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Whitepaper:
The Singapore Electricity Sector and Biodiversity

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This whitepaper is part of a broader series of (academic and industry) papers on the topic of biodiversity impact of business operations, stemming from the collaboration between the Singapore Green Finance Centre and Impact Institute.

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Executive Summary

This white paper demonstrates how biodiversity impact assessment can be applied to a national electricity sector. In Singapore electricity generation relies on 95% on natural gas imports and combustion. In our analysis, we show how considering biodiversity impacts is relevant for policymakers and regulators in Singapore. For this analysis, biodiversity impact refers to the measurable pressure that the electricity sector and its upstream value chain place on ecosystems, expressed as the loss or degradation of species, habitats, and ecosystem services.

The assessment finds that Singapore's electricity system generated an estimated 270,000 PDF.ha.yr (Potentially Disappeared Fraction of species per hectare per year) of biodiversity loss in 2024, equivalent to approximately US$1.14 billion in monetised ecosystem service losses. Climate change is the dominant driver, accounting for around 79% of total biodiversity impact, followed by air pollution at 19%. These impacts arise both from domestic power generation and from upstream activities linked to imported gas. Indonesia and Malaysia together contribute nearly 40% of upstream climate-related biodiversity loss due to the carbon intensity and methane leakage associated with extraction and liquefaction infrastructure. This demonstrates that even comparatively "clean" fossil fuels such as natural gas carry substantial biodiversity burdens once full value chain effects are accounted for – we estimate US$ 1.14 bln in monetised biodiversity impact of electricity sector against US$ ~4 bln GDP from electricity sector.

We suggest four key learnings for policymakers in Singapore. First, decarbonisation is the most effective biodiversity strategy for the electricity sector given that biodiversity impacts are highly concentrated in climate-related pathways. Second, optimising upstream gas extraction and distribution can minimise emissions and reduce GHG intensity of gas. Third, integrating biodiversity valuation into electricity planning, infrastructure design, and regulatory frameworks allows to pre-empt environmental externalities before developing new policies or national projects. Finally, regional coordination with source countries such as Indonesia and Malaysia is vital to reduce biodiversity impact and align ASEAN's biodiversity and energy transition frameworks.

Taken together, the findings show that biodiversity assessment is a powerful tool to align energy transition choices with environmental protection. In this white paper, we demonstrate that integrating biodiversity impact analysis into Singapore's electricity sector strategy is not only feasible but essential for managing long-term ecological risks, guiding decarbonisation pathways, and supporting national commitments to a resilient, nature-positive energy future.

1. Introduction

Southeast Asia is one of the richest regions in terms of biodiversity on the planet: it is home to tropical forests, coral reefs, mangroves, and wetlands that support a vast number of endemic species. At the same time, the region is also experiencing some of the highest rates of biodiversity loss globally. According to Sodhi et al. (2004), the region could lose up to 75% of its original forest cover by 2100, with potentially 40% of global biodiversity loss occurring within its boundaries. And this projection remains largely on track two decades later: between 2000 and 2020, ASEAN member states collectively lost more than 160,000 km² of forest, driven mainly by agricultural expansion, infrastructure development, and urbanisation (ASEAN Centre for Biodiversity, 2023). The rate of primary forest conversion remains among the highest worldwide, particularly in Indonesia, Malaysia, and Myanmar (Global Forest Watch, 2024).

Habitat conversion is the dominant driver of biodiversity decline and is supplemented by several other impacts. Climate change, overexploitation of fisheries, pollution, and invasive species all add to the cumulative loss of ecosystems. The ASEAN Biodiversity Outlook (2023) notes that over 60% of assessed species in the region are now threatened or declining, while key ecosystem services such as water regulation, soil fertility, and coastal protection are deteriorating. Terrestrial and marine ecosystems across Southeast Asia are under severe stress, with growing implications for the region's economies and societies, which depend heavily on natural resource extraction, agricultural exports, and rapid urban development.

The region's biodiversity loss is not only an ecological concern but an economic and social one. Southeast Asia's industries, from agriculture and forestry to energy and transport, depend on the very ecosystems that are deteriorating. This creates a feedback loop in which risks to business operations and biodiversity loss reinforce each other, increasing both environmental and financial vulnerability. Understanding this connection is critical for sectors such as energy production, which is the focus of this white paper.

The energy transition underway across Southeast Asia is reshaping the region's economic and environmental landscape. Out of the 11 ASEAN governments, 8 are committed to meet net-zero targets by mid-century, including Singapore, Vietnam and Laos (WEF, 2023). Yet, as the International Energy Agency (IEA, 2023) notes, Southeast Asia's energy demand is projected to rise by more than 50% by 2040, driven by rapid urbanisation and industrial growth. Balancing this rising demand with decarbonisation ambitions creates a complex trade-off: expanding clean energy infrastructure while preventing further harm to ecosystems.

While the broader energy system encompasses extraction, refining, transport, and end-use consumption, energy generation under the form of electricity is where biodiversity impacts converge most visibly. Power generation is rising sharply in demand in Southeast Asia and represents a key point where decarbonisation can directly reduce both climate and biodiversity impacts (IEA, 2024). In Singapore, where gas accounts for more than 94 percent of the electricity mix, biodiversity impacts are linked not only to local operations but also to the upstream supply chain that provides the fuel for the grid (IEA, 2023). Understanding these linkages is essential to align climate mitigation policies with biodiversity protection ones in the country's electricity transition.

The following chapters build on this introduction. Section 2 defines the type of analysis and the system boundaries applied to Singapore's gas-based electricity system. Section 3 describes the footprinting and monetisation methodology based on the Global Impact Database Biodiversity (GID Biodiversity). Section 4 presents the results of the biodiversity impact assessment, identifying the main environmental drivers of biodiversity loss within the electricity sector. Section 5 provides an upstream analysis of climate-related impacts associated with gas imports. Section 6 translates the results into findings and recommendations for policymakers and industry practitioners, and Section 7 discusses limitations of the analysis and concludes with key takeaways for aligning biodiversity and decarbonisation strategies in Singapore's electricity transition.

2. System Boundaries, Principles of Analysis

This paper presents a biodiversity footprint impact assessment of Singapore's electricity system, which is powered for a vast majority by natural gas combustion. For the purpose of this white paper, biodiversity impact refers to the measurable pressure that the electricity sectors' operations and value chain place on ecosystems, quantified as the loss or degradation of species, habitats, and ecosystem services. The analysis aims to quantify and monetise the biodiversity impacts generated across the upstream value chain and direct operation activities of imported natural gas used for power generation (for a detailed explanation of the concepts of value chains and monetisation, please refer to explanation boxes 1 and 3 respectively). We exclude downstream value chain impacts as these would be driven by the economic activities that use electricity in Singapore[1].

The analysis uses the Global Impact Database Biodiversity (GID Biodiversity) to estimate both impacts at direct operations of the electricity sector and the upstream value chain impacts in footprint and monetary terms. The goal is to identify the key drivers of biodiversity loss in the electricity sector in Singapore and to provide recommendations to policy-makers in Singapore for the decarbonisation and greening of Singapore's electricity grid.

The boundaries of the analysis cover the supply chain of electricity generation. Upstream activities include gas extraction and processing, and direct operations include the burning of natural gas in Singapore to generate electricity. Each driver is expressed in PDF.ha.yr (Potentially Disappeared Fraction of species per hectare per year. For more information, please refer to explanation box 2) and monetised through the estimated value of ecosystem services lost due to these impacts. The analysis is based on data for the fiscal year 2024, using the US$ impact as the functional unit of measurement. By combining biodiversity footprinting with monetary valuation, the approach translates environmental externalities into financial metrics.

Explanation Box 1: Value Chains

For the purpose of this study, value chains are defined as the interconnected network of activities, organizations, and processes involved in the production, distribution, and consumption of goods and services. These value chains are categorized into three segments: upstream, direct operations, and downstream. **Upstream activities** include all inputs and processes that occur before the focal activities, such as raw material extraction, supplier operations, and transportation. **Direct operations** refer to the activities and impacts directly attributable to the sector itself, including its production processes, facilities, and immediate outputs. **Downstream activities** encompass all processes that occur after the product or service leaves the sector, such as distribution, consumption, and disposal. In this analysis, only upstream and direct activities are considered.

[1] Focusing on downstream value chain impact would mean looking at the impact of all of Singapore economic activities that rely on the national electricity grid: in other words, the whole Singaporean economy. This is not the aim of this paper.

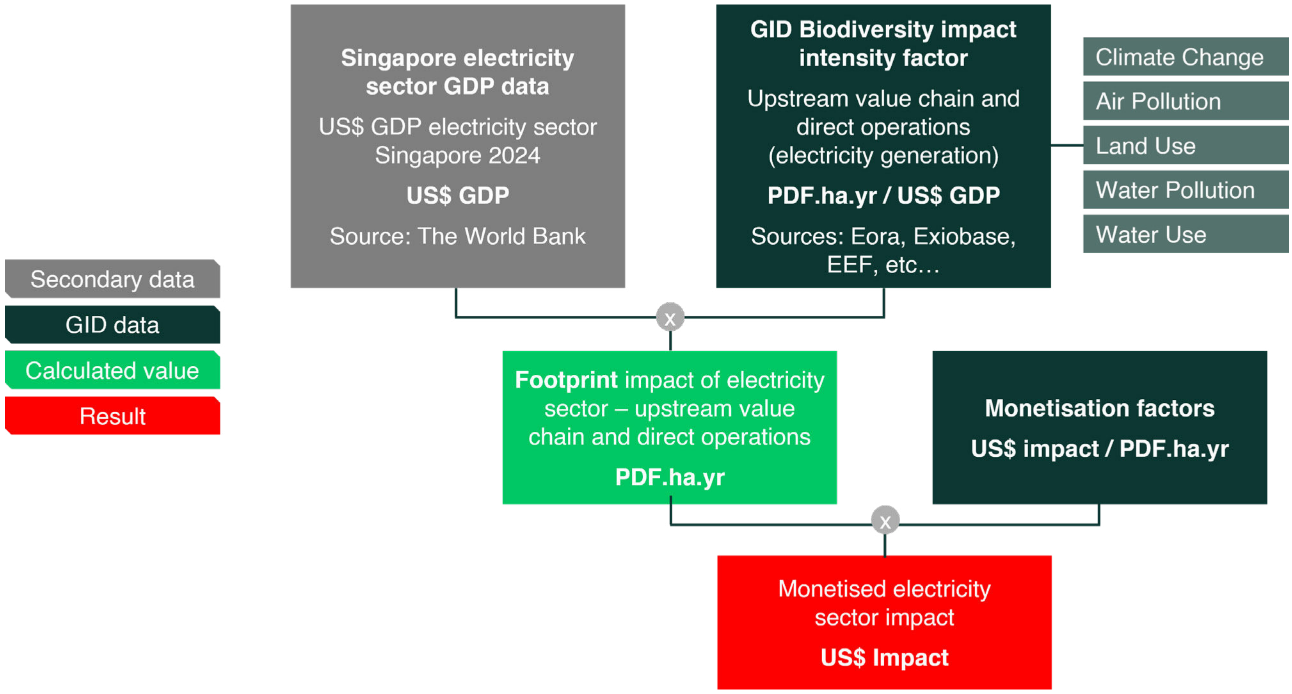
3. Methodology

The biodiversity impact analysis in this whitepaper has been conducted using the Global Impact Database (hereafter GID Biodiversity), proprietary database owned by Impact Institute. GID Biodiversity uses top-down country sector analysis to quantitatively provide impact estimates for countries and sectors in the global economy. Results cover both direct and upstream value chain impact. GID Biodiversity estimates this impact using input-output analysis based on data on the interconnectedness of industries in various countries and their environmental and economic performance.

Five drivers of biodiversity impact are included in the analysis: land use, air pollution, climate change, water pollution, and water use. These drivers are an aggregation of relevant indicators and are measured as either a direct physical footprint on biodiversity or an indirect loss of biodiversity[2]. Then, these values are converted to footprint measure of the state of ecosystems, namely, PDF.ha.yr (more information in explanation box 2). All impact results are also presented in monetised units. This is done based on the value of the ecosystem service loss associated with the original state of biodiversity for a given area of land (for more detail on monetisation of ecosystem services, see explanation box 3).

During the analysis, we combine the estimated number of US$ GDP generated by the electricity sector in Singapore in 2024 with GID Biodiversity upstream value chain and direct operations impact factors to estimate the impact of the electricity sector in Singapore. See visual of the calculation below.

Figure 1: Visual representation of the calculation performed in the analysis



[2] An example of direct driver is the use of land, which directly displaces species from a given ecosystem. An example of indirect driver is GHG emissions, which warm the atmosphere and affect the composition of ecosystems, indirectly driving species away from that ecosystem.

Explanation Box 2: PDF.ha.yr

What is a PDF.ha.yr?
PDF.ha.yr is a footprint measure to quantify the biodiversity impact on the state of an ecosystem. PDF stands for Potentially Disappeared Fraction, the proportion of species expected to be lost in an area due to human pressures (such as land use, emissions, water use, or pollution).

How to interpret a PDF.ha.yr?
It indicates the fraction of species lost (or at risk of loss) in one hectare of land over the course of one year due to human pressures.1 PDF.ha.yr can be interpreted as a 100% loss of one species across one hectare for one year, or a 10% loss across ten hectares, or equivalent combinations.

Figure 2: Biodiversity impact of the Singapore electricity sector due to gas imports by impact driver, 2024

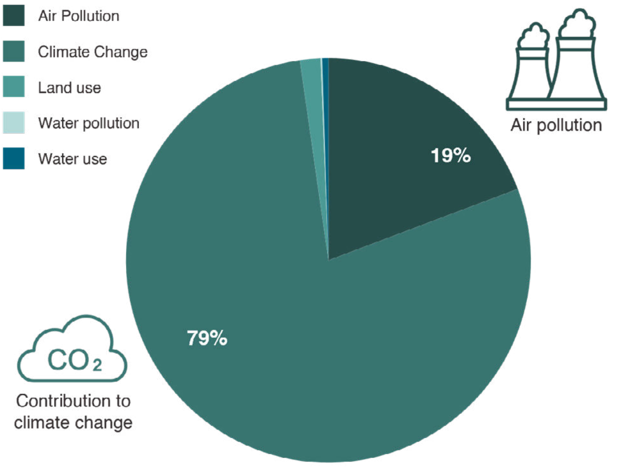
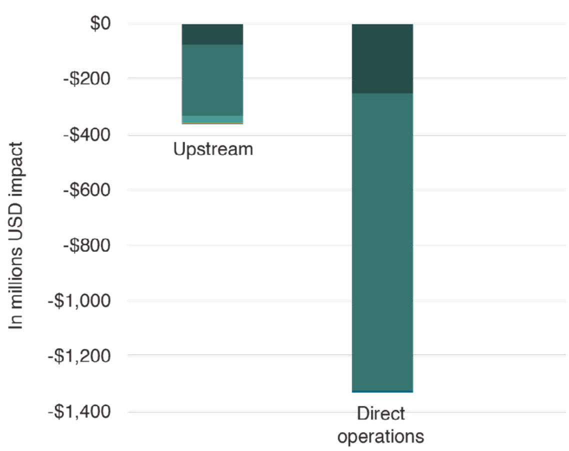


Figure 3: Biodiversity impact of the Singapore electricity sector by value chain step, 2024



4. Impact Assessment

Figure 2 shows the upstream and direct biodiversity impact for the year 2024 of Singapore's electricity system generated by the gas imports. When measured in PDF.ha.yr, total biodiversity loss attributed to gas use for power generation corresponds to around 270,000 PDF.ha.yr. This number reflects both the impact of the upstream value chain (gas extraction, manufacturing and distribution) and the direct operations (the running of gas plants to produce electricity). In monetary equivalent, the estimated biodiversity loss amounts to approximately US$ 1.14 billion[3] for 2024, of which around 80% originates from environmental impacts occurring within Singapore's electricity sector (as illustrated in figure 3).

Among the five drivers assessed (climate change, air pollution, water pollution, land use, and water use) climate change is by far the most significant, accounting for about 79% of total biodiversity impact. The combustion of natural gas releases large volumes of carbon dioxide and methane, both potent greenhouse gases. These emissions contribute to temperature rise, ocean acidification, and changes in precipitation patterns that directly and indirectly threaten species survival (IPBES, 2019). Upstream gas extraction and processing also release fugitive methane, which has a high global warming potential and further amplifies

[3] This amounts to approximately one fourth of the electricity sector GDP of Singapore, estimated at US$ ~4 bln. While the valued impact number (US$ 1.14 bln), if compared to Singapore's total GDP (~ US$ 547 bln) seems quite negligible, this paper argues that it can be substantially reduced by using a cleaner electricity mix. Environmental impact of electricity generation from gas can be estimated around 0.40 $/kwh. As an example, solar electricity generation can reduce impact by around 0.30 $/kwh (Impact Institute, internal estimates). This theoretically means impact could be reduced by 75% with a shift to renewable energy generation.

climate-related impacts on biodiversity (EPA, 2025). The dominance of this driver demonstrates that even cleaner-burning fossil fuels such as gas remain major contributors to biodiversity loss through their role in climate change.

The second-largest driver is air pollution, responsible for roughly 19% of the total impact. Air pollutants emitted during gas extraction, transport, and especially combustion (particularly nitrogen oxides (NO_x) and sulfur dioxide (SO_2)) can acidify soils and water bodies, disrupt nutrient cycles, and reduce plant and animal health (Britannica, 2025). These impacts often occur near power plants and urban areas, where dense population and limited land amplify local exposure. Air pollution thus represents both a direct local environmental concern and an indirect biodiversity risk through the degradation of supporting ecosystems.

Water use and water pollution together contribute less than 2% of the total impact but remain relevant from a local industrial perspective. Gas-fired plants require cooling water and may discharge effluents that alter thermal and chemical conditions in nearby marine or coastal environments. Although these effects are relatively contained compared with climate-related impacts, they can influence local biodiversity, particularly in Singapore's already stressed coastal ecosystems (EIA, 2014).

Land use change, the fifth driver, plays only a minor role in terms of biodiversity impact in Singapore's system boundaries, given the nature of gas-generated electricity: gas plants take up little surface area and can produce high amounts of electricity throughout their lifetime, thus distributing the land occupation impact across their useful life. However, it becomes more significant upstream, where gas extraction and processing infrastructure in countries such as Indonesia and Malaysia involve land clearing, habitat disturbance, and increased access to previously undisturbed areas (Mardhika, 2018).

In a nutshell, climate change, both from direct operations and from upstream value chains is by far the biggest driver of biodiversity loss from the gas-powered electricity sector in Singapore. This shows that for certain sectors decarbonisation plans provide also major gains for biodiversity – provided that a biodiversity impact analysis is conducted hand in hand with a carbon footprint exercise, showing the magnitude of the other impact drivers for comparison. In the next chapter, the paper will dive deeper in the distribution of climate change impact in the upstream value chain, showing how GID Biodiversity can provide insights in the different sectors and geographies that Singapore imports gas from.

Explanation Box 3: Monetisation through Ecosystem Services

What is Monetisation?
Impact monetisation (or impact valuation) is the process of expressing environmental and social impacts into financial terms. For biodiversity, it means expressing ecological changes such as habitat loss or pollution in dollar values that reflect the cost of damage, restoration, or lost benefits. This allows impacts to be compared with financial performance and made visible in business decisions.

What are Ecosystem Services?
Ecosystem services are the benefits people gain from nature, supported by biodiversity. They are classified in four kinds:

- Provisioning services (food, water, materials),
- Regulating services (carbon storage, water purification),
- Supporting services (soil formation, nutrient cycling),
- Cultural services (recreation, heritage).

Businesses depend on these services for inputs, stability, and resilience—making their loss a direct financial risk.

This approach values biodiversity loss by estimating the economic cost of reduced ecosystem services. For example, deforestation may be valued through the cost of (man-made) water purification facilities or restoration per hectare. Databases such as the Ecosystem Services Valuation Database (ESVD) provide benchmarks that allow biodiversity loss to be expressed in dollars and compared to returns.
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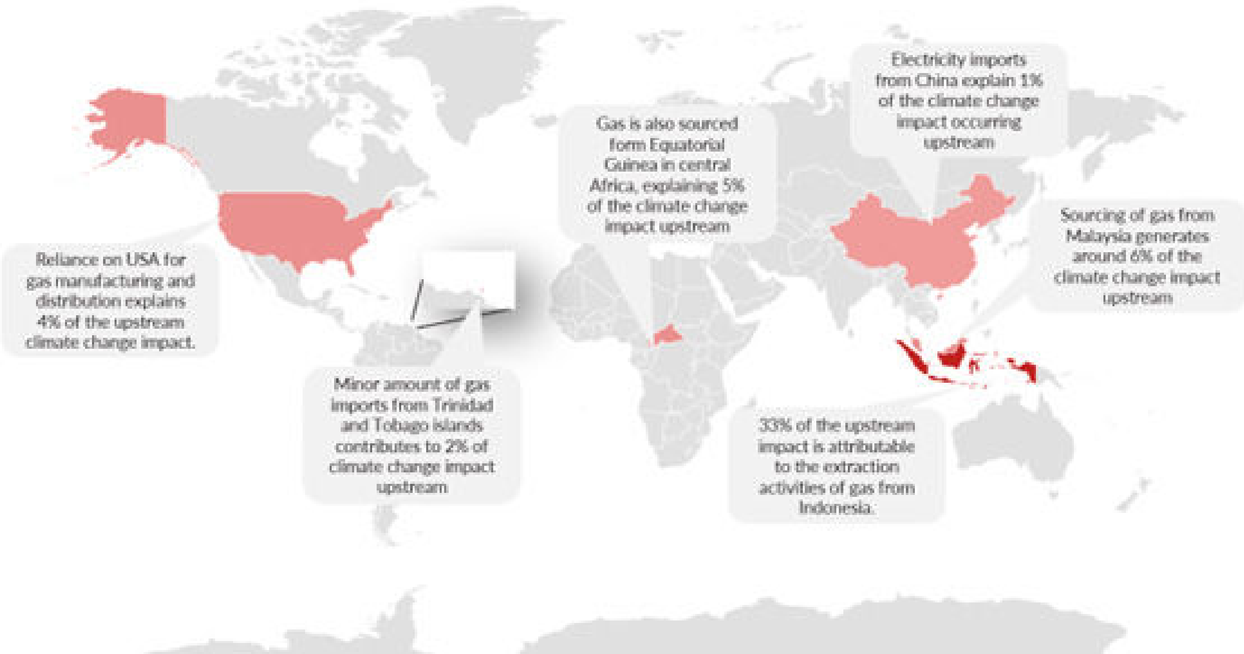
How to Interpret Results
Biodiversity impact expressed in monetary terms represents the US$ of forgone benefits that ecosystem services could have provided if the activity generating the impact didn't take place – and the surrounding nature would be allowed to grow back to its pristine state.

Why Use Monetisation?
Monetisation puts biodiversity in the language of finance, enabling comparison with other impacts, prioritisation of hotspots, and clearer engagement with stakeholders. It supports compliance with emerging frameworks like TNFD and the Global Biodiversity Framework (Target 15), which require disclosure and management of biodiversity risks. Above all, it bridges science and finance, helping practitioners integrate biodiversity into strategy and capital allocation.

5. Upstream Climate Change Impacts

This section explores the upstream component of biodiversity impact associated with Singapore's gas-based electricity system. It focuses on the climate change driver of biodiversity loss, which accounts for nearly 80% of the total loss modelled in the analysis. The upstream value chain includes extraction, processing, and transport of natural gas imported from key supplier countries, primarily Indonesia, Malaysia, and Equatorial Guinea, along with smaller volumes from Australia, China, the United States, and Trinidad and Tobago.

Figure 4: Top 10 country operations driving climate change impact in the upstream value chain



The map highlights the top ten country sources contributing to the upstream climate change footprint of the Singapore electricity sector upstream value chain. It depicts how scope-3 (upstream) emissions (from extraction, processing, and transport) are geographically dispersed. Notably, most impacts originate in Southeast Asia, where Indonesia (33%) and Malaysia (6%) dominate, reflecting their large offshore gas operations and intensive liquefied natural gas (LNG) infrastructure. Together, these two countries alone explain nearly 40% of the total upstream climate impact, given the proximity to Singapore that allows for pipes to supply gas to the city.

Indonesia's gas extraction represents 33% of the climate change upstream impact, the single largest contributor to upstream biodiversity loss linked to Singapore's gas use. Its main gas fields (such as the Tangguh project in Papua) are located near ecologically sensitive forest and coastal ecosystems, posing severe threat to the surrounding biodiversity (Trend Asia and Recourse, 2025). Emissions during LNG extraction arise from both combustion and fugitive methane leakage, a potent greenhouse gas with a global warming potential roughly 30 times that of CO_2 over 100 years. Routine flaring and venting at extraction and liquefaction plants add further carbon emissions (World Bank, 2023). This combination of high extraction intensity, significant flaring, and ecosystem sensitivity explains Indonesia's dominant share of the upstream footprint.

Malaysia is world #5 LNG exporter, and its gas sector is responsible for around 6% of the upstream climate change impact of the electricity sector of Singapore. Malaysia conducts a significant amount of its gas extraction operations offshore, which have the potential of harming biodiversity-rich ocean ecosystems.

While Indonesia and Malaysia together represent around 40% of the upstream climate change impact, other countries contributing to this impact are the USA (providing manufacturing and distribution infrastructure and services), Trinidad and Tobago (largest Caribbean producer and exporter of natural gas), Equatorial Guinea (among the top producers of natural gas in central Africa) and finally China (supplying electricity heavily reliant on coal).

What the data from GID Biodiversity imply is that decarbonisation of gas supply chains cannot rely solely on end-use efficiency, and that one sector's activities can only be as green as its value chains. Meaningful reductions of impact require upstream interventions such as methane leak detection and repair (LDAR) in Indonesian and Malaysian fields or cleaner LNG liquefaction technologies, or a shift in electricity generation all along. We explore this further in the next chapter.

6. Implications for the Singaporean Electricity Sector

The analysis confirms that Singapore's electricity sector, dominated by natural gas, exerts substantial indirect impacts on biodiversity largely through climate-driven pathways. The total biodiversity loss associated with gas use for power generation amounts to round US$ 1.14 billion in 2024, with approximately 80% of impacts occurring within Singapore's electricity sector itself. Among the five assessed drivers – climate change, air pollution, land use, water use, and water pollution – climate change alone accounts for roughly 79% of the total biodiversity footprint.

This demonstrates that even a comparatively "cleaner" fossil fuel such as gas remains a major indirect driver of biodiversity loss through greenhouse-gas emissions and fugitive methane from upstream extraction and liquefaction. Indonesia (33%) and Malaysia (6%) emerge as the dominant contributors to Singapore's upstream climate-related biodiversity impacts, reflecting their proximity, large-scale offshore gas infrastructure, and the carbon intensity of liquefied natural gas (LNG) operations. Other suppliers such as Equatorial Guinea, the United States, and Trinidad and Tobago contribute at a smaller scale but still with material shares, revealing the global dispersion of Singapore's gas-related ecological footprint.

The dominance of climate-related impacts underscores the alignment of decarbonisation and biodiversity goals: reducing emissions through a cleaner energy mix would yield substantial biodiversity co-benefits. However, the analysis shows that transition pathways matter. For example, the replacement of gas with renewables may reduce atmospheric and marine stressors but can introduce new land-use and ecosystem trade-offs if not properly managed.

In view of the following conclusions, we bring forward four main learnings for policy-makers in Singapore to reduce the biodiversity impact of Singapore's electricity sector: 1. Accelerate shift towards low-carbon electricity generation, 2. Infrastructure optimisation is needed given that the decarbonisation pathway is dependent on natural gas in the mid-to-long term, 3. Integrate biodiversity impact assessments in project planning, 4. Collaboration across regional actors.

Learning #1: The shift towards low carbon economy is the most efficient way to reduce biodiversity impacts

Transitioning from gas to solar and other low-carbon technologies remains the most direct pathway to reduce both climate and biodiversity impacts. Singapore's target of deploying at least 2 GW[4] of solar capacity by 2030 represents a critical step towards decoupling power generation from fossil fuels. Yet, as solar capacity expands, land and aquatic ecosystems must not become collateral casualties of decarbonisation. Floating and rooftop installations can be prioritised over land-intensive projects, coupled with biodiversity-sensitive designs. Aligning decarbonisation pathways to biodiversity considerations ensures that the energy transition can also be a nature-positive transition.

Learning #2: Infrastructure optimisation is needed given that the decarbonisation pathway is dependent on natural gas in the mid-to-long term

Optimising the functioning of current gas extraction and distribution infrastructure can only lead to marginal gains on reducing biodiversity impact, yet minimisation of negative impact should be considered as part of the solutions as per the mitigation hierarchy. When avoiding an activity is not possible (e.g. generating electricity using fossil-free energy sources), minimisation is the next logical step (minimise emissions associated to gas by improving infrastructure). Optimisation could occur in the upstream value chain in the Indonesian and Malaysian gas extraction and distribution practices, through procurement leverage from the Singapore government to drive upstream improvement. These improvements could take place via mandatory methane leak detection and repair (LDAR) systems or adoption of low-carbon liquefaction technologies. These measures could address scope 3 emissions of the electricity generation in Singapore.

[4] Current installed electricity generation capacity in Singapore: approx. 15 GW (Singapore Energy Market Authority, 2025)

Learning #3: Integrate biodiversity impact assessments in project planning

Singapore's regulators and energy companies own several processes that can significantly affect biodiversity, e.g. scenario modelling, project and policy development, procurement frameworks. They should embed biodiversity footprinting using tools such as GID Biodiversity or location-specific environmental impact assessment so that biodiversity becomes one of the core performance metric for energy imports and electricity generation projects.

Learning #4: Collaborate across regional actors.

Biodiversity impacts in Southeast Asia transcend national boundaries. Given Singapore's reliance on imported gas, regional coordination with source countries such as Indonesia and Malaysia is vital to improve transparency, share monitoring data, and align mitigation measures under ASEAN's biodiversity and energy transition frameworks. Joint initiatives could include shared data platforms for methane emissions, cross-border biodiversity monitoring, and financial incentives for verified nature-positive operations.

7. Limitations, Conclusion

The analysis presents three main limitations. The first limitation concerns the granularity of the input data from the electricity sector; the second limitation is inherent to footprinting approaches, and the third limitation is the reliance of GID Biodiversity on potentially old data sources. We discuss these in the following paragraphs.

The first limitation concerns the granularity of data used as input for the analysis, namely, the GDP data of the electricity sector of Singapore. While this data, combined with GID Biodiversity provides an estimate of the impact of the electricity sector and its upstream supply chain, the estimate of the upstream impact can be refined using data from the upstream gas imports from each country and combining this data with the country specific GID Biodiversity factors. While this would still provide a top-down estimate, the analysis would reflect more accurate impact estimates taking in consideration the different country of import-specific impact factors.

The second limitation is inherent to the footprinting approach. GID Biodiversity, like many footprinting assessment databases, relies on aggregated data at the level of countries and sectors. This can reduce the granularity and specificity of its impact assessments. GID Biodiversity uses input-output models and global databases to estimate environmental and economic impacts. While this provides comprehensive coverage, it also means that the results are based on averages for each country-sector combination, rather than specific data for individual companies, regions, or activities. Therefore, companies performing activities more sustainably will still present a similar impact profile to less sustainable companies active in the same country and sector.

Final limitation of GID Biodiversity is its reliance on source data that is not always updated frequently, for example databases on environmental impacts and biodiversity metrics. For example, changes in land use, industrial practices, or environmental regulations that have occurred since the last update of these databases may not be captured. This can lead to an underestimation or overestimation of impacts in certain sectors or regions. Additionally, the use of older data can make it challenging to align GID Biodiversity results with the most current sustainability goals, policies, or market conditions.

To conclude, this whitepaper shows that Singapore's gas-based power system concentrates the bulk of its biodiversity footprint in climate-driven impacts, with total losses of ~270,000 PDF.ha.yr valued at ~US$1.14 billion in 2024; climate change accounts for ~79% of the impact, followed by air pollution (~19%). These impacts arise both in direct operations and across the upstream supply chain, which is geographically dispersed but dominated by Indonesia (33%) and Malaysia (6%) due to extraction and LNG activities supplying Singapore's grid. Translating these effects into financial terms clarifies the scale of externalities and aligns decision-making with risk management. The core implication is straightforward: accelerating decarbonisation delivers outsized biodiversity gains, provided transition choices (e.g., siting and design of solar) avoid shifting burdens to land and habitats.

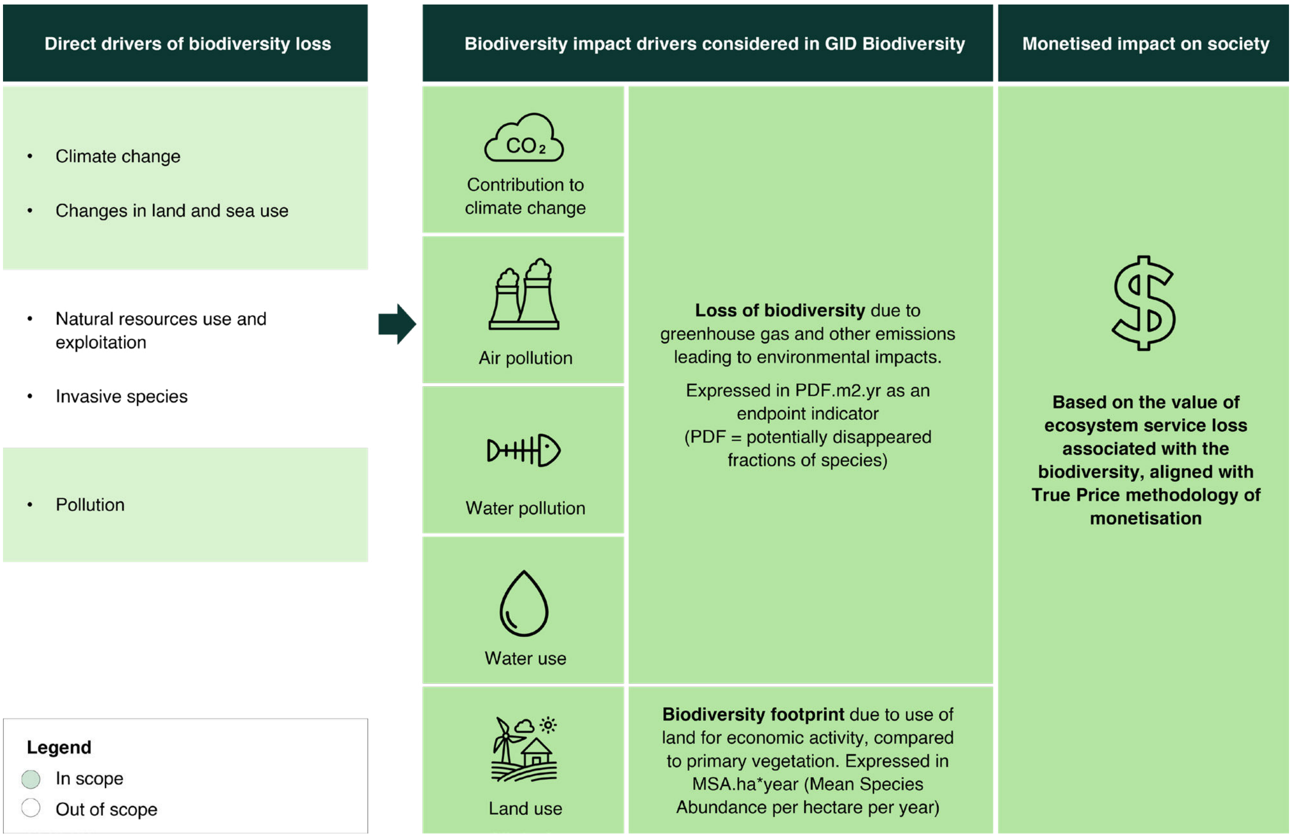
This whitepaper therefore acknowledges four main learnings for policy makers in Singapore. First, biodiversity impacts are highly concentrated in climate-related pathways, underscoring that decarbonisation is the most effective biodiversity strategy for the electricity sector. Second, optimising upstream gas extraction and distribution can minimise unavoidable emissions. Third, integrating biodiversity valuation into electricity planning, infrastructure design, and regulatory frameworks allows environmental externalities to be considered alongside financial and system reliability metrics. Finally, regional coordination with source countries such as Indonesia and Malaysia is vital to reduce biodiversity impact and align ASEAN's biodiversity and energy transition frameworks. Together, these actions align Singapore's energy transition with broader ecological resilience, ensuring that progress on climate goals also contributes to protecting biodiversity.

Appendix

A. Methodology: The Global Impact Database

The Global Impact Database Biodiversity (GID Biodiversity) provides a comprehensive framework for assessing biodiversity impacts across value chains, leveraging both quantitative and monetized approaches. The methodology integrates data from global databases, such as GTAP, FAOSTAT, and GIS sources like GLOBIO and WWF, to evaluate the interconnectedness of industries and their environmental performance across 140 countries and 65 sectors. Biodiversity loss is quantified using indicators such as Mean Species Abundance (MSA) and Potentially Disappeared Fractions (PDF), which measure the reduction in species abundance or probability of occurrence compared to undisturbed habitats. These indicators are then converted to a common unit in PDF. The drivers of biodiversity loss included in the database are land use, climate change, air pollution, and water pollution and water use.

The GID Biodiversity methodology employs a full chain impact (FCI) approach to attribute biodiversity impacts across the entire value chain, ensuring a holistic assessment. It uses Multi-Regional Input-Output (MRIO) analysis to link economic activities to environmental impacts, translating emissions and land use into relative species loss across terrestrial, freshwater, and marine ecosystems. The methodology also incorporates monetization by valuing ecosystem services (ESS) such as carbon storage, air purification, and water regulation. This allows biodiversity impacts to be expressed in monetary terms, providing a tangible measure of the economic magnitude of biodiversity loss.



Explanation Box 4: Calculation Example

In this box, we display an example of the calculation that we have performed to generate the results of the analysis. We use the climate change impact for direct operations as an example.

1. Footprint Impact
First step is to take a measure of added value of the Singapore electricity sector and multiply it with the GID country sector value for the electricity sector of Singapore.

$$(US\$)\ GDP_{Singapore\ Electricity} \times (PDF.ha.yr/US\$)\ GID\ Biodiversity_{Climate\ Change,\ Singapore,\ Electricity}$$
$$= 3{,}806{,}921{,}570 \times 0.000044 = \mathbf{168{,}387\ PDF.ha.yr}$$

2. Monetise Impact
Second step is to monetise the footprint that we have calculated.

$$(PDF.ha.yr)\ Footprint\ impact \times (US\$/PDF.ha.yr)\ Monetisation\ factor_{Climate\ Change}$$
$$= 168{,}387 \times -4273 = \mathbf{-719{,}516{,}057\ US\$}$$

This calculation is performed across the board for all impacts and value chain parts (upstream value chain and direct operations).

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