Deloitte.

Ore else: preliminary nature impacts of a green iron value chain

Technical Appendix B

March 2025

Contents

List of Abbreviations & Definitions

Acronym	Full name
BAU	Business as Usual
BF-BOF	Blast Furnace Basic Oxygen Furnace
CO2-e	Carbon Dioxide Equivalent
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EPBC	Environment Protection and Biodiversity Conservation Act (1999)
GHG	Greenhouse Gas
GL	Gigalitres
GW	Gigawatt
H2	Hydrogen
Ha	Hectares
H2-DRI	Hydrogen-based Direct Reduced Iron
H2-DRI-EAF	Hydrogen based integrated Direct Reduced Iron & Electric Arc Furnace
ILUA	Indigenous Land Use Agreement
IUCN	International Union for Conservation of Nature
kL	Kilolitres
L	Litres
Mha	Million hectares
Mt	Million Tonnes (metric)
MW	Megawatt
MTCO2-e	Million Tonnes Carbon Dioxide Equivalent
NTD	Native Title Declaration
NG	Natural Gas
NG DRI	Natural gas based Direct Reduced Iron
NG-DRI-EAF	Natural gas based integrated Direct Reduced Iron & Electric Arc Furnace
NRS	National Reserve System
P.A.	Per Annum
PV	Photovoltaic
REE	Rare Earth Element
t	Tonnes (metric)
TNFD	Taskforce for Nature-related Financial Disclosures
UK	United Kingdom
WWF-A	WWF-Australia

Term	Definition
Low emissions iron/steel	Steel produced with an emissions intensity of between 0.05 to 0.4 tons of CO2-e per ton of steel depending on scrap ratio used. (ResponsibleSteel & IEA)[1]
Green iron/steel	Iron and steel produced using solely renewable energy sources and renewable hydrogen, mitigating fossil fuel use[2].

Source(s): 1. Global Efficiency Intelligence, 2023. 2. World Economic Forum, 2022.

Executive Summary

60 Second Summary

1. Australia is in the early stages of its climate transition, with rules and incentives beginning to increase the pace of decarbonisation and flatten our emissions curve. The stakes are high – **by choosing rapid decarbonisation, Australia is making a bold play for 240,000 more jobs** and a bigger, more complex economy.[1]
2. Green iron is one of the most significant new industries emerging as Australia becomes a renewable energy superpower. **Estimates of the scale of the opportunity range from $96bn[2] per year to $295bn.[3]** Much of the enabling investment will be concentrated in regional Australia and transition-exposed places.
3. Delivering a scaled green iron industry will require a **step change in renewable energy.** Hundreds of gigawatts (GW) of wind, solar and storage will be needed to channel green electrons into mining projects and hydrogen electrolysers – up to 7GW of renewable capacity may be required to underpin each 2.5Mt of green iron production.[4]
4. Unfortunately, **Australia is not on track to realise green iron exports anytime soon.** Our renewable deployment rates are averaging less than 3GW per annum. Even doubling our deployments will only be sufficient to decarbonise existing industries, not open new export opportunities.[5]
5. The only path to an orderly transition, which also sees Australia reap the dividends of the energy transition, is to **turbocharge the huge capital investment** in renewables and green iron by increasing deployment speed and **leveraging this investment to regenerate nature prospectively**.
6. However, this high reward and sustainable pathway can only be met if we 'look beyond' the strict commercial imperatives in order to establish that elusive, yet critical, social licence.[6]
7. Project proponents consistently rate **community engagement and approvals processes as pain points in the development process**.[7] Communities are no longer accepting of the superficial or abstract trade-offs between nature and regional communities for industrial development, and increasingly they are pushing for a share of the upside of projects. Equally, there are persistent and significant challenges with current environmental and project approvals processes which are not delivering outcomes.[8]
8. Social licence linked issues will only **intensify as Australia seeks to raise deployment rates**. A significant share of announced solar and wind projects are concentrated in Australia's 15 biodiversity hotspots and more than 45% of announced projects overlap with First Nations land. Almost half of announced hydrogen projects are in areas of high-water stress.
9. Raising deployment rates looks **challenging without a new approach to nature**. But prioritising nature using traditional planning and approval schemes risks delaying climate action. Prioritising pace of decarbonisation without recognition of **planetary boundaries undermines systemic economic resilience and risks a repeat of Indonesia's nickel market**.
10. So how do we deliver a new Operation Warp Speed to accelerate renewable deployments and regenerate nature? **We need to thread the needle** through reform and practice by understanding that:
    a. Going faster will **create additional commercial value** for developers, and
    b. Speed must be conditional on an element of this new value being reinvested in regeneration and shared prosperity.
11. This is a **new approach, with innovation in the planning system at its heart.** This means:
    a. Coordinating at place level
    b. Adopting a culture of regulatory experimentation
    c. Proactively conditioning production incentives
    d. Embracing digitisation and data-enabled tools

Notes: 1. Deloitte Access Economics 2023. 2. Accenture 2023. 3. Superpower Institute 2024. 4. Deloitte analysis. 5. AEMO 2024. 6. Australia Energy Infrastructure Commissioner 2023. 7. Clean Energy Council 2023. 8. Samuel Review 2020.

Key findings

Extractives	Energy	Hydrogen
• Existing mining activities interact with highly biodiverse regions – in the Pilbara and Northern Kimberley areas of WA – and two International Union for Conservation of Nature (IUCN) protected areas. Australia's **30 by 30 conservation target** will likely lead to more interaction in future. • Iron ore mining is water intensive, requiring more water than coal to produce. There are some existing critical iron projects situated in areas of **arid and lower water use** which may require increased dewatering and adoption of circular models to minimise impacts to water security in vital regions for exploration. • Historically, Indigenous people have disproportionately been impacted from mining activities. It may be necessary to negotiate amendments to existing and new Indigenous Land Use Agreements (ILUAs) and Native Title Determinations to **incorporate nature conservation practices** and facilitate Traditional Owner **involvement in environmental management**. • Hydrogen DRI uses almost three times more iron ore than BF-BOF processing and requires critical minerals for renewables. However, it leads to a **more positive climate impact** than other production pathways.	• A combined 7.1GW solar PV and wind turbine plant is estimated to require **1.4MT of materials**. This is primarily comprised of five key materials which would consume **less than 10% of Australia's annual domestic production** of each resource. • While only 4.5% of announced projects are expected to be located within IUCN protected areas, they would **interact with at least 10 of Australia's 15 biodiversity hotspots**. Global guidelines and directives are showcasing best practice methods and opportunities to create environmental benefits across renewable energy development. • More than 45% of announced renewable energy projects will be situated on Indigenous lands. However, **only 1% of Australia's existing renewable energy projects provide equity benefits** to Indigenous peoples, compared to Canada's 20%. • Renewables make up **16% of the land required for H2-DRI production**. Unlike land for mining, land used for renewables can be used for multiple purposes, including improving biodiversity and environmental value.	• Announced hydrogen project sites interact with at least **half of Australia's biodiversity hotspot areas and three IUCN designated areas**. Future project developments will need to consider the expansion of protected regions to receive favourable outcomes. • Renewable energy inputs to produce green hydrogen requires sizable land compared to the footprint for gas-powered facilities. This will likely mean greater disturbances to bioregions, however impacts are mostly attributable to facility construction. • Hydrogen production is water intensive, with a single **2.5Mt p.a. steel facility requiring 1.78GL of water**. This is equivalent to just over 13% of the annual water consumption by BHP's South Australia copper mine and 0.01% of Australia's annual water consumption. • There are efforts to improve First Nations participation and leadership on the development of hydrogen projects. The East Kimberley Clean Energy hydrogen project will see an opportunity for **three Traditional Owner groups to have a 75% stake** in the project. Funding allocated through the Hydrogen Headstart program could also see further engagement with First Nations communities.

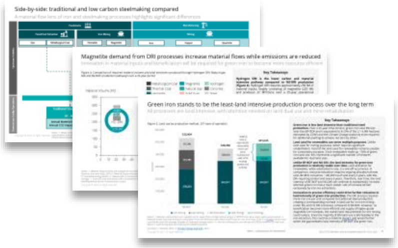
Navigating this report

This report summarises the work undertaken as part of an investigation of the interdependencies between climate, regeneration, and green iron.

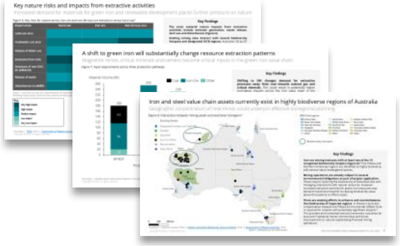
It includes an overview of the nature risks associated with the green iron value chain, with a focus on water, biodiversity value and Indigenous interests.

Context for the green iron opportunity, including dependencies on regeneration and decarbonisation, and methodology for this assessment.

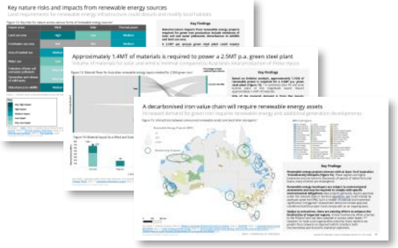
Comparison of the environmental impacts of low carbon steelmaking and the traditional steelmaking process through a material flow lens.



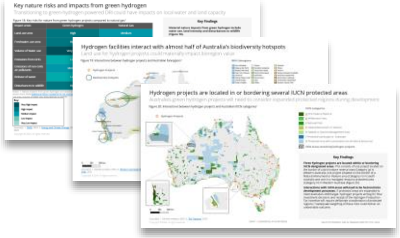
High level overview of nature impacts of mining for ironmaking including water risk, biodiversity value and Indigenous interests.



High level overview of nature impacts of the energy inputs into ironmaking including water risk, biodiversity value and Indigenous interests.



High level overview of nature impacts of the hydrogen inputs to green ironmaking including water risk, biodiversity value and Indigenous interests.



Bettering the Climate & Nature

Context and Purpose

Context

WWF-Australia (WWF-A) has recently launched a forward-looking strategy to Regenerate Nature by 2030. This is framed by a mission to restore and regenerate areas of Sky, Country and Saltwater, allowing nature to heal. One of the key ambitions for WWF-A is to focus on fast, best and just outcomes for communities, nature and climate.

A push for faster decarbonisation of high-emitting industries is driving innovations in the development of green metals. Increased uptake of low-carbon alternatives to steel production, such as the use of direct reduced iron (DRI) furnaces and renewable electricity sources, will require increased deployment of wind, solar and hydrogen assets. Australia is well-placed to be a key player in the green iron value chain, capitalising on its vast reserves of iron ore and other precious minerals, as well as its suitable conditions for renewable energy development.

However, the underlying nature and climate impacts of the green iron value chain is currently undervalued. Competing demands on land and landscape from industry will require data, dynamism and highly localised development conditions to ensure a net positive impact for nature. These two mutually dependent issues will require consideration of the cumulative impacts in place as well as considerations of the macro and microeconomic impacts across the lifecycle from a shift to a decarbonised value chain.

This report assesses the high-level climate and nature impacts and dependencies of the green iron value chain. It considers the counterfactual case across the value chain from the fossil fuel-powered process and transitory gas-powered iron production method to a future green iron opportunity for Australia. The analysis underpins a suite of key factors to ensure nature regeneration is intrinsically considered within the economic and decarbonisation movement.

Purpose

This report seeks to answer two fundamental questions about climate and regeneration considerations for green iron:

1. *What types of impacts will the development of a commercial scale green iron value chain have on Australia's natural environment?*
2. *What considerations should organisations such as WWF-A take into account to ensure a green iron value chain maximises regeneration?*

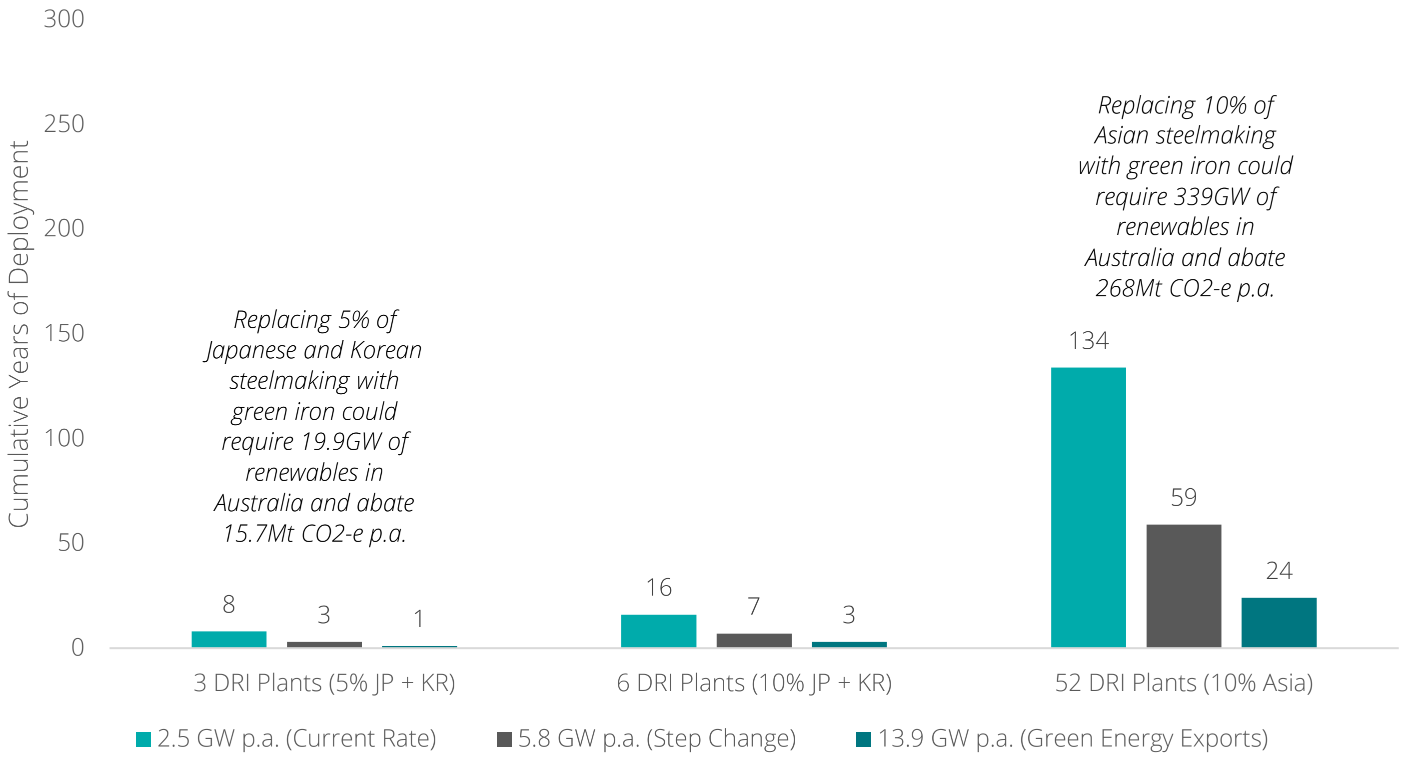
Answering these questions will provide an understanding of the key policy conditions and decisions to maximise regeneration outcomes from a green iron value chain.

Note: This report and Mined the Gap: Navigating the Transition to Australia's Green Iron Future solely considers the nature impacts from the green iron value chain to Australia quantifiable by Deloitte's Green Value Chain Explorer – Iron and Steel.

Asia's steel decarbonisation turns on the speed of Australian renewable deployment

Raising the pace of Australian renewable deployment is a prerequisite to becoming a green iron exporter

Figure 1: Years to deploy sufficient renewables based on different Asian steel decarbonisation scenarios under various deployment assumptions



Notes: Steelmaking capacity numbers are taken from Worldsteel, 2023. Abatement potential and renewable requirements are taken from Deloitte's Green Value Chain Explorer – Iron and Steel. Deployment rates are taken as a 5 year rolling average in 2030 from 2024 ISP scenarios. The SunShot report - Accenture 2023 assumes 100% of Australia's met coal exports are replaced by an equivalent volume of green iron. It is important to note the years of deployment estimates assume all renewables are dedicated to green iron which is unlikely to ever be the case. It is also important to note that there are supply limited to DR-grade iron ore which could also limit green iron via a green H2-DRI-EAF process for Australia.

Key Takeaways

The support for Australian-made green iron creates an imperative to focus on renewable deployment. Unlocking a sustainable economy is contingent on rapid decarbonisation, which will be impossible without the widespread and swift roll out of renewable energy projects and supporting infrastructure.

Achieving meaningful emissions reductions from Asian steelmakers would require significant renewable deployment. Replacing 5% of Japanese and Korean steelmaking (7.7Mt) with green iron could require 3 Australian DRI plants. Replacing 10% of steelmaking across Asia (131Mt) would be closer to 52 DRI Plants, requiring upwards of 330GW of renewable capacity in Australia.

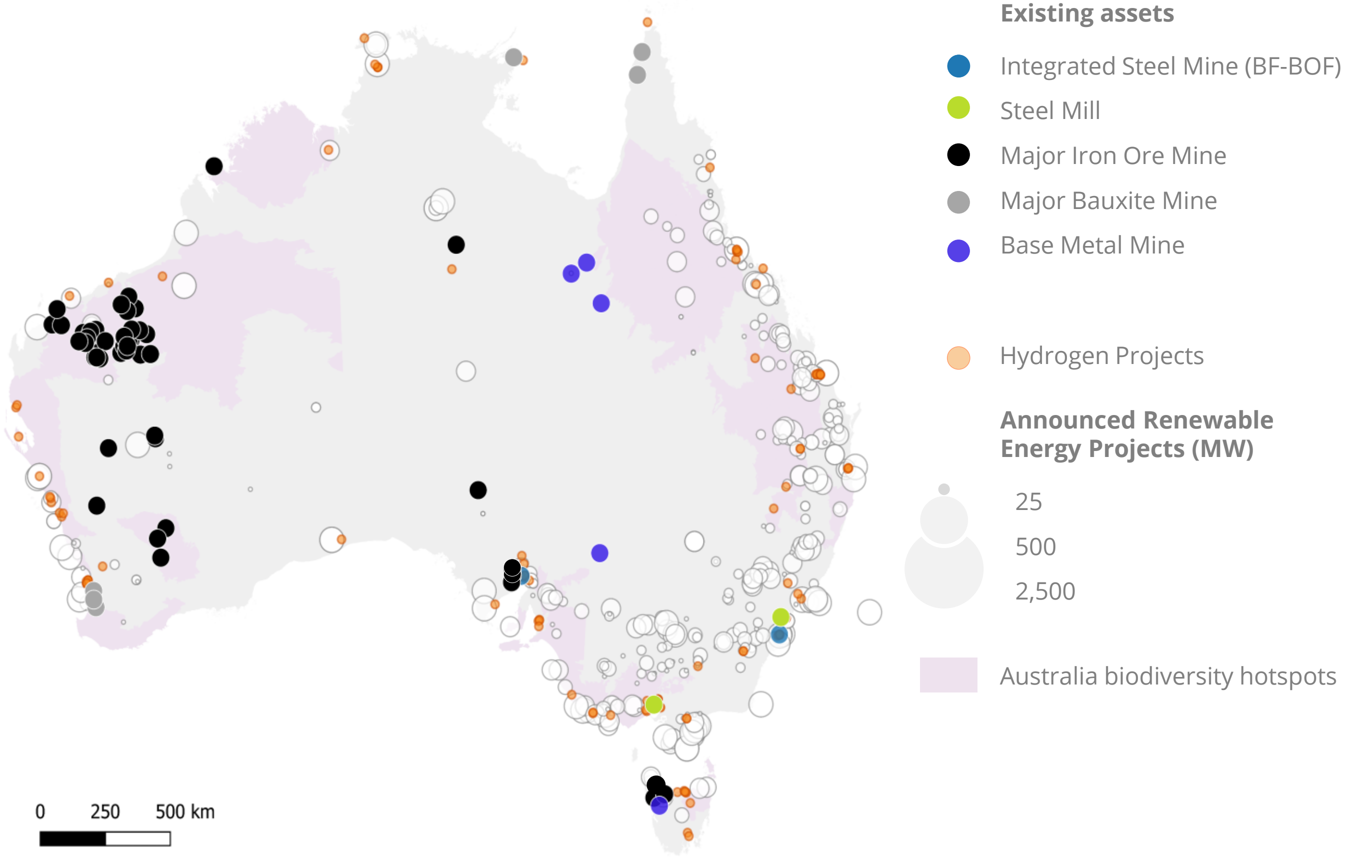
Australia's renewable deployment rates must be substantially lifted to accelerate steel decarbonisation in Asia. Currently, our deployment rates are too slow to drive scaled emissions reductions in the 2040s. Figure 1 highlights the significant discrepancy between where we currently sit and the rate we need to achieve to unlock green iron exports to Asia.

Building out the value chain is likely to have significant impacts and dependencies on nature. Deploying renewables and green manufacturing will be a resource-intensive endeavour, requiring increased extraction of minerals and land use. Understanding these impacts ex ante will be essential to successfully navigating the mutually reinforcing objectives of decarbonisation and regeneration.

Australia’s projected iron ore asset deployment is inextricably linked to nature

Acceleration of development will require structural consideration of nature impacts

Figure 2: Overlaying key elements of the green iron value chain with Australia’s biodiversity hotspots[1]



Notes: 1. Biodiversity hotspots are approximate and provide an illustrative example based on information from the Western Australian Biodiversity Science Institute. Extraction and processing assets, announced renewable energy projects and hydrogen projects is based on databases from GeoScience Australia, DISER, the Global Energy Monitor, DCCEEW and WABSI. 2. Williams et al., 2011

Key Takeaways

There is significant overlap between Australian biodiversity hotspots and assets within the green iron value chain. Biodiversity hotspots are areas under threat from human activity, often with high concentrations of endemic species. More than half of Australia’s fifteen hotspots interact with current or announced projects required to deliver green iron exports (Figure 2).

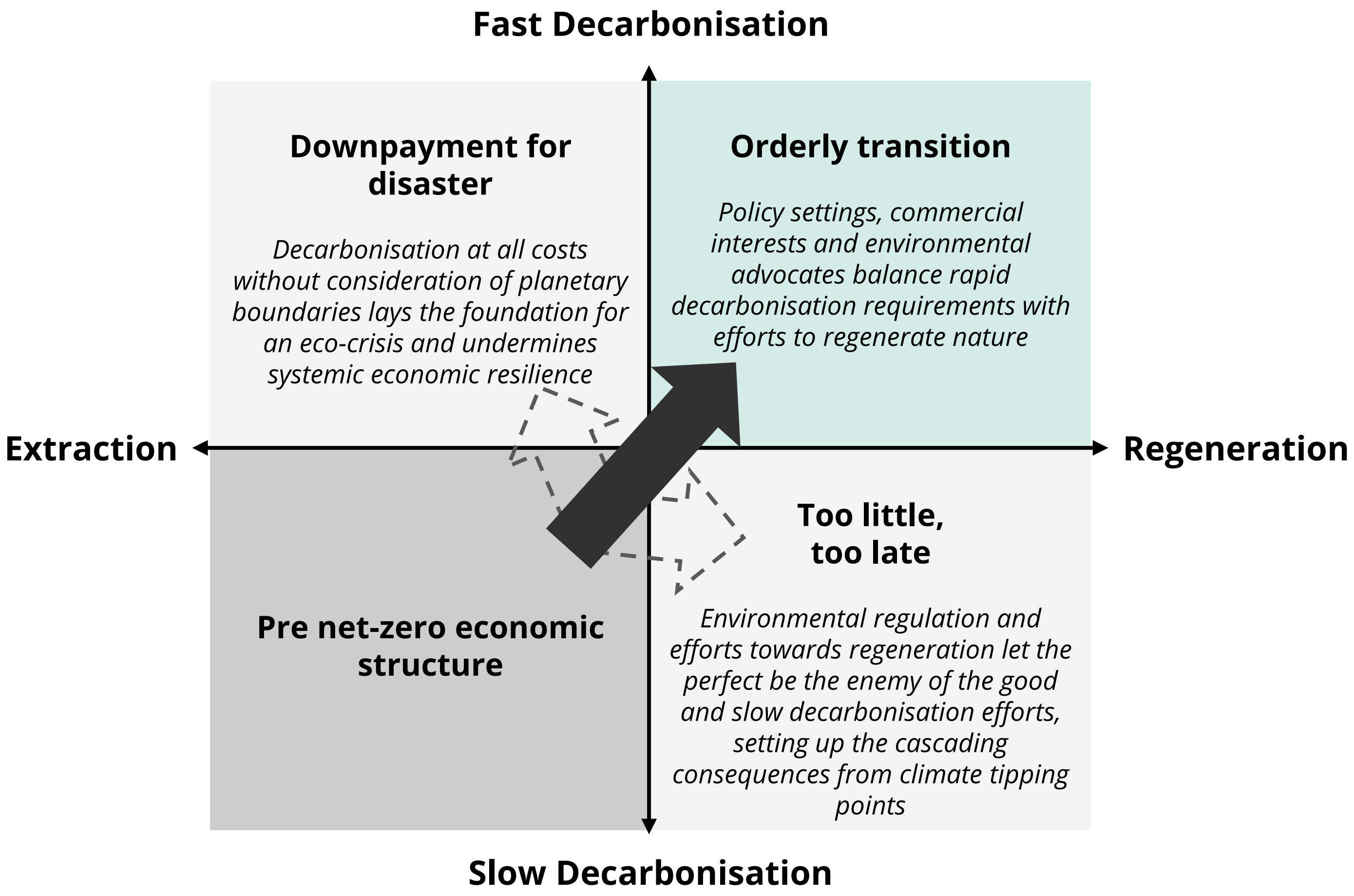
The entire value chain process infringes on areas of high natural value. Under the current deployment trajectory, extractive activities, energy assets and hydrogen projects will impose on Australia’s critical biodiversity areas. In particular, there is high concentration of development expected along the west and east coasts of Australia which include Australia’s two internationally recognised hotspots.[2]

A new approach will be required to deploy at pace while managing the impacts on these hotspots. Adopting a new mindset of coupling nature regeneration with development could reduce further degradation of these areas. Several organisations such as Carbon Positive Australia and Western Australia Biodiversity Science Institute (WASBI) are leading efforts to support this by contributing to knowledge sharing and supporting efforts to minimise residual impacts from increased development.

An orderly climate transition depends on regeneration as well as speed & scale

Failure to couple decarbonisation with regeneration risks significant economic consequences

Figure 3: Conceptual framework for understanding the relationship between decarbonisation & regeneration



Source(s): 1. Climate Rights International, 2024.

Key Takeaways

Unlocking Australia's green iron and steel export opportunity is dependent on resource availability and swift action. Moving too slowly risks both irreversible climate impacts and an inability for Australian companies to break into an already saturated international green metals markets. Exploitative mineral extraction and land use will create immense pressure on Australia's natural capital, risking collapse of ecosystems and limited availability of resources.

At present, our development trajectory is not tracking towards an orderly transition. Our current approach is both extractive and slow. Without intervention, we are on track to lose out on economic prosperity while also suffering repercussions from a concurrent eco-crisis and climate catastrophe.

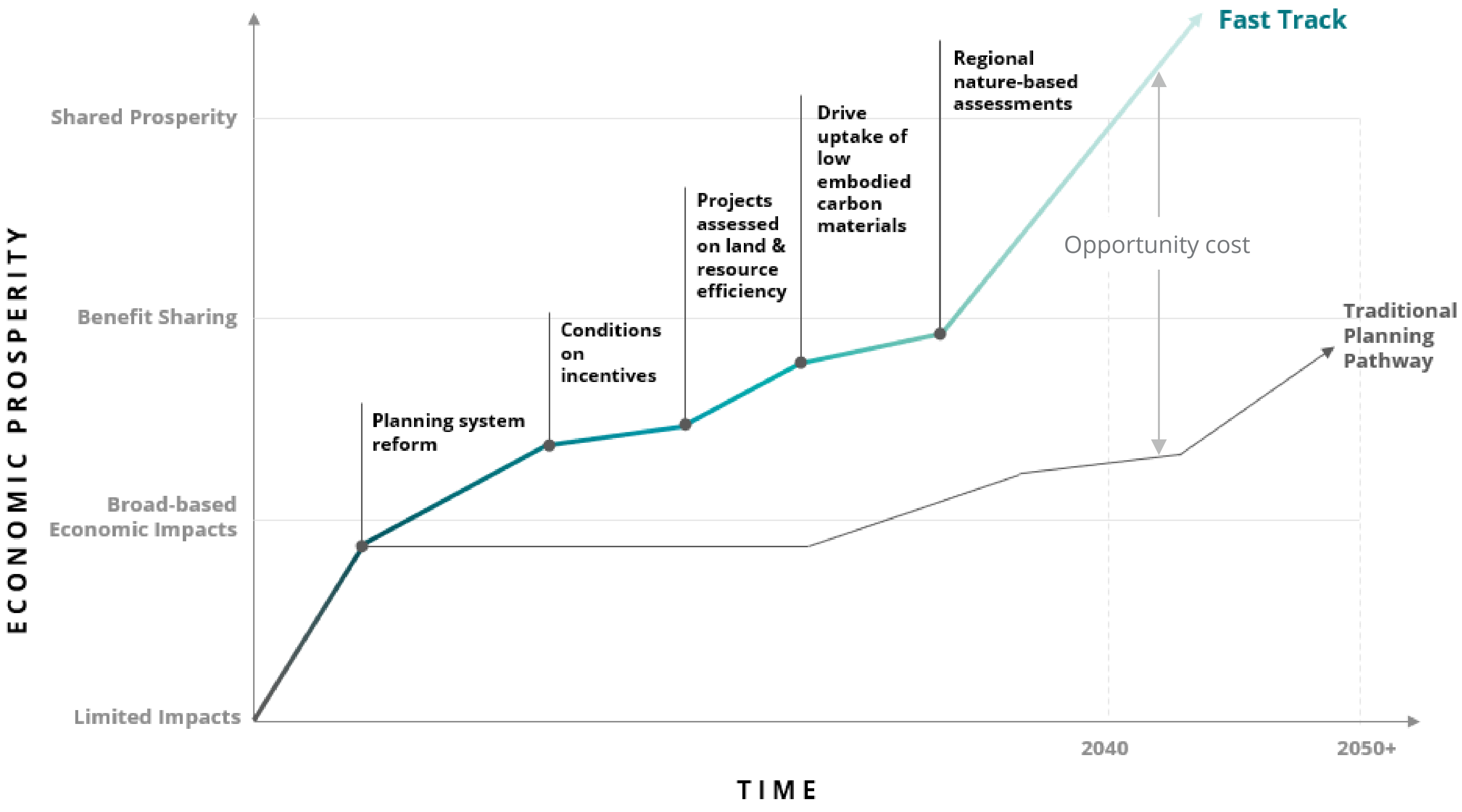
Too much haste in addressing climate change could inadvertently exceed other planetary boundaries with significant consequences. For example, growing demand for Indonesian nickel in the development of electric vehicle batteries is causing catastrophic impacts to nature with widescale deforestation and loss of habitat.[1]

Going faster is only viable if we regenerate. Achieving an orderly transition will require a shift in thinking, moving away from unadulterated extraction towards a regenerative approach. This means significantly increasing the efficiency of the way we approach resource use and land use.

Without planning innovation, green iron development risks a missed regeneration opportunity

Five focus areas have the potential to accelerate deployment while maximising regeneration

Figure 4: Future-proofing Australia's planning system will unlock more economic prosperity sooner[1]



Source(s): 1. Deloitte analysis, 2024.

Key Takeaways

There are 5 focus areas to future-proof the planning pathway and fast track economic prosperity:

1. **Green planning/permitting sandbox:** The current process is too slow and inconsistently delivers environmental and social outcomes. Without change, the increased volume of energy transition projects will not be delivered. A regulatory sandbox style pilot drawing lessons from financial regulation could test iterative improvements.
2. **Conditions on incentives:** Companies need to be incentivised to actively regenerate nature as part of BAU operations. Introducing nature restoration conditions on announced government incentives may encourage action.
3. **Projects assessed on land & resource efficiency:** The current approvals process has a strong focus on the economic efficiency of a project. While this consideration must remain, the land efficiency and resource efficiency should also be assessed.
4. **Drive uptake of low embodied carbon materials:** New renewables investment will create significant demand for construction materials. This demand could be leveraged to drive uptake of construction materials with low embodied carbon.
5. **Regional nature-based assessments:** Similar to the concept of a Renewable Energy Zone, regional nature zones would allow for centrally managed biodiversity and cultural heritage assessments. This could streamline project application processes and enable more efficient scenario planning and regional monitoring.

Leading global innovations could be localised into the Australian context

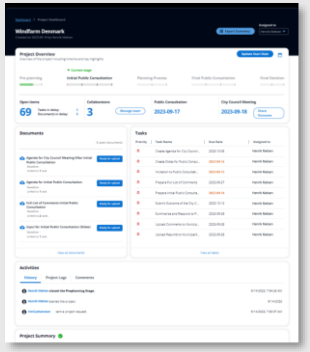
Successful innovation globally is: (1) convened across sector lines, (2) relies heavily on digitisation, (3) is piloted at a regional level, and (4) delivers better commercial and nature outcomes

Regulatory Sandboxes

- **Regulatory Sandboxes** such as those used to facilitate innovation in [financial services](#) in the UK and [customs processes](#) in Australia create a dedicated approach to trials and new products within an environment of enhanced regulatory scrutiny to test what works, understand impacts, and build an evidence base for wider scale up and adoption.

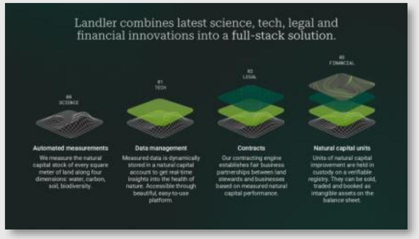
Digital Permitting

- **Digitisation** of existing permitting and approvals processes has been identified as essential to process applications faster and in a transparent and fair manner. Wind Europe has recently worked to pilot [EasyPermits](#) in Denmark. The system has since been customised and rolled out in other European jurisdictions.



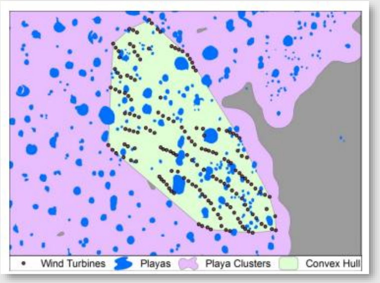
Impact Quantification & Hyperlocal Monitoring

- **Impact baselining, monitoring and verification** are essential to assess how development impacts the natural capital of land over time. Increasingly financial investors are relying on tools such as [Landler.io](#) – a platform which automates water, carbon, soil and biodiversity measurements for land parcels and uses these to structure performance-based commercial contracts.



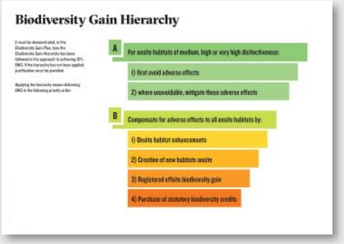
Regional Coordination & Innovation

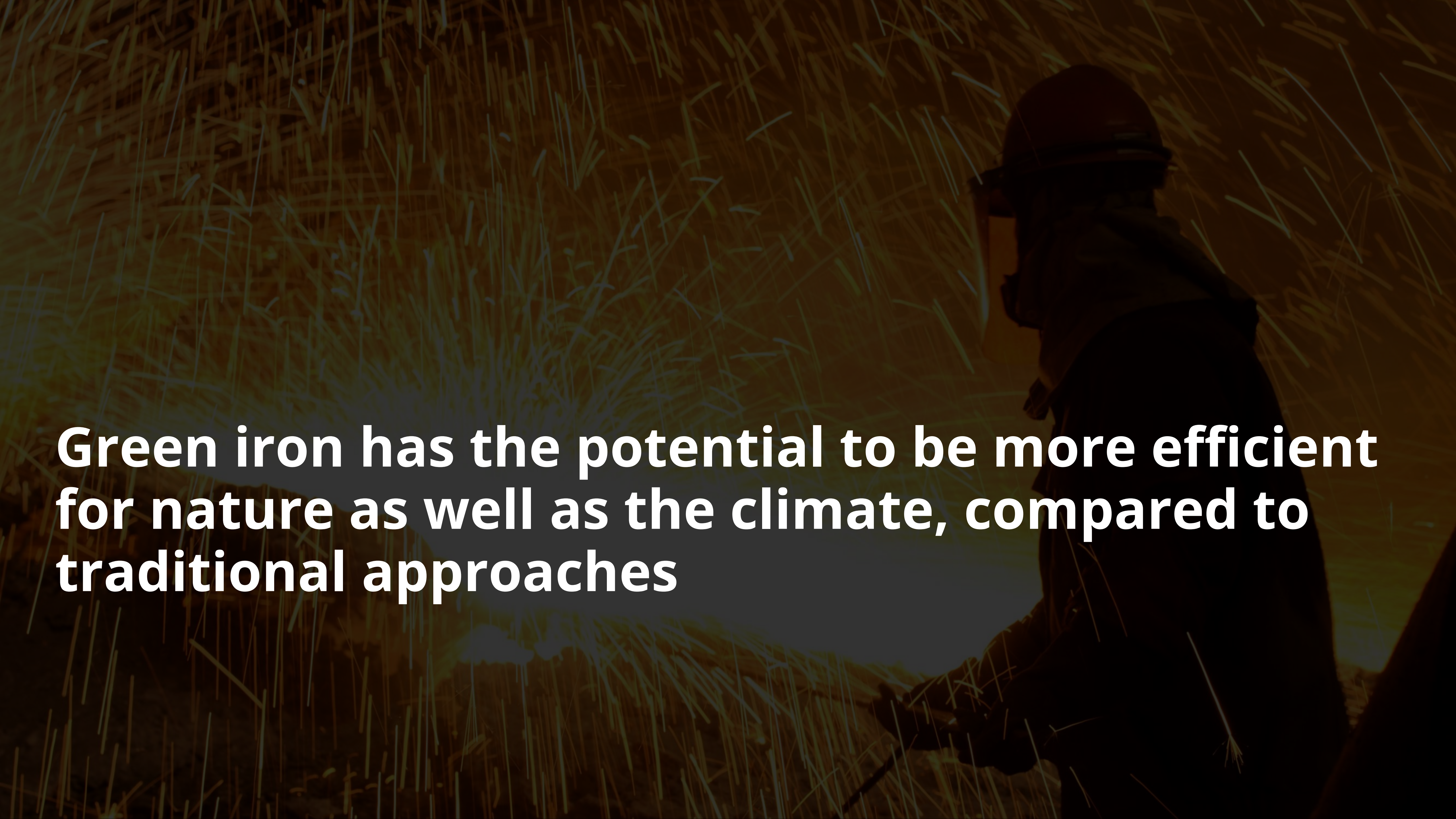
- **Place-based initiatives** such as the [Playa Lakes Joint Venture](#) in the United States are increasingly combining cutting edge conservation with renewables deployment. For example, the initiative has developed a place-based [siting tool](#) to support developers. [Partnerships to regenerate](#) the region have also been reached with existing projects including with Ørsted.



Nature-linked Development Conditions

- **Conditionalities** are increasingly reshaping project development, with these attached to incentives in the Inflation Reduction Act and from February 2024 a minimum [10% biodiversity net gain](#) has been a mandatory development condition in the UK. The BNG framework in the UK has already resulted in developers either identifying pathways and plans to enhance biodiversity on site or participating in the early-stage biodiversity credit market.




Green iron has the potential to be more efficient for nature as well as the climate, compared to traditional approaches

Unpacking nature impacts of an Australia green iron value chain is a prerequisite to change

We have taken a 5-step process to review impacts across the value chain and considerations for future inquiries

1

Quantify nature impacts across value chain from iron model

Undertaking a material flows analysis is the only way to understand the extent of the value chain impacts

2

Review literature, approvals, risk documentation including TNFD sector guidance to identify further impacts

Further investigation into actual experiences and contemporary issues is required to supplement quantifiable consequences

3

Review announced projects across value chain by place to identify hot spots of activity & risk

Evaluating the place-based and cumulative impacts from the value chain to identify which nature systems under pressure

4

Distil considerations across the value chain for insights

The value chain may not be vertically integrated and nature impacts will need to be co-ordinated

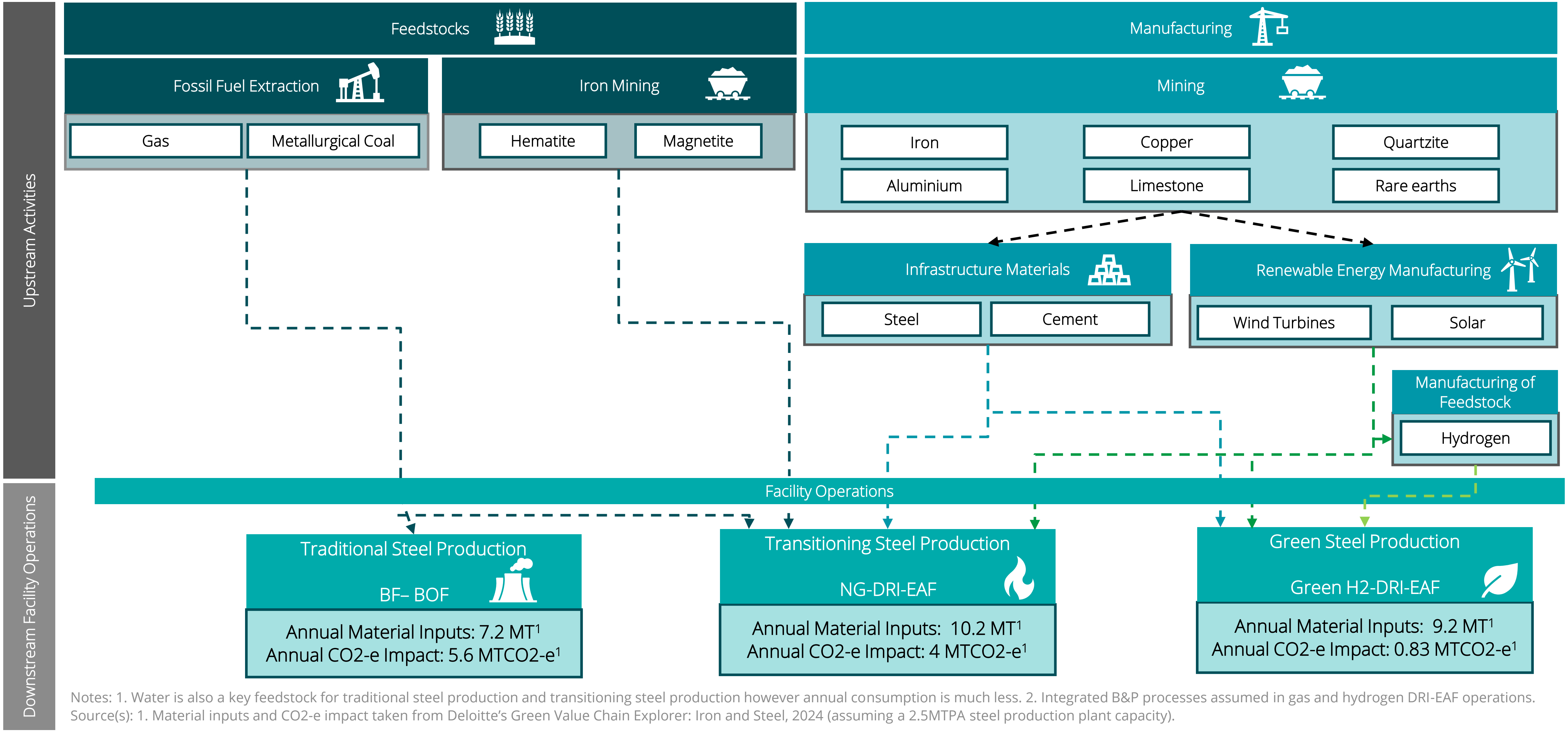
5

Identify upcoming tactical opportunities for to inject regeneration into green steel policy

There is a discrete policy window with a need to act now to set up for future success

Side-by-side: traditional and low carbon steelmaking compared

A material flow lens of iron and steelmaking processes highlights significant differences

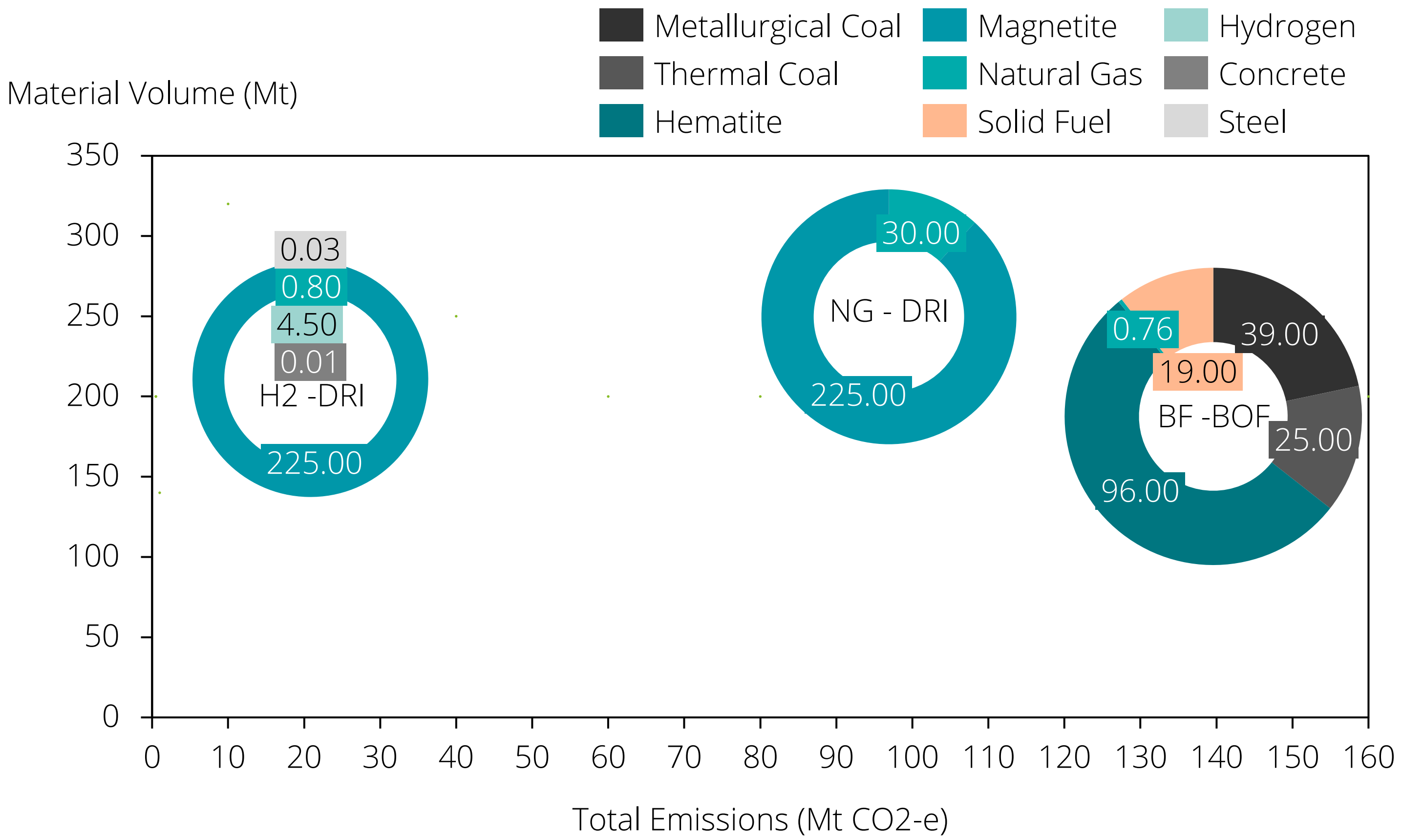


Notes: 1. Water is also a key feedstock for traditional steel production and transitioning steel production however annual consumption is much less. 2. Integrated B&P processes assumed in gas and hydrogen DRI-EAF operations.
Source(s): 1. Material inputs and CO2-e impact taken from Deloitte's Green Value Chain Explorer: Iron and Steel, 2024 (assuming a 2.5MTPA steel production plant capacity).

Magnetite demand from DRI processes increase material flows while emissions are reduced

Innovation in material inputs and beneficiation will be required for green iron to become more resource efficient

Figure 5: Comparison of required material volume and total emissions produced through Hydrogen DRI, Natural gas DRI and BF-BOF production pathways over a 25-year period



Key Takeaways

Hydrogen DRI is the lower carbon and material intensive pathway compared to NG-DRI production (Figure 5). Hydrogen DRI requires approximately 230Mt of material inputs, largely consisting of magnetite (225Mt) and produces 21 MtCO2-e over a 25-year operational lifespan. Comparatively, natural gas DRI requires approximately 255Mt of material inputs, however, produces approximately five times the total emissions (100 MtCO2-e).

BF-BOF plants requires the least material inputs (180 MT), but are significantly more carbon emission intensive (140 MTCO2-e). BF-BOF uses lower grade hematite ore, requiring fewer material inputs than DRI production. The material inputs and emissions involved in the beneficiation and pelletisation process for DRI production also contribute to the higher material intensity. Innovation in this area will be required to improve resource efficiency.

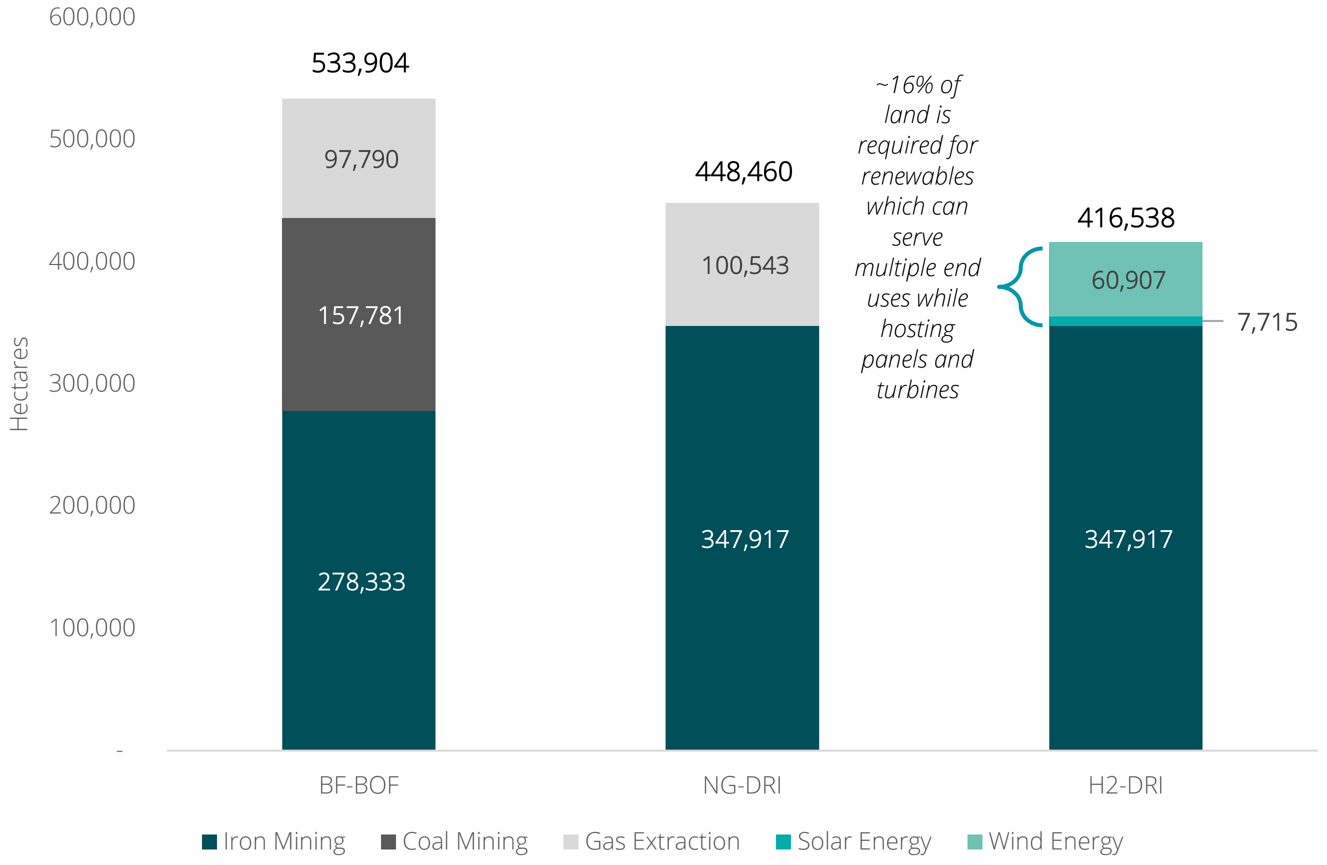
It is assumed that NG-DRI and BF-BOF will be located on brownfield sites, while green H2-DRI projects would be greenfield. Manufacturing inputs such as concrete and steel materials increases the resource requirements for H2-DRI projects, compared to BF-BOF and natural gas DRI facilities which would likely be established through retrofitting existing plant infrastructure.

Notes: 1. Material requirements are mapped across value chain configurations using a 2.5MTPA steel value chain capacity assumption. 2. Material inputs and total emissions were taken from the Deloitte Green Value Chain Explorer: Iron and Steel, 2024 3. Material inputs and emissions intensity of the beneficiation and pelletisation processes are embedded within the two DRI pathways. 4. A 25 year horizon was used based upon the average lifespan of renewable energy assets. 5. Natural gas conversion factor (GJ to metric tonnes): 1GJ = 0.019 t) from: British Columbia Ministry of Finance 6. It is assumed the NG-DRI pathway used conventional grid electricity (no renewable energy). 7. Concrete and steel inputs were included for the H2-DRI pathway, as it was assumed hydrogen projects would be greenfield developments, with existing NG-DRI and BF-BOF assumed to be retrofitted (brownfield developments); hence no construction costs.

Green iron stands to be the least-land intensive production process over the long term

All processes are land intensive, with attention needed on land dual use and mine rehabilitation

Figure 6: Land use by production method, 25th year of operation[1,3]



Notes: 1. Material requirements are mapped across value chain configurations using a 2.5MTPA steel value chain capacity assumption. 2. Material inputs and total emissions were taken from the Deloitte Green Value Chain Explorer: Iron and Steel, 2024 3. A 25-year horizon was used based upon the average lifespan of renewable energy assets. 4. Iron ore mining land use intensity of 0.0028 ha/tonne (Correa, et.al, 2023). 5. Coal mining land use intensity of 0.00383 ha/tonne. 6. Renewable land intensity of 2.5ha/MW (solar) and 18.1ha/MW (wind) (CSIRO, 2021).

Source(s): 1. Deloitte, 2024. 2. Climate Change Authority, 2024. 3. CSIRO, 2021.

Key Takeaways

Green iron is less land intensive than traditional steel production. Over a 25-year time horizon, green iron uses 22% less land than BF-BOF and is equivalent to 8-23% of the 2.1-5.9M hectares estimated by CSIRO and the Climate Change Authority to be required for additional planting to achieve net zero by 2050.[2]

Land used for renewables can serve multiple purposes. Unlike land used for mining purposes, which requires significant rehabilitation, most of the land used for renewables remains useable for a secondary purpose. Since renewables make up ~16% of green iron land use, this represents a significant number of hectares available for dual land uses.

Unlike BF-BOF and NG-DRI, the land intensity for green iron production is relatively stable over time. Land allocation for renewables, while substantial in size, is a one-off occurrence. In comparison, resource extraction requires ongoing allocation of new land. BF-BOF consumes ~100,000 ha of land every 5 years, with NG-DRI requiring similar land every 6 years. Therefore, over time, the land intensity of BF-BOF and NG-DRI will continue to substantially increase, whereas green iron has a much slower rate of increase (driven exclusively by iron ore extraction).

Innovation in process efficiency could drive further reduction in land intensity of green iron production. The DRI process requires more iron ore per unit compared to traditional steel production, creating a corresponding increase in land use for iron ore mining under NG and H2 DRI processes compared to BF-BOF. However, as beneficiation becomes more efficient and supply of higher-grade magnetite ore increases, the overall land requirements for ore mining could reduce. Since the majority of DRI land use is attributable to the ore extraction, this could be a material impact, and would further widen the gap between land intensity of BF-BOF and green iron.

Green ironmaking has inherent dependencies on nature which can guide future planning processes

Extraction

Key nature risks and impacts from extractive activities

Increased demand for materials for green iron and renewable development places further pressure on nature

Figure 7: Key risks for nature across iron ore and non-ferrous ore extraction versus hard coal[1]

Impact areas	Hard coal	Iron ore	Non-ferrous ores
Land-use area	Medium	Medium	Medium
Freshwater-use area	High	High	Very High
Volume of Water use	Medium	Medium	High
Emissions from GHG	Very High	Medium	High
Emissions of non-GHG air pollutants	High	Medium	High
Release of waste	Medium	Very High	High
Disturbances to wildlife	High	High	Very High

Notes: 1. Non-ferrous ores are representative of critical minerals for the energy transition, 2. Deloitte have conducted analysis across the following impact areas: land-use area, volume of water use, disturbances to wildlife

Key:

- Very High impact
- High impact
- Medium impact
- Low impact
- Very Low impact

Key Findings

The most material nature impacts from extractive activities include emission generation, waste release, land use and disturbances (Figure 7).

Existing mining sites interact with several biodiversity hotspots and designated IUCN regions. Australia's '30 by 30' target will potentially intensify the interactions between mining sites and protected areas.[2] Efforts towards minimising impacts include the Pilbara biodiversity offset fund which was set up to counteract impact from large projects and deliver $90 million in projects across the next 40 years.[3] It is less clear this scale of investment is commensurate with anticipated development.

Approximately 60% of mining sites and iron facilities are in areas of low to medium water stress. However, two key iron ore reserve regions – Pilbara and Whyalla – are situated across areas of arid to low water use. Increased water extraction required for mining could also affect groundwater levels kilometres away.

Historically, Indigenous and Traditional Owner groups have been disproportionately impacted from mining activities. Despite efforts to maximise Indigenous benefit sharing from mining through various legal mechanisms, there is still often a gap in economic participation for First Nations groups. Incentivising nature restoration outcomes through voluntary ILUAs could improve environmental outcomes from future mining activities.

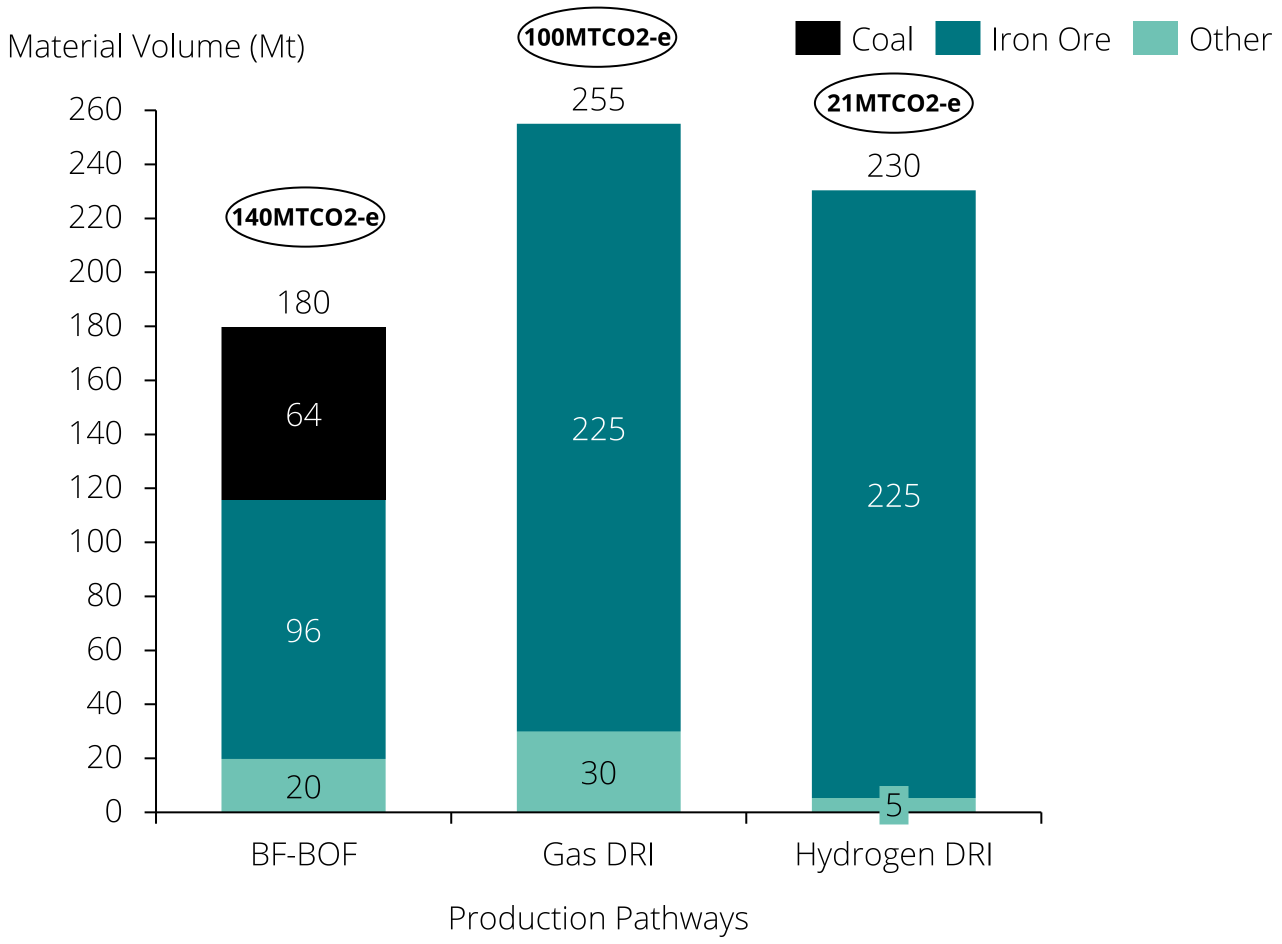
The following slides provide analysis of existing mining sites and facilities required for green iron against nature dimensions such as IUCN categories, Australian bioregions, water scarcity and Indigenous interests.

Source(s): 1. TNFD, 2024. 2.DCCEEW, 2024. 3. Government of Western Australia, 2024

A shift to green iron will substantially change resource extraction patterns

Magnetite mines, critical minerals and cement become critical inputs in the green iron value chain

Figure 8: Input requirements across three production pathways[1]



Key Findings

Shifting to DRI changes demand for extractive processes away from coal towards natural gas and critical minerals. This could result in potentially higher cumulative impacts across the iron value chain in the context of land disturbance, water usage and other related nature impacts. However, the absence of coal in the process provides some climate benefits.

The most significant demand shift is to magnetite ores and the associated beneficiation process. Hydrogen and Natural Gas-based DRI processing is inefficient and uses almost three times more iron ore than traditional BF-BOF processing (Figure 8). This may require closer attention to treatment of waste materials generated from various mining activities.

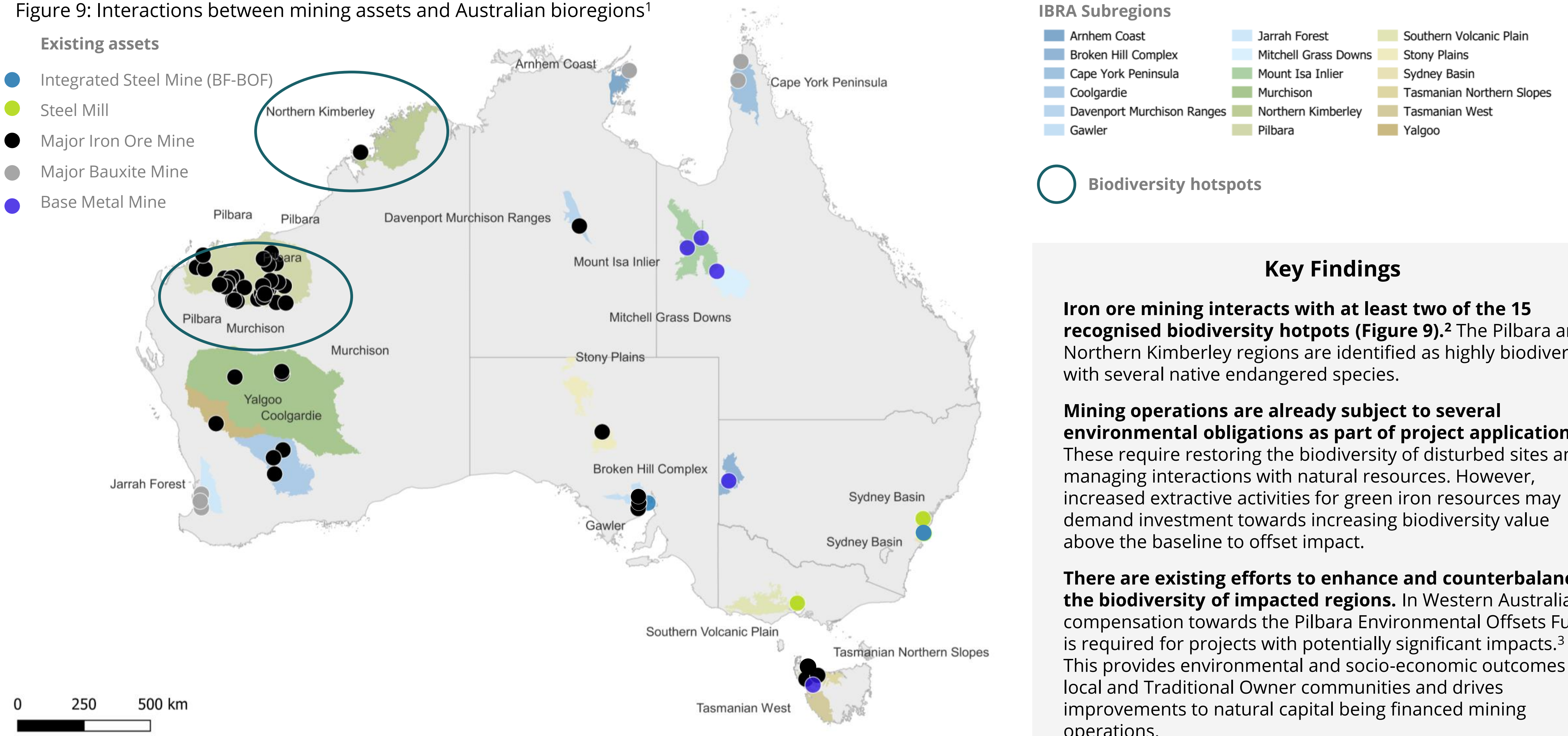
The components for green iron processing, while low volume, require a complexity of inputs. This means each project will have proportionally less influence over its upstream value chain and a greater number of individual extractive sites are likely to be required to sustain deployment. However, future innovations in the beneficiation process and greater uptake of recycled inputs could lead to material efficiencies and lower demand for extractive activities.

Source(s): 1. Deloitte Green Value Chain Explorer: Iron and Steel, 2024

Iron and steel value chain assets currently exist in highly biodiverse regions of Australia

Geographic concentration of new mines could underpin effective bioregional planning

Figure 9: Interactions between mining assets and Australian bioregions[1]



Key Findings

Iron ore mining interacts with at least two of the 15 recognised biodiversity hotpots (Figure 9).[2] The Pilbara and Northern Kimberley regions are identified as highly biodiverse, with several native endangered species.

Mining operations are already subject to several environmental obligations as part of project application. These require restoring the biodiversity of disturbed sites and managing interactions with natural resources. However, increased extractive activities for green iron resources may demand investment towards increasing biodiversity value above the baseline to offset impact.

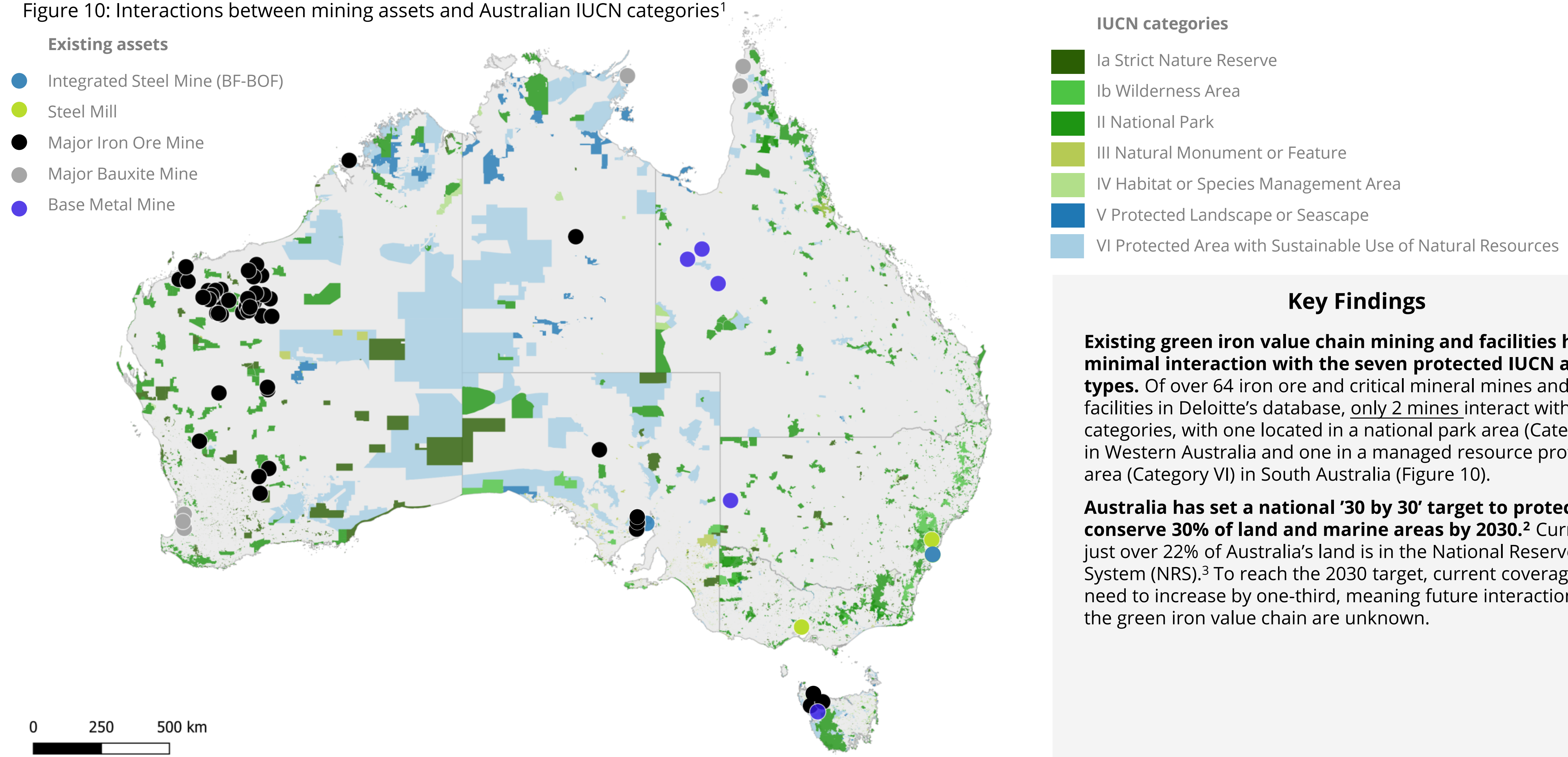
There are existing efforts to enhance and counterbalance the biodiversity of impacted regions. In Western Australia, compensation towards the Pilbara Environmental Offsets Fund is required for projects with potentially significant impacts.[3] This provides environmental and socio-economic outcomes for local and Traditional Owner communities and drives improvements to natural capital being financed mining operations.

Source(s): 1. Deloitte analysis (based on data from DCCEEW), 2024. 2. Western Australian Biodiversity Science Institute, 2024. 3. Government of Western Australia, 2024

Current iron value chain assets have little overlap with IUCN protected areas

The national '30 by 30' target may lead to increased overlap with protected areas in future

Figure 10: Interactions between mining assets and Australian IUCN categories[1]



Key Findings

Existing green iron value chain mining and facilities have minimal interaction with the seven protected IUCN area types. Of over 64 iron ore and critical mineral mines and facilities in Deloitte's database, only 2 mines interact with IUCN categories, with one located in a national park area (Category II) in Western Australia and one in a managed resource protected area (Category VI) in South Australia (Figure 10).

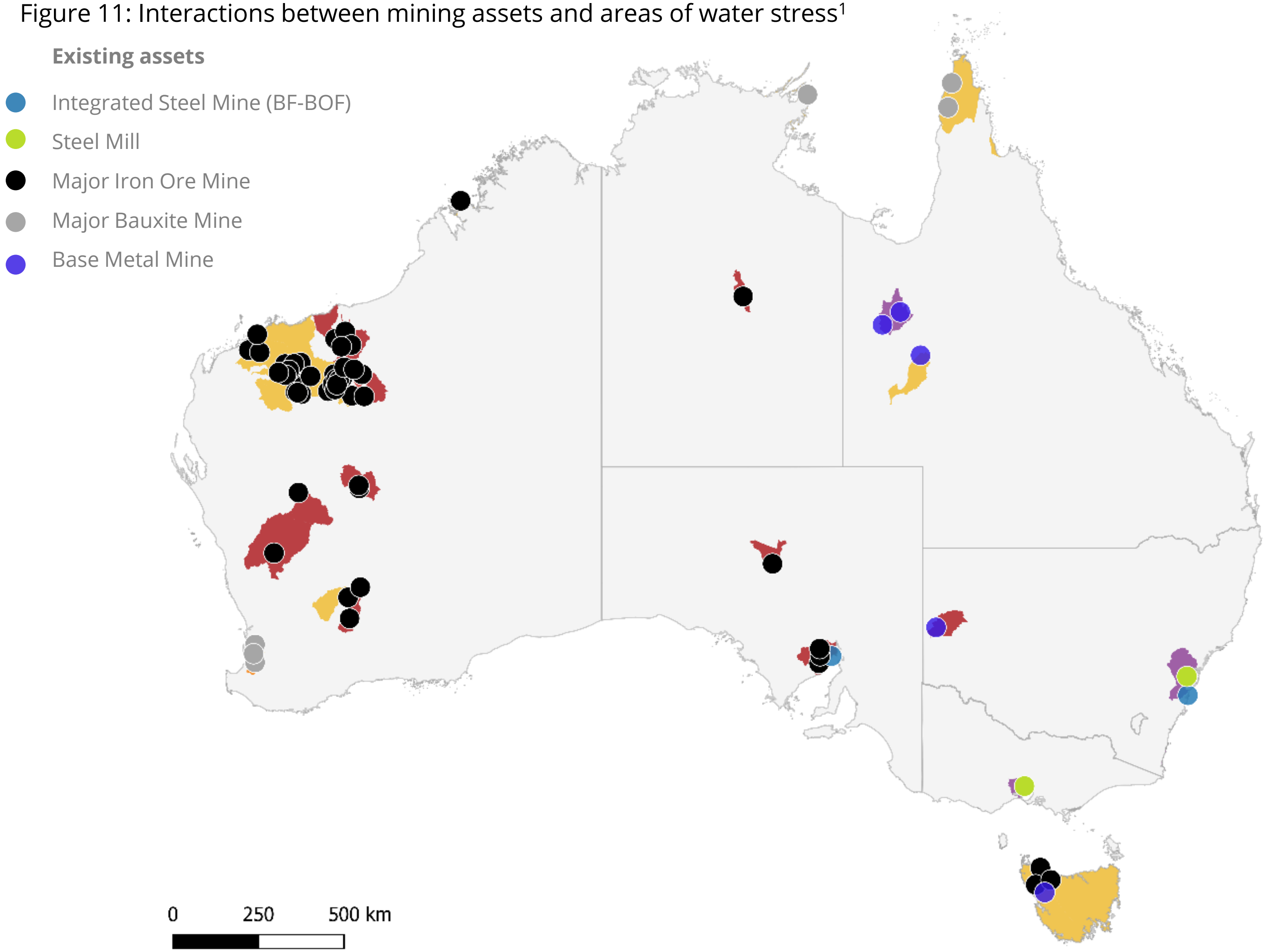
Australia has set a national '30 by 30' target to protect and conserve 30% of land and marine areas by 2030.[2] Currently, just over 22% of Australia's land is in the National Reserve System (NRS).[3] To reach the 2030 target, current coverage will need to increase by one-third, meaning future interactions with the green iron value chain are unknown.

Source(s): 1. Deloitte analysis (based on data from DCCEEW), 2024. 2. DCCEEW, 2024. 3. DCCEEW, 2023

Most critical mine sites and facilities are in areas of arid water stress

New mining assets will add to water demand across areas of water stress, with water efficiency a key focus

Figure 11: Interactions between mining assets and areas of water stress[1]



Key Findings

Over one third of Australian mines and facilities required for green iron are in areas of high water stress (Figure 11).

Critical areas for the green iron value chain, including the Pilbara and South Australian iron ore reserves, are in areas of arid water stress, potentially placing further pressure on water availability. Iron ore processing is water intensive, with an estimated 2 – 5kL of water required to produce a tonne of iron ore, compared to coal which requires 0.65kL per tonne.[2] With 40% of iron ore mining operations in the Pilbara region expected to be below the water table by 2040,[3] increased dewatering and borefields could be required without better resource management.

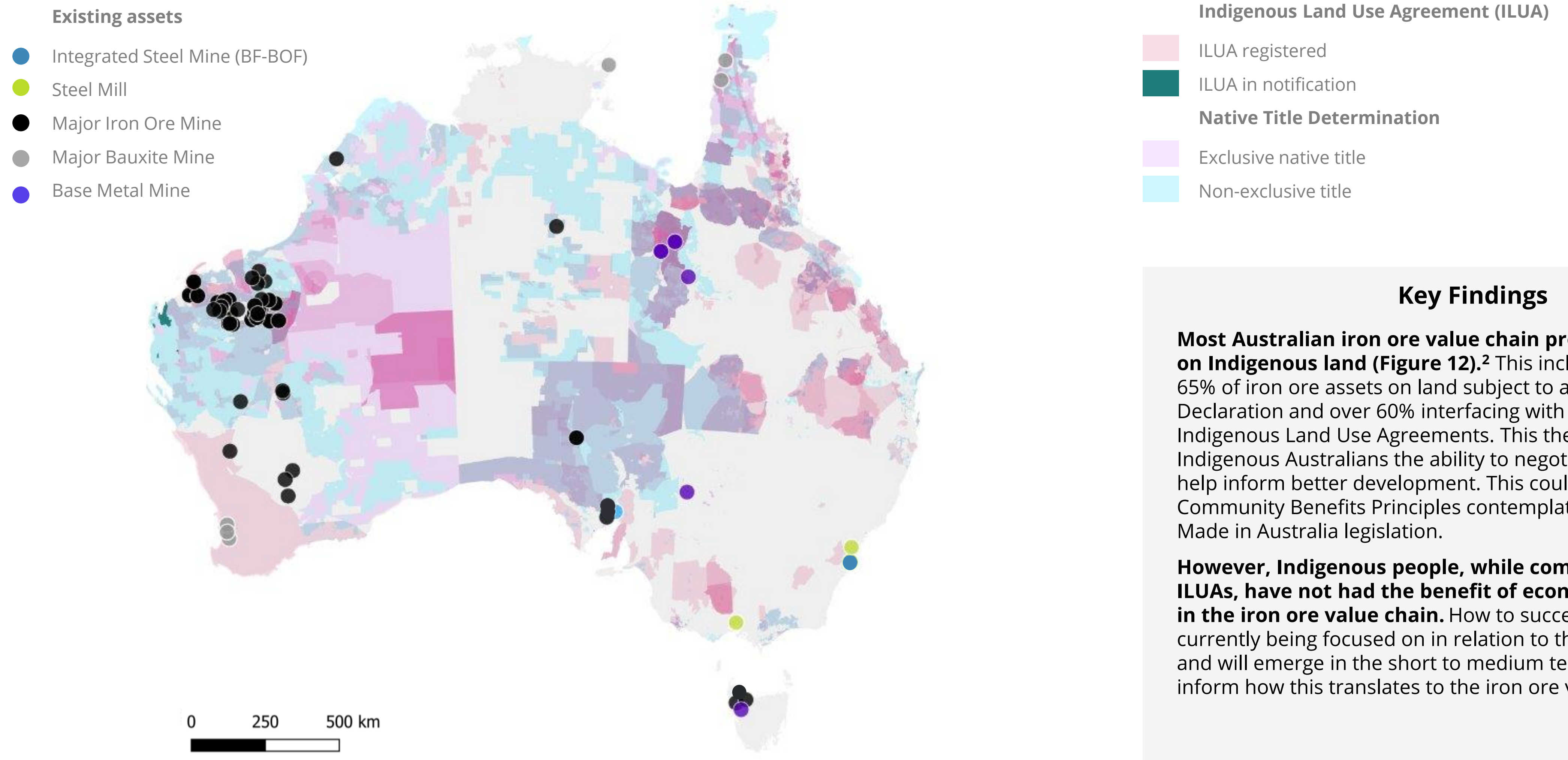
Adoption of circular water models and innovations, including shared desalination plants and reinjection into the water table, and ensuring the industry is minimising water impact may be considered to reduce overall impacts to water security in impacted regions.

Source(s): 1. Deloitte analysis (based on data from World Resource Institute), 2024. 2. Mork Water, 2024. 3. Mork Water, 2024

The green iron opportunity provides an avenue for Indigenous Australians to benefit

Promoting nature regeneration through Agreements could provide positive socio-economic outcomes

Figure 12: Interactions between mining assets and Indigenous Agreements or Declarations[1]



Key Findings

Most Australian iron ore value chain projects are located on Indigenous land (Figure 12).[2] This includes approximately 65% of iron ore assets on land subject to a Native Title Declaration and over 60% interfacing with registered Indigenous Land Use Agreements. This theoretically provides Indigenous Australians the ability to negotiate land use and help inform better development. This could align well with the Community Benefits Principles contemplated under the Future Made in Australia legislation.

However, Indigenous people, while compensated under ILUAs, have not had the benefit of economic participation in the iron ore value chain. How to successfully achieve this is currently being focused on in relation to the energy transition and will emerge in the short to medium term. This will help inform how this translates to the iron ore value chain.[3]

Source(s): 1. Deloitte analysis, 2024 (based on data from NTT, GeoScience Australia and DISER). 2. Deloitte analysis, 2024. 3. World Economic Forum, 2023

Green ironmaking has inherent dependencies on nature which can guide future planning processes

Energy

Key nature risks and impacts from renewable energy sources

Land requirements for renewable energy infrastructure could disturb and modify local habitats

Figure 13: Key risks for nature across various forms of renewable energy sources[1]

Impact areas	Wind	Solar	Thermal power
Land-use area	High	Low	Medium
Freshwater-use area	N/A	N/A	Medium
Area of seabed use	Medium	N/A	N/A
Water use	Low	Low	Medium
Emissions of toxic soil and water pollutants	Very Low	Low	Very High
Generation and release of solid waste	Very Low	Very Low	High
Disturbances to wildlife	Medium	Very Low	Very High

Notes: 1. Deloitte have conducted analysis across the following impact areas: land-use area, disturbances to wildlife

Key:
- Very High impact
- High impact
- Medium impact
- Low impact
- Very Low impact

Source(s): 1. TNFD, 2024. 2. Deloitte Green Value Chain Explorer: Iron and Steel, 2024. 3. Climate TRACE, 2024. 4. Australian Aluminium Council, 2022. 5. Cement Industry Federation, 2022. 6. Deloitte analysis, 2024. 7. Australian Government (Department of Agriculture, Fisheries and Forestry), 2024. 8. Deloitte analysis, 2024. 9. The Guardian, 2024.

Key Findings

Material nature impacts from renewable energy projects required for green iron production include emissions of toxic soil and water pollutants, disturbances to wildlife and land use area.

A 2.5MT per annum green steel plant could require approximately 7.1GW of renewable power. A joint solar PV and wind plant of this magnitude would require 1.4MT of materials[2], largely consisting of concrete, polymers, rare earth elements, aluminium and steel. To satisfy this demand, approximately 7% of Australia's domestic concrete production[3], 5.5% aluminium production[4] and 0.80% steel production[5] would be required.

Australia's upcoming renewable energy assets do not significantly impinge upon IUCN protected areas. Only 4.5% of projects are expected to be located within areas covered by IUCN categories.[6] Further, a combined 5.2Mha of land is required for all renewables projects depicted in Figure 16, which is approximately 1.2% of the land required by Australia's agricultural industry.[7]

Over 84% of announced renewable energy projects are situated on Indigenous lands. [8] **Most of these projects have been coordinated under voluntary ILUAs.** However poor equity sharing has seen only 1% of current renewable energy projects involve Indigenous equity, compared to 20% achieved in Canada.[9]

The following slides provide analysis of existing renewable projects required for green iron against nature dimensions such as IUCN categories, Australian bioregions and Indigenous interests.

Approximately 1.4MT of materials is required to power a 2.5MT p.a. green steel plant

Volume of materials for solar and wind is minimal compared to Australia's total production of these inputs

Figure 14: Material flows for Australian renewable energy inputs needed for 2.5Mt green iron[1]

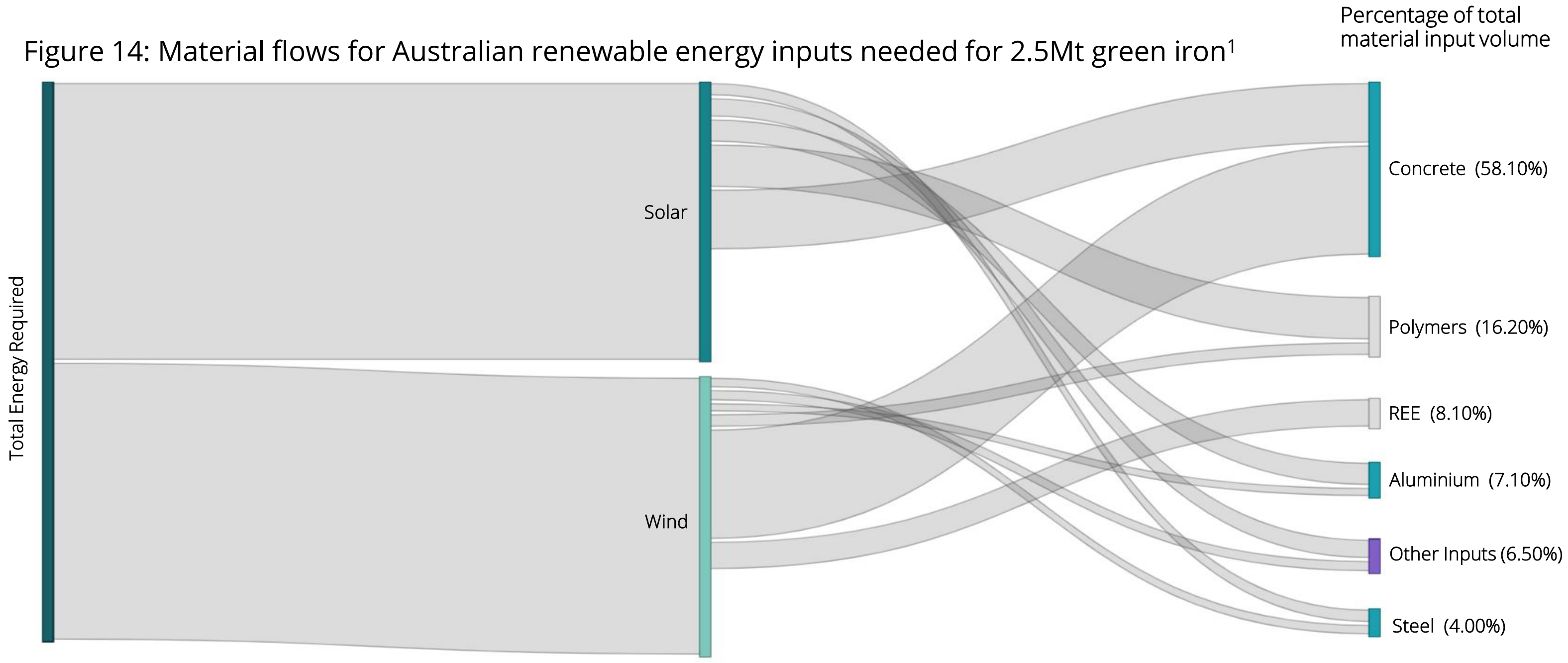
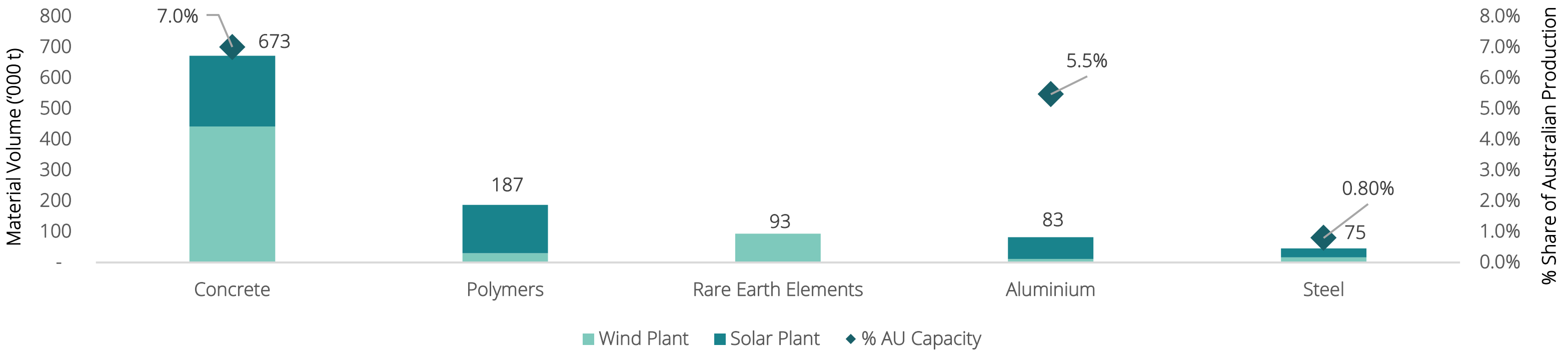


Figure 15: Material Inputs for a Wind and Solar plants needed for 2.5Mt green iron[1]



Source(s): 1. Deloitte Green Value Chain Explorer: Iron and Steel, 2024. 2. DNV, 2022. 3. NIH, 2019. 4. Vestas, 2024. 5. Aluminium Association, n.d. 6. Climate TRACE, 2024. 7. Australian Aluminium Council, 2022. 8. Cement Industry Federation, 2022

Key Findings

Based on Deloitte analysis, approximately 7.1GW of renewable power is required for a 2.5MT p.a. green steel plant (Figure 14). [1] A combined solar PV and wind turbine plant of this magnitude would require approximately 1.4 MT of materials.

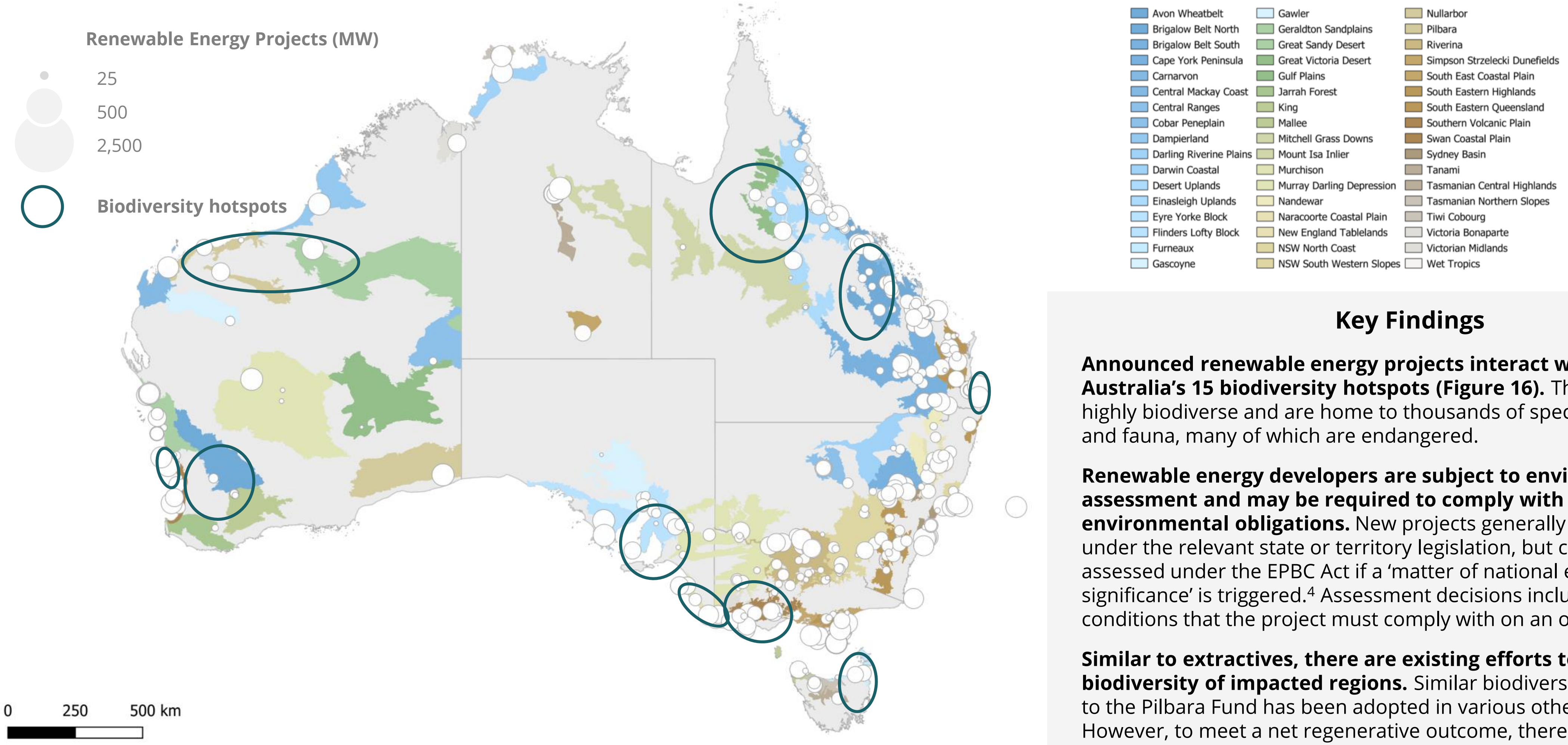
93% of the material demand is from five inputs: concrete, polymers, steel, rare earth elements and aluminium. Concrete contributes 58% of the total material volume, mostly towards wind turbine footing supports.[2] Polymers make up over 16% of material volume and are largely used in protective and reflective films used in solar panels.[3] Rare earth elements (REE) are used to create and enhance the performance of magnets inside wind turbine generators.[4] Aluminium is primarily used in solar PV framing and mounting structures as it is lightweight and corrosion resistant.[5]

Material inputs for a single 7.1GW renewable plant would demand a small proportion of Australia's annual production of key inputs. In 2022, Australia produced approximately 5.8MTPA of steel[6], 1.51MTPA of aluminium[7] and 9.6MTPA of concrete.[8] It is estimated that a 7.1GW solar PV and wind turbine plant would approximately consume 7% of Australia's domestic concrete production, 5.5% of domestic aluminium production and 0.8% of local steel production (based upon 2022 production).

A decarbonised iron value chain will require renewable energy assets

Increased demand for green iron requires renewable energy and additional generation developments

Figure 16: Interactions between announced renewable assets and Australian bioregions[1]



Key Findings

Announced renewable energy projects interact with at least 10 of Australia's 15 biodiversity hotspots (Figure 16). These regions are highly biodiverse and are home to thousands of species of native flora and fauna, many of which are endangered.

Renewable energy developers are subject to environmental assessment and may be required to comply with specific environmental obligations. New projects generally require approval under the relevant state or territory legislation, but could instead be assessed under the EPBC Act if a 'matter of national environmental significance' is triggered.[4] Assessment decisions include approval conditions that the project must comply with on an ongoing basis.

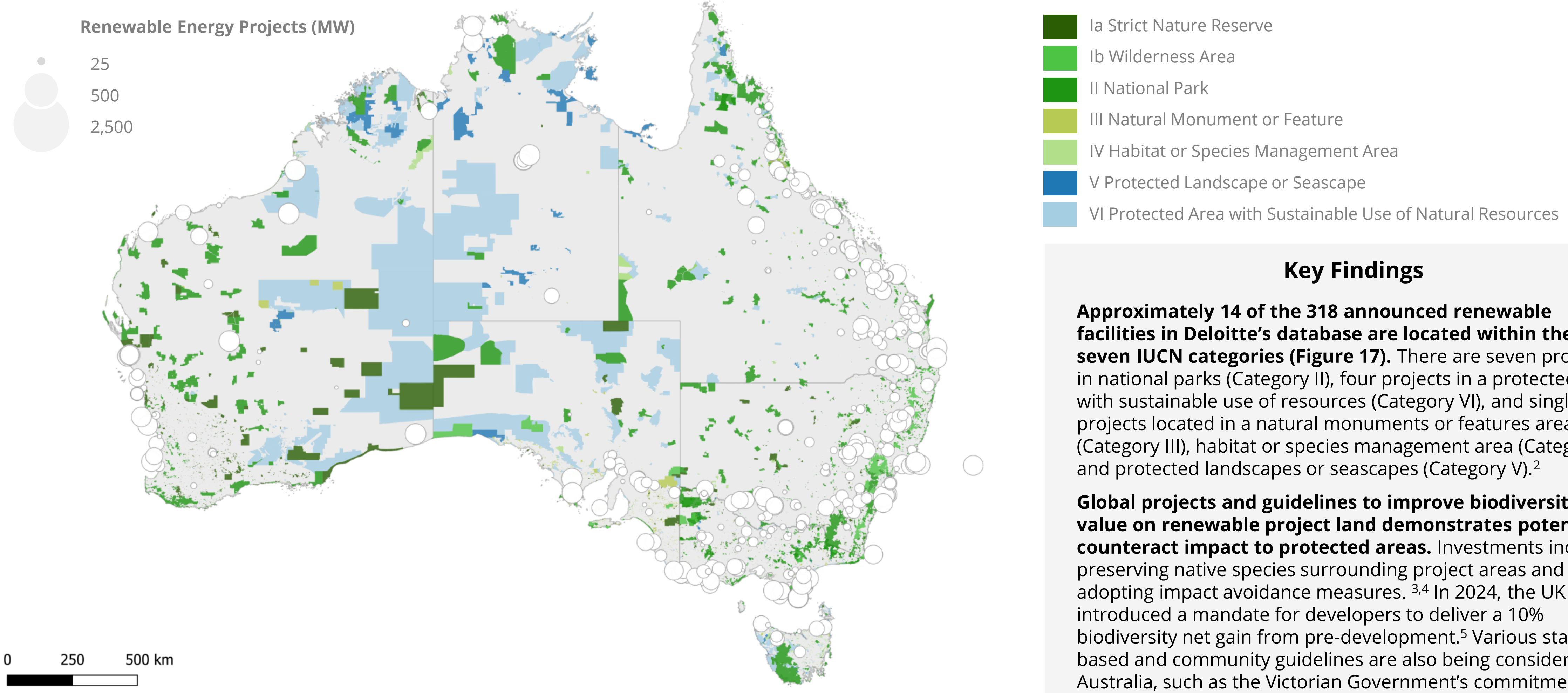
Similar to extractives, there are existing efforts to enhance the biodiversity of impacted regions. Similar biodiversity offset schemes to the Pilbara Fund has been adopted in various other states. [5,6,7] However, to meet a net regenerative outcome, there needs to be greater focus towards an approach which considers both environmental and economic transition objectives.

Source(s): 1. Deloitte analysis (based on data from DCCEEW), 2024. 2. Western Australian Biodiversity Science Institute, 2024. 3. DCCEEW, 2023. 4. Australian Government (DCCEEW), 2013. 5. Clean Energy Investor Group, 2022. 6. Victoria State Government (Energy, Environment and Climate Action), n.d. 7. Government of South Australia (Department of Environment and Water), n.d.

Announced renewable energy sites will have little interaction with IUCN protected areas

Renewable energy assets interactions with IUCN areas is less than the agricultural industry

Figure 17: Interactions between announced renewable projects and Australian IUCN categories[1]



Key Findings

Approximately 14 of the 318 announced renewable facilities in Deloitte's database are located within the seven IUCN categories (Figure 17). There are seven projects in national parks (Category II), four projects in a protected area with sustainable use of resources (Category VI), and single projects located in a natural monuments or features area (Category III), habitat or species management area (Category IV) and protected landscapes or seascapes (Category V).[2]

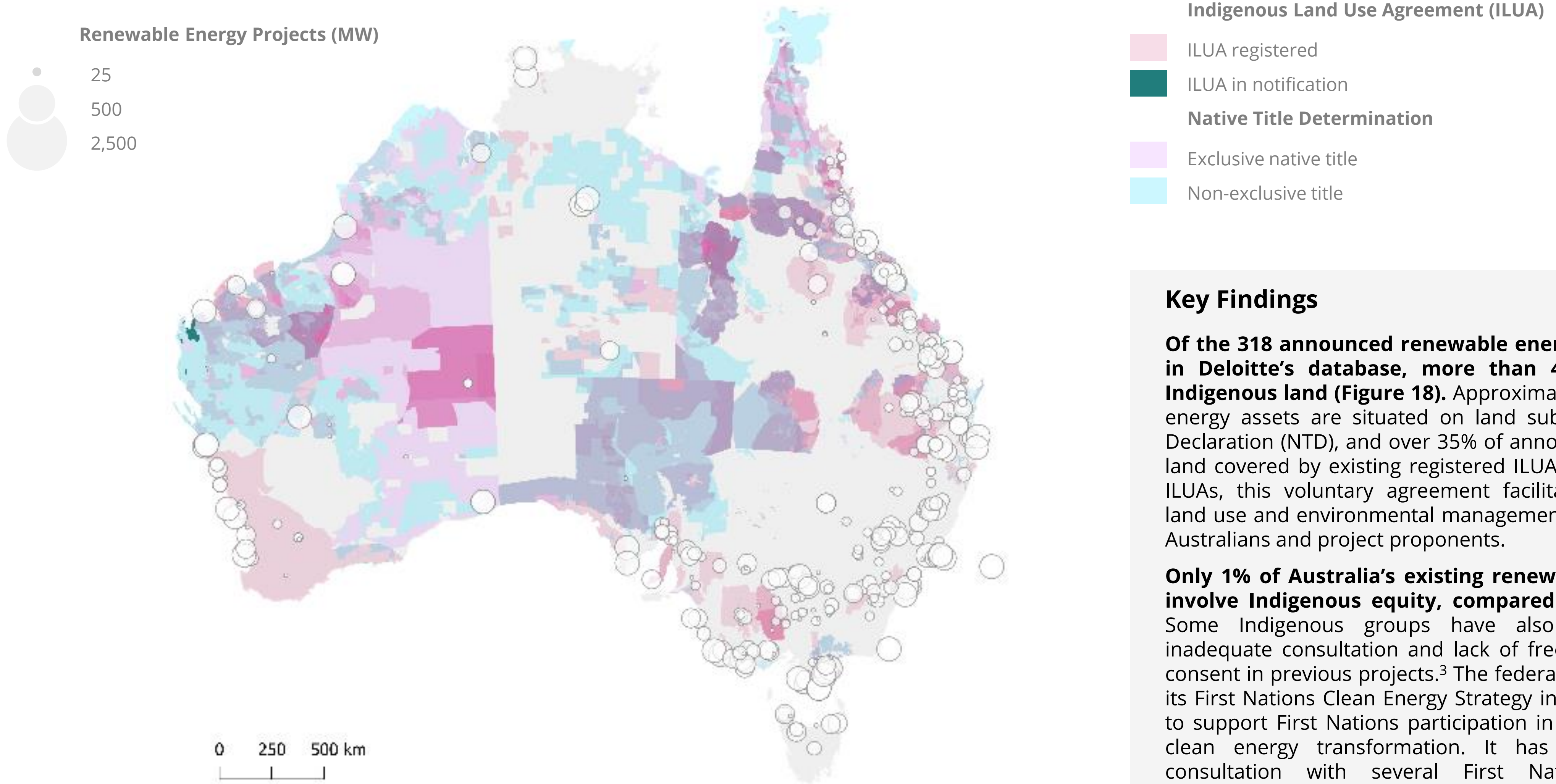
Global projects and guidelines to improve biodiversity value on renewable project land demonstrates potential to counteract impact to protected areas. Investments include preserving native species surrounding project areas and adopting impact avoidance measures. [3,4] In 2024, the UK also introduced a mandate for developers to deliver a 10% biodiversity net gain from pre-development.[5] Various state-based and community guidelines are also being considered in Australia, such as the Victorian Government's commitment to develop a handbook with mandatory guidelines for renewable projects to better consider environmental management.[6]

Source(s): 1. Deloitte analysis (based on data from DCCEEW), 2024. 2. Deloitte analysis, 2024. 3. Orsted, 2023. 4. Playa Lakes, 2024. 5. Government of UK, 2024. 6. DEECA, 2024

The green iron opportunity provides an avenue for Indigenous Australians to benefit

Promoting nature regeneration through Agreements could provide positive socio-economic outcomes

Figure 18: Interactions between announced renewable projects and Indigenous Agreements or Declarations[1]



Source(s): 1. Deloitte analysis, 2024 (based on data from NTT and GEM). 2. The Guardian, 2024. 3. University of Notre Dame Australia, 2021. 4. DCCEEW, 2024

Key Findings

Of the 318 announced renewable energy projects included in Deloitte's database, more than 45% are located on Indigenous land (Figure 18). Approximately 10% of renewable energy assets are situated on land subject to a Native Title Declaration (NTD), and over 35% of announced projects are on land covered by existing registered ILUAs.[1] Similarly to mining ILUAs, this voluntary agreement facilitates negotiation over land use and environmental management between Indigenous Australians and project proponents.

Only 1% of Australia's existing renewable energy projects involve Indigenous equity, compared to 20% in Canada.[2] Some Indigenous groups have also reported cases of inadequate consultation and lack of free, prior and informed consent in previous projects.[3] The federal government finalised its First Nations Clean Energy Strategy in late 2024 which aims to support First Nations participation in and benefit from the clean energy transformation. It has been developed in consultation with several First Nations agencies and communities to ensure it reflects their perspectives.[4]

Green ironmaking has inherent dependencies on nature which can guide future planning processes

Hydrogen

Key nature risks and impacts from green hydrogen

Transitioning to green-hydrogen powered DRI could have impacts on local water and land capacity

Figure 19: Key risks for nature from green hydrogen projects compared to natural gas[1]

Impact areas	Green hydrogen	Natural Gas
Land-use area	High	Medium
Freshwater-use area	High	High
Volume of Water use	Very High	High
Emissions from GHG	Low	High
Emissions of non-GHG air pollutants	Medium	High
Release of waste	Low	High
Disturbances to wildlife	High	High

Notes: 1. Nature impacts from green hydrogen are based on literature and analysis; Natural Gas impacts based on Natural Gas Exploration drivers from TNFD Additional Sector Guidance for Oil and Gas 2. Deloitte have conducted analysis across the following impact areas: land-use area, volume of water use, disturbances to wildlife

Key:

- Very High impact
- High impact
- Medium impact
- Low impact
- Very Low impact

Source(s): 1. TNFD, 2024. 2. Energy and Climate Change, 2024. 3. RMI, 2023. 4. BHP, 2009. 5. ABS, 2023. 6. The Guardian. 2023, 7. DCCEEW, 2023

Key Findings

Material nature impacts from green hydrogen include water use, land intensity and disturbances to wildlife (Figure 19).

The majority of hydrogen land use is attributable to renewables and will likely interact with areas of high biodiversity. There is a higher risk of disturbance during the construction process resulting from renewable energy development compared to natural gas which has a high environmental impact attributed to the operations phase from gas refining and processing.[2]

Hydrogen production is a highly water-intensive process, requiring almost 2,000 – 3,000L per tonne of green hydrogen produced.[3] A single 2.5Mt steel facility would require 1.78GL of water, equivalent to just over 13% of the annual water consumption by BHP's South Australia copper mine [4] and 0.01% of Australia's annual water consumption.[5] However, reuse of water during downstream processes could lower the impact on water use across the lifecycle.

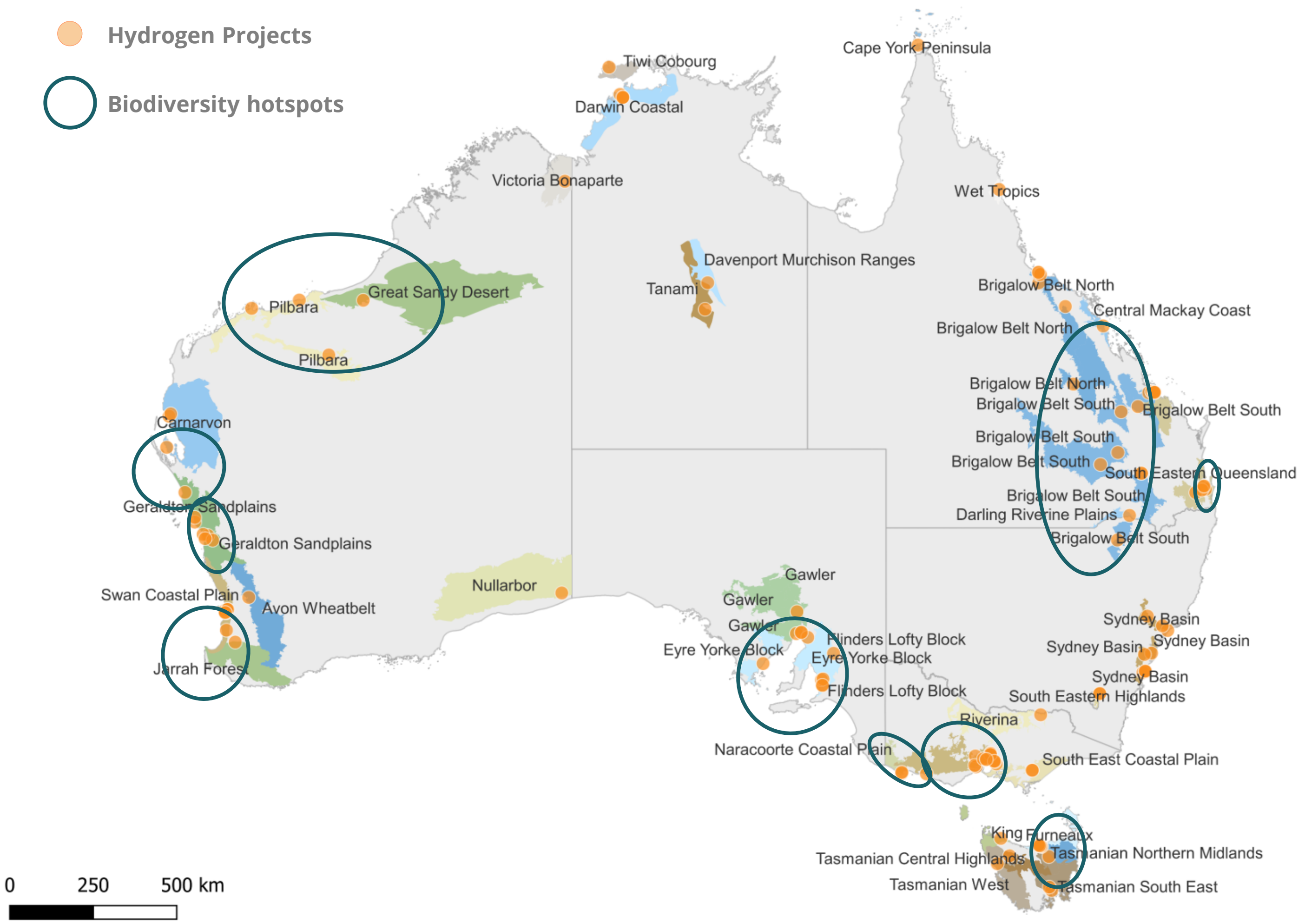
Similar to renewables, there is precedence for First Nations collaborations for hydrogen projects. The Eastern Kimberley green hydrogen project will see a 75% share between three Indigenous groups.[6] Additionally, the Hydrogen Headstart program has allocated funding towards supporting First Nations engagement with projects.[7]

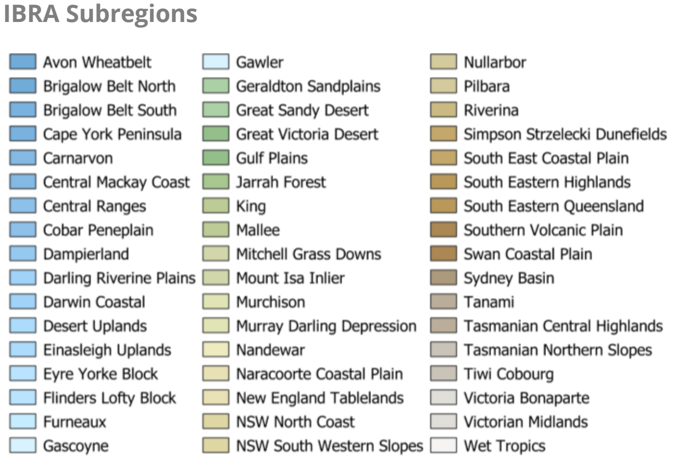
The following slides provide analysis of existing hydrogen facilities against nature dimensions such as IUCN categories, Australian bioregions, water scarcity and Indigenous interests. For all impacts, local assessment will be required to understand incremental demand in local context.

Hydrogen facilities interact with almost half of Australia's biodiversity hotspots

Land use for hydrogen projects could materially impact bioregion value

Figure 20: Interactions between hydrogen projects and Australian bioregions[1]





Key Findings

Announced hydrogen projects are situated across at least half of Australia's biodiversity hotspot regions (Figure 20). A large proportion of projects are within biodiversity hotspots across Queensland, WA, SA, TAS and VIC regions.[2]

While hydrogen provides climate benefits, it has the potential to cause a higher environmental impact over other energy sources (e.g. natural gas). Renewable energy inputs to produce green hydrogen requires sizable land compared to the footprint for gas-powered facilities. This will mean greater disturbances and changes to bioregions.

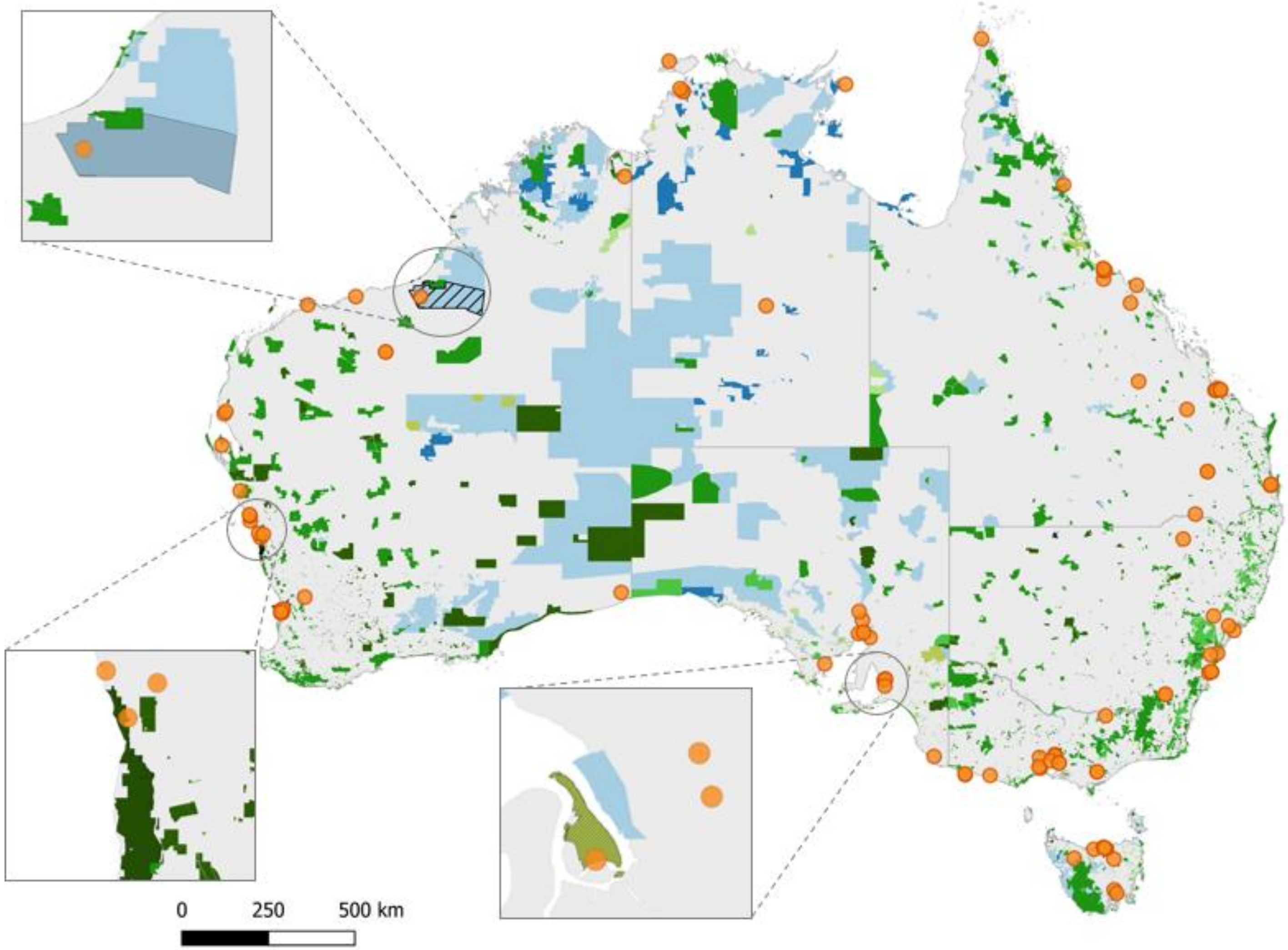
Land use impacts are primarily attributable to facility construction.[3] This includes ground disturbance, soil and water contamination and minimal air pollution.[4] Resource co-location and appropriate management measures could lower the impact cost.

Source(s): 1. Deloitte analysis (based on data from DCCEEW), 2024. 2. Western Australian Biodiversity Science Institute, 2024. 3. Energy and Climate Change, 2024. 4. GHD, 2023

Hydrogen projects are located in or bordering several IUCN protected areas

Australia's green hydrogen projects will need to consider expanded protected regions during development

Figure 21: Interactions between hydrogen projects and Australian IUCN categories[1]



IUCN categories

- Ia Strict Nature Reserve
- Ib Wilderness Area
- II National Park
- III Natural Monument or Feature
- IV Habitat or Species Management Area
- V Protected Landscape or Seascape
- VI Managed Resource Protected Area
- **IUCN areas containing hydrogen projects**

Key Findings

Three hydrogen projects are located within or bordering IUCN designated areas. This consists of one project located on the border of a strict nature reserve area (Category Ia) in Western Australia, one project situated on the border of a Natural Monument or Feature area (Category III) in South Australia and one in a managed resource protected area (Category VI) in Western Australia (Figure 21).

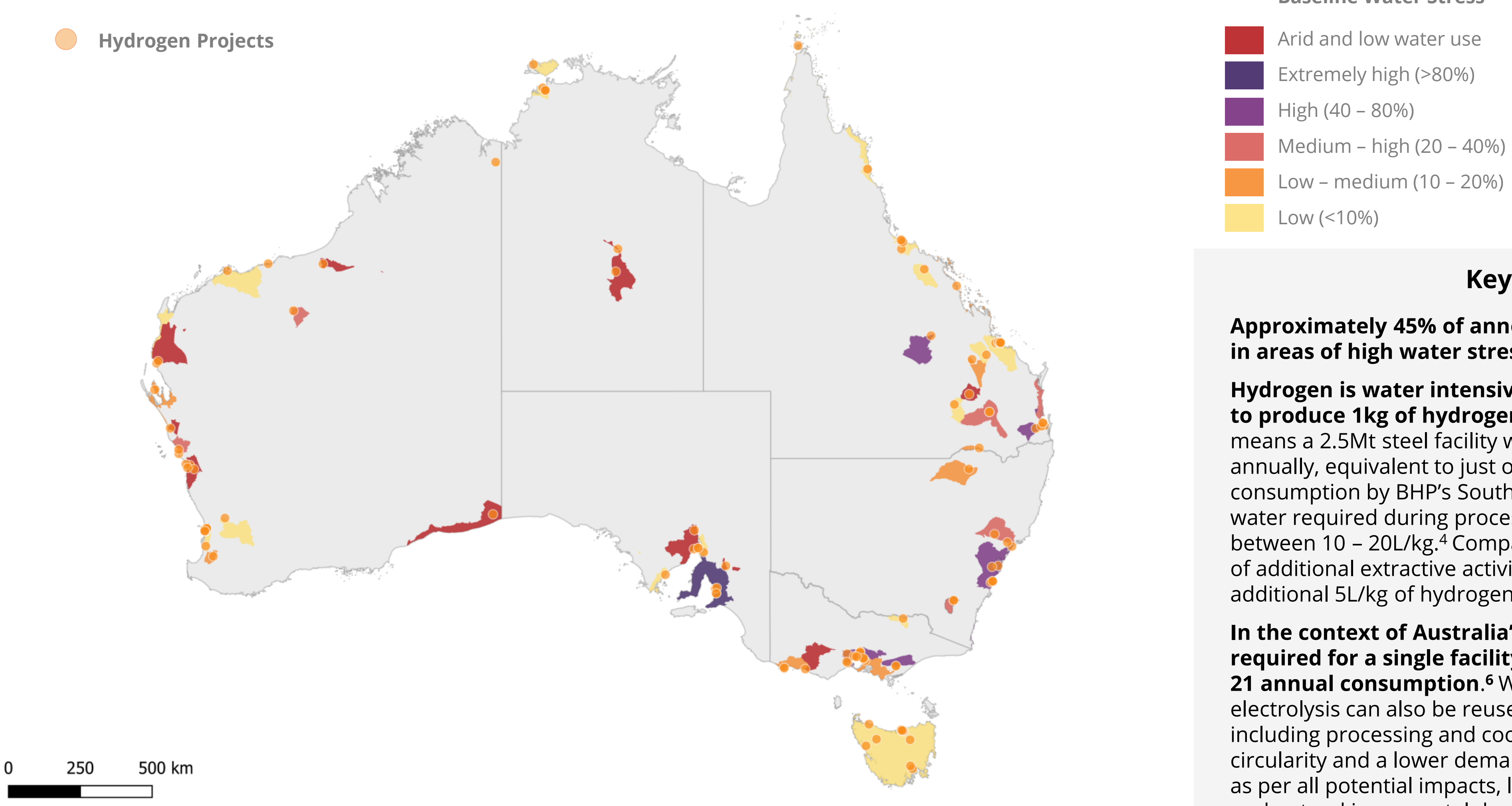
Interactions with IUCN areas will need to be factored into development processes. If protected areas are expanded to meet Australia's 2030 target, hydrogen projects aiming for final investment decisions and receipt of the Hydrogen Production Tax Incentive will require deliberate consideration of protected regions.[2] Inadequate weighting of these risks could deliver an undesirable outcome.

Source(s): 1. Deloitte analysis (based on data from DCCEEW), 2024. 2. The Treasury, 2024

Existing hydrogen projects are dispersed across regions of varying water scarcity

High water intensity in the electrolysis process will require increased circularity to avoid compounding impact

Figure 22: Interactions between hydrogen projects and areas of water stress[1]



Key Findings

Approximately 45% of announced hydrogens projects are in areas of high water stress (Figure 22).

Hydrogen is water intensive, requiring almost 9L of water to produce 1kg of hydrogen through electrolysis.[2] This means a 2.5Mt steel facility would require 1.78GL of water annually, equivalent to just over 13% of the annual water consumption by BHP's South Australia copper mine.[3] Additional water required during processing is estimated to range between 10 – 20L/kg.[4] Comparatively, water consumed as part of additional extractive activities for NG-DRI could add an additional 5L/kg of hydrogen.[5]

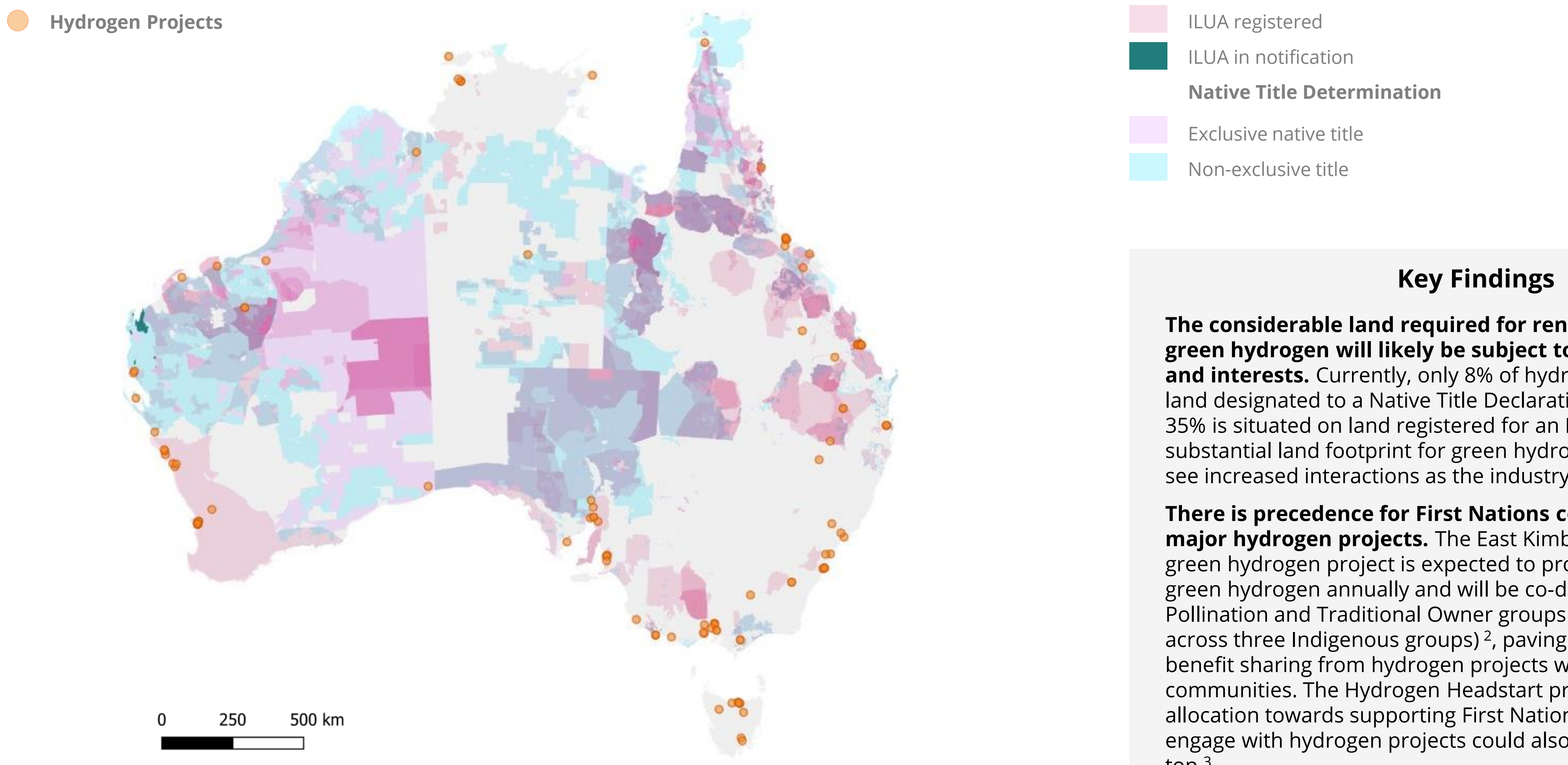
In the context of Australia's yearly water use, the water required for a single facility is less than 0.01% of the 2020-21 annual consumption.[6] Water consumed through electrolysis can also be reused in downstream activities, including processing and cooling, allowing for increased circularity and a lower demand from water shelves. However, as per all potential impacts, local assessment will be required to understand incremental demand within the local context.

Source(s): 1. Deloitte analysis (based on data from World Resource Institute), 2024. 2. International Energy Agency, 2019. 3. BHP, 2009. 4. RMI, 2023. 5. RMI, 2023. 6. ABS, 2023.

Australia's growing hydrogen footprint will increasingly interact with First Nations interests

The land size required for green hydrogen requires greater focus on Indigenous rights to land use

Figure 23: Interactions between hydrogen projects and Indigenous Agreements or Declarations[1]



Key Findings

The considerable land required for renewables to produce green hydrogen will likely be subject to First Nations rights and interests. Currently, only 8% of hydrogen projects are on land designated to a Native Title Declaration, while just over 35% is situated on land registered for an ILUA. However, the substantial land footprint for green hydrogen production could see increased interactions as the industry grows.

There is precedence for First Nations collaboration on major hydrogen projects. The East Kimberley Clean Energy green hydrogen project is expected to produce 50,000t of green hydrogen annually and will be co-developed between Pollination and Traditional Owner groups (with a 75% share across three Indigenous groups) [2], paving the way for increased benefit sharing from hydrogen projects with Indigenous communities. The Hydrogen Headstart program's $4m allocation towards supporting First Nations communities to engage with hydrogen projects could also see a race to the top.[3]

Source(s): 1. Deloitte analysis, 2024 (based on data from NTT and CSIRO). 2. The Guardian, 2023. 3. DCCEEW, 2023

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