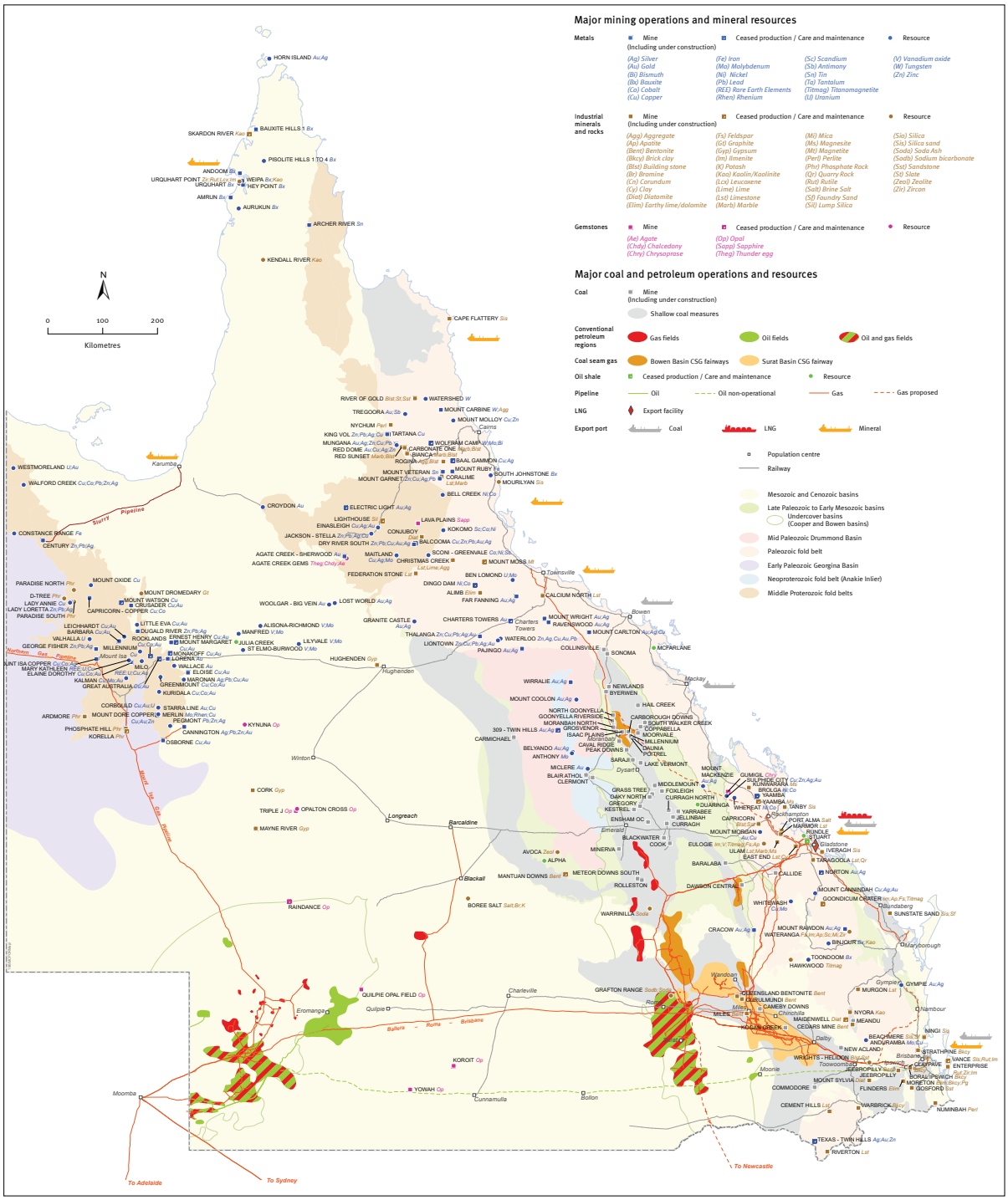
[5] Metallurgical coal is of two types: hard coking coal and semi-soft coking/pulverized coal injection (PCI) coal.

The majority of LNG from Central Queensland is sold under long-term contracts with customers. Some spot cargoes are shipped when prices are attractive and production volumes exceed contracted supply.

The balance of Central Queensland gas production is for domestic electricity generation and industrial use. Domestic gas from Central Queensland is transported by multi-user pipelines to Australian East Coast markets.

Figure 6: Queensland's Major Mineral, Coal and Petroleum Operations and Resources



Source: Department of Resources (2019)

Table 2 summarizes resources-based production from Central Queensland. Coal and LNG are the dominant products and the most relevant to the discussion on supply chains. Governments do not publish production values for many products. For Queensland coal, however, export value in 2021-22 was a record AU$72 billion, up from AU$47 billion in 2020-21 (Queensland Treasury 2022). This is expected to be a temporary increase, driven by a spike in demand due to the impacts of the war in Ukraine.

Table 2: Production of Major Resources Products from Central Queensland Study Area

Type	Output Tonnes 2021-22
Metallurgical (coking) coal	150 million
Thermal coal	77 million
LNG	25 million
Alumina	6.8 million
Aluminum	500,000
Ammonium nitrate	800,000
Sodium cyanide	95,000

Source: Queensland Government (2022), company sources and author's estimates

The GRP of Central Queensland, plus Mackay-Isaac-Whitsunday, is estimated at more than AU$50 billion (2021), or about 13 per cent of the total product for the state of Queensland (Remplan 2022b), but one-third less than the GRP of the Pilbara.

The Central Queensland coalfields are much more densely populated than the Pilbara. The region has 24 towns in inland areas, plus four regional service centres and satellite communities along the coast: from south to north, Gladstone, Rockhampton, Mackay and Bowen. Some of the towns were originally established to service the agricultural sector or railways, plus local populations, and now also service the coal industry. Other towns were purpose-built for the coal industry. Gladstone, Rockhampton and Mackay are cities with populations of more than 40,000. Greater Rockhampton and greater Mackay each have service populations greater than 100,000.

4.2 SUMMARY OF DEVELOPMENT HISTORY

Until British colonisation from 1853, the sole inhabitants of Central Queensland and adjacent regions were Aboriginal people, who have lived there for more than 40,000 years.

Central Queensland has produced coal since the late 1860s following the discovery of high-quality thermal coal at Blair Athol. Initial markets were exclusively domestic: railways and industrial processes and, later electricity generation. It was not until the 1960s that export markets were developed and coal production expanded to meet international demand.

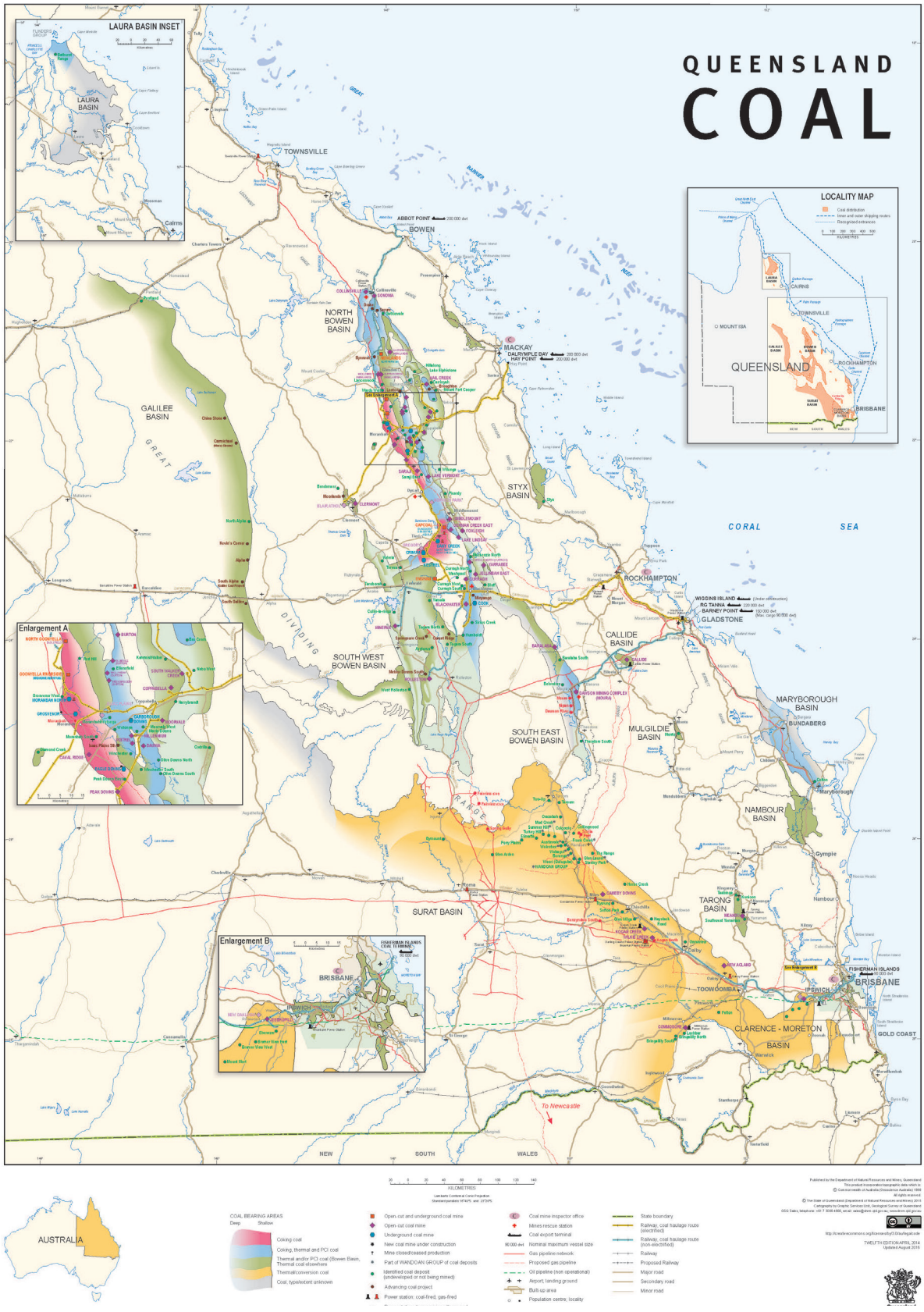
Expansion of production and exports of thermal coal have continued to this day. From the 1970s, the region also became a leading global producer of metallurgical coal.

Japan is the most important market for the region's coal, both thermal and metallurgical. Two other north Asian economies, Taiwan and South Korea, are the next most important markets. India, Vietnam. Taiwan, Brazil and the Netherlands are growing as markets for metallurgical coal. After Japan, Korea, Vietnam, Taiwan, India and Indonesia are top markets for thermal coal. In October 2020, China began an informal ban on imports of Australian coal, but Queensland producers were successful in pivoting to a supply of alternative markets.

Figure 7 on page 29 is a map of the coal-producing regions of Queensland, showing major transportation infrastructure, towns and cities. The Central Queensland study area is outlined.

In the early 2000s, development of coal seam gas began, driven by Asian demand for LNG, which is now produced by three plants operating on Curtis Island, just off Gladstone.

Figure 7: Coal Deposits Queensland, with Central Queensland Coalfields Area Outlined



Source: Department of Resources (2015)

Table 3 summarizes the principal development milestones of the Central Queensland coalfields.

Table 3: Development Milestones of the Central Queensland Coalfields

Year	Milestone
40,000 BC+	First human habitation
1853	First European settlement
1864	High-quality coal discovered
1892	First commercial exploitation of Central Queensland coal
1907	Intensive exploration for coal began
1922	Australia's first open-cut coal mine opened at Blair Athol
1949	First coal exports, via Port of Gladstone
1960s	First major multinational coal mining projects commenced
1968	First coal-dedicated heavy-haul rail line commissioned
1971	First dedicated coal port (Hay Point) built, with two associated terminals
1980s	Network of Central Queensland rail lines rebuilt, interconnected and extended for coal haulage, including 1,600 km of electrified track
1997	Open-access regime for coal rail lines implemented
2010	Open-access regime for coal rail lines enhanced
2008/9	Multi-user gas pipeline corridors created
2014	LNG exports commence from first of three plants
2015	New coal export terminal at Wiggins Island opened, taking the number of Central Queensland terminals to five, spread over three ports

4.3 OVERVIEW OF ECONOMIC INFRASTRUCTURE

Infrastructure in the Central Queensland coalfields consists of railways, ports, gas pipelines and electricity and water supply facilities, mostly built since 1960 and largely by the Queensland government. Coal companies established some Central Queensland towns to support nearby mining operations, while others were pre-existing and grew due to resources-driven economic activity. Central Queensland's established cities and towns provided a base of workforce and service provision, whereas the Pilbara had only a few small settlements when development began.

This section summarizes how infrastructure is planned, built and operated, with details in the Appendix. This section also describes the supply chains that infrastructure enables and supports. There are six principal supply chains in the Central Queensland coalfields:

- Coal production and logistics
- Gas production and transport
- Inputs to coal and gas production
- Electricity and water supply
- Inputs for other industries
- People and services supply chains

Each of these supply chains is described in the Appendix.

4.3.1. Ports

Central Queensland has three major ports, which host a total of five coal terminals. The ports are:

- Port of Gladstone (two coal terminals totalling 68 Mtpa capacity plus other minerals, metals and chemicals)
- Port of Hay Point (two coal terminals totalling 140 Mtpa capacity)
- Port of Abbot Point (one coal terminal 25 Mtpa)

4.3.2. Railways

An extensive network of coal, general freight and passenger railways in Central Queensland is leased to a private below-rail operator, with open access for above-rail service provision under specific regulations. The coal networks are organized into four systems that transport coal from mines to the three ports (see Figure 12 in the Appendix for a map). Railways were constructed over 120 years and operated by an integrated government-owned entity, with progressive implementation of competition policy and privatization of below- and above-rail services, leading to the current open-access arrangements.

4.3.3. Gas Production, Processing and Transport

Central Queensland's three export LNG plants are supplied by dedicated pipelines from coal-seam gas fields in the Bowen Basin and Surat Basin to the south. Total plant capacity is 25.3 Mtpa. Domestic gas pipelines supply electricity generation in Central Queensland and regions and states to the south. Gas is also supplied to alumina refineries and an aluminum smelter in the region, as well as fertilizer and chemical plants within and outside Central Queensland.

4.3.4. Roads

State and federal governments fund public main roads, such as state highways, and the Queensland government manages them. Local government authorities build and maintain minor urban and rural roads. The highway network within and connecting to Central Queensland transports most physical inputs to economic activities.

4.3.5. Electricity

Electricity generation and transmission services in Central Queensland are part of an integrated public-private system which is operated as a component of the National Electricity Market covering the East Coast and south of Australia. The region hosts three large coal-fired power stations. As with other systems, there is a shift to greater proportions of renewable generation (predominantly solar in Central Queensland), together with large-scale storage.

4.3.6. People and Services Supply Chains

The many large and small communities of Central Queensland require many and varied goods and services to sustain them. Goods are transported by rail and road along the coast from the Brisbane region and by road to inland areas. Services such as human services and retail are generally delivered locally, with the larger centres being retail destinations for those living in smaller towns.

Unlike in the Pilbara, a big majority of the Central Queensland workforce lives in the region. Weekly DIDO-commuting between cities near the coast and mine sites inland is common, however, enabled by the extensive and high-quality road network.

4.4 INFRASTRUCTURE GOVERNANCE AND PLANNING

Infrastructure governance and planning in Central Queensland have gone through several phases as the region has developed and lessons have been learned.

4.4.1. Current Approach

The current approach to infrastructure in Central Queensland is forward-looking, considering both current development needs and expectations for the future. There is considerable uncertainty about future coal-based development, however, particularly in the context of global reduction of carbon emissions and the impact on global coal consumption. The approach to infrastructure, therefore, is increasingly options-based, with emphasis on planning rather than construction of major new infrastructure. For example, new corridors for potential future railways and pipelines have been identified and reserved, with baseline environmental studies completed. Similarly, new and expanded ports have been scoped and designed. This approach allows for rapid construction if and when infrastructure is required.

Current infrastructure governance in Queensland is under the umbrella of, or influenced by several key policy and planning instruments:

- State Infrastructure Strategy, June 2022, which provides an overarching approach by the Queensland government to infrastructure across the state, including the Central Queensland coalfields (DSDILGP 2022);
- Regional infrastructure plans for Central Queensland, and Mackay, Isaac and Whitsunday (in development as of August 2022);
- 2021 Australian Infrastructure Plan by Infrastructure Australia, adviser to the Australian government, including specific recommendations relating to the development of northern Australia (Infrastructure Australia 2021);
- National Freight and Supply Chain Strategy and National Action Plan (Transport and Infrastructure Council 2019);
- Queensland Freight Strategy 2019, which complements the national strategy and "sets a shared vision for the state's freight system, outlining a series of commitments that will guide policy, planning and investment decision making over the next ten years to give customers greater choice and support economic growth" and is used to guide the rolling two-year Freight Action Plans (DTMR 2019);

- Queensland Freight Action Plan 2020-2022, which is "the key driver to identify and implement actions and activities that support the shared commitments and critical enablers outlined in the QFS to ensure the transport system continues to keep up to date with the changing and expanding freight environment" (Department of Transport and Main Roads 2020); and
- Queensland Resources Industry Development Plan, June 2022, which includes the following infrastructure initiatives: facilitating and investigating common user infrastructure in partnership with industry and completing the Bowen Basin pipeline concept study (Department of Resources, Queensland 2022).

4.4.2. Future Approach

Future coal development in the Galilee Basin, if it proceeds, is expected to use two privately owned and operated railways connecting very large-scale mines to Abbot Point port over distances of about 450 kilometres. The port's capacity would be expanded by up to 80 Mtpa. Coal is expected to be loaded via either an expanded Abbot Point Coal Terminal, operated by the state government's North Queensland Bulk Ports Corporation (NQBPC), or by a new stand-alone terminal or terminals, operated by the coal producers or dedicated operators.

If the private sector approach is adopted for both rail and coal terminal operations, arrangements will have moved close to the current approach in the Pilbara. It is uncertain whether regulated access arrangements would be applied to the railways and private coal terminal(s).

4.5 MEETING CHALLENGES AND TAKING OPPORTUNITIES

Development of the Central Queensland coalfields has faced a number of challenges as well as opportunities over the past 60 years of export-focused growth. The major challenges, opportunities and approaches are summarized in this section.

4.5.1. Constructing Infrastructure Despite Constrained Government Resources

The Queensland government owned and operated a rail network and a port in Central Queensland and began to haul and export coal from the late 1940s. As multi-national companies entered coal production in the 1960s, the government identified coal haulage and ship loading as profitable monopoly businesses. Coal haulage profits were able to make up losses on other freight services, and potentially to contribute to general government coffers on top of coal royalties.

Initially, the government built or upgraded, and operated all coal railways. To finance construction, the government required coal mining companies to pay a refundable security deposit. These deposits were repaid over time from coal freight revenue, with rates adjusted as the government determined, subject to what the coal market could bear.

This later became a source of dispute between coal producers and the government, with the former alleging over-charging for haulage services. Upon privatization of coal railways, however, introduction of multi-user access and application of economic regulation, disputes dissipated as market forces were able to influence pricing more strongly. That said,

regulatory consideration of periodic access undertakings and associated pricing schedules for the coal network attract much attention and input from coal producers.

Financial constraints and a desire for commonality with the rest of the Queensland railway system led the government to upgrade and construct in the ruling 3-foot 6-inch gauge, which has inhibited haulage capacity relative to the standard gauge (4-foot 8½-inch) used in most heavy-haul railways globally. The coal networks in Central Queensland, however, operate at world-leading axle loads for narrow-gauge systems.

As in the Pilbara, ports have remained exclusively government-controlled, through government trading enterprises. These are regulated to ensure capital expenditure is justified and charges are commercially viable. The five terminals in the three ports are operated variously by public and private owners.

While only one coal terminal is currently regulated (the privately operated, multi-user Dalrymple Bay Coal Terminal), benchmark competition is a key factor in keeping coal-handling charges to commercially viable levels in other multi-user terminals.

4.5.2. Overcoming Inefficiencies of Non-integrated Supply Chains

Unlike iron ore supply chains in the Pilbara, coal supply chains in Central Queensland are not vertically integrated, with all producers using access to common railway tracks and signalling, most accessing multi-user terminals at ports and some having exclusive access to their own terminals.

Separate ownership and operation of mines, rail services and coal terminals have resulted in inefficiencies of operation and shortcomings in long-term planning. The review of the Goonyella coal chain in 2007 recommended much closer co-ordination between each party (O'Donnell 2007). Implementation has resulted in increased coal throughput along the entire chain and co-operative planning of system upgrades.

In determining approved capital expenditure on the rail network and charging for track access, there is intense discussion before the regulator between the track owners and above-rail access seekers.

One metallurgical coal producer, the BHP Mitsubishi Alliance, constructed and operates its own terminal at Hay Point and now operates its own trains on the common rail network in efforts to improve its supply chain efficiency. These arrangements are close to the Pilbara model, save for use of common railway tracks. The coal supply chains proposed for development of the Galilee Basin include privately operated, standard-gauge railways and coal terminals, as developers seek to control the whole chain in common with iron ore producers in the Pilbara.

4.5.3. Meeting Technical Challenges of Heavy-haul Narrow-gauge Railways

As noted, coal railway lines were constructed in the narrow 3-foot 6-inch gauge of the existing state network. The ruling axle load was just 12 tonnes in 1963 when export coal haulage began in volume. Technical innovation in track and wagons enabled axle loads progressively to be increased to 20 tonnes by 1982 and 26.5 tonnes in 2002, not far off the 30 tonnes axle load applying to the standard-gauge coal rail system in the state of New South Wales. Studies have been undertaken into the technical and financial viability of

increasing the CQCN ruling axle load to 30 tonnes, which would deliver a 13 per cent increase in capacity within current train lengths (Smith 2017).

4.5.4. Facilitating Gas Development While Minimizing Impacts

The advent of the coal seam gas and LNG industry in the early 2000s provided opportunities for the Queensland government to both facilitate development and mitigate or avoid negative environmental, social and economic impacts. With eight projects proposed initially, there was potential for multiple supply pipelines over different routes to LNG plants on the coast. In response, the government decided to create dedicated pipeline corridors and a dedicated LNG development precinct on Curtis Island, adjacent to the city of Gladstone.

These State Development Areas allow expedited development and reduced impacts on the environment and communities through close co-ordination between government and between the three operators of pipelines and gas plants for environmental assessments, engagement of landholders and communities and construction (Department of State Development, Infrastructure, Local Government and Planning 2022). The current Bowen Basin pipeline concept study has similar outcomes as part of its objectives (Department of Resources, Queensland 2022).

4.5.5. Facilitating Production of Gas for Domestic Markets

An early concern about development of coal seam gas for export is that export LNG production would tend to result in diversion of domestic gas to export and local prices rising towards export parity. This has been borne out, at least in part, with domestic customers on the East Coast facing shortages and historically high domestic gas prices in 2022. While gas development policy in Australia is complicated and influenced by moratoriums and delays in development in some states, the gas shortages in the East Coast market are driving prices higher, threatening price-sensitive manufacturing.

In response, the Queensland government from 2018 has released some 20,000 square kilometres of land for tender by gas explorers (one quarter of the total land available for coal seam gas production) for exclusive supply to domestic markets. The Australian Market Supply Condition has been applied to seven tenures granted since 2018 (Aurecon 2020). A total of 60,000 square kilometres of tenure had been previously dedicated to gas production for export.

As noted, LNG development in the Pilbara is subject to a domestic gas reservation system, under which 15 per cent of production must be made available to the Western Australia domestic market. Distance and pipeline economics have to date precluded connection to the East Coast market.

4.5.6. Gaining Access to Land for Development

Unlike land in the Pilbara, which is held by government (Crown land) or leased to graziers (ranchers), much of the land in Central Queensland is privately owned under freehold or leased from government for farming and grazing purposes. In these cases, project developers must negotiate with the landowner or leaseholder to complete a compensation agreement (Department of Natural Resources, Mines and Energy 2020).

Native title may exist where past grants of tenure have not extinguished it. Land other than under freehold title generally is subject to underlying native title and therefore triggers the provisions of the *Australian Native Title Act 1993*. The act provides that Indigenous people have rights and interests in the land under their traditional laws and customs and have a right to negotiate with a party that wishes to conduct an activity deemed as a "future act" that may impinge on these rights. A right to mine under a mineral development licence and mining lease is a future act, triggering an obligation to negotiate in good faith with a view to reaching an agreement, which is then registered as an ILUA (Queensland Government 2022c).

ILUAs generally include benefits packages for the native title parties.

Infrastructure leases (in this case, mining leases for infrastructure) are subject to ILUAs, but do not trigger a right to negotiate. In practice, however, access agreements are sought and concluded.

As discussed in section 4.5.8, the Queensland Coordinator-General is responsible for acquisition and administration of State Development Areas (SDAs), including infrastructure corridors. The Coordinator-General therefore undertakes negotiations with landowners and native title parties for access to create the SDAs. Access by third parties (for example, a pipeline operator) is controlled by the Coordinator-General under the provisions of a SDA Development Scheme (Queensland Government 2022b).

4.5.7. Delivering Community Benefits

Central Queensland has been able to capture considerable value from coal and gas development and production, particularly compared to the Pilbara. Nevertheless, local concerns that Central Queensland communities, and others near large resource projects elsewhere, were not receiving adequate benefits from those projects gave rise to new Queensland government policy and legislation in 2017. The *Strong and Sustainable Resource Communities Act 2017* (SSRC Act) seeks to ensure that residents of communities within 125 kilometres of such projects benefit from the construction and operation of those projects (Queensland Coordinator-General 2022a).

The SSRC Act has three elements:

1. Prohibition of the use of 100 per cent fly-in, fly-out (FIFO) workforce arrangements on operational large resource projects that have a nearby regional community;
2. An anti-discrimination provision that makes it an offence for large resource projects to discriminate against locals in recruiting workers; and
3. Mandatory social impact assessment as part of environmental impact statements for large resource projects in accordance with a social impact assessment guideline.

Local government bodies in both regions have been strong advocates for delivery of stronger value flows to their jurisdictions. They have also been key in delivery and operation of a range of municipal facilities and services. In Queensland, reform of local government has resulted in greater geographic size of each municipality and larger scale of operations, generally improving service delivery.

4.5.8. Facilitating Development of Resources Operations and Infrastructure

The Queensland Coordinator-General's role was established in 1938 to co-ordinate the provision of public infrastructure, encourage development and support the creation of jobs following the Great Depression.

In recent decades, the Coordinator-General has played a key role in facilitating economic development though major projects and infrastructure. The role has strong and wide-ranging powers to plan, deliver and co-ordinate, within government, large-scale private and public sector projects. Most projects are related to minerals, energy and related manufacturing sectors.

The Coordinator-General's powers include:

- Facilitation of projects through direction of government authorities, setting of binding programs of works and even taking control of government processes and decisions;
- Managing assessments and approvals of projects, including environmental and social impacts;
- Establishing SDAs for industry, infrastructure corridors and major public works to promote industrial development opportunities;
- Compulsory acquisition of land for infrastructure development; and
- Implementing the Strong and Sustainable Resource Communities policy.

4.5.9. Adapting to Changes in Market Dynamics

The high-quality coal resources of Central Queensland and existing and adaptable infrastructure have enabled mineral and energy producers there to adapt to changing market circumstances and take on new opportunities, responding to changing standards expected by customers, governments and host communities. Low-cost coal-fired electricity generation and availability of gas at competitive rates (at least until recently) in turn have enabled development of alumina refining and aluminum smelting near the Port of Gladstone.

The major market changes relevant to Central Queensland are like Pilbara's, but with national and international climate change responses expected to heavily impact future demand for thermal coal. Protection of the marine environment from the impacts of coal mining and shipping is also a priority for governments.

The changes in market dynamics can be summarized as follows:

- Government responses to climate change, including increasingly rigorous licensing and regulatory requirements placed on developers and operators, reducing thermal coal demand for domestic power generation, increasing export and domestic gas demand and increasing medium-term uncertainty for export demand for thermal coal;
- Increasingly stringent government licensing and regulation requirements to meet community expectations and protect lands, waterways and the marine environment from impacts of resources production, processing and shipping, in particular ensuring the Great Barrier Reef World Heritage Area, located offshore of Central and North Queensland, is not damaged;

- Corporate responses to global climate change, with several producers seeking to reduce scope 1 and 2 emissions towards goals of net zero over various timeframes, and engaging with shippers and customers in scope 3 emissions reduction along value chains, with the approach set out in metallurgical coal producer BHP's Climate Transition Action Plan as an example (BHP Group Limited 2021);
- Corporate responses to environmental, social and governance (ESG) requirements, especially in relationships with traditional owners, local communities, protection of Indigenous heritage and protection of rivers and seas, with the approach of LNG operator Santos as an example (Santos Limited 2022);
- Uncertain demand scenarios for thermal coal as the world transitions to renewable energy, with Queensland pursuing a target of 50 per cent renewable energy by 2030 (Queensland Government 2022e), resulting in a phase-down of coal-fired generation, but with gas required in the medium term to provide dispatchable generation to facilitate transition, and with greater short-term gas demand due to geopolitical ructions;
- Rapidly increasing demand for strategic minerals such as aluminum to enable energy transformation, energy efficiency and infrastructure expansion; and
- Increasing costs of inputs to development and production, in particular energy and labour, and competition from producers in other countries.

Most operators have committed to carbon emissions reduction targets and adopted comprehensive ESG strategies.

Commodity prices are expected to remain high in the short term, before falling below the current peak prices but still remaining strong to 2030 (Department of Industry, Science and Resources 2022b). Long-term reductions in demand for coal and gas energy products are unlikely to be duplicated in similar timeframes for metallurgical coal and feedstock gas. The Queensland government (Queensland Treasury 2022) expects that coal production could be sustained at 2021 levels out to 2050, based on International Energy Agency (IEA) forecasts under a scenario of how nations are currently responding to climate change. Stronger global responses to climate change will reduce coal demand faster, the IEA says (International Energy Agency 2022).

The IEA expects that demand for metallurgical coal will decline much less than for thermal coal. Current technologies for steelmaking are dominated by coal-hungry processes. As shown in Table 2, Central Queensland produces metallurgical coal at twice the rate of thermal coal. Exports are 2.5 times higher. Similarly, gas as a feedstock for manufacturing and process heat is non-substitutable but comprises a small proportion of domestic and export demand.

As for the Pilbara, the resources investment outlook for Central Queensland is heavily influenced by government policies. Policies of both the Australian and Queensland governments support the expansion of minerals and energy production while reducing greenhouse gas emissions. The exception is expansion of thermal coal production, where the Queensland government's energy policy will result in reduction of domestic demand, while the new Australian government has an equivocal policy about expansion of thermal coal exports. Relevant government policies include:

- A legislated commitment to reducing Australia's greenhouse gas emissions by 43 per cent below 2005 levels by 2030, and net zero by 2050 (Department of Climate Change, Energy, the Environment and Water 2022);
- The Queensland government's climate change response, including its renewable energy initiatives (Queensland Government 2022e);
- Seeking to secure future domestic gas supplies through exploration for, and development of new gas resources (Queensland Government 2021); and
- Pursuing long-term growth, diversity and resilience of the Queensland resources sector through implementation of the Queensland Resources Industry Development Plan (Queensland Government 2022d).

Despite uncertainties of policy and future coal demand, the immediate investment pathway for coal mines is strong. As of December 2021, four new projects in Central Queensland had been committed, 27 new or expansion projects were undergoing feasibility studies and 12 projects had been publicly announced (Department of Industry, Science and Resources 2021). The split between predominantly metallurgical coal projects and thermal coal projects is not revealed in the data, although thermal coal is often co-produced by metallurgical coal mines.

4.6 REALIZING BENEFITS

The Queensland government has had a clear focus on delivering economic benefits from resources development for the Central Queensland region and the state. It has adaptively managed policies for resources development to optimize benefits.

Near-coastal cities and satellite communities have clearly benefited, evidenced by the strong rate of population growth during the past four decades and associated residential, civic, retail and industrial development.

Some smaller communities near coal operations have experienced opportunity costs, however, due to being bypassed for service delivery to them in favour of FIFO workers from the capital, Brisbane, and other heavily populated southeastern cities. These communities also suffer from lack of scale, which affects their capacity to deliver services to mining and even to attract and retain skilled and semi-skilled workers.

The government's Strong and Sustainable Resource Communities initiative will help by requiring companies to engage with their local communities, but small scale is likely to remain a problem. Improvements to highways in Central Queensland now make it possible to commute for longer distances to and from workplaces, which favours larger communities.

The coal industry has benefited from government willingness to invest in railways and ports and facilitate co-ordinated development through State Development Areas, including corridors. This has lowered the cost of development, transport and shipment of coal and gas resources.

The Queensland government has in turn benefited from strong revenue streams derived from royalties, coal haulage and ship loading, and strong and sustained economic activity in the region. The Australian government has benefited from company tax and income tax receipts.

The new Queensland Resources Industry Development Plan not only seeks to transform, grow and diversify the sector, but also to deliver stronger benefits through:

- Strengthening ESG credentials and protecting the environment;
- Fostering coexistence and sustainable communities;
- Ensuring strong and genuine First Nations partnerships;
- Building a safe and resilient future workforce; and
- Improving regulatory efficiency.

5. LESSONS FOR FUTURE CORRIDOR DEVELOPMENT

Development of the Pilbara and Central Queensland hold lessons for each other and for resource-rich regions elsewhere. In the early periods of development in the 1960s and 1970s, governments in Western Australia and Queensland approached development of infrastructure differently, due to development characteristics and stages, financial capacities and geographies.

By 2022, however, both governments' approaches had grown more alike as regional resources development matured, as they faced similar issues and as economic policies became more harmonized across Australia.

Key lessons for Canada's North and other resource-rich regions which can be drawn from the experiences in these two northern Australian regions are discussed in the following sections.

5.1 DECISION-MAKING UNDER UNCERTAINTY

5.1.1 Experience in the Pilbara and Central Queensland

Decision-making on infrastructure is often undertaken in the face of uncertainty, particularly around the timing and scale of major resources projects, future requirements of supply chains and patterns of population growth. Development in both regions has demonstrated that it is difficult if not impossible to forecast long-term commodity market behaviour and regional development potential of resources investment and production. Production volumes and values from both regions are far, far greater than what was expected when resources development began in the 1960s. For example, mining from each of the three initial operations in the Pilbara was at the rate of about 1 Mtpa. Today, the four major producers mine more than 800 Mtpa.

Further, new markets have developed, and new types of resources discovered. Japanese demand initially drove development in the Pilbara and Central Queensland. Now market destinations are much broader, covering much of Asia and Europe for regular cargoes of metallurgical coal and recently, spot cargoes of LNG.

Unconventional coal seam gas production in Queensland that was not envisaged in the 1960s gave rise in the 2000s to a large-scale LNG industry, with demand increasing due to global energy shortages and the transition to renewables.

At the same time, some expected production routes have not been viable. For example, two large-scale attempts to process Pilbara ores into iron failed, variously for technical and commercial reasons.

Expectations of a large-scale petrochemicals industry in the Pilbara have yet to be realized, despite it being a producer of the two primary inputs, gas and salt.

These examples highlight the upside and downside uncertainties facing infrastructure planning in resources regions. In both regions, governments and companies in the past have made assumptions and taken decisions that, in the light of the pattern of development that has occurred, have been proven suboptimal.

Examples include requiring initial iron ore developers in the Pilbara to develop all their own infrastructure, which has led to asset duplication, non-integrated electricity systems, separate iron ore supply chains and towns that are too small to provide all the services that industries and populations now demand.

In Central Queensland, the government's decision to upgrade and build coal railway networks with narrow-gauge track resulted in weight and system capacity limits that technology is only slowly overcoming. The plethora of small communities interacting with the coal industry has increased costs to government for providing community services, and to companies that must bring skilled labour and technology-intensive services from elsewhere.

Governments in both Queensland and Western Australia have learned from developing the two regions. The fact that the two states' approaches have more in common now than in the past shows they have identified similar leading practices and seek to move towards them.

Key examples of current policies and practices are:

- Establishing and enlarging infrastructure corridors to accommodate multiple pipelines and/or other services operated by several entities, now and in the future;
- Maintaining state ownership of ports, which are natural monopolies, while allowing for multiple private sector users to contract and operate their own bulk terminals, integrated with their supply chains;
- Planning for new and/or expanded ports to accommodate increased throughputs and changing needs now and over future decades;
- Establishing state development precincts, and planning and facilitation mechanisms to accommodate new and future handling and processing facilities for resources products;
- Implementing efficient project assessment, approval and facilitation processes that work across agencies and between levels of government;
- Conducting strategic land access negotiations and environmental assessments for corridors and development precincts that allow proponents to fast-track assessment and approvals for particular projects using them;
- Allowing producers to enhance supply chain efficiencies by constructing and operating their own railways and terminals at ports, while also requiring access arrangements for other producers;

- Integrating Pilbara electricity systems to enhance efficiency of delivery for multiple customers;
- Increasing the focus on improving liveability in regional cities and towns to better attract and retain workers and their families, while allowing regional DIDO worker commuting in Queensland, and FIFO commuting to and from the Pilbara; and
- Stronger measures to deliver lasting regional economic and social benefits from resources activity.

5.1.2 Options-based Approaches to Infrastructure

In the light of development experience in the two regions over the decades, in particular the growth and diversification of resources activity and production volumes, it is clear that early decisions were based on assumptions that bore little relation to the actual outcomes decades later. The nature and scale of current development was not envisaged when development began. That may have had benign consequences, except that several early decisions locked in development and infrastructure pathways and in many cases locked out future alternatives. Infrastructure policies and investment strategies variously have resulted in inefficient infrastructure; underused or even stranded assets; governments' inability to take up opportunities arising from changing market conditions; and regrets where in hindsight, different earlier decisions would have delivered better long-term outcomes.

Decision-making under uncertainty is difficult, given the limitations of available data and the unpredictability inherent in assessing future development scenarios and needs. Experience has shown that new approaches to decision-making are required to take advantage of opportunities, manage risks and keep future options open. Maximizing rather than restricting future options for development outcomes and infrastructure is a primary goal.

Leading practice in infrastructure planning today includes options-based approaches that can enhance decision-making in the face of uncertainty, reduce downside risks, enhance abilities to pursue opportunities as they arise, improve decisions on infrastructure timing and capacity and reduce biases towards the short term and against long-term projects. Options-based approaches, such as using real-options economic tools (see box), value infrastructure approaches and investment that deliver flexibility required to adapt to inevitable changes and provide infrastructure with robustness across the range of plausible futures. These approaches also help avoid infrastructure decisions that cut off future options which may lead to more beneficial outcomes.

Options-based approaches also assist in staging infrastructure planning and provision. For example, governments can use their control of land and planning powers to investigate, design and designate development areas and transportation corridors without any expensive and irreversible physical activity such as construction taking place. Such designations have great value when development commences, in terms of savings to governments and project developers, more speedy project delivery, flexibility if circumstances change and minimization of impacts on environments and communities.

5.1.3 Lessons for Development Elsewhere

For Canada's North and other resource-rich regions, the chief lessons from the Australian experience in resources development and making infrastructure decisions under uncertainty are:

- Identifying regions and sub-regions with resources development potential, assessing scenarios for markets and development and undertaking corridor and precinct planning that can cater for a range of potential futures; and
- Applying options-based approaches to scenarios and planning to maximize flexibility is response to changing circumstances, including scale and output upside and downside.

5.2 CREATING EFFICIENT SUPPLY CHAINS

The key to the success of both study regions as world-scale producers and exporters has been the efficiency of their product supply chains. Governments and project operators in each region adopted different initial approaches to the development of supply chains.

In the Pilbara, iron ore producers built and operate railways and port terminals to create integrated "pit to ship" supply chains that are regarded as a global leading practice in efficiency.

The construction of four separate Pilbara railway systems over a period of 50 years, however, is inherently economically inefficient. The railways connect mines that are near each other, and for three systems, run to the same port. Railways even cross each other in several places. Further, other producers' inability to access railways until recently has delayed development of some new mines.

In response, the government of Western Australia, spurred by a national competition policy, has required the operators of the two

Real-Options Tools

Real-options analysis enables investors to recognize the value of flexibility in decisions on policy and investment and to incorporate flexible approaches to better manage development that is significantly impacted by uncertainty.

A real-options approach to investment planning, justification and management, supplements and addresses limitations in more traditional investment decision-making tools such as discounted cash flow modelling and cost-benefit analysis. These limitations are acutest where there are high levels of uncertainty about future developments that could impact the value of an investment or contract commitment, and where there is scope for adapting the strategy to emerging information about future conditions. Real options embed flexibility into a decision or investment and reduce the risks of locking out future pathways.

Where there are high levels of uncertainty, the value of a set of options is heavily dependent on both the robustness of those options in dealing with the likely range of possible futures, and the resilience and flexibility offered in the light of emerging information about markets, technologies, competitors, environmental threats and lessons from development experience.

Real-options analysis can be valuable when:

- There is a contingent valuation decision;
- There is sufficient uncertainty that it may be sensible to wait for more information — or to invest, before commitment, in gathering information;
- Value flows from the possibility of future growth options rather than just current cash flow;
- Uncertainty is great enough to make flexibility worthwhile; and
- There will be project updates and mid-course corrections.

Real options incorporate a broad range of methodologies and tools that vary in purpose and complexity and can be deployed to best suit the requirements of a particular development scenario or project.

Adapted from ACIL Tasman (2013) and Department of Treasury and Finance (2018)

most recently built railways to provide access to other producers. The government has also acted to create an integrated electricity system from privately owned components.

In Central Queensland, the state government built and operated the CQCCN coal railways and most coal terminals for several decades before later privatizing parts of the supply chains. This has enabled additional coal producers to enter the market quite easily and with moderate capital expenditure on infrastructure.

The resulting non-integrated supply chains, however, with different operators at each stage, have struggled to meet nameplate capacities of each component and this has led to bottlenecks, particularly at intermodal points. There have also been disagreements on allocation of new capital, on maintenance and on charges for haulage and handling.

In part, as a result, government agencies, coal producers and logistics providers have endeavoured to improve efficiency through closer co-ordination between supply chain components. Privatization of the CQCCN and open access to above-rail operators has led at least one large coal producer, BMA, to create a more integrated supply chain using its own trains between most of its metallurgical coal mines and its own coal terminal at Hay Point.

Potential development of the Galilee Basin coal region would involve privately constructed railways and possibly exclusive coal terminals as well, so it is moving towards the model adopted in the Pilbara, but with government taking a more hands-on role in corridor planning.

Gas development in both regions has used exclusive supply pipelines to LNG plants, but with open-access pipelines for domestic gas supply. Provision of multi-user corridors for pipelines, and in some cases other utilities, is important for both ease of development and reduction of environmental and social impacts.

5.2.1 Lessons for Development Elsewhere

It is clear from the Australian experience that supply chain efficiency is paramount to investment in mineral and energy projects. At the same time, host jurisdictions wish to ensure economic efficiency by avoiding unnecessary duplication of infrastructure and to minimize barriers to new entrants. For Canada's North and other resource-rich regions, the chief lessons for enabling supply chain and economic efficiency are:

- Plan for infrastructure while simultaneously prioritizing supply chain efficiency for producers, access for new entrants and economic efficiency;
- Plan and provide infrastructure corridors and development precincts that can be used by multiple entities and for multiple compatible uses, thereby helping to meet the efficiency and new entrant goals; and
- Integrate regional energy and water systems to enhance efficiency of delivery for multiple customers.

5.3 POLICY AND CO-ORDINATION ROLE OF GOVERNMENTS

The role of governments in designating resources corridors and development areas has been crucial to the successful development of export resources and maximization of benefits to economies. So too has been co-ordination and facilitation of development.

5.3.1 Development Areas and Corridors

Government in Australia, as in Canada, is the principal owner of land and has unique powers over both public and private land, particularly corridors and development areas for infrastructure use. Somewhat different approaches were adopted by the Western Australia and Queensland governments to corridor designation and development co-ordination.

In the Pilbara, a state agreement ratified by Parliament governed construction and operation of mines, infrastructure and logistics for each major development. Some recent developments have not required state agreements, as existing legislation and planning powers have been deemed sufficient. State agreements include designation of corridors and development areas.

During the past two decades, the government of Western Australia has also designated Strategic Industrial Areas (SIAs) around the state, including five in the Pilbara. These SIAs target processing industries that need large areas of land close to ports and near potential workforces in population centres.

The government of Western Australia led in creating a very long pipeline corridor for domestic gas in the 1970s, later widening it to allow for expansion, as well as creating another corridor from the Pilbara to the Goldfields mining region.

Queensland has adopted similar approaches to Western Australia's SIAs and corridors, designating multiple State Development Areas in Central Queensland to accommodate industry near the coast and pipelines and other linear infrastructure along corridors.

5.3.2 Co-ordination and Facilitation

As discussed in sections 3.4.6 and 5.3.2, both Queensland and Western Australia have adopted frameworks to ensure government co-ordination and expedite assessment and approval processes.

The Queensland Coordinator-General has broad and strong powers to facilitate development of major projects and infrastructure, including directing government agencies and even taking control of processes.

The Lead Agency Framework in Western Australia emphasizes effective co-ordination between government agencies and guidance to project proponents.

The end results for development in both Central Queensland and the Pilbara are similar. The more light-handed approach of co-ordination and guidance in Western Australia, however, has proven effective without risk of excessive government intervention.

Effective co-ordination between state and national governments on infrastructure was problematic until recent years, in part because of the constitutional, vertical fiscal imbalance between levels of government that puts most of the revenue-raising powers in the Australian government's hands, while states are responsible for much of the on-the-

ground spending. This has resulted in states having insufficient financial resources to construct infrastructure, forcing them to apply for funds to the Australian government and compete with other states for funding. The lack of nationally agreed assessment frameworks has made it difficult to prioritize infrastructure funding consistently.

Infrastructure Australia (IA) was established in 2008 as the national independent infrastructure advisor (Infrastructure Australia 2022a). IA set up an assessment framework to provide a national standard for best-practice infrastructure development. IA also publishes its Infrastructure Priority List, which is revised annually. Particularly relevant to the Pilbara and Central Queensland is the Australian Infrastructure Plan 2021 (AIP) (Infrastructure Australia 2021), which is a roadmap for infrastructure reform. AIP includes a section called "Unlocking Opportunity in Northern Australia and Developing Regions." Recommended reforms include:

- Infrastructure planning to complement and support the recently refreshed plan for northern development, *Our North, Our Future 2021–26* (Office of Northern Australia 2021);
- Improving co-ordination across and between governments on economic development and infrastructure planning;
- Identifying opportunities for shared infrastructure and reduced costs by undertaking joint assessment of enabling infrastructure requirements for major industry developments; and
- Supporting informed decision-making by investors and government, by collecting and publishing better data in a co-ordinated way across governments.

5.3.3 Lessons for Development Elsewhere

The lessons on governmental policies and co-ordination that apply in Canada's North and resources regions elsewhere include:

- Use governments' powers over land and planning to identify potential ports, development precincts and infrastructure corridors. Undertake reservation and conclude strategic land access agreements and environmental assessments to facilitate development by multiple users; and
- Implement efficient project assessment, approval and facilitation processes that work across agencies and between levels of government, and where possible include strategic access agreements and environmental approvals of corridors and precincts.

5.4 ADDRESSING THE PEOPLE FACTOR

Much discussion, including in this paper, focuses on hard infrastructure to service supply chains for outputs and inputs. A more urgent factor in the past decade is infrastructure for people, or social infrastructure, in several contexts:

- Building towns in resources regions that have adequate infrastructure and associated services to attract skilled people and their families to live there. Both workers for mineral and energy operations and workers to provide essential services such as education and health are required;
- Making policy and business decisions about whether operations are more feasibly serviced by local towns or by FIFO workforces;
- Ensuring towns have sufficient scale to be able to host workers and businesses that deliver services to mining; and
- Ensuring resources regions and their people derive sustained benefits from construction and operation of resources projects and associated infrastructure.

The 2009 study of 21 Australian resources regions commissioned by the Minerals Council of Australia (ACIL Tasman 2009) found that community infrastructure was a priority in the Pilbara, as schools, health-care facilities and sporting and recreation facilities do not meet residents' needs. These shortfalls were a key reason for the problems in attracting and retaining workers in the Pilbara.

For Central Queensland, the Minerals Council report found:

> The growth of mining and processing has been constrained by the difficulty of attracting and retaining staff who are concerned about the adequacy of health, education, and childcare services, as well as the price and availability of housing. Adequate housing and community infrastructure is therefore a priority.

In Queensland, the introduction of the Strong and Sustainable Resource Communities policy in 2017 (Queensland Coordinator-General 2022a) was driven by residents' concerns, particularly in Central Queensland, that their communities were being bypassed for supply of labour and services to coal and gas production.

In both regions, local government has played an increasingly important role in enhancing liveability through investment in municipal facilities such as parks, swimming pools and sporting and cultural facilities. Local governments also provide a range of services from maintenance of local roads to waste collection and management, to recreation services.

5.4.1. Lessons for Development Elsewhere

The key lessons for Canada and elsewhere on people and communities include:

- Where substantial regional cities and towns exist, improve liveability to better attract and retain workers and their families, while seeking scale to further improve liveability and potential for services hubs;
- Where there are few and/or sub-scale regional settlements and resources operations are remote from existing communities, support FIFO working arrangements from cities elsewhere; and
- Stronger measures to deliver lasting regional economic and social benefits from resources activity and taking action to help link Indigenous peoples in development to the economic benefits of resources development.

APPENDIX: REGIONAL PROFILES

A. THE PILBARA

A.1 PHASES OF DEVELOPMENT

Development in the Pilbara has occurred in four phases, each with a distinct approach to infrastructure (Limerick and Satchwell 2015). It is useful to understand this history to appreciate the path taken to arrive at the current situation:

1. **Iron Foundations 1962-1982**: Initial development of three large-scale iron ore projects, principally to supply the Japanese market, with government requiring each project developer to provide associated infrastructure and towns.
    - At the time of initial development of iron ore, Western Australia had a much smaller economy, based substantially on agriculture and gold mining. The state government did not have the financial resources to invest in major mining-related infrastructure.
    - Mining companies built most of the infrastructure required to support their projects. This resulted in exclusively operated railways, port terminals and utilities, as well as several towns built and governed by the companies, with Port Hedland, an existing open town, expanded through the satellite town of South Hedland.
2. **Emerging Energy 1982-2002**: Commencement of the LNG industry, to supply Japan and South Korea markets initially, and large-scale domestic gas supply from offshore fields and the onshore North West Shelf LNG plant, plus development of salt, gold, copper and tantalum operations.
    - The first LNG operator was required to provide housing for its workers in the open town of Karratha and financially contribute to government-operated community facilities such as schools and health-care centres.
    - So-called normalization of company towns began, with municipal assets and responsibility for services transferred to local government.
3. **China Growth 2002-2018**: Rapid expansion of the iron ore industry, by both existing and new project operators and with large amounts of foreign direct investment from China; plus development of three new LNG projects, similarly driven in large part by demand from China.
    - Operators built the necessary infrastructure to service new capacity, including railways, pipelines, iron ore and LNG terminals, and workers' accommodation facilities adjacent to operations.
    - National competition policy principles applied via state agreements to require operators of new railways to negotiate third-party access.
    - Project operators built more worker housing in Karratha and Onslow, but with most new operations and expanded capacity being staffed by fly-in, fly-out workers from the populated southwest of the state, plus some from other states.

- The two largest iron ore producers established processing plants (one in the Pilbara, one near Perth) to convert ore to iron metal, but with both closing after a few years of operation due to economic and/or technical shortcomings.
- At the urging of the private sector and local government, the state government invested in improvements to city and town centres as well as affordable housing and community facilities, such as schools, training colleges and hospitals, to improve liveability and assist with attraction and retention of skilled workers.
- Government negotiated with project operators and utility companies to create an integrated electricity system.

4. **Market Consolidation 2018–present**: Slower growth of iron ore production and LNG investment because of market uncertainties and a slowing of China's economic growth, and industry diversification into ammonia and urea manufacture, and lithium production, together with a focus on reducing iron ore production costs and diversifying iron ore and LNG markets.
   - Closer co-ordination between all levels of government in prioritizing and planning infrastructure.
   - Preparation, consultation and release of the Australian Infrastructure Plan by Infrastructure Australia, adviser to the Australian government, including specific recommendations relating to the development of northern Australia.
   - Preparation and release of the National Freight and Supply Chain Strategy (Transport and Infrastructure Council 2019) and complementary state strategies and action plans.
   - Preparation, consultation and release of the State Infrastructure Strategy, "Foundations for a Stronger Tomorrow," by the government of Western Australia (Infrastructure Western Australia 2022).

A.1.2 SUPPLY CHAINS IN THE PILBARA

Iron Ore Production and Logistics

Rail Networks

Unlike Central Queensland, with its integrated, open-access coal chain network, major mining companies have built and are operating railways in the Pilbara. In 2022, there were four separate iron ore rail networks in the Pilbara, operated by each of the four largest producers. Together, these networks transport 69 per cent by volume of the entire national freight task (Transport and Infrastructure Council 2019).

Three of these networks run parallel along much of their length to Port Hedland. Two networks, operated by BHP and Rio Tinto, are used exclusively by these two producers. Their long-standing State Agreements with the government of Western Australia provide for this, and they are not covered by the Western Australia Rail Access Regime (Economic Regulation Authority 2022). BHP's currently non-operational Goldsworthy Railway is covered by the National Access Regime, however (Australian Competition & Consumer Commission 2022).

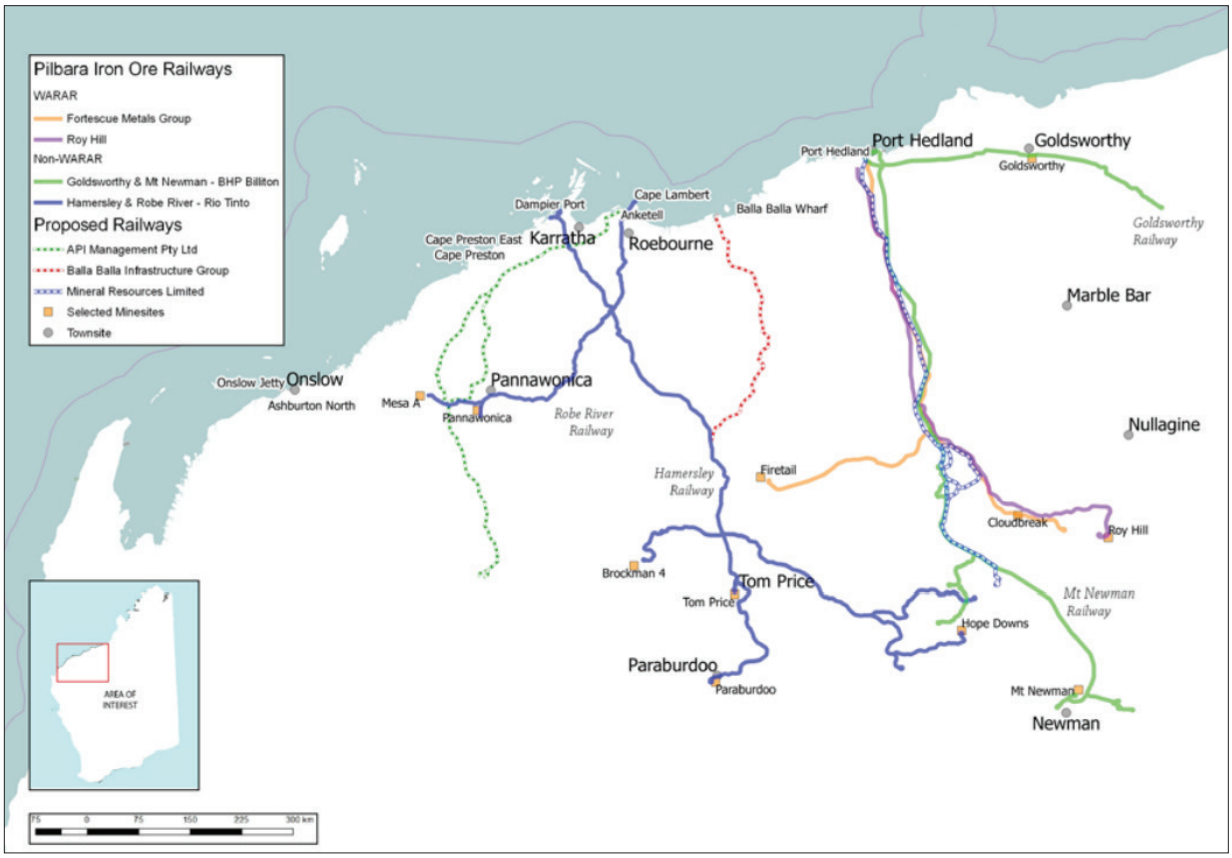
Aspiring middle-tier mining companies do not have access to this privately owned rail and port infrastructure, despite extensive litigation, and this has presented a major barrier to new iron ore market suppliers.

The Pilbara railways are acknowledged as among the most efficient in the world (Singleton 2002) and operators are understandably keen to maintain and improve efficiencies. In 2019, Rio Tinto implemented driverless, automated operations, dubbed AutoHaul, across its entire network. BHP and Rio Tinto also argue, with strong justification, that their rail networks are part of integrated production systems that run from mines to ship loaders. Mining, train loading, rail transport, unloading, management of ore stockyards and ship loading are closely co-ordinated to deliver the quantities and ore blends customers require at particular times. Use of BHP and Rio Tinto rail networks is expected to remain exclusive to the owners for the foreseeable future.

Two more recently built networks, operated by The Pilbara Infrastructure (a subsidiary of Fortescue Metals Group) and Roy Hill Iron Ore, are subject, under their State Agreements, to the Western Australia Rail Access Regime (WARAR). The WARAR provides for other parties to access the infrastructure under certain conditions. While the WARAR has not yet been applied to a specific access arrangement for The Pilbara Infrastructure, it has been undertaking rail haulage of iron ore for other producers and shipment via its berths (The Pilbara Infrastructure 2017). Roy Hill Iron Ore in 2021 reached agreement with another producer, Mineral Resources Ltd., to share existing rail infrastructure and build new shared port infrastructure (Mineral Resources Limited 2022). The government of Western Australia made sharing of terminal infrastructure a condition of allocation to Roy Hill Iron Ore of space for an additional berth at Port Hedland.

Mineral Resources, the operator of the under-construction Onslow Iron Development, will build a dedicated 150-km long-haul road from the mine to the Port of Ashburton, and use autonomous road trains for haulage. The relatively short-haul distance and autonomous truck technology have enabled Mineral Resources to avoid the high capital cost of a railway.

Figure 8: Existing and Proposed Pilbara Railways in 2017



Source: Treasury, WA (2017)

Review of Rail Access Regime

In 2017, the government of Western Australia commenced a review of the Western Australian Rail Access Regime. This review covered all multi-user railways in the state, but also examined the unique issues in access to the two subject Pilbara rail networks. The review identified the main benefits of facilitating effective third-party access in the Pilbara region as:

> Enabling further development of the iron ore industry in the region, particularly by 'junior' miners who would otherwise not be able to transport their product to ports for export.
>
> Preventing unnecessary duplication of rail infrastructure, which may lead to inefficient economic outcomes. (Treasury, WA 2017)

The review set out two issues:

1. Delays in access and increased costs for potential mineral investors, which might deter investment in exploration and development; and
2. Costs to railway owners because of compliance and monitoring requirements relating to specific and detailed technology standards used in vertically integrated iron ore railways, and potential loss of efficiency and flexibility in running their railway not captured by pricing arrangements.

The review recommended strengthening the below-rail access regime so that it:

> enables access seekers and railway owners to arrive at a commercially negotiated agreement that reflects the terms, conditions and risks specific to their access arrangements. At the same time, the Regime should maximise the efficiency of the regulatory process, so that railway owners, access seekers and the Regulator spend as little time and money as necessary in applying the Regime. (Treasury, WA 2020)

The review also considered a potential haulage regime but did not make specific recommendations. It did note, however, that "a haulage-based access regime could allow rail owners to retain control over the technical operation of the entire rail system, facilitating optimisation and management of risks."

The review found that the scale of these advantages remains to be clearly articulated or quantified.

Ports and Terminals

As in Queensland, ports in Western Australia are owned and operated by a government business enterprise, in the Pilbara's case, the Pilbara Ports Authority. Figure 9 shows the location of ports. The Pilbara Ports Authority, in conjunction with other state agencies, has planned several additional ports to the current operational ones.

At the ports, iron ore terminals comprising train unloaders, ore stackers, stockyards, berths and ship loaders are owned and operated by the larger iron ore companies.

The Port of Dampier consists of separate terminals for iron ore, salt, petroleum products and general cargo. Under State Agreements, Hamersley Iron (Rio Tinto Iron Ore) and Dampier Salt (Rio Tinto Minerals) operate from private facilities at Parker Point, East Intercourse Island and Mistaken Island. Five berths are used to export iron ore and a separate berth exports salt. These six berths account for over 80 per cent of the port's throughput.

Also at the Port of Dampier, the North-West Shelf Venture (NWSV) exports LNG, LPG and condensate from private berths at Withnell Bay, operated under a State Agreement. Trade from these facilities accounts for over 16 per cent of the port's throughput. An additional LNG berth was built in 2011 to service exports from the Woodside-operated Pluto LNG project.

Cape Lambert is an iron ore export port and terminal operated by Rio Tinto.

Port Hedland handles iron ore exports for BHP Billiton Iron Ore (BHPIO), Fortescue Metals Group (FMG), Roy Hill Iron Ore (RHIO) and several smaller producers, plus salt and other minerals (copper, manganese). Major producers operate under State Agreements that include the construction and operation of exclusive terminals. Smaller producers of iron ore and other minerals have access to a multi-user bulk-handling berth operated by the Pilbara Port Authority.

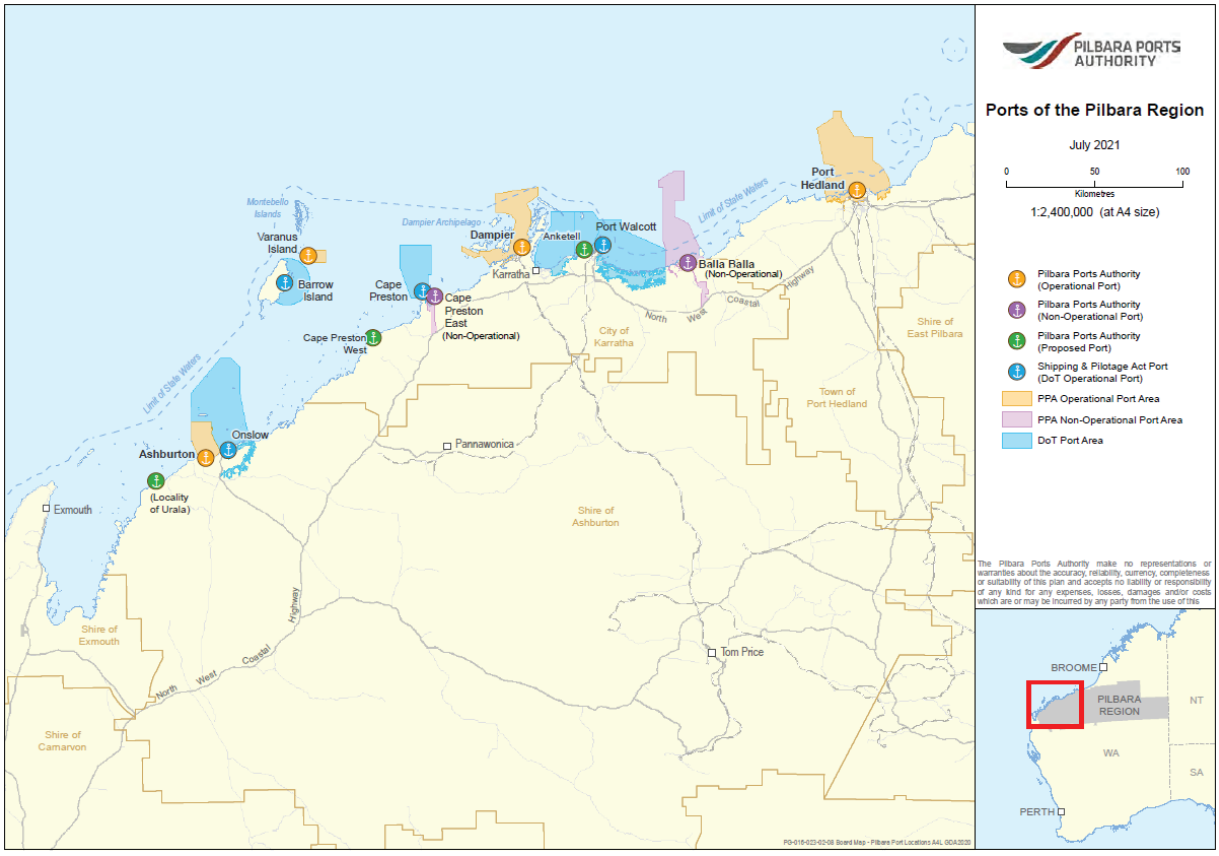
Accommodating ships of up to 270,000 tonnes, Port Hedland is the world's largest bulk port in terms of tonnage throughput, achieving a record 733 million tonnes in the 12 months ended June 2022.

As with Pilbara railways, third-party access arrangements vary between iron ore terminals depending on provisions in State Agreements. Those applying to FMG and RHIO require that third-party access be granted under commercial arrangements. The two other large producers are not required to provide access under their much older State Agreements.

Unlike Central Queensland ports, ports in Western Australia are not overseen by an economic regulator but come under port authorities legislation. Port authorities operate as government trading enterprises, with accountability to the state government.

The privately owned terminals operating within ports are not economically regulated, save for provisions in the relevant State Agreement between operator and government. This may seem anomalous with regulated access arrangements applying to some railways. In practice, however, access to terminals is negotiated between the owner and the access seeker or partner as part of rail access negotiations.

Figure 9: Pilbara Ports, Current and Proposed



Source: Pilbara Ports Authority

Figure 10: Aerial View of Port Hedland

Source: Pilbara Ports Authority

Gas Production, Processing and Transport

Since North West Shelf Joint Venture established the first LNG plant in 1989, it has been expanded with additional processing trains, and three additional plants, together with offshore infrastructure comprising platforms, floating production and storage vessels and pipelines.

Total capacity of the four plants is currently 46 Mtpa, with an additional 5 Mtpa of capacity to commence construction soon.

Most LNG from the Pilbara is sold under long-term contracts with customers. Some spot cargoes are shipped when production volumes permit and prices are attractive. For example, there have been a number of shipments to the United Kingdom and Europe during 2022, with gas shortages there instrumental in driving up global prices.

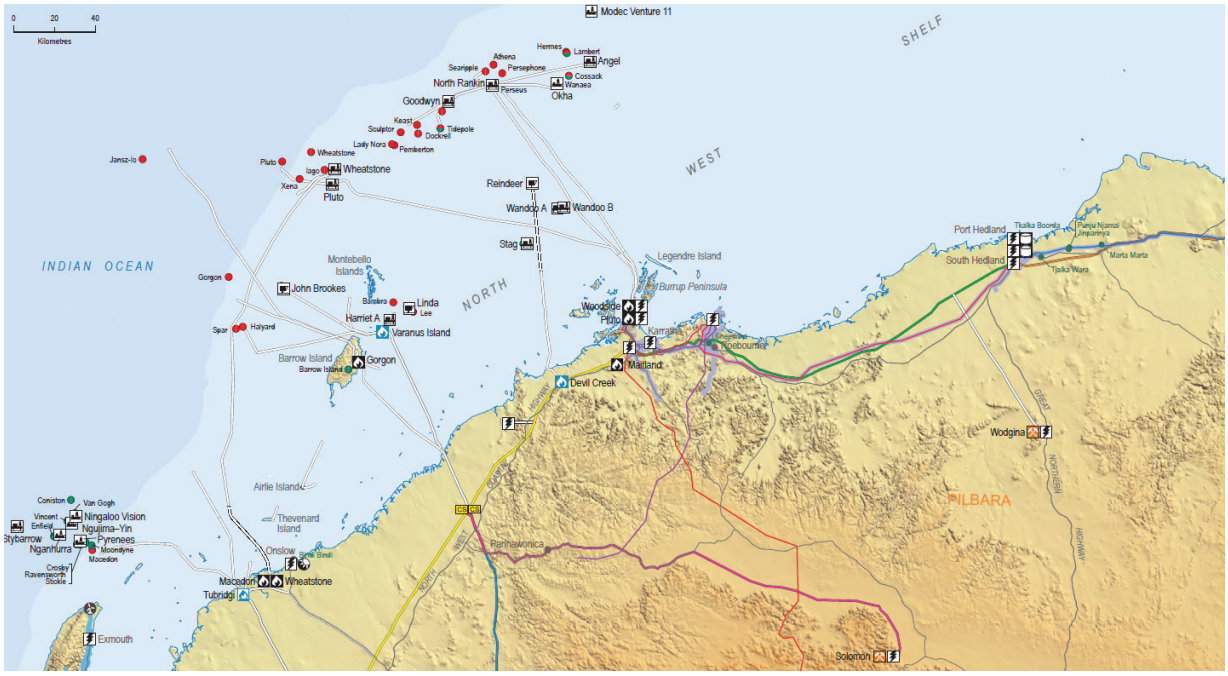
As shown in Figure 11, offshore pipelines are extensive and have been built to supply specific LNG plants from gas fields discovered and developed by the same operators. LNG plants are separately owned and operated, though there is cross-shareholding between some plants.

The location of gas fields of course is determined by geology. Locations of LNG plants reflect the availability of suitable land and adjacent waters suitable for LNG shipping. In one case (the Gorgon project), the availability of geological structures suitable for carbon dioxide storage was a location factor also.

Gas fields have been discovered, and infrastructure and LNG plants built over more than 30 years. Consequently, some pipelines cross others on the seabed, while routes and length of some pipelines are not as optimal as if they were planned and developed in an integrated way.

Recent business agreements between owners of gas fields and owners of LNG plants indicate that there is some rationalization of transport and processing, whereby gas is to be sold to existing LNG operators rather than supplying a new greenfields plant built by gas fields operators. Such arrangements will enhance economic efficiency.

Figure 11: Pilbara Energy Infrastructure



Source: Geological Survey and Resource Strategy, Western Australia (2021b)

As well as supplying LNG plants, gas from the Pilbara also supplies industry, electricity generation, businesses and households elsewhere in Western Australia. Gas provides about half the state's primary energy needs.

Gas is transported to domestic market via two major pipelines: the Dampier–Bunbury Natural Gas Pipeline (DBNGP) and the Goldfields Gas Pipeline. The DBNGP was built as part of the initial development of gas in the Pilbara. Funded by the government of Western Australia, it was underpinned by take-or-pay contracts with industry, and electricity and gas utilities.

Under Western Australia's Domestic Gas Policy, introduced in 2006, LNG project developers must also make gas equivalent to 15 per cent of exports available to the domestic market. This has resulted in ample supply for power generation and industrial uses in Western Australia, unlike East Coast gas markets.

The DBNGP corridor is approximately 1,600 kilometres long. While the pipeline itself was sold to private interests in 1998, the government retained management of the corridor. Also in 1998, the government commenced a project to acquire land and widen the corridor

to accommodate additional pipelines. The longest section, from Dampier in the Pilbara to the outskirts of Perth is now 100 metres wide. Pipeline operators may apply for and be conferred rights to construct and operate pipelines in the corridor (Government of Western Australia 2022a).

Inputs to Mineral and Gas Production

The Pilbara's resources operations and associated towns and ports require large volumes of inputs, including fuel, food, machinery and consumables for industry and communities. While fuel is supplied via ship from Singapore, the bulk of other inputs is supplied via road transport from the state capital, Perth, 1,400 to 1,600 kilometres distant. There are smaller volumes of freight out of the Pilbara, mostly by road to Perth. There is no rail link between Perth and the Pilbara.

Inbound road freight is estimated at 4.5 Mtpa and outbound at 1.4 Mtpa. By contrast, just 640,000 tonnes of general freight are moved by ship to and from the region (Australian Floating Decks 2019).

Tonnages of general freight to and from the Pilbara make up a large proportion of the intrastate freight in Western Australia, which is estimated at 30.3 billion-tonne kilometres in 2020 (Bureau of Infrastructure and Transport Research Economics 2022). The bulk of tonnage is transported via one road, the Great Northern Highway, which is just two lanes wide for most of its length. The Pilbara supply chain is thus fragile and prone to disruption from wet-season flooding and vehicle incidents. For this reason, the government of Western Australia has undertaken a continuous program of highway upgrading, with funding support from the Australian government.

Electricity and Water Supply

Unlike Central Queensland's integrated and predominantly state-owned electricity system, electricity infrastructure in the Pilbara initially was constructed by the various resources companies to supply their operations and associated towns. This resulted in several stand-alone systems that were not interconnected. Later, the systems were rationalized into two grids, one operated by a private company and another by a government trading enterprise.

In 2020, agreement was reached and legislation passed to create the North West Interconnected System (NWIS). Several companies own generation and transmission assets in the NWIS. Some stand-alone systems remain to service individual mining operations.

The state government is implementing reforms for the NWIS to improve the efficiency and effectiveness of electricity services. The two main components of these reforms are:

- Light-handed regulation to facilitate third-party access to designated electricity network assets in the NWIS; and
- An independent system operator.

People and Services Supply Chains

The Pilbara's resources operations are spread over a very large area. Long distances, the harsh climate in summer and costs of servicing small towns in remote locations have driven a preference for fly-in, fly-out (FIFO) operations for new mines and gas plants. Of the Pilbara's operational workforce of 52,000 forecast in 2012 by 2020, some 43,000 were expected to be FIFO workers (PricewaterhouseCoopers 2012). In resources operations across Western Australia, an estimated 50 per cent of the total workforce of 240,000 is employed under FIFO arrangements (Perth Airport 2022).

This contrasts with Central Queensland, where government has sought to minimize FIFO working in coal mining operations, requiring them to use locally resident workers and preference local suppliers.

Jet-capable airports and workers' accommodation have been built near each new major mining and gas operation in the Pilbara. There are now 17 jet-capable airports in the region, with most servicing individual mining operations or production hubs. Airports associated with cities and towns are serviced by regular public transport (RPT) flights, while charter flights service those adjacent to mining and gas operations. More than 150 RPT and charter flights a day operate to and from the Pilbara and southwestern residential population centres in Western Australia. Pilbara airports are variously owned by local government, private sector infrastructure organizations and in the case of those adjacent to mining operations, by mining companies.

At the same time, the need to attract and retain residential workers, both for the resources sector and to deliver services in the Pilbara, has driven government and private sector efforts to improve the liveability of Pilbara cities and towns. The state government's Pilbara Cities Initiative from 2011 supported town and city centre revitalizations for four cities and towns, plus community facilities to accommodate then-anticipated growth of Karratha and Port Hedland into cities of 50,000 people (DPIRD, WA 2022).

Population projections may not happen, however, given the climatic conditions, remoteness, costs of living and costs of servicing townships. Moreover, FIFO working has become the most popular mode for employees, with FIFO workers outnumbering residential employees. Further, remote control and automation of mining and supply chain processes is progressively reducing the intensity of employment on-site.

Adequate telecommunications are vital in this remote and large region for both connectivity for businesses and people, for telemedicine and to facilitate remote operations overseen from high-technology centres in Perth. For this reason, government, telecommunications providers and resources companies have made large investments in telecommunications infrastructure.

A.2 CENTRAL QUEENSLAND COALFIELDS

A.2.1 Supply Chains

Coal Production and Logistics

The Queensland government characterizes coal production and export processes and infrastructure as "coal chains." In Central Queensland, there are four coal chains, together making up the Central Queensland Coal Chain Network (CQCCN) (see Figure 12).

As discussed in section 5.2, the structure and operation of coal chains contrast markedly with iron ore chains in the Pilbara. The coal production and logistics systems in CQCCN are:

- Newlands system (incorporating the Goonyella-Abbot Point line completed in 2012)
- Goonyella system
- Blackwater system
- Moura system

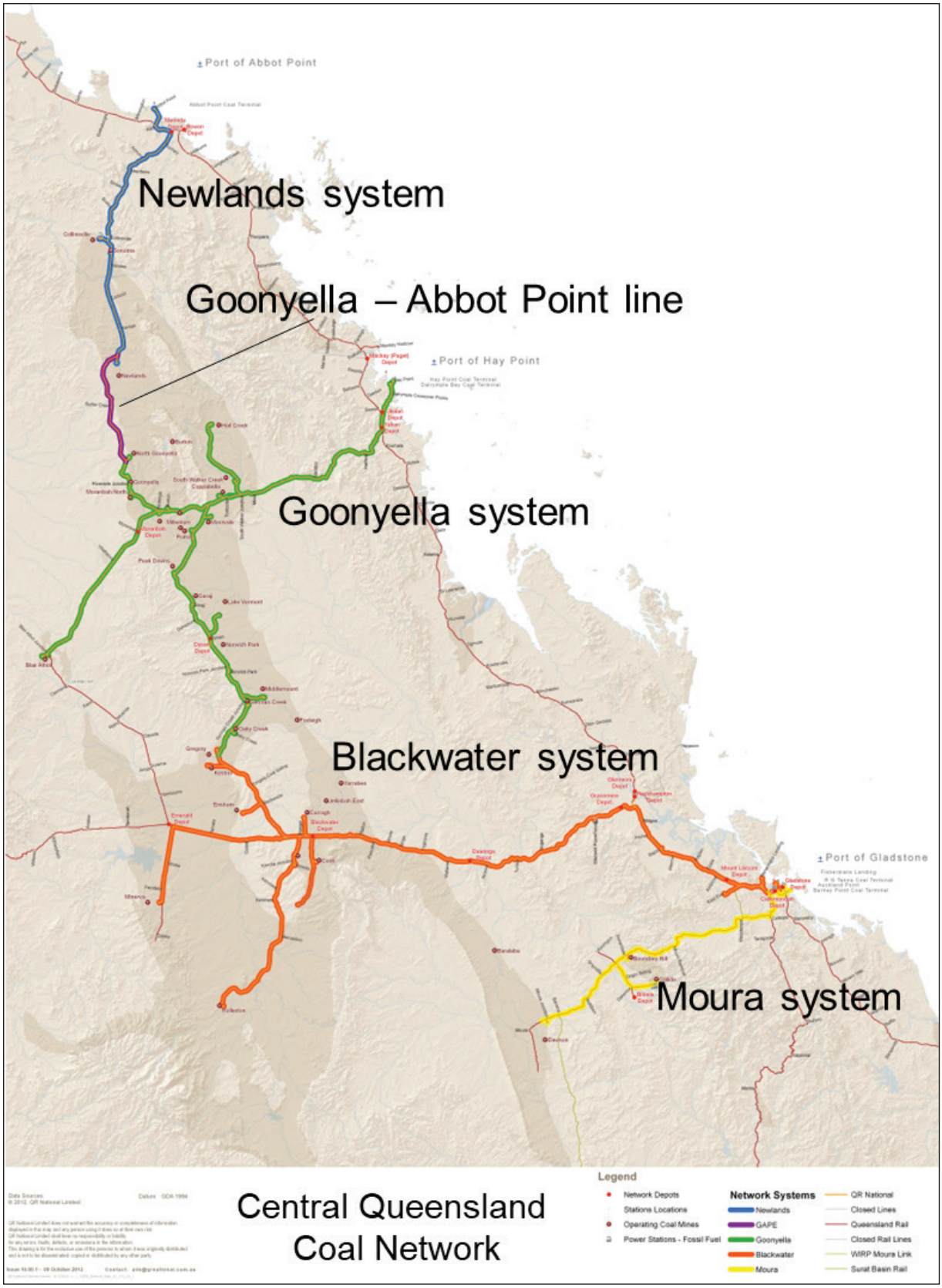
Rail is used to transport coal in the CQCCN for both domestic and export markets, due to high tonnages, long distances and efficiency of rail in transporting bulk product.

A coal chain, based on the Queensland definition, comprises:

- Mines and coal preparation plants, coal stockpiles and rail load-out facilities;
- Regional road, electricity and water infrastructure;
- A rail network (below rail and signalling) and rail haulage providers (above rail) that deliver product coal to export ports and domestic users (principally power stations);
- Coal export terminals, comprising rail unloading facilities, coal stockpiles and coal blending infrastructure;
- A deep-water coal export port to service coal terminals, with channels, wharves, conveyors and shiploaders; and
- Bulk ships to transport coal to overseas import ports.

Each component of these systems is separately owned and operated, though in some cases mine operators may also run a coal export terminal. There is a mix of public and private ownership, as discussed in the following sections.

Figure 12: Central Queensland Coal Chain Network



Source: Aurizon Ltd (2019), adapted by author

Ownership and Operation of Rail Networks

Until 2010, when new railway lines were constructed, or existing lines upgraded, they were financed and operated by the Queensland government's rail enterprise, Queensland Rail or QR (later QR National), which also operated the trains hauling coal. Coal producers and analysts expressed concern about this government-owned monopoly arrangement, its impact on supply chain efficiency and the prices QR charged (Freebairn 1992; Gill 1988).

In 1997, Queensland introduced an open-access regime to the coal rail network, aligned with the National Competition Policy (National Competition Council 2022). While QR National remained as owner of the rail network (below rail), other operators could seek access to operate trains (above rail). This enabled a private rail operator, Pacific National, to gain a foothold in the market, competing with QR National.

In 2010, the Queensland government announced further changes to the ownership and operation of coal rail networks, both below and above rail (Queensland Government 2010). The changes were designed to foster competition between above-rail operators, using the natural monopoly below-rail network. They comprised:

- Privatization of QR National and its listing on the Australian Securities Exchange
- Strengthening open-access arrangements and regulatory safeguards, including:
- Regulated access charges to prevent monopoly pricing;
- Strengthening open-network access;
- Preventing higher access charges through cost shifting from unregulated operations to the regulated coal network business;
- Preventing price discrimination favouring QR National's above-rail operations;
- Ensuring equivalent service levels for all operators; and
- Continuing network investment and maintenance programs to foster above-rail competition.

The Queensland Competition Authority (QCA), Queensland's independent economic regulator, oversees the regime. The QCA role (Queensland Competition Authority 2022) is to ensure:

- Significant government business activities which compete with the private sector do so fairly (competitive neutrality);
- Government and non-government owned monopolies do not abuse their market power (monopoly prices oversight); and
- Essential economic infrastructure is accessible to all potential users (third-party access).

In 2022, there were three operators of above-rail coal haulage services: Aurizon, Pacific National and BMA Rail, which is a division of coal producer BHP-Mitsubishi Alliance (BMA). BMA Rail hauls most of the coal produced by six of BMA's seven mines to the BMA-owned Hay Point Coal Terminal. This arrangement allows BMA to operate an integrated pit-to-port operation, albeit sharing access to the rail network with other operators. This contrasts with the Pilbara rail systems where both above-rail and below-rail components are used exclusively by each iron ore producer.

Future development of coal from the Galilee Basin to the west of the Bowen Basin coal measures, if it occurs, is expected to be facilitated by railways built and operated by the private sector, either coal producers themselves or dedicated rail operators. The Queensland government has established the Galilee Basin State Development Area, including two lengthy corridors for rail to Abbot Point, as well as provision for other services.

Coal Ports and Terminals

The CQCCN has five coal terminals spread between three government-owned ports:

- Port of Gladstone: operated by the Gladstone Ports Corporation (GPC)
- RG Tanna Coal Terminal: operated by Gladstone Ports Corporation, the port owner (60 Mtpa capacity); and
- Wiggins Island Coal Export Terminal: owned by a consortium of resources companies (8 Mtpa).
- Port of Hay Point: operated by the Queensland government's North Queensland Bulk Ports (NQBP)
- Dalrymple Bay Coal Terminal: owned by the Queensland government and leased to Dalrymple Bay Infrastructure, a listed infrastructure entity (85 Mtpa); and
- Hay Point Coal Terminal: owned by BHP Mitsubishi Alliance (55 Mtpa).
- Port of Abbot Point
- Abbot Point Coal Terminal: owned by the North Queensland Bulk Ports, and operated by North Queensland Export Terminal, another government entity (25 Mtpa).

Ports are operated by statutory bodies established by the Queensland government. Coal terminals are operated variously by publicly and privately owned entities.

Under Queensland legislation, the Queensland Competition Authority (QCA) may regulate all the ports in Queensland if directed to do so. The QCA currently regulates only the privately operated Dalrymple Bay Coal Terminal, for both access and pricing. The remaining three multi-user coal terminals and port authorities are not subject to formal competition regulation. The single-user Hay Point Coal Terminal, operated by the BHP Mitsubishi Alliance, is closed to third-party access and is therefore unregulated.

Efficiency of Coal Chains

The experience of Queensland coal chains has been that their efficiency rests largely on effective co-ordination between components along a coal system (PricewaterhouseCoopers Consulting (Australia) and Ranbury 2017). This has improved markedly since 2007, when all participants realized that the coal chains' capacity fell short of the nameplate capacities of each component. Initiatives to improve co-ordination between components were implemented from 2009, including establishing co-ordination centres where representatives of operators of coal chain components work together (see case study).

A government-commissioned review of the Goonyella coal chain in 2007 (O'Donnell 2007) found that the efficiency shortfalls were economically costly: "The Goonyella Coal Chain (GCC) is a vital link for delivering Australian-produced coal to market yet has been performing at below plan for the last twelve months. This underperformance has resulted in a lost economic benefit in excess of $1 billion during the past year alone."

Gas Production and Transport

Coal seam gas in Central Queensland is produced using hydraulic fracturing from wells dispersed through production fields. Networks of pipelines, owned and operated by gas producers, gather gas for treatment at in-field plants before it is transported along owner-operated trunk pipelines to three LNG plants located on Curtis Island near Gladstone. Each dedicated underground supply pipeline network has a total length of up to 750 km.

The three LNG plants and their nameplate capacities are:

- Australia Pacific LNG (9 Mtpa)
- Queensland Curtis LNG (8.5 Mtpa)
- Gladstone LNG (7.8 Mtpa)

Some gas is transported via multi-user domestic gas pipelines to Australian customers, including electricity generation plants and manufacturers of hydrocarbon-based products such as chemicals and fertilizers. These pipelines have been built and are operated by pipeline companies, which transport gas for parties at a fee.

The Queensland government, in co-operation with the coal seam gas industry, implemented a strong hand in infrastructure planning and co-ordination for this new industry sector as it began to develop. In particular, the government defined and reserved pipeline corridors, and conducted assessments required for environmental approvals of the corridors. These corridors are designed to accommodate multiple pipelines for gas and other products that are built and operated by different operators now and in the future. The corridors are:

- Callide Infrastructure Corridor State Development Area (SDA), which was declared in 2009 and can accommodate up to eight underground gas pipelines, with different

Case Study: Dalrymple Bay Coal Chain Co-ordinator (DCCC)

The Dalrymple Bay Coal Terminal (DBCT) is a common-user facility servicing several mines in the central Bowen Basin. DBCT is owned by the Queensland state government and leased to DBCT Management (Brookfield Asset Management).

A central co-ordination role was created for the DBCT following the recommendations of a joint Queensland government and Queensland Resources Council supply chain review conducted by Stephen O'Donnell in 2007.

A consortium of terminal users is responsible for the day-to-day operation of the terminal under the terms of the operating and maintenance contract. DCCC members currently include Rio Tinto, Peabody Energy, Pacific National (PN) and Glencore.

Members have implemented an agreement and charter, which includes:

- Appointing a central co-ordinator to oversee the coal chain operations; this is currently PN, which acts on behalf of all members in submitting orders to the port and the below rail operators;
- Identifying improvement Initiatives;
- Developing an integrated plan across the whole of the coal chain; and
- Monitoring and reporting on the whole of coal chain performance.

Source: PricewaterhouseCoopers Consulting (Australia) and Ranbury (2017)

operators. There are currently three pipelines. It is 44 kilometres long and generally 200 metres wide and is designed to allow the transport of gas to LNG plants on Curtis Island in the Gladstone SDA;

- Stanwell-Gladstone Infrastructure Corridor SDA, declared in 2008, is a 90-kilometre long, 100-metre wide corridor designed to accommodate up to seven underground pipelines for purposes such as water supply (treated, raw or sea), gas, mineral slurries and telecommunication cables; and
- Proposed Bowen Basin pipeline corridor, which is currently under investigation, including for the potential for infrastructure, including a gas pipeline, to connect gas reserves in the Bowen Basin to domestic and export markets, in addition to contributing to Queensland's energy transition though productive use of incidental coal mine gas (Department of Resources 2022).

The Queensland government identifies the following benefits of infrastructure corridors (Queensland Coordinator-General 2022c, d):

- Providing greater certainty about approval processes;
- Safeguarding land from incompatible uses;
- Acquiring of easements through public and privately owned land, allowing infrastructure operators to more easily obtain permits to construct and operate pipelines;
- Minimizing impacts to landholders and the environment through efficient use of land and pre-identification of ecological and heritage values;
- Minimizing disturbance to existing infrastructure;
- Optimizing corridor length and avoiding terrain constraints;
- Maximizing the potential to consolidate compatible infrastructure;
- Providing ease of access for construction and operations; and
- Giving guidance and development certainty to industry.

Inputs to Coal and Gas Production

The CQCCN also facilitates movements of inputs for coal production. Inbound goods in the CQCCN include bulk liquids (diesel fuel and acids), fertilizers, cement, explosives, machinery and spare parts.

Road freight is the preferred transport mode for these goods as it is flexible around size of shipments, origins and destinations and speed of delivery.

Electricity and Water Supply

Supplies of water and electricity are essential to coal and gas production, as they are to other industries and communities in Central Queensland.

Water for mining is either abstracted from underground sources, pumped from river systems or supplied from dams via pipelines.

Urban water is supplied from rivers and dams by either Queensland government agencies or local government authorities.

Irrigated agriculture uses large amounts of water supplied by dedicated water storage and irrigation infrastructure constructed and operated by government.

The Queensland government historically has owned and operated electricity generation and infrastructure. During the past three decades, and in line with national competition policy, generation, transmission, distribution and retail functions have been split from former integrated utilities and in some cases, privatized.

Central Queensland hosts three large coal-fired power stations, with two operated by government-owned corporations and one by a U.S.-based private sector corporation. The Queensland government has established renewable energy zones, including one in Central Queensland, to host renewables projects and offtake customer industries.

Inputs for Other Industries

Other industries in Central Queensland also depend on effective and efficient supply chains for transport and processing of the goods they produce, and for inputs. Agriculture and cattle-grazing industries use principally road transport for their products, though some bulk agriculture products are transported also by rail.

People and Services Supply Chains

The numerous towns and cities in Central Queensland require many goods and services. Along the coast, goods are transported by both road and containerized rail, while inland, road transport is the preferred mode due to its flexibility and efficiency.

Movement of people between population centres and to and from these worksites, including mines and farms, is undertaken mostly by road, with air transport used extensively to and from the state capital of Brisbane. Unlike the Pilbara's charter-dominated air transport, however, most air services to and from Central Queensland are regular public transport (RPT) services. Five airports are serviced frequently by a mix of turboprop and jet services.

Central Queensland Towns

As noted in section 4.1, the inland part of the Central Queensland coalfields region has 24 towns, many of which service elements of the coal and gas production sectors. Sixteen of these towns existed prior to modern coal development, while eight were developed by coal companies to service their mining operations. All have now been normalized and operate as conventional communities, though some are mostly populated by workers and families associated with the coal industry (Queensland Coordinator-General 2022a).

Several shortcomings have been identified with the pattern of town development:

- Some towns are sub-scale in terms of population and therefore unable to attract the full range of services residents expect, including high-quality secondary schooling, health and family services, comprehensive retail services and recreation services;
- Lack of scale of towns sufficient to host substantial service industries supplying the coal and gas sectors;

- Shortfalls in available and diverse housing stock, leading to shallow and sometimes expensive rental markets, which inhibit the towns' ability to attract service workers;
- High costs of providing government and private sector services to small, scattered communities;
- Some communities bearing the costs of coal development, while the bulk of benefits flow to larger cities and towns (Rolfe, Miles et al. 2007); and
- The above issues leading to larger drive-in, drive-out (usually weekly) workforces that have their usual residences in cities near the coast.

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