Expert Opinions Related to Potential Environmental and Human Health Impacts of the Middle Arm Sustainable Development Precinct as well as the Adequacy of the Draft Terms of Reference for Strategic Assessment

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Contents

1 Personal Statement

- I have prepared this report on behalf of Environment Centre Northern Territory as requested by Environmental Defenders Office.
- This report sets forth my professional opinions regarding:
    - The potential severity of environmental and health impacts, based on comparable facilities, community experiences, and scientific research related to similar industries elsewhere. My assessment focuses primarily on air quality impacts, with additional consideration of water quality, water quantity, and the acute risks that these facilities might pose, such as in the case of an accident or cyclone.
    - The adequacy of the Terms of Reference for the Strategic Assessment (https://ntepa.nt.gov.au/__data/assets/pdf_file/0006/1098231/masdp-proponent-draft-terms-reference.pdf) to identify, evaluate, and mitigate/manage these impacts.
- The documents I have cited in this report are referenced and linked within footnotes throughout.
- A list of documents not referenced but considered when forming my opinions is within the available document folder.
- An up-to-date copy of my curriculum vitae that includes a list of all my publications is in the final section of the report.
- I have reviewed, and made every attempt to comply with, the Expert Report Code of Conduct outlined in Practice Direction No 6 of 2015 Expert Reports and I agree to be bound by it.[1]

I declare under penalty of perjury that the information in this report is true and correct to a reasonable degree of scientific certainty. I reserve the right to update this report, or my opinions, should new information become available.

Michael D. Petroni, PhD, MPA
June 9, 2022

[1] NT Supreme Court Practice Direction for Expert Reports and the Expert Witness Code of Conduct. Available here https://supremecourt.nt.gov.au/__data/assets/pdf_file/0010/727507/expert-reports-6-of-2015.pdf

2 Professional Background Relevant to Expert Opinions

This report sets forth my opinions regarding the potential severity of environmental and health impacts of industrial development in the Middle Arm Sustainable Development Precinct (MASDP) and the adequacy of the planned Strategic Assessment of those risks laid out in the draft Terms of Reference. Due to a lack of details regarding the exact operations to be placed in this industrial precinct, this report presents a broad opinion about potential impacts for the purposes of adhering to the precautionary principle during impact assessments.

My opinions are based on my education, including a PhD in environmental and natural resource policy with a focus on environmental health and risk assessment and a Master of Public Administration with a focus on administering and evaluating environmental policy. My knowledge is also based on several years of experience as an environmental scientist, consultant, and subject matter expert. My experience with petrochemical and large manufacturing began when I worked with the United States Environmental Protection Agency as a Toxics Release Inventory University Partner, where I developed a website analysis platform for identifying pollution prevention solutions for, and health risks from, industrial facilities in the United States. I then worked as a consultant for the US EPA, working on their Toxics Release Inventory (TRI), Pollution Prevention (P2), and Risk Screening Environmental Indicators Model (RSEI). In this role, I developed expertise in a broad range of manufacturing sectors, pollution reporting and management, and the development of fate and transport models. I have published and presented studies on quantifying and evaluating cumulative risk to enable policy makers to appropriately protect vulnerable populations.

As a consultant and subject matter expert, I have worked with several clients to comment on, communicate risks from, and research proposed petrochemical development and pollution control rulemaking. I developed pollutant dispersion models for several industrial facilities in Louisiana for an award-winning series by ProPublica titled ‘Polluters Paradise’. I also served as a subject matter expert reviewer for the ProPublica series ‘Sacrifice Zones’. Recently I helped the City of Syracuse avoid substantial remedial action liability by uncovering and successfully communicating a pattern of deception executed over several decades by a large foundry and metal finishing company. Knowledge gained from these past experiences was fundamental in reviewing, organizing, and interpreting the information associated with the MASDP. This report reflects my views as a professional and may not necessarily reflect the views of the Environmental Defenders Office, or the Environment Centre Northern Territory.

3 Executive Summary

This report presents a prospective emissions summary and health screening analysis of one possible development scenario of the Middle Arm Sustainable Development Precinct (MASDP), a proposed petrochemical development near Darwin in Australia's Northern Territory. Activities proposed here include the production of fertilizers, fuels, petrochemicals, and refined mineral products. I simulated the potential emissions of criteria pollutants, air toxics, and greenhouse gases from the facilities that have been proposed for the Precinct by assessing and scaling emissions reports from similar facilities across the globe. I have grounded this analysis in the specific industry types and their production quantities that Jason Howe, the Executive Director of the Northern Territory's Gas Taskforce, suggested would be likely in the MASDP in his late 2021 presentation to industry, titled "Industry Briefing on Consultancy - Middle Arm Sustainable Development Precinct Market Analysis."[2]

My analysis shows that air pollution and industrial accident risk from the MASDP pose significant human health threats to residents of the Greater Darwin Region. Pollutant increases projected to result from the MASDP based on this analysis are detailed in Table 1. I estimate, with all uncertainties and caveats expressed, that the MASDP may

- increase industrial fine particulate emissions by 513% in the region, resulting in $75 million of additional health impacts, equivalent to 15 additional premature deaths, per year;
- drive up greenhouse gas emissions in the Territory by 75%, leveling an annual social cost of $310 million; and
- increase the industrial cancer hazard in the region four-fold due to releases of formaldehyde, acetaldehyde, polycyclic aromatic compounds (PACs), and additional air toxics.

Table 1. Summary of emissions changes that may occur due to the studied MASDP development scenario compared to the Greater Darwin Region[3] or the Northern Territory.

Pollutant	MASDP scenario estimated annual total air emissions	Increase in emissions vs Greater Darwin Region* or Northern Territory**
Carbon Monoxide	34770.97 (Tonnes)	805%*
PM2.5 Primary	633.05 (Tonnes)	513%*
PM10 Primary	501.83 (Tonnes)	391%*
Sulfur Dioxide	1278.82 (Tonnes)	245%*
Volatile Organic Compounds	4753.8 (Tonnes)	233%*
Nitrogen Oxides	4852.89 (Tonnes)	192%*
Greenhouse Gases (CO2e)	15.52451 (Megatonnes)	75%**

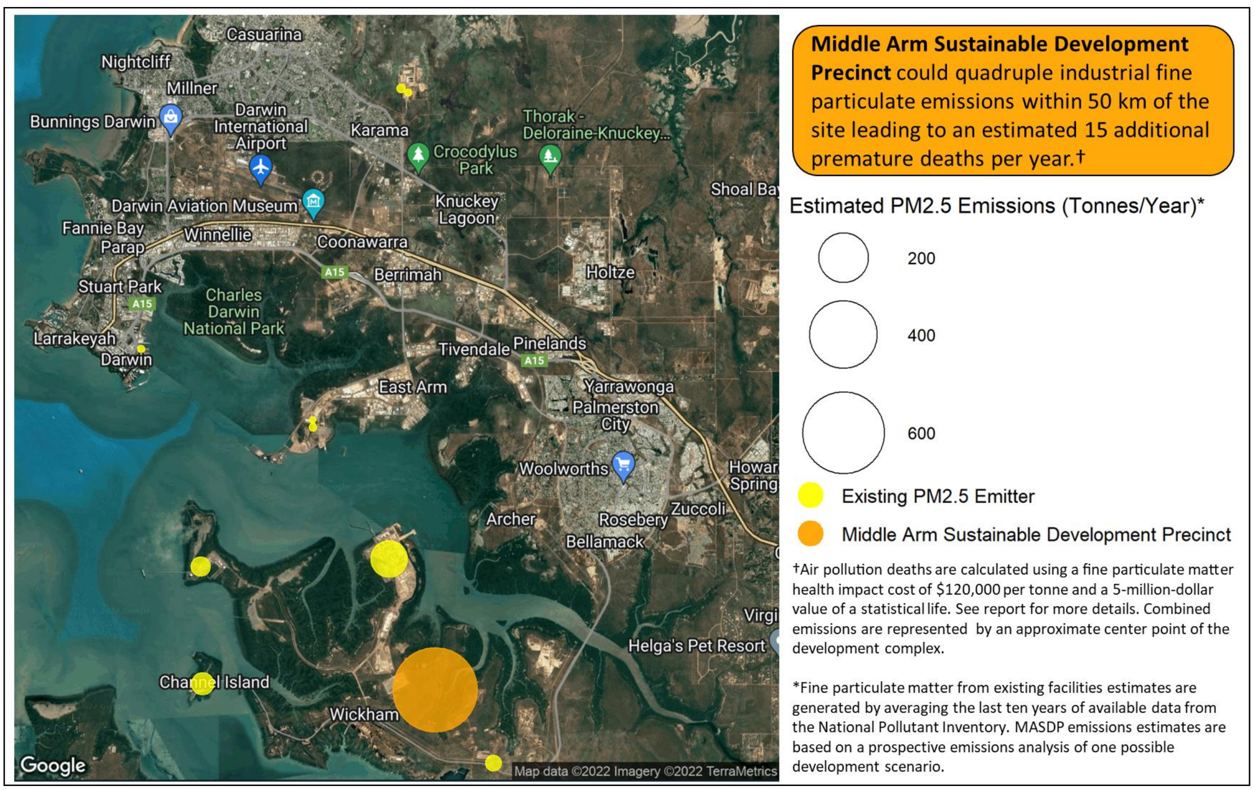
[2] This briefing was limited to an industry audience, and a live link to the slides is therefore unavailable to the public.

[3] The baseline emissions for the Greater Darwin Region are obtained from average National Pollutant Inventory emissions in the last ten years from facilities within 50km of the Middle Arm Peninsula.

The second section of this report presents recommendations for how the strategic assessment for the MASDP can be strengthened to better quantify and communicate these risks. These include calls for:

- A clearly defined and justified Strategic Assessment Area (SAA)
- A publicly available comment period and participatory methods for developing a transparent and comprehensive regional airshed model
- A clearly defined and justified method for measuring baseline levels of ambient air toxics in the region
- The inclusion of the assessment of light pollution and its impact on cultural amenities in Darwin Harbour
- An assessment of the viability of all pollution abatement technologies proposed for the facility, including carbon capture, use, and sequestration technologies
- A refined Health Impact Assessment which, among other things, requires:
    - Assessment of preexisting conditions among affected populations
    - Development of health monitoring plans
    - Development of a risk communication system that must meet certain levels of penetration within the region for relaying added process pollution and accident risks
    - Resident surveys to obtain better information about potential psychological impacts of the accident risks posed by the development

Figure 1. Map of potential fine particulate emissions from the studied MASDP development scenario compared to other emitters. Circles represent the comparative quantities of emissions released annually, not the geographic extent of the plume created by the emissions.



4 Introduction

The development scenario of the Middle Arm Sustainable Development Precinct (MASDP) studied here includes traditional petrochemical processing, fertilizer manufacturing, and metals refinement facilities. Traditional manufacturing operations based on extraction of finite resources represent most of the investment in this development and only some sustainable technologies, such as hydrogen made from renewable energy, are proposed. Labeling this precinct 'sustainable' may undermine the public's ability to accurately assess and manage the substantial health and environmental risk this petrochemical complex would present.

Petrochemical developments pose significant risks to the health and wellbeing of proximate communities, to the climate, and to the local environment, both through normal operating emissions and accidental releases of toxic compounds. In particular, the facilities slated for development at the MASDP will emit substantial volumes of air pollution, which is the single largest environmental health risk in the world. The World Health Organization (WHO) has shown that there are strong links between air pollution exposure and cardiovascular diseases, such as strokes and ischaemic heart disease, respiratory diseases, including acute respiratory infections and chronic obstructive pulmonary diseases, and cancer.[4]

The health harms associated with the air pollution from the type of facilities proposed at the MASDP have been well-documented in peer-reviewed journals. A 2020 review of 16 epidemiological studies published in the journal of environmental science found that communities living within five kilometers of petrochemical facilities had a 30% higher chance of developing leukemia than communities without petrochemical activity.[5] Disadvantaged communities experiencing low income and adverse social determinants of health are even more likely to be burdened by additional cancer cases when living with petrochemical emissions.[6] Yet while the region surrounding petrochemical facilities on the Gulf Coast of the United States have become known as Cancer Alley, cancer is not the only, or even the primary health concern resulting from the air pollution generated by petrochemical facilities like the MASDP. Fine particulate matter (PM2.5) forming through the combustion of fuels or through gaseous emissions reacting with the environment, will, when inhaled over long periods, shorten the lives of the people breathing it by causing chronic inflammation and exacerbating heart disease.[7] In the case of the MASDP, those living downwind of these emissions in Darwin and its suburbs, including Palmerston City, would be impacted.

Petrochemical facilities also come with an ever-present risk of accidents, and accompanying fear. These facilities will handle large quantities of flammable and explosive materials that can lead to high-casualty

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[4] World Health Organization. (2014). 7 Million Premature Deaths Annually Linked to Air Pollution. Available here https://www.who.int/news/item/25-03-2014-7-million-premature-deaths-annually-linked-to-air-pollution

[5] Jephcote, C., Brown, D., Verbeek, T., & Mah, A. (2020). A systematic review and meta-analysis of haematological malignancies in residents living near petrochemical facilities. *Environmental Health, 19*(1), 1-18. Available here https://ehjournal.biomedcentral.com/articles/10.1186/s12940-020-00582-1

[6] Terrell, K. A., & St Julien, G. (2022). Air pollution is linked to higher cancer rates among black or impoverished communities in Louisiana. *Environmental Research Letters, 17*(1), 014033. Available here https://iopscience.iop.org/article/10.1088/1748-9326/ac4360

[7] Di, Q., Wang, Y., Zanobetti, A., Wang, Y., Koutrakis, P., Choirat, C., ... & Schwartz, J. D. (2017). Air pollution and mortality in the Medicare population. *New England Journal of Medicine, 376*(26), 2513-2522. Available here https://www.nejm.org/doi/full/10.1056/nejmoa1702747

accidents that are difficult to contain if anything goes wrong.- These facilities' location directly on a coastline known for severe cyclones adds additional risks, not only because of potential damage they may suffer in a storm, but also because facilities often emit large unplanned releases of air pollutants when they are shut down and restarted around severe weather events.[8]

Finally, by enabling further fossil fuel, petrochemical, plastics, and synthetic fertilizer developments, the MASDP threatens Australia's climate and sustainability goals.

This report is divided into two parts. First, I estimate the potential impact of pollutant releases that may enter the environment as part of the proposed development, including criteria pollutants, air toxics and greenhouse gases. Second, I review the draft Terms of Reference (TOR) for implementing the required Strategic Environmental Assessment (SEA) for this project and identify ways in which this assessment must be improved so that citizens, communities, regulators, and other stakeholders may make truly informed decisions about moving forward with the project.

My methods and conclusions are grounded in the guiding principles and precautionary approach to health impact analysis (HIA) put forth by the Australian Government Department of Health (Box 1).[9] The SEA is also required to adhere to these HIA principles and guidance.[10] This approach is defined by the following language taken directly from pages 13-14 of the report.

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[8] Texas Commission on Environmental Quality. (2022). Ambient Air Monitoring Following Natural Disasters and Industrial Accidents, 2017- 2021, Available here https://www.tceq.texas.gov/downloads/publications/as/ambient-air-monitoring-following-natural-and-industrial-events_01_28_22_with-appendices-as-230.pdf

[9] Australia Department of Health. (2017). Health Impact Assessment Guidelines. Available here https://www1.health.gov.au/internet/main/publishing.nsf/content/A12B57E41EC9F326CA257BF0001F9E7D/$File/Health-Impact-Assessment-Guidelines.pdf

[10] Northern Territory Environment Protection Authority. (2022). Additional references. Available here https://ntepa.nt.gov.au/publications-and-advice/environmental-management/additional-references

Box 1: Guiding Principles for Health Impact Assessment

Democracy

People have the right to participate in the formulation and decisions of proposals that affect their life, both directly and through elected decision makers. In adhering to this value, the HIA method should involve and engage the public, and inform and influence decision makers. A distinction should be made between those who take risks voluntarily and those who are exposed to risks involuntarily.

Equity

The desire to reduce inequities that result from avoidable differences in health determinants and/or health status within and between different population groups. Particular attention should be paid to the distribution of health impacts and groups that may be more vulnerable to adverse impacts and consideration of ways to improve the proposed development for affected groups.

Sustainable Development

This principle emphasises that development should meet the needs of the current generation without compromising the ability of future generations to meet their needs. This requires a short- and long-term consideration of the potential health impacts and subsequent management of a proposal. Good health is the basis of resilience in the human communities that support development.

Ethical use of evidence

Transparent and rigorous processes are used to synthesize and interpret evidence, best available evidence from different disciplines and methodologies is utilised, all evidence is valued, and recommendations are developed impartially. In adhering to this value, the HIA method should use evidence to judge impacts and inform recommendations; it should not set out to support or refute any proposal, and should be rigorous and transparent.

Comprehensive approach to health

Physical, mental and social well-being is determined by a broad range of factors from all sectors of society (known as the wider determinants of health). In adhering to this value, the HIA method should be guided by the wider determinants of health.

Source: Adapted from Quigley et al, 2006.

The widely accepted definition of Health Impact Assessment cited by the Health Impact Assessment Guidelines is broadly defined as,

> "A combination of procedures or methods by which a policy, program or project may be judged as to the effects it may have on the health of a population."[11]

Health assessments are predictive and consider both the positive and negative outcomes of a proposed action. Health is determined by a range of factors including social and cultural constructs like families, employment, social networks, lifestyle, opportunities and much more. It is also determined by the

[11] Australia Department of Health. (2017). Health Impact Assessment Guidelines. P. 11. Available here https://www1.health.gov.au/internet/main/publishing.nsf/content/A12B57E41EC9F326CA257BF0001F9E7D/$File/Health-Impact-Assessment-Guidelines.pdf

natural and built environment. The potential social benefits of the MASDP have been outlined by the land development corporation[12] which describe positive impacts the project might bring, including to:

- Create jobs in the near, medium, and long term
- Attract private investment
- Support current and emerging industries
- Build on the Territory's competitive advantages
- Unlock the potential of the Territory's regions.

These reports have noted the potential environmental impact of the MASDP and the steps they will take to ensure that studies will be completed to assess these impacts, and stakeholders involved, but they have not described the negative impacts in plain language, in contrast to the way they have described the potential positive impacts.

In the section **Human Health Impacts**, I present a *limited* human health impact screening assessment. Due to constraints, I am only able to do a screening level analysis of *some* potential risks. Under this precautionary approach, I make no assumptions that the proposed facilities will release fewer toxic chemicals and harmful pollutants than comparable facilities already in operation around the world. I do not make any assumptions that special designs which have not been described in detail or proven to work at scale or under real-world economic constraints will reduce emissions. My opinions are also oriented to hold the SEA accountable for providing a comprehensive, risk-weighted, transparent, and rigorous process of determining health impacts.

In this section I present a method for describing some of the likely negative impacts of the MASDP, including:

- Increases to industrial emissions of criteria air pollutants in the region and their public health costs
- Increases to industrial emissions of cancer-causing chemicals
- Increased frequency of accidents and risks from unintentional releases of toxins
- Increases to greenhouse gas emissions and their impacts

In the second section, **Evaluation of the MASDP Draft Terms of Reference for Strategic Assessment**, I review, and comment on, select sections of the draft TOR which outlines the necessary components of the strategic assessment process. The Northern Territory Environment Protection Authority (NT EPA) sets a rigorous standard for the review of significant impacts in environmental impacts assessments. Per the NT EPA Environmental Factors and Objectives technical assistance document, the following factors must be taken into account during the assessment process;

> "In planning, assessing, and carrying out an action that has the potential for significant impact on the environment, the following will be inherently considered as part of the NT EPA

[12] Middle Arm Sustainable Development Precinct. Land Development Corporation. Available here https://landdevcorp.com.au/project/middle-arm-sustainable-development-precinct/
Our Territory Gas Strategy. Middle Arm Sustainable Development Precinct. Available here https://territorygas.nt.gov.au/projects/middle-arm-sustainable-development-precinct

environmental factors and objectives[13] also listed in Part 2 of the NT EP Act[14] implemented by the Environment Protection Regulations[15] and must be considered:

- the principles of ecologically sustainable development
  - decision making principle
  - precautionary principle
  - principle of evidence-based decision-making
  - principle of intergenerational and intragenerational equity
  - principle of sustainable use
  - principle of conservation of biological diversity and ecological integrity
  - principle of improved valuation, pricing and incentive mechanisms
- the environmental decision-making hierarchy
- the waste management hierarchy
- ecosystem-based management
- the cumulative impacts of a proposed action or strategic proposal
- the existing threats and pressures on the environmental values
- the impacts of a changing climate"[16]

Using these principles as standards, I suggest ways in which the SEA process can be improved so that the public can have a say in and be able to rely upon a comprehensive, rigorous, and transparent assessment.

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[13] NT EPA (2018) NT EPA Environmental factors and objectives. Available here https://ntepa.nt.gov.au/__data/assets/pdf_file/0020/804602/guide-ntepa-environmental-factors-objectives.pdf

[14] Environment Protection Act. (2019). Northern Territory of Australia. Available here https://www.fao.org/faolex/results/details/en/c/LEX-FAOC197036/

[15] Environment Protection Regulations 2020 (2020). Northern Territory of Australia. Available here http://extwprlegs1.fao.org/docs/pdf/nt198065.pdf

[16] NT EPA (2018) NT EPA Environmental factors and objectives. p. 7-8. Available here https://ntepa.nt.gov.au/__data/assets/pdf_file/0020/804602/guide-ntepa-environmental-factors-objectives.pdf

5 Methods

There are several methods utilized in this report. These include:

- Prospective health impact assessment
- Techno-economic analysis
- Emissions toxicity weighting
- Emissions health impact valuation

5.1 Prospective health impact analysis

Prospective health impact analysis is a methodology which seeks to identify, predict, and evaluate changes in health risk of a policy, plan, development, or program for a defined population.[17] The main goal of these studies is to consider the health impacts of public investments to improve knowledge about a development plan and inform decision makers and affected people. This analysis uses a screening method to rapidly appraise impacts of the MASDP related to air emissions and accident risk. Risk screening is a shorter and less complex process than risk assessment. It is intended not as a comprehensive analysis, but to guide furthermore detailed assessments and risk communications. The limitations section describes why this analysis is a screening and not a full assessment.

Additional risks and adverse impacts also associated with petrochemical and minerals processing facilities are not studied here. These include, to name a few, impacts to water quality in Darwin Harbour from industrial process water releases, effects on sensitive and ecologically important wetland and mangrove ecosystems, degradation of drinking water sources from discharges or deposition of air toxins, soil contamination associated with heavy metal deposition, risks to endangered species, risks to community cohesion, visual degradation of heritage areas and national parks, and more.

5.2 Techno-economic analysis

The main method for developing emissions estimates used in this study is manufacturing techno-economic analysis (TEA). TEA is a modeling approach for simulating production processes and can be used to assess developments and improve development decision making.[18] For this TEA model, I identified facilities that may have similar production processes to those in the proposed scenarios, accessed these facilities' emissions reports and outputs using emissions inventories, public business information, environmental impact statements, and permits. I then scaled their emissions to match outputs proposed in the development scenario. The process generates an approximate, but evidence-based model of the MASDP development scenario and allows for assessment of cumulative emissions from all the facilities.

Though the precise industries and production quantities may vary in later MASDP proposals, the general nature and scale of the impacts identified here reflect those effects that would be expected from the categories of industries in Howe's presentation and in the Draft Program -- that is, industries built

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[17] Parry, J., & Stevens, A. (2001). Prospective health impact assessment: pitfalls, problems, and possible ways forward. *BMJ, 323(*7322), 1177-1182. Available here https://www.bmj.com/content/323/7322/1177

[18] Yang, M., & Rosentrater, K. A. (2019). Techno-economic analysis of the production process of structural bio-adhesive derived from glycerol. *Journal of Cleaner Production*, 228, 388-398. Available here https://doi.org/10.1016/j.jclepro.2019.04.288

primarily on fossil gas and gas liquid feedstocks, and on gas boilers and gas turbines to power the high-heat and high-energy industrial processes required for the chemical conversion of these hydrocarbons.

5.3 Emissions toxicity weighting

Once emissions were estimated, a method called toxicity weighting was applied to the cancer-causing air toxics. Toxicity weighting a prioritization tool. In this case, toxicity weights are obtained from the United States (US) Environmental Protection Agency (EPA) program titled the Risk Screening and Environmental Indicators Model (RSEI). This program identifies inhalation unit risk (IUR) estimates for hundreds of regulated chemicals emitted from industrial facilities. IUR's are obtained from reviews of epidemiological evidence performed by the EPA's Integrated Risk Information System, the Agency for Toxic Substance and Disease Registry, California Environmental Protection Agency's Office of Environmental Health Hazard and Assessment, and others. The IUR is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 mg/m^3 in air. These IURs are then adjusted by RSEI toxicity weights so higher results indicate higher levels of concern. This process transforms the mass of chemical releases of different toxicities into comparable hazard-based estimates.[19] For this analysis, additional steps were taken to match RSEI toxicity weights with pollutants reported in the US National Emissions Inventory and the ASTL National Pollutant Inventory. First, NEI pollutant codes were matched with Toxics Release Inventory identifiers using a published crosswalk.[20] Second, I manually matched chemical names in the National Pollutant Inventory by name to the list so that IURs and toxicity weights could be applied to NPI emissions.

5.4 Emissions health impacts valuation

Lastly, emissions damage values were generated. This general process includes several steps, some of which have already been achieved by the prior described analysis;

1. Identifying emissions sources
2. Estimating emissions
3. Simulating air pollutant concentrations in the atmosphere
4. Estimating exposure of humans to air pollutant concentrations
5. Identifying the effects of air pollution on humans
6. Completing and economic valuation of the physical effects
7. Calculating a dollars per ton emission values

For the bulk of this analysis (steps 3-7), I rely on prior research by others which is detailed in the **Assessing the Economic Human Health Impacts of Air Quality Changes** section. In short, I rely on more comprehensive studies performed by government agencies that produce general or region-specific emissions factors. The same methods are applied for calculating carbon emissions.

5.5 Data Sources

A host of data sources have been utilized in this analysis.

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[19] US Environmental Protection Agency. (2020). EPA's Risk-Screening Environmental Indicators (RSEI) Methodology. Version 2.3.9. Available here https://www.epa.gov/sites/default/files/2020-12/documents/rsei_methodology_v2.3.9.pdf

[20] TRI/NEI Pollutant Crosswalk. Available here https://www.epa.gov/sites/default/files/2018-01/tri-nei-crosswalk.xlsx

- National Pollutant Inventory (NPI), an annual inventory of 93 toxic substance releases into the environment by facilities meeting reporting requirements in Australia.[21] It also includes diffuse sources when information is available. All years of data were accessed. Years of data going back to 2011 were used in this study.
- National Emissions Inventory (NEI), is a comprehensive and detailed estimate of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources in the United States released every three years.[22]
- Risk Screening Environmental Indicators Model (RSEI) Chemical File is a dataset of toxic chemicals covered by the US Toxics Release Inventory alongside associated toxicity information.[23]
- This study utilizes multiple Environmental Impact Statements (EIS) and emissions permits for the purposes of modeling potential facilities as well as understanding emission rates. Each EIS and permit is referenced throughout.
- Emissions cost factors were obtained from three sources. First a study of the cost of fine particulate emissions in Australia.[24] Second, general emissions factors were obtained from the UK United Kingdom Department of Environment, Food, and Rural Affairs.[25] Third, social costs of carbon were obtained from the 2021-22 Australian Capital Territory Budget.[26]
- Some Health and vulnerability data were obtained from Australia Bureau of Statistics, specifically the interactive maps that have been generated to display modeled results of the National Health Survey[27]
- Greenhouse gas emissions were accessed from two sources, the US EPA's greenhouse gas reporting program (GHGRP)[28] and the Australian Governments National Greenhouse and Energy Reporting[29]

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[21] Australian Government Department of Agriculture, Water, and the Environment. (2022). National Pollutant Inventory. Accessed 5/15/2022. Available here http://www.npi.gov.au/

[22] US EPA. (2017). National Emissions Inventory 2017 NEI Data. Accessed 5/15/2022. Available here https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

[23] US EPA. (2022). Risk-Screening Environmental Indicators Model Data Dictionary: Chemical Data. Accessed 5/15/2022. Available here https://www.epa.gov/rsei/rsei-data-dictionary-chemical-data

[24] PAEHolmes. (February, 2013). Methodology for Valuing the Health Impacts of Changes in Particle Emissions – Final Report. Available here https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/air/HealthPartEmiss.ashx

[25] United Kingdom Department of Environment, Food, and Rural Affairs. (2020). Air Quality Damage Costs. Published by Defra. The current damage cost values are published at: https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance#damage-costs

[26] Act Government. (October 10, 2021). Considering the 'social cost of carbon'. Available here https://www.cmtedd.act.gov.au/open_government/inform/act_government_media_releases/rattenbury/2021/considering-the-social-cost-of-carbon#:~:text=%E2%80%9CAs%20part%20of%20the%202021,its%20operational%20emissions%20each%20year.

[27] Australian Bureau of Statistics. (2022). Interactive Maps. Accessed 5/31/2022. Available here https://www.abs.gov.au/websitedbs/d3310114.nsf/home/interactive+maps

[28] US EPA. (2022). Greenhouse Gas Reporting Program. Accessed 5/27/2022. Available here https://www.epa.gov/ghgreporting

[29] Australian Government Clean Energy Regulator. (2022). National Greenhouse and Energy Reporting (NGER). Accessed 5/27/2022. Available here http://www.cleanenergyregulator.gov.au/NGER

5.6 Assumption and Limitations

This is a risk screening assessment, not a risk assessment. Outcomes of this screening assessment rely on several assumptions, generalizations, and examinations performed by other parties. These aspects of the study introduce significant uncertainty and the results must be communicated with this uncertainty in mind. These assumptions and uncertainties include:

- Emissions data come largely from facilities that self-report their industrial emissions, either through monitoring, engineering calculations, or calculations made by consultants. Emissions estimates may be inaccurate but must be taken as-is to perform this analysis without significant expense.
- Toxicity values utilized in emissions cancer hazard weighting are products of epidemiological studies and government review processes that reflect the best available science at the time the study, or when the assessment was made. Not all toxicity information for each substance is up to date or includes all relevant information.
- Estimates are based on one possible development scenario, that presented in, the Gas Taskforce table.[30] I do not consider any alternatives, as no other scenarios with sufficient detail upon which to build this analysis have yet been published. When different scenarios are announced, further assessments of emissions associated with those scenarios can be developed from this initial study.
- In some cases, only one year of emissions data are used to represent each facility. The most recent reporting presents some additional uncertainty within the final figures as some facilities may have faced some recent changes in output due to the Covid-19 pandemic. The most recent year of data was used when available, which was often 2019/2020 or 2017. See specific facility information for more details in the following sections.
- Comparison facilities were assumed to have the same equipment and same pollution control systems installed as a new facility at the MASDP. While recently constructed facilities were sought out as comparison facilities, it is still possible that facilities at the MASDP will use more efficient or less efficient technologies. I assume that electricity for these facilities will come from the burning of natural gas. Electricity sources used could substantially change the emissions at the precinct.

There are further limitations which need to be expressed so that readers can properly interpret results of this screening level analysis. The research does not incorporate several desirable components due to resource and information constraints, including:

- Additional emissions information for substances not tracked by pollutant release and transfer registries could not be incorporated (e.g. PFAS compounds).
- Hazards only describe potential releases that are toxicity weighted. Ideally atmospheric modeling would be performed to assess the fate of these compounds and the populations that would face additional modeled concentrations at their locations.
- Some emissions sources are not captured in this analysis, including support services (e.g. material handling, constructions services, etc.), small industries, and mobile sources, among others.

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[30] This briefing was limited to an industry audience, and a live link to the slides is therefore unavailable to the public.

- IUR values for NPI pollutants were matched to the best of my ability, but some chemicals did not have identifiable coverage in the US systems.
- Valuation of particulate matter emissions are derived from reduced form methods performed by consultants, not through atmospheric modeling of the Darwin region. This method presents greater uncertainty than would more sophisticated modeling techniques that would better estimate how additional emissions translate into elevated pollutant concentrations at population centers in the region. Such a modeling exercise would require data that does not yet exist in the public domain but will be critical to a future evaluation of the likely impacts of the facility (see TOR Review below).

6 Contextual Factors Shaping MASDP Impacts on the Greater Darwin Region

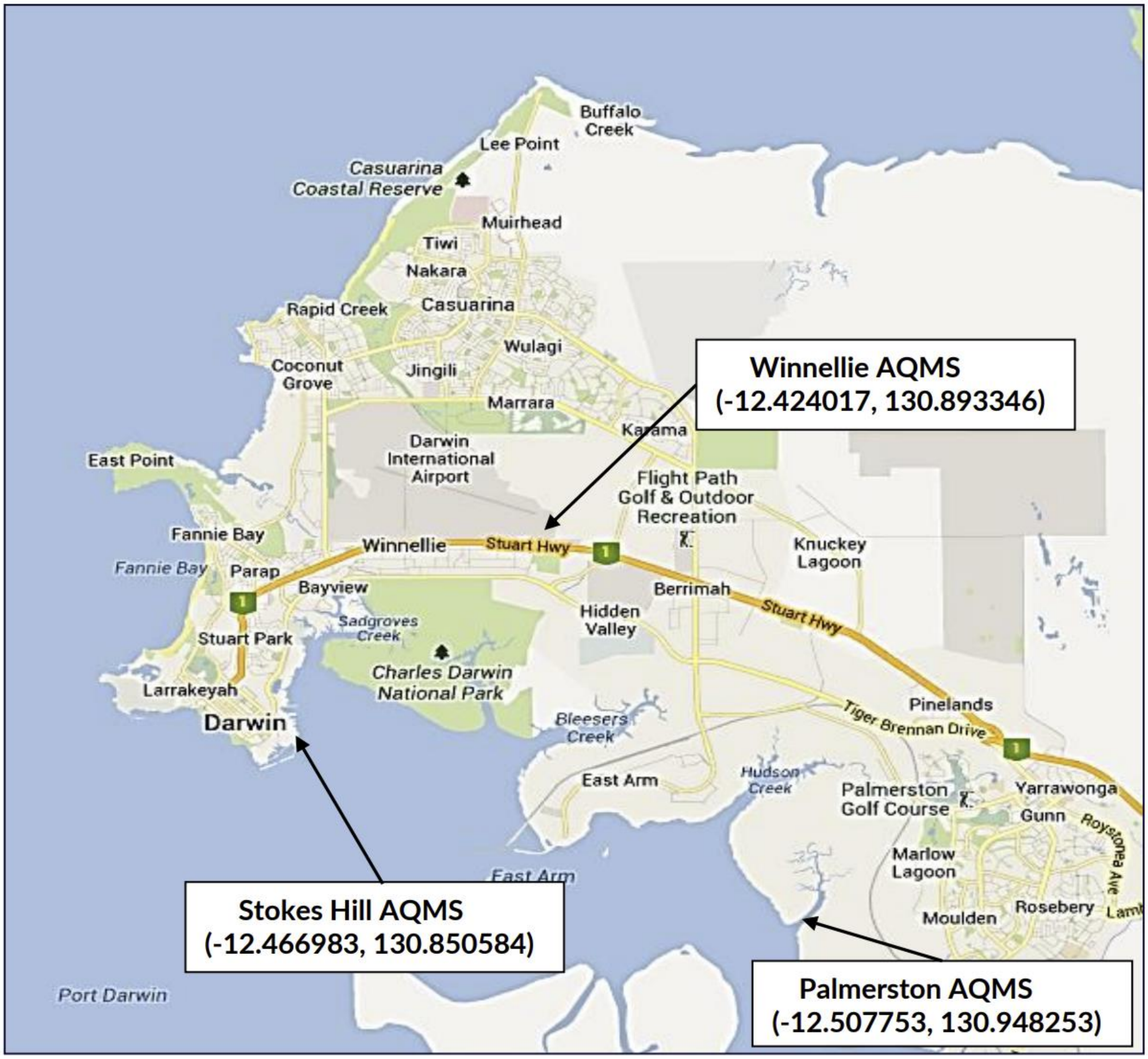
There are several important contextual factors that will shape the impacts of any new industrial facility on the local environment and surrounding communities. Among these are ambient air quality, population vulnerability, and accident susceptibility, particularly from climatic conditions. This section summarizes each of these contextual factors for the Middle Arm and surrounding region in turn, laying a foundation upon which to interpret the likely effects of the proposed MASDP on this receiving environment.

6.1 Ambient Air Quality

The Greater Darwin Region (GDR) has three air monitoring stations, the locations of which are displayed in Figure 2. These sites monitor carbon monoxide (CO), nitrogen dioxide (NOX), ozone (OZ), sulfur dioxide (SO2), particulate matter (PM10) and fine particulate matter (PM2.5).[31] Based on an analysis comparing monitoring results to ambient air quality goals, the only pollutant close to exceeding its annual average regulated concentration limit is PM2.5.

[31] Northern Territory Environment Protection Authority (NT EPA). (2020). Northern Territory Ambient Air Quality Monitoring Report.

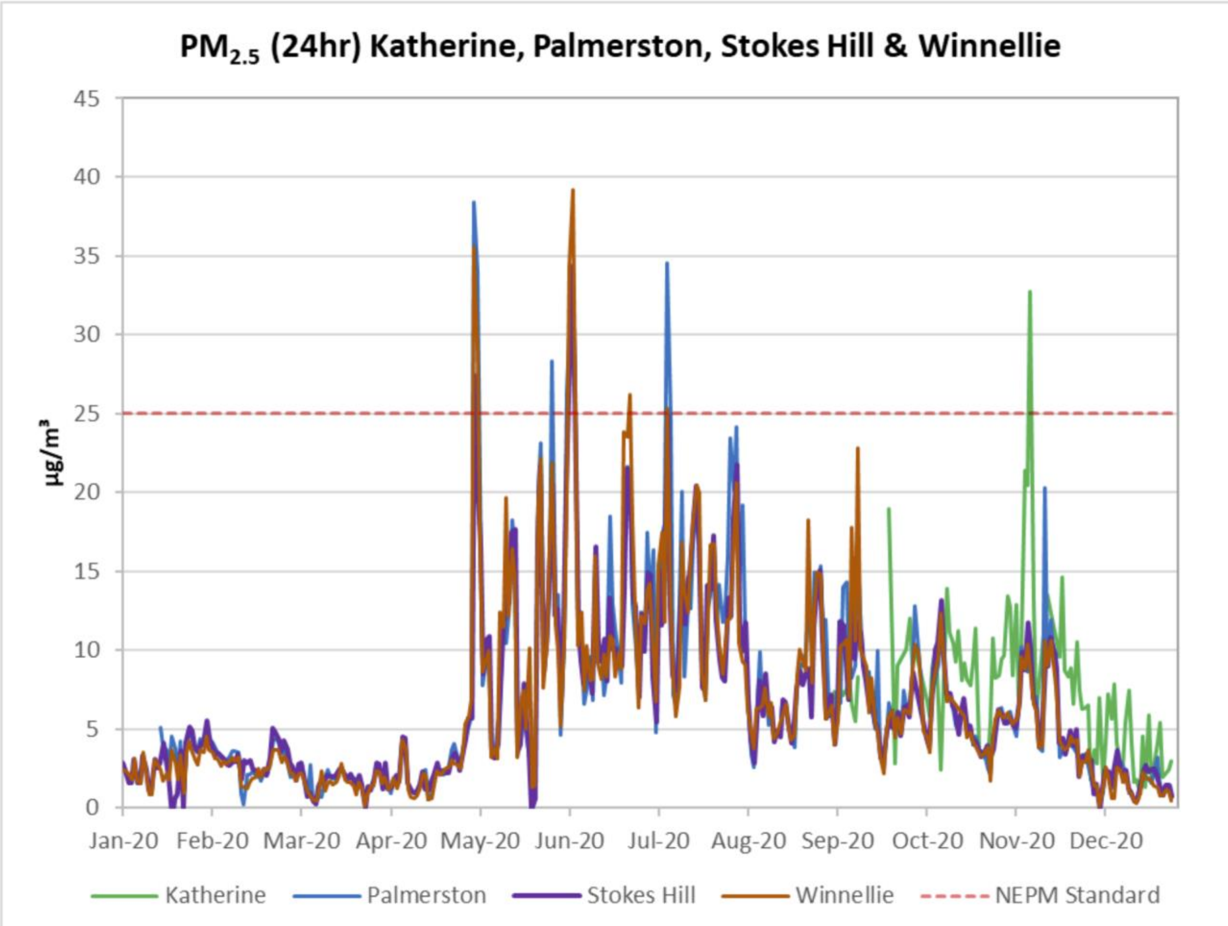
Figure 2. Darwin region air monitoring stations.[32]



According to the 2020 NT EPA Ambient Air quality monitoring report, the Palmerston monitor recorded 7 exceedance days that averaged more than 25 µg/m^3 (the standard for a 24-hour average) and had a yearly average of 7 µg/m^3 which was just under the annual standard of 8 µg/m^3. Figure 3 displays the distribution of 24-hour average PM2.5 concentrations over 2020 for each station, showing elevated levels in the summer months when prevailing wind directions change. As far as I can tell, the NT does not have regular air toxics monitoring equipment.

[32] Northern Territory Environment Protection Authority (NT EPA). (2020). Northern Territory Ambient Air Quality Monitoring Report.

Figure 3. 2020 recorded PM2.5 concentrations at Northern Territory monitoring sites.



As previously discussed, fine particulate matter exposure poses many health risks. The World Health Organization has set an air quality guideline for fine particulate matter at 5 µg/m^3.[33] New sources of PM2.5 in the region will burden nearby populations with additional health risks and may threaten the NT's compliance with ambient air quality standards.

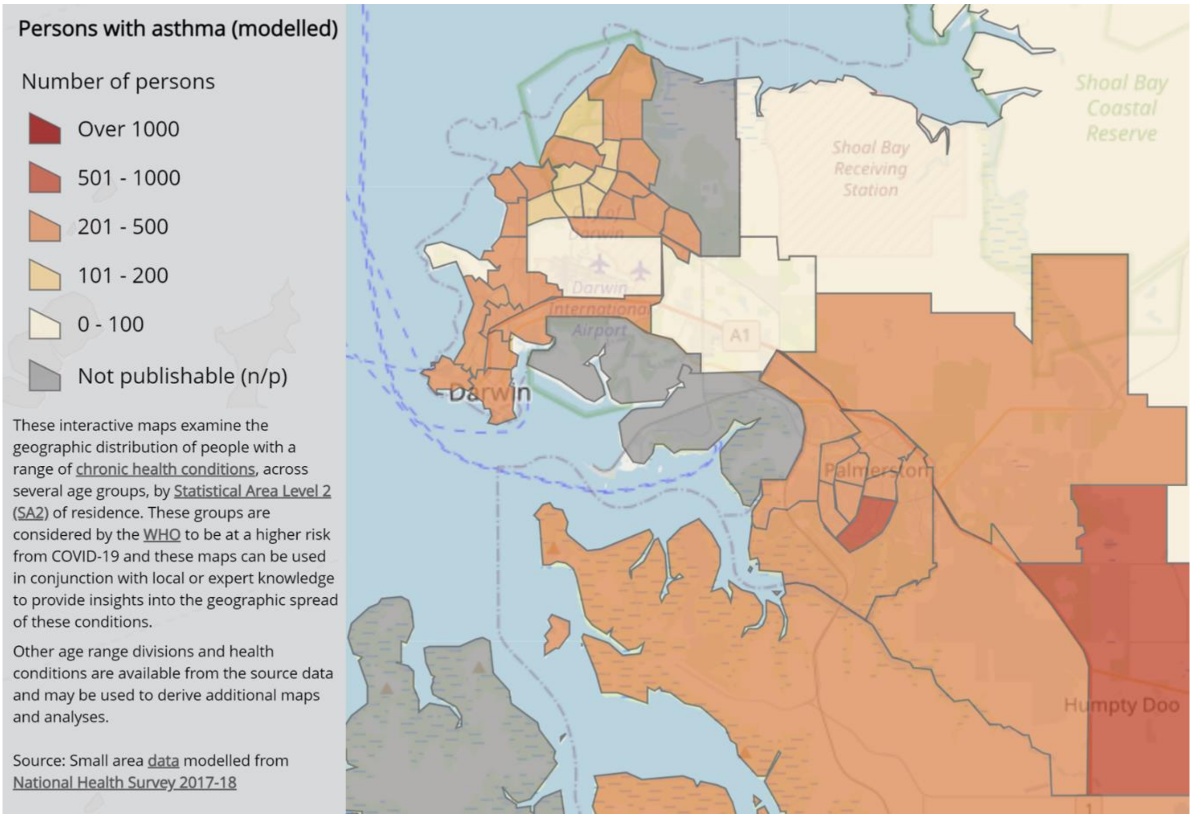
6.2 Population Vulnerability

Data from the 2017-18 Australian National Health Survey indicate that many people of the Northern Territory live with one or more chronic conditions. The distribution of one of these conditions, asthma, is presented in Figure 4. Populations with chronic conditions like asthma, diabetes, obesity, and heart disease are considered sub-populations who will experience higher acute and chronic air pollution risks.[34] Vulnerable individuals are more likely to experience the need for emergency services on poor air quality days or have their conditions worsen under higher ambient concentrations of air pollutants. Some of these individuals live within 5km of the MASDP site.

[33] World Health Organization. (2021). WHO Global Air Quality Guidelines. Available here https://www.who.int/news-room/questions-and-answers/item/who-global-air-quality-guidelines

[34] Chen, H., & Goldberg, M. S. (2009). The effects of outdoor air pollution on chronic illnesses. *McGill Journal of Medicine*: MJM, 12(1), 58. Available here https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2687917/

Figure 4. Map of estimated persons with asthma in the Greater Darwin Region taken directly from the Australian Bureau of Statistics Interactive Maps.[35]



The presence of vulnerable populations and the possibility of exceeding air quality standards are some of the risk factors that stakeholders must consider when considering development scenarios for the MASDP.

6.3 Accident Risk from Severe Weather and Rising Seas

Another important petrochemical development consideration is the risk of cyclones in the region. Severe weather can lead to unintended releases of hazardous materials and damage facilities. One prime example of this is the recent hurricanes along the gulf coast of the United States and their impact on the petrochemical industry there. Figure 5 displays a New York Times map of air pollution releases that resulted from Hurricane Harvey in Texas.

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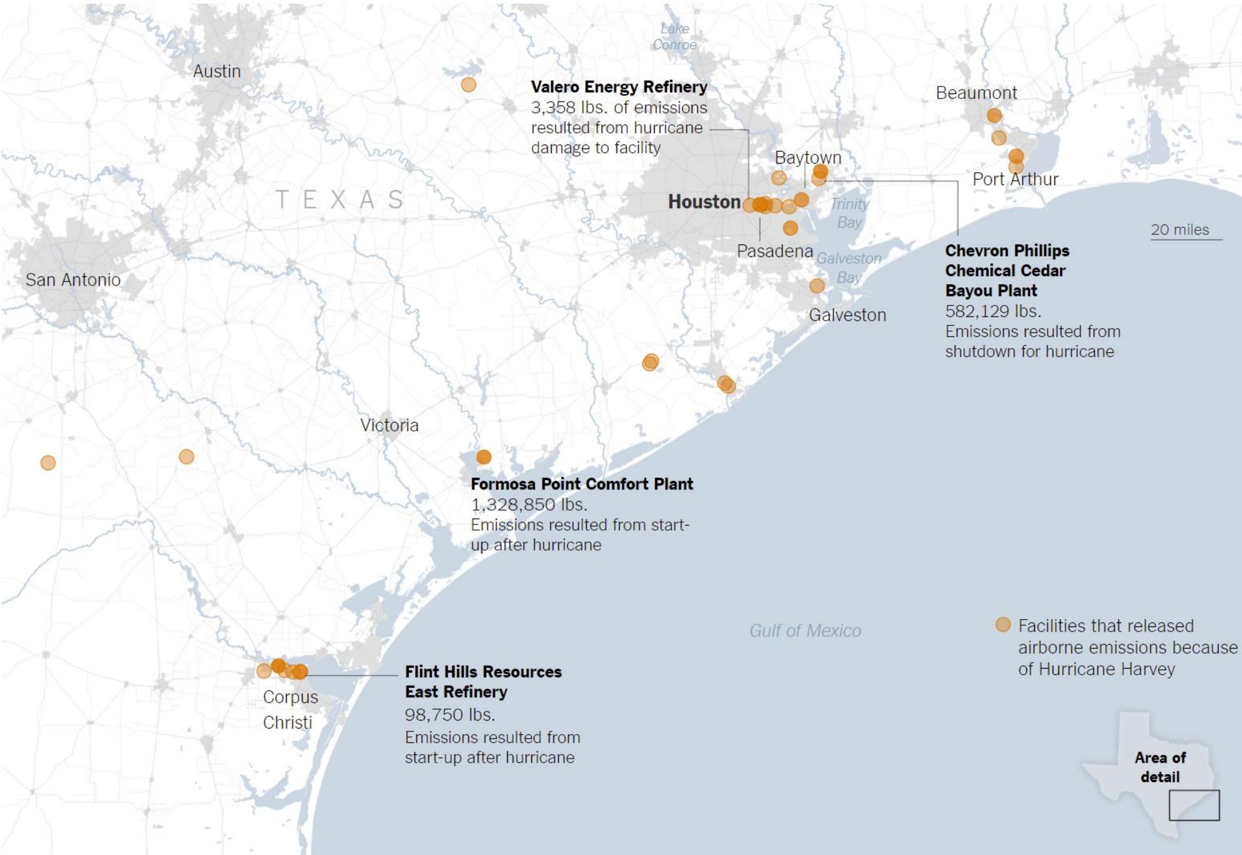
[35] Australian Bureau of Statistics. (2022). Interactive Maps. Accessed 5/31/2022. Available here https://www.abs.gov.au/websitedbs/d3310114.nsf/home/interactive+maps

Figure 5. Reported air pollutant releases as a result of Hurricane Harvey in 2017.[36]



There are multiple reasons why weather releases of both air and water pollutants may occur. These include shutdown and startup releases, and releases due to flooding carrying contaminated materials outside of containment areas at the plant. High winds and flooding can damage storage equipment leading to leaks, spills, and in the case of Arkema the failure of a refrigeration system and subsequent explosion and chemical fire.[37]

Darwin is a coastal city with a history of large cyclones making landfall. Figure 6 displays a photo of the devastation left by Cyclone Tracy in 1974. Figure 7 displays the paths of hundreds of tropical cyclones along the coast of Northern Australia from 1989-2003.

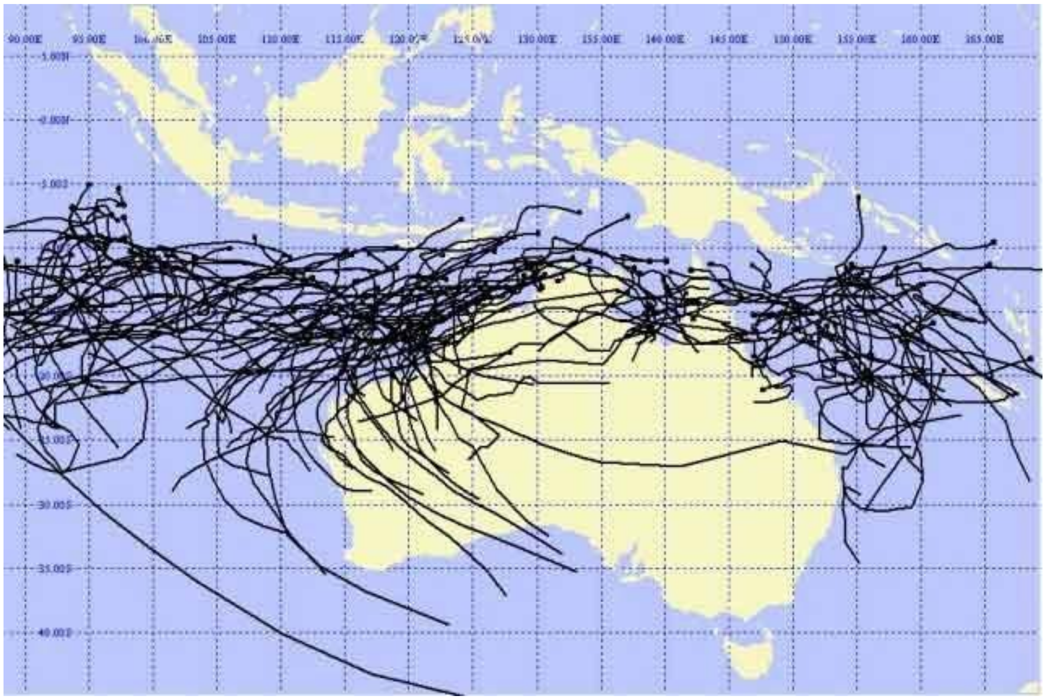
[36] Griggs, T. (September 8, 2017). More than 40 Sites Released Hazardous Pollutants Because of Hurricane Harvey. New York Times. Available here https://www.nytimes.com/interactive/2017/09/08/us/houston-hurricane-harvey-harzardous-chemicals.html

[37] Chemical Safety Board. (2018). Arkema Inc. Chemical Plant Fire. Available here https://www.csb.gov/arkema-inc-chemical-plant-fire-/

Figure 6. Photo of the devastation left in Darwin when Cyclone Tracy hit on Christmas Day, 1974.[38] Additional cyclone history can be found online.[39]

[38] https://www.nma.gov.au/defining-moments/resources/cyclone-tracy
[39] http://www.darwinstorms.com/cyclones/

Figure 7. Tracks of cyclones in the Australia region from 1989-2003.[40]



The threat of accidental releases resulting from storm surges, high winds, and flying debris are a real concern for industrial developments and facilities that store and handle toxic materials on the Middle Arm. For example, a recent risk assessment of the TNG Darwin Mineral Processing facility proposed to be built on Middle Arm describes these risks as 'High'.[41] Figure 8 compiles two compounding risk factors, storm surge and climate change induced sea level rise, which would pose a high threat to the facility's containment of wastewater in treatment ponds.

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[40] Australian Government Bureau of Meteorology. (2022). Climatology of Tropical Cyclones in Western Australia. Available here http://www.bom.gov.au/cyclone/climatology/wa.shtml

[41] TNG Limited Draft Environmental Impact Statement Darwin Processing Facility. (November 2019). PDF p 27. Available here https://ntepa.nt.gov.au/__data/assets/pdf_file/0005/761450/draft_eis_darwin_processing_facility_main_report.pdf. Note that TNG subsequently decided to build its processing facility by its mine site, partially in response to concerns from multiple stakeholders about wastewater releases into Darwin Harbour (see Fitzgerald, D. (September 29 2021). TNG Limited scraps plan for controversial mineral-processing facility for Darwin Harbour. Available at https://www.abc.net.au/news/2021-09-30/nt-tng-limited-mining-company-moves-operation-to-centrals-aus/100503612

Figure 8. Storm surge related risk assessment for the proposed Middle Arm TNG mineral processing facility.[42]

Environmental Aspect	Risk Pathways	Impacts	Likelihood	Consequence	Risk Rating	Risk Treatment/Management/Mitigation Strategy	Likelihood	Consequence	Residual Risk Rating	Level of Certainty
Tertiary storm surge (1 in 10,000 AEP) event	Inundation during storm surges	Contamination of surface water due to breaching of process or wastewater treatment ponds.	2	5	High	Locate primary infrastructure in areas above the 1 % AEP flood levels. Model 0.1% AEP inundation and flood levels and locate processing plant infrastructure above these levels. Implementation of the ESCP (Contained within Appendix O), including: • Construct a diversion bund around site infrastructure.	1	5	High	Medium
Projected impacts of climate change resulting in an increased frequency of extreme storm surge events	Inundation from extreme storm surge	Contamination of surface water due to breaching of processing or wastewater treatment ponds.	2	5	High	Locate primary infrastructure in areas above the 1 % AEP flood levels. Model 0.1% AEP inundation and flood levels and locate processing plant infrastructure above these levels. Implementation of the ESCP (Contained within Appendix O), including: • Construct a diversion bund around site infrastructure.	1	5	High	Medium

Ambient air quality, population vulnerability, and accident potential are all important underlying factors that will define the impact of a facility, and must be considered when carrying out an SEA and making development decisions. Developers should be asked to make comprehensive assessments of these risks and vulnerabilities to accurately predict impacts on Territorians and their surrounding environment.

[42] TNG Environmental Impact Statement Appendix G - Risk Assessment. (2019). Selected storm surge risk taken from the document. Available here https://ntepa.nt.gov.au/__data/assets/pdf_file/0010/761482/draft_eis_darwin_processing_facility_appendixG_risk_assessment.pdf

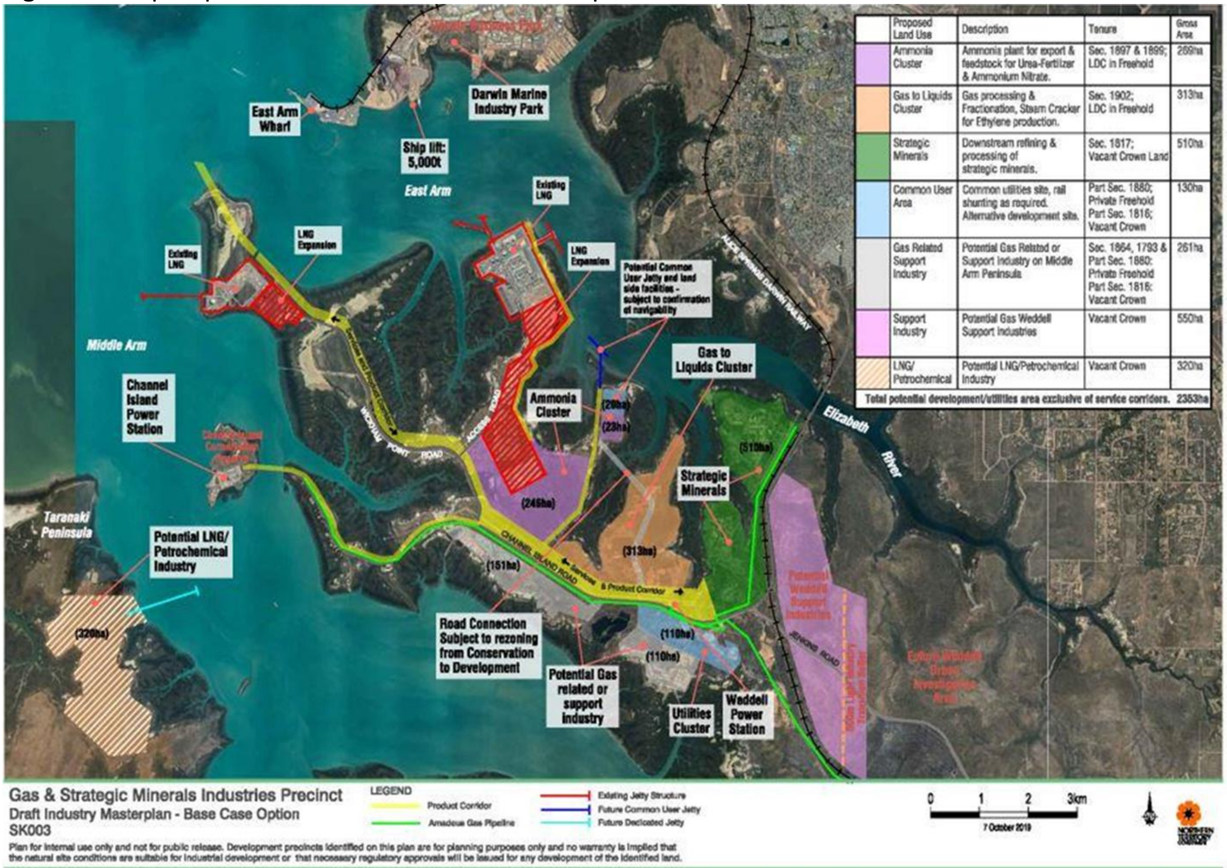
7 Proposed New Facilities and Potential Impacts

The Middle Arm Sustainable Development Draft Program provides a limited development plan that includes the industries listed below.[43] The map in Figure 9, which comes from a tender opened in 2020 for Middle Arm Industry Development- Provision of Infrastructure Studies (D20-0236), offers an initial sense for where these industries might be located within the facility.

- Liquefied Natural Gas (LNG)
- Ammonia and derivatives
- Urea and derivatives
- Ethylene and derivatives
- Methanol and derivatives
- Gas to liquids (GTL)
- Hydrogen
- Carbon capture and storage
- Minerals processing
- Advanced manufacturing
- Support service industries

[43] Middle Arm Sustainable Development Precinct Draft Program (January 2022), p. 26. Available at https://ntepa.nt.gov.au/__data/assets/pdf_file/0007/1092463/masdp-draft-program.pdf

Figure 9. Map of potential industries to be developed at the Middle Arm.[44]



The MASDP development scenario analyzed in this study is taken from a similar, but somewhat more detailed and therefore more informative list provided in a presentation given by Jason Howe, Executive Director of the Northern Territory Gas Taskforce (NT Department of Chief Minister and Cabinet), at which Figure 10 was presented (henceforth, the Gas Taskforce table). The primary differences between the industry list provided in the Gas Taskforce table and that given in the Draft Program is the reference in the Draft Program to the additional production of "derivatives" of urea, ammonia, ethylene, and methanol, and to "advanced manufacturing." While it is not possible to accurately predict emissions from such a vague description of these manufacturing processes as given in the Draft Program, it is important to note that any additional manufacturing operations above and beyond what are provided for in Gas Taskforce table would produce additional emissions that are not accounted for in the present analysis. The modeling I have undertaken based on the development proposed in the Gas Taskforce table to estimate operating emissions is likely to therefore underestimate actual emissions if additional manufacturing facilities are added to the facility, as the NT EPA list suggests they may be.

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[44]Northern Territory Government. (2020) Request for Tender. Darwin - Consultancy - Middle Arm Industry Development - Provision of Infrastructure Studies for a Period of 12 Months. Attachment A. p. 29. Available at https://d3n8a8pro7vhmx.cloudfront.net/lockthegate/pages/7022/attachments/original/1605651466/D20-0236_-_Request_For_Tender.docx?1605651466

Figure 10: Gas Taskforce Table: Potential Industrial Facilities in the MASDP, Sourced from Industry briefing on Consultancy – Middle Arm Sustainable Development Precinct Market Analysis, by Jason Howe, Executive Director, Northern Territory Gas Taskforce.

MASDP Industry Types		Inputs	Outputs	Typical uses
Liquid Natural Gas **LNG**	5 Mtpa		LNG	
Gas to Liquid **GTL**	36.5 mmbbls pa	CONDENSATE	DIESEL PETROL AV1 LIGHT OIL	E F
Blue Hydrogen **H_2**	600 Tpd		CCUS CO_2 NH_2	E F
Green Hydrogen **H_2**	300 Tpd		H_2	E F
Hydrogen **H_2 - Green NH_3**	300 Tpd		NH_3	E F
Ammonia	1.1 Mtpa		NH_3	Chemicals N Fertiliser
Urea	2 Mtpa		UREA	Pharma N
Methanol	1.6 Mtpa		METHANOL	E F
Ethane	400 Ktpa	NGL	ETHYLENE	Paint Textiles Plastics
Mineral Processing 1				
Mineral Processing 2				N
Carbon Capture, Utilasation & Storage **CCUS**	12 Mtpa			CO_2

Using the industries and production levels detailed in Figure 10, I conduct a limited, prospective health impact analysis of the MADSP. The following sections go through the impacts from each industry at the scale proposed in the table, identifying emissions from similar facilities operating across Australia, the United States, and beyond. In addition to estimating emissions from standard operations of each of these facilities, I describe the accident risk associated with each kind of facility, which would likely produce their own additional emissions not accounted for in the baseline operations analysis.

7.1 Liquified Natural Gas (LNG)

Production quantity in MASDP assumed based on Gas Taskforce Table: 5 Mtpa

7.1.1 What Is An LNG Terminal?

Liquefied natural gas (LNG) is natural gas that has been cooled to a liquid state, at about -162° Celsius, for shipping and storage. The volume of natural gas in its liquid state is about 600 times smaller than its volume in its gaseous state. Liquefying gas makes it possible to transport it via LNG carriers to places pipelines do not reach.[45] There are two types of LNG terminals, one for condensing and shipping LNG (LNG export terminals) and the other for receiving LNG (LNG import terminals). LNG facilities also often include pre-liquefaction gas processing, as LNG has to be extremely pure methane, free of other substances, including water, which would be frozen when the methane is cooled to be liquefied, posing a significant explosion risk.

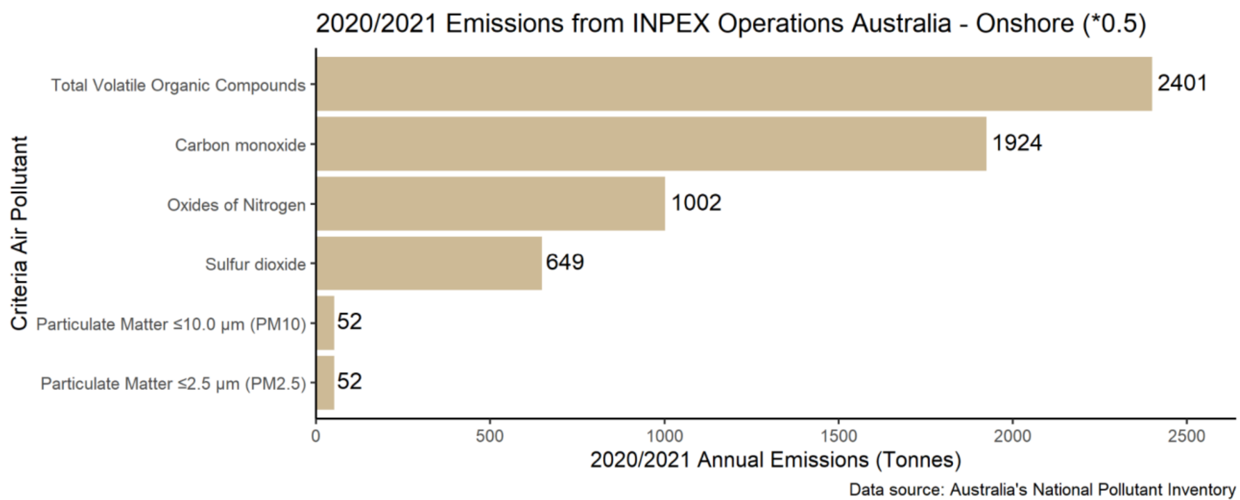
7.1.2 Comparable Facilities

The Inpex Ichthys LNG Onshore Processing Facility in Wickham, NT, Australia is likely the best comparison to what is being proposed as it is operated in the MASDP. Inpex onshore facilities operate

45 US Department of Energy, Office of Fossil Energy and Carbon Management. (2022). Liquefied Natural Gas (LNG). Available here https://www.energy.gov/fecm/liquefied-natural-gas-lng

two LNG processing trains, LPG condensate plants, product storage tanks, and a combined cycle power plant. The facility has the capacity to produce 8.9 mtpa LNG and 1.65 mtpa of condensate annually.[46] For the purposes of this analysis, I will assume that the new facility will produce half the emissions of this existing plant, in essence, adding a third train to the operation. Emissions information is derived from the National Pollutant Inventory (NPI), scaled, and presented in Figure 11.[47]

Figure 11. Possible emissions from the third LNG train at the Inpex facility, obtained by dividing the most recent year of emissions from Inpex by half.



One note here is that the reported 2020/2021 emissions from Inpex are much higher than what they estimated in their Environmental Impact Statement from 2011.[48] For example, as seen in Figure 12, the onshore facility estimated it would produce just 500 tonnes of volatile organic compounds (VOCs) per annum, but in 2020/2021 reported emitting 4801.378 tonnes, nearly ten times the anticipated amount.

[46] Inpex Ichthys Development Concept. Available here https://www.inpex.co.jp/english/ichthys/concept.html

[47] Australian Government Department of Agriculture, Water, and the Environment. (2022). National Pollutant Inventory. Accessed 5/15/2022. Available here http://www.npi.gov.au/

[48] Inpex Draft Environmental Impact Statement. Chapter 5 Emissions, Discharges, and Waste. Available here https://ntepa.nt.gov.au/__data/assets/pdf_file/0010/287443/draft_eis_chapter_5.pdf

Figure 12. Estimated annual combustion emissions from routine operations of the Ichthys Project.[49]

Table 5-1: Estimated annual combustion emissions from routine operations of the Ichthys Project

Ichthys Project emissions* (t/a)		
Air emission	**Offshore facilities**	**Onshore processing plant**
NO_x (as NO_2)	5000	2700
CO	5800	Not calculated
SO_x (as SO_2)	16	950
CH_4	8500	10 500
PM_{10}†	Not calculated	150
VOCs	1100	500

* Values are based on normal operating conditions and do not include fugitive or vented emissions.

† PM_{10} from dust is not included in this calculation because quantification of a non-point-source emission is difficult.

7.1.3 Accidents

Vapor cloud explosions that can occur at LNG storage facilities present significant risk to surrounding facilities and communities. A 2021 *Washington Post* article highlights the dangers of these risks and recent explosions in Puerto Rico and in Venezuela.[50] A *Delaware Currents* article details several accidents that have occurred in the United States related to LNG terminals, including that depicted in Figure 13 below.[51] More details about the accident are available from the US Department of Transportation.[52]

[49] Inpex Draft Environmental Impact Statement. Chapter 5 Emissions, Discharges, and Waste. Table 5-1. Available here https://ntepa.nt.gov.au/__data/assets/pdf_file/0010/287443/draft_eis_chapter_5.pdf

[50] Englund, Will. (June 3. 2021). Engineers raise alarms of the risk of major explosions at LNG plants. The Washington Post. Available here https://www.washingtonpost.com/business/2021/06/03/lng-export-explosion-vce/

[51] Mele, Chris. (March 11, 2021). 'The Storage and Transportation of LNG: What could go wrong?'. Delaware Currents. https://delawarecurrents.org/2021/03/11/the-storage-and-transportation-of-lng-what-could-go-wrong/

[52] US Department of Transportation. (2016). Failure Investigation Report – Liquefied Natural Gas (LNG) Peak Shaving Plant, Plymouth, Washington https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/FIR_and_APPENDICES_PHMSA_WUTC_Williams_Plymouth_2016_04_28_REDACTED.pdf

Figure 13. Failed adsorber caused explosions and natural gas fires in Delaware.

7.2 Gas to Liquid Production

Production quantity in MASDP assumed based on Gas Taskforce table: 36.5 mmbbls pa

7.2.1 How Are Liquid Fuels Produced From Gas?

Figure 14. Construction of the Sasol 30.8 mmbbl/a GTL facility in Uzbekistan.[53]

[53] Penetron. (2021). Energy Industry Leaders Team Up With Penetron To Build A Liquid Synthetic Fuel. Available here https://www.penetron.com/news-media/media-releases/view/Energy-Industry-Leaders-Team-up-with-Penetron-to-Build-a-Liquid-Synthetic-Fuel-Plant

Developed in the 1920s by German scientists, the Fischer-Tropsch process (see Figure 15) converts natural gas or coal into liquid fuel. The technology, known generally as "Gas to Liquids" (GTL) was utilized in Germany and Japan during the Second World War due to limited supply of oil and then commercialized in South Africa in response to oil embargoes during the apartheid.[54] Major applications of the technology only exist in regions devoid of natural gas transportation infrastructure, including in Malaysia, Qatar, South Africa, Uzbekistan, and Nigeria.[55] Plants proposed in North America have all been abandoned or placed on indefinite hold due to unstable economics of this energy intensive process. A draft proposal for the development of a GTL facility in the NT explains the reasoning for producing GTL in the region:

> The Northern Territory with its uncommitted offshore reserves, is sited in a region that is not currently attractive for major reticulation to a large metropolis or general industry, and where the economics of using it only for power generation are not good. NG typically contains some percentage of NGLs (natural gas liquids), which can be combined with the GTL LPG and naphtha (minor sulphur content not an issue for these products). The value-adding nature of the GTL-power complex will provide better returns than 'quarrying' the gas for sale as LNG, as well as a greater in-country economic stimulation and opportunity.[56]

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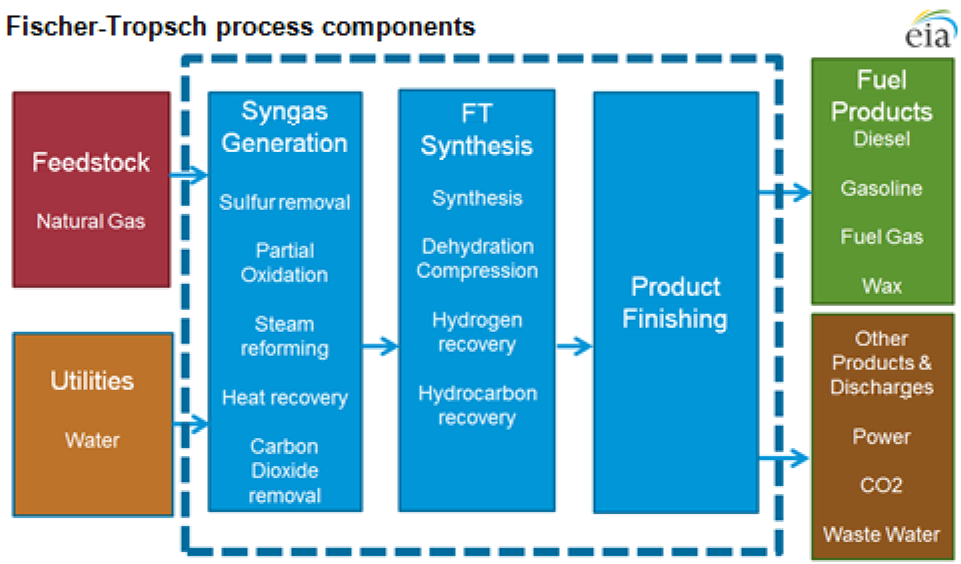
[54] Broder, J. and Krauss, C. (December 17, 2012). A Big, and Risk, Energy Bet. *The New York Times*. Available here https://www.nytimes.com/2012/12/18/business/energy-environment/sasol-betting-big-on-gas-to-liquid-plant-in-us.html

[55] Hydrocarbons Technology. (2022)Escravos Gas-to-Liquids Project, Niger Delta. Available here https://www.hydrocarbons-technology.com/projects/escravos/

Shell. (2022). GAS-TO-LIQUIDS. Available here https://www.shell.com/energy-and-innovation/natural-gas/gas-to-liquids.html

[56] Payton, H. A Draft Proposal for a Generic Gas-to-Liquids (GTL) Project with Co-Production for the Northern Territory, Australia. M.E.T.T.S – Consulting Engineers. Available here http://www.metts.com.au/gtl-northern-territory.html

Figure 15. The three major processes of GTL operations (gas reforming, FT synthesis, and product upgrading) and their major inputs and outputs.[57] Missing from the other products and discharges category are the cobalt or iron catalysts spent in FT synthesis.[58]



GTL refineries produce significant air emissions, process wastewater, and spent catalyst solid waste.[59] Without comparable operating facilities in countries with reliable pollutant release and transfer registries, it is difficult to estimate the exact quantities of toxic discharges that might be expected from a GTL facility in the MASDP. The general waste streams are as follows, taken directly from Sarvanan et al.'s 2010 study:

- Air emissions

  The major air emissions from GTL industries are greenhouse gases (GHG), volatile organic compounds (VOC) and acidifying gases. Most of the world's GTL industries use natural gas for combustion, which accounts for release of very small amounts of oxides of sulphur (SOx) and nitrogen oxides (NOx), virtually no particulate matter, lower levels of carbon monoxide and other reactive hydrocarbons. Hence the acidification impacts arise in particular from SOx, NOx and particulate emissions are very low.

  GHG emissions are mainly associated with flue gas emission from energy generation units, flaring of un-reacted raw materials, byproducts, purge and combustible gases from gas reforming and FT sections. Carbon dioxide (CO2) contributes over 95% to the total GHG emission and the balance is contributed by methane (CH4) and nitrous oxide

[57] US Energy Information Administration (EIA). (February 19, 2014). Gas-to-liquids plants face challenges in the U.S. market. Available here https://www.eia.gov/todayinenergy/detail.php?id=15071

[58] Martinelli, M., Gnanamani, M. K., LeViness, S., Jacobs, G., & Shafer, W. D. (2020). An overview of Fischer-Tropsch Synthesis: XtL processes, catalysts and reactors. Applied Catalysis A: General, 608, 117740. Available here https://doi.org/10.1016/j.apcata.2020.117740

[59] Pon Saravanan, N. *et al*.(2010, October). Risk Based Environmental Management System for Gas-to-Liquids Industries. In Middle East Health, Safety, Security, and Environment Conference and Exhibition. OnePetro. Available here https://drive.google.com/file/d/1vQA9G6gg1BOOHguX_RK1-lu87pkbxNrx/view?usp=sharing

(N2O) in the GTL industries. Life cycle assessment studies also confirm that the GTL process has significantly higher GHG releases during the production phase due to a lower overall system-wide process efficiency.[60]

- Process wastewater discharges

  Process wastewater management focuses both on pollution prevention by source reduction and closed water systems, in which wastewater recycling plays a major role. A byproduct of the FT synthesis reaction is process wastewater, generated in large volumes, 25% more than hydrocarbon products, on a weight basis.

- Solid waste

  GTL facilities generate significant amounts of non-hazardous and hazardous wastes. Non-hazardous industrial wastes consist mainly of exhausted molecular sieves from air separation unit, catalyst support materials, as well as packaging materials, construction rubble, and scrap metal. Hazardous waste can be determined according to the characteristics and source of the waste and applicable regulatory classification. Hazardous wastes consist mainly of waste oils, oily rags and sludge, hydraulic fluids, waste chemicals, contaminated wax wastes, spent catalysts and used filters.

For more information regarding the possible pollutants in GTL wastewater treatment outfalls, I present the following table from the US EPA's recent analysis of water pollution from the petroleum refining sector.

[60] Five winds international, 2004, Gas-to-Liquids Life cycle assessment report. Available here https://www.eco-conception.fr/data/sources/users/8/gas-to-liquids-life-cycle-assessment-synthesis-report.pdf

Figure 16. Table Average Effluent Concentrations of Pollutants of Interest at 82 Refineries with Discharge Monitoring Report (DMR) data for outfalls discharging wastewater treatment effluent.[61]

Table 5-3. Average Effluent Concentrations of Pollutants of Interest at 82 Refineries with DMR Data for Outfalls Discharging WWT Effluent

Pollutant	Number of Refineries with Data	Average Pollutant Concentration (mg/L)
Ammonia as N	76	3.50
Arsenic	15	0.0179
BOD_5	79	8.49
BTEX	3	0.000192
Cadmium	11	0
Chromium	65	0.00245
COD	73	76.1
Copper	19	0.00333
Cyanide	15	0.0122
Lead	17	0.000982
Mercury	25	0.0000860
Nickel	12	0.00547
Nitrate-Nitrite	0	No Data
Nitrogen, Total	5	16.9
Oil & Grease	63	2.16
PAH[a]	0	No Data
Phenol	25	0.00894
Phosphorus	16	0.954
Selenium	26	0.0536
Sulfide	70	0.0296
TDS	7	1440
TKN	8	6.78
TOC	11	11.2
TSS	77	12.9
Uranium-238	0	No Data
Zinc	20	0.0261

Note: All concentrations are rounded to three significant figures.
a – The EPA's analysis includes only data listed as the combined PAH parameter in ICIS-NPDES. Some refineries may collect samples for individual PAH compounds that was not included in this analysis. The EPA determined that comparing concentrations for varying number of individual PAH compounds at different refineries may not be representative.

7.2.2 Comparable Facilities

Two comparable facilities were identified for the purposes of estimating wastes from a new GTL facility in the MASDP, the Sasol Synfuels and PETRONAS OLTIN YO'L Gas to Liquids Project[62] in Tashkent, Uzbekistan and a Sasol Canada GTL facility[63] proposed to be built in Strathcona County, Alberta, Canada.

[61] US EPA. (2019). Detailed Study of the Petroleum Refining Category – 2019 Report. Page 39. Available here https://www.epa.gov/sites/default/files/2019-10/documents/petro-refining-elg-study-2019.pdf

[62] Uzbekistan GTL LLC and Golder Associates. (2014). Draft Environmental Impact Assessment Oltin Yo'l Gas To Liquid (GTL) Project. Available here https://www.adb.org/sites/default/files/project-document/80065/46953-014-eia-01.pdf

[63] Sasol. (2013). Canada Gas-to-Liquids Project Volume 1: Project Description. Available here https://open.alberta.ca/dataset/f31e6946-ac74-44cf-90e9-2fec83808ab7/resource/76eec2b0-92c7-4b25-9ef2-85cc4abea88b/download/sasol-gtl-project-volume-1-project-description.pdf

OLTIN YO'L is in the construction phase (see Figure 17) and the Alberta facility is on hold, but both have had environmental impact studies performed. While both studies can serve as references, I use the Sasol Canada facility.

Figure 17. Google Maps satellite image of the PETRONAS OLTIN YO'L Gas to Liquids Project.

The proposed Alberta GTL facility will produce 35 mmbblspa of petroleum products, nearly equivalent to the 36.6 mmbblspa proposed for the MASDP. Sections 5.3-5.6 of the project description describe environmental concerns and control measures while Section 6 describes an overview of estimated environmental impacts. As this facility is the largest and most impactful of the set proposed in the MASDP, this EIA is critically useful for understanding potential impacts. A second, more detailed volume of the EIA for the site is available containing air modeling and emissions estimates (p. 89 and p. 153)[64] measured in tonnes per day. Since many parts of the facilities may operate continuously, for the purpose of a precautionary "similar facility construction" analysis, I assume 365 day/year operation. Emissions rates and total emissions for the Alberta facility are presented in Figures 18 through 19, while total emissions predicted from the MASDP GTL plant are given in Figure 20.

[64] Sasol. (2013). Canada Gas-to-Liquids Project Volume 2: Environmental-Impact-Assessment. Available here https://open.alberta.ca/dataset/f31e6946-ac74-44cf-90e9-2fec83808ab7/resource/ac81aa0f-9047-4e82-a43a-5e8fb075a547/download/sasol-gtl-project-volume-2-environmental-impact-assessment.pdf

Figure 18. Summary of Emissions Table for the Sasol Alberta GTL facility reported in tonnes per day.

Table 3-5 Summary of Emissions Associated with the Project

Substance (t/d)	Combustion Stacks	Flare Stacks	Vent Stacks	Sub-Total Stacks	Storage Tanks	Process Areas	Sub-Total Fugitive	Cooling Tower	Project Total
NO_X (t/d)	5.80	0.46	0	6.26	0	0	0	0	6.26
SO_2 (t/d)	0.12	1.20	0	1.32	0	0	0	0	1.32
CO (t/d)	5.20	2.50	0	7.70	0	0	0	0	7.70
$PM_{2.5}$ (t/d)	0.48	0.10	0	0.58	0	0	0	0.0016	0.58
VOC/PAH (t/d)	0.34	0.95	8.30	9.60	0.41	0.63	1.04	0	10.64
VOC/PAH (t/d) (annualized)	0.34	0.09	2.70	3.13	0.10	0.63	0.73	0	3.89
RSC	0	0.013	0	0.013	0	0.00003	0	0	0.013
H_2O (t/d)	5,512	751	0	6,263	0	0	0	32,981	39,244
Greenhouse Gas Emissions (annualized)									
CO_2 (t/d)	15,061	691	0	15752	0	5.2	5.2	0	15,757
Methane (t/d)	0.35	14	0	14.33	0	0.82	0.82	0	15.15
N_2O (t/d)	0.31	0.017	0	0.33	0	0	0	0	0.33
CO_{2E} (t/d)	15,164	990	0	16,153	0	22	22	0	16,176

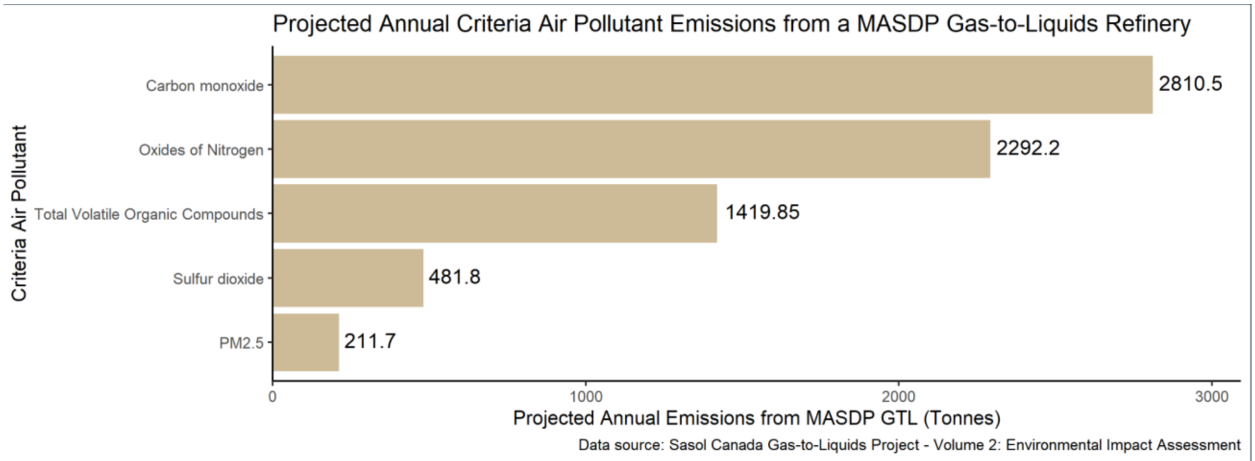
NOTES:
VOC/PAH does not include methane or C2; it focuses on the VOC and PAH substances (see Table 3-4).
Emission rates, except where indicated, represent all emission sources operating simultaneously at full load conditions. Annualized average emission rates are shown for the VOC/PAH and the GHG emissions.
The conventional stack CO_2 emission includes 1,408 t/d from the HPU methane process feed.
Subtotals and totals may not appear to match individual entries because of rounding.

Figure 19. Other emissions predicted from the Sasol Alberta GTL facility reported in tonnes per day.

Table 3-25 Other Substance Emission Rates

	Emission Rate (t/d)			
	Project-alone	**Base Case**	**Application Case**	**PDC**
Inorganic Compounds				
Carbon monoxide	7.70	471.94	479.64	481.50
Hydrogen chloride	0.0053	0.075	0.080	0.080
Hydrogen fluoride	0.00037	0.131	0.131	0.131
Hydrocarbons				
Acetaldehyde	0.0027	1.1860	1.1887	1.1890
Benzene	0.0019	0.6156	0.6175	0.6178
Benzo(a)pyrene	0.00014	0.00010	0.00024	0.00024
Ethylbenzene	0.00016	0.2333	0.2334	0.2335
Formaldehyde	0.211	1.548	1.759	1.764
n-hexane	0.169	2.710	2.878	2.903
Cumene	0.0000042	0.0150	0.0150	0.0150
Styrene	0.000021	0.0587	0.0588	0.0588
Toluene	0.119	1.369	1.487	1.488
Xylenes	0.0054	0.859	0.864	0.865
Total Reduced Sulphur Compounds				
Carbon disulphide	0.0091	0.188	0.197	0.197
Hydrogen sulphide	0.0024	0.0896	0.0920	0.0920
Metals				
Arsenic	0.000012	0.00042	0.00043	0.00043
Chromium	0.000009	0.00597	0.00598	0.00598
Lead	0.000009	0.00255	0.00256	0.00257
Manganese	0.000028	0.00560	0.00563	0.00564
Nickel	0.00020	0.0117	0.0119	0.0119

Figure 20. Projected annual emissions from a MASDP GTL facility.



7.3 Hydrogen Production and Distribution Facilities

Production quantity in MASDP assumed based on Gas Taskforce table: 600 Tpd of Blue Hydrogen and 300 Tpd of Green Hydrogen

7.3.1 How Is Hydrogen Produced?

This development scenario identifies two types of hydrogen production facilities, a 300 Tpa green hydrogen facility, produced via electrolysis from solar power and water and a 600 Tpa blue hydrogen system – which is gray hydrogen (gas-based hydrogen) produced using a steam methane reforming (SMR) process that then includes the energy intensive process of carbon capture and storage (CCS) added to scrub some of the CO2 from the flue gas. It must be emphasized both that 1) the facility to capture the CO2 emitted by the plant is still considered in the Draft Program to be "highly prospective"[65]; and 2) carbon capture and storage does nothing to capture harmful co-pollutants produced during SMR. Here I will focus on the impacts from the SMR facility because the electrolysis facility impacts are uncertain and are determined in large part by the electricity powering the plant. The emissions permit for the comparison facility, Air Products and Chemicals, Inc. in Catlettsburg, KY, USA, describes the SMR process:

> The steam methane reforming (SMR) process includes a reformer, which contains catalyst filled tubes. Natural gas is the process feed. The reforming reactions that produce hydrogen occur in the catalyst-filled tubes. The reformer combusts fuels to generate the necessary heat of reaction. Pressure swing adsorption (PSA) purge gas, natural gas, and reformer synthesis gas (syngas) are possible fuels. Emissions go out through the hydrogen reformer flue gas stack.[66]

7.3.2 Comparable Facilities

The Air Products and Chemicals Hydrogen Reformer Inc. in Catlettsburg, KY, USA has the capacity to produce 34 million standard cubic feet (mmscf) of hydrogen per day. Assuming this facility operates

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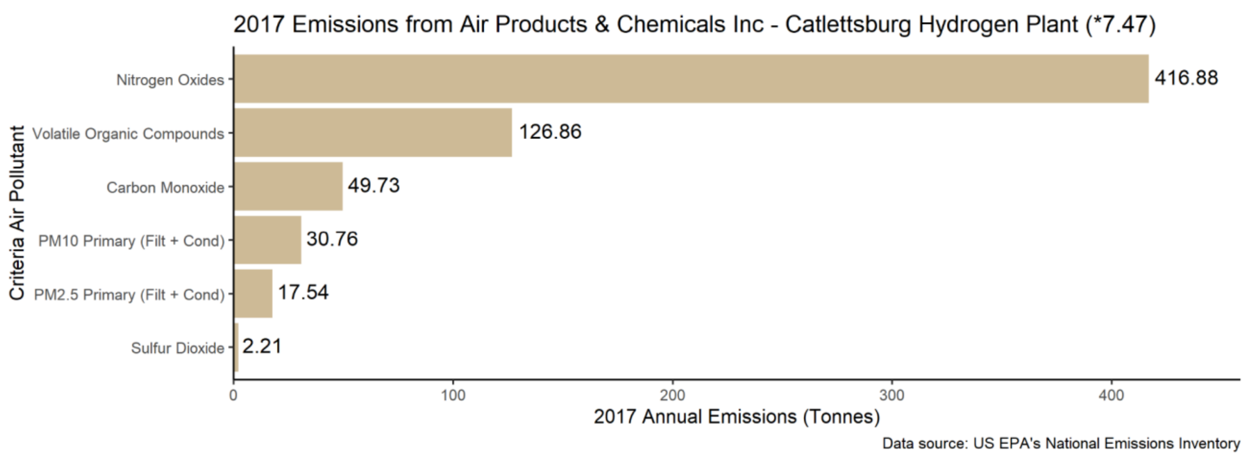
[65] Middle Arm Sustainable Development Precinct Draft Program Referral Report (January 2022), p. 1. Available at https://ntepa.nt.gov.au/__data/assets/pdf_file/0007/1092463/masdp-draft-program.pdf

[66] Commonwealth of Kentucky Energy and Environment Cabinet Department for Environmental Protection Division for Air Quality. AIR QUALITY PERMIT Issued under 401 KAR 52:020. Available here http://dep.gateway.ky.gov/eSearch/Search_AI_Detail.aspx?AgencyID=83915

year-round without stopping, and that 1lb of hydrogen equals 192 standard cubic feet,[67] this facility has a capacity of 80.32 Tpd, meaning that it would take 7.47 of these facilities to meet the proposed 600 Tpd facility at the MASDP. To simulate emissions at a SMR hydrogen reformer at the MASDP, I have therefore obtained the most recent year of emissions from this facility and multiplied them by 7.47. The facility only reported emitting one hazardous air pollutant, methanol. Scaled, the simulated MASDP reformer has the potential to emit 10,144 kg of methanol to the air each year. Figure 21 displays the projected total criteria air pollutant emissions from the MASDP blue hydrogen plant and Figure 22 displays the comparable facility's footprint - likely much smaller than that of the MASDP facility because of its much smaller production capability. Note that because CCS technology for blue hydrogen would make the plant less efficient, it is likely that the criteria emissions would rise significantly as a result of the CCS addition.[68]

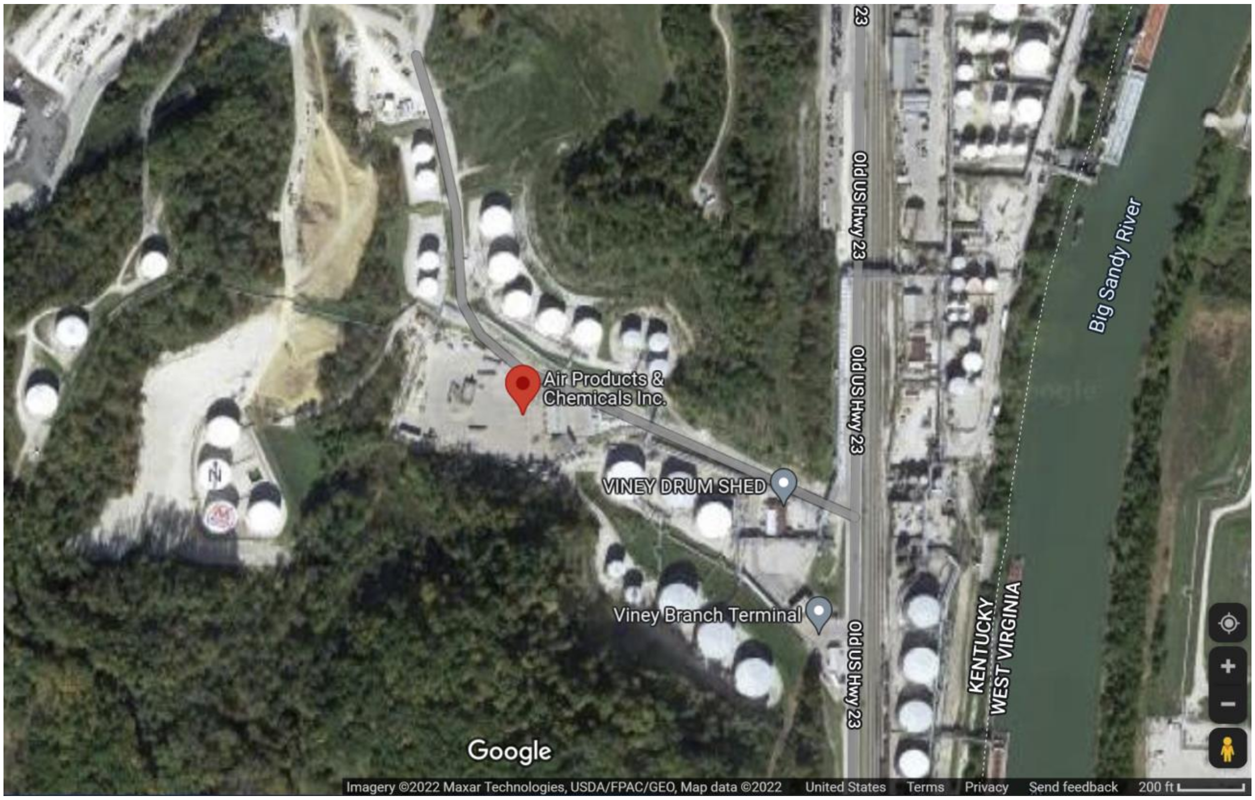
Figure 21. Projected emissions from a MASDP 600 Tpd gray hydrogen plant.



[67] Keen Compressed Gas Co. (2022). Hydrogen Conversion Data. Available here https://keengas.com/gases/hydrogen/

[68] Howarth, R. and M.Z. Jacobson. (October 2021). "How Green Is Blue Hydrogen?," *Energy Science & Engineering* 9, no. 10 : 1676–87. Available here https://doi.org/10.1002/ese3.956.

Figure 22. Google maps satellite image of the Air Products and Chemicals Hydrogen Reformer Inc. in Catlettsburg, KY, USA.



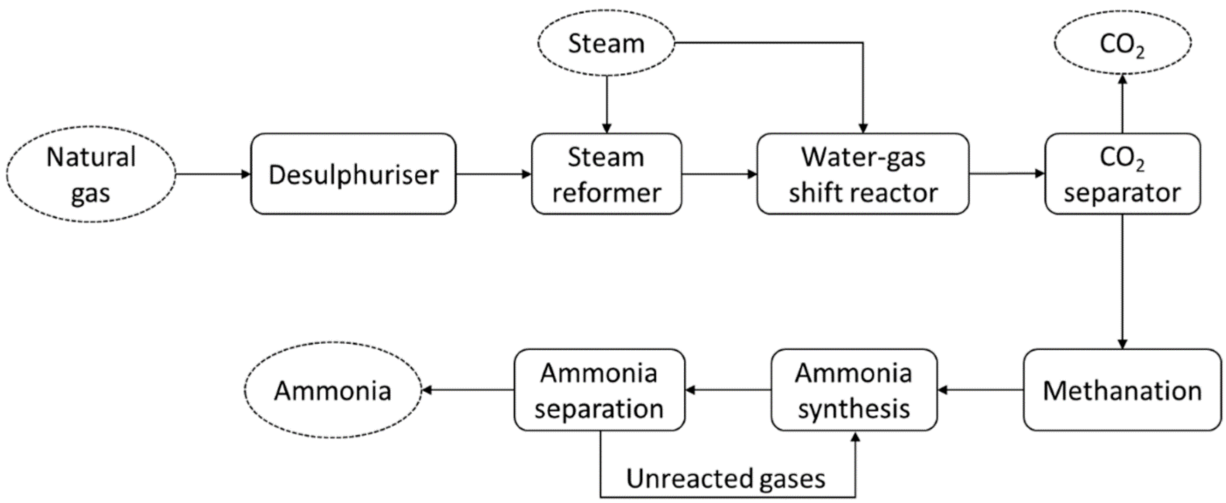
7.4 Ammonia and Urea Production

Production quantity in MASDP assumed based on Gas Taskforce Table: 1.1 Mtpa of ammonia, and 2 Mtpa of urea

7.4.1 How Are Ammonia and Urea Produced?

Ammonia–Urea plants convert natural gas products into ammonia and urea for use in fertilizers. The most common process of creating ammonia from natural gas is the Haber–Bosch process diagrammed in Figure 23 below. After the ammonia is produced it can be reacted with CO2 and evaporated to create granulated urea. These products, rich in nitrogen, are utilized for fertilizer.

Figure 23. Schematic diagram of ammonia production from natural gas, employing the Haber–Bosch process.[69]



Based on a 2002 proposed ammonia-urea production facility on the Burrup Peninsula,[70] the following infrastructure may be developed as part of the ammonia-urea plant proposed for the MASDP.

- a natural gas supply pipeline
- ammonia plant
- urea plant
- fluid bed granulation plant
- seawater desalination, treatment, and storage
- internal power generation and distribution
- product storage facilities for ammonia (on-site) and urea (on-site and near wharf)
- pipelines for ammonia export (to be located in a multi-user corridor proposed by others)
- urea formaldehyde storage on site

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[69] Scholarly Community Encyclopedia. (2022). Ammonia Production. Available here https://encyclopedia.pub/entry/1129#:~:text=The%20production%20of%20ammonia%20from,for%20the%20main%20ammonia%20synthesis

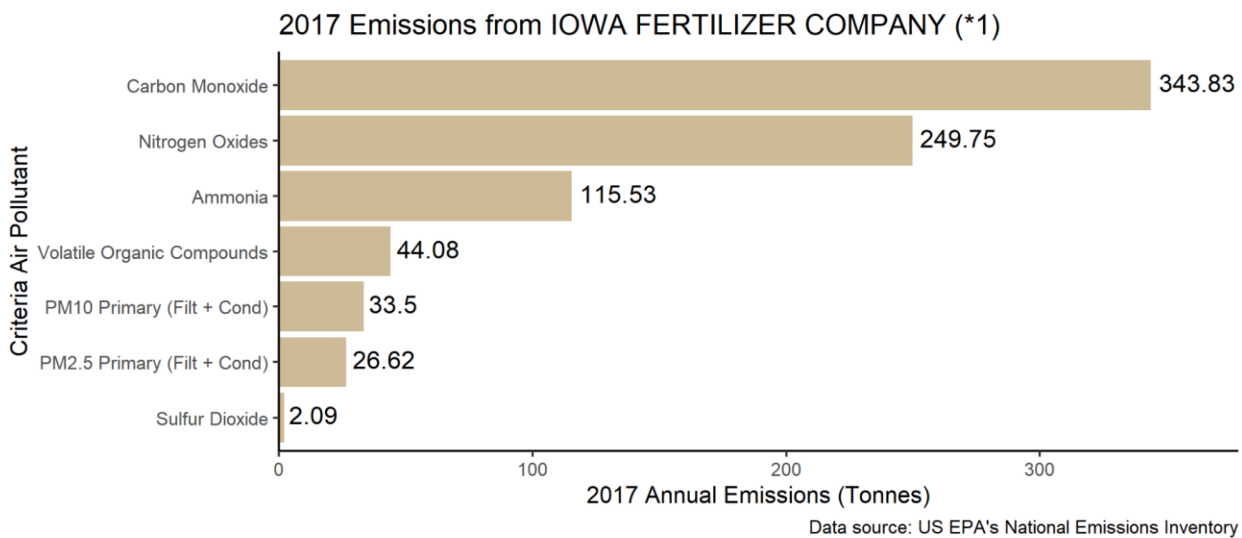
[70] Dampier Nitrogen Pty Ltd. (2002). Ammonia-Urea Plant, Burrup Peninsula: Report and recommendations of the Environmental Protection Authority. Available here https://www.epa.wa.gov.au/sites/default/files/EPA_Report/Bull_1065.pdf

- transfer conveyor systems and ship load out facilities for bulk granular urea
- ship loading facilities for load out of anhydrous (liquid) ammonia
- all other utilities and infrastructure required

7.4.2 Comparable Facilities

While proposed in 2002, It appears there is no urea production yet on the Burrup Peninsula. One ammonia–urea plant was recently operating in Australia, the Incitec Pivot Gibson Island fertilizer plant which has been operating for decades, manufacturing up to "300,000 tonnes of ammonia, 280,000 tonnes of urea and 200,000 tonnes of ammonium" per year.[71] Due to the age of this facility, a more modern comparison site was selected from the United States. The Iowa Fertilizer Company completed building its facility in 2016.[72] The facility generates 2 Mtpa of ammonia products from natural gas including granulated urea.[73] This facility also produces diesel exhaust fluid, which has not been mentioned in the MASDP plan. While the MASDP development plan calls for a facility with more urea and ammonia capacity than the Iowa facility, due to the additional production of diesel exhaust fluid, I will assume that they will have similar emissions profiles, the total of which is presented in Figure 24. Figure 25 shows the footprint of the Iowa facility.

Figure 24. Projected emissions of a MASDP ammonia-urea plant based on the Iowa Fertilizer Company.



[71] ABC Australia. (November 2021). Fertiliser prices boom as Incitec Pivot plans closure of Gibson Island plant. Available here (https://www.abc.net.au/news/rural/2021-11-13/incitec-pivot-shut-brisbane-plant-amidst-fertiliser-price-boom/100610750#:~:text=The%20facility%20has%20spent%20decades,and%20200%2C000%20tonnes%20of%20ammonium.

[72] Iowa Fertilizer Company. (2020). Title V Operating Permit. Available here https://www.iowadnr.gov/portals/idnr/uploads/air/operpermit/finalpermits/20-TV-001.pdf

[73] OCI N.V. Investor Presentation. (September 2017). https://www.oci.nl/media/1674/oci-n-v-ir-presentation-sep-2017.pdf

Figure 25. Aerial image of the Iowa Fertilizer Company facility.[74]

7.4.3 Accidents

Fertilizer plants pose significant accident risks due to explosion hazards. Several accidents have occurred in the United States which have led to injuries, evacuations, and deaths. Images of accidents in North Carolina and in Texas are displayed in Figures 26 and 27.

Figure 26. Image of a plume of smoke from the Winston Weaver Co. fertilizer plant fire in Winston-Salem, N.C. from February 2, 2022.[75]

[74] Weitz. (2022). Iowa Fertilizer Project. Available here https://www.weitz.com/projects/iowa-fertilizer-project/

[75] Associated Press. (2022) Explosion fears remain as North Carolina fertilizer plant burns for a third day. Available here https://www.npr.org/2022/02/02/1077713303/explosion-fears-remain-as-north-carolina-fertilizer-plant-burns-for-a-third-day

Figure 27. Image of a massive explosion at a fertilizer storage and distribution facility in West, Texas which killed twelve volunteer firefighters, two members of the public and caused hundreds of injuries.[76]

7.5 Methanol Production

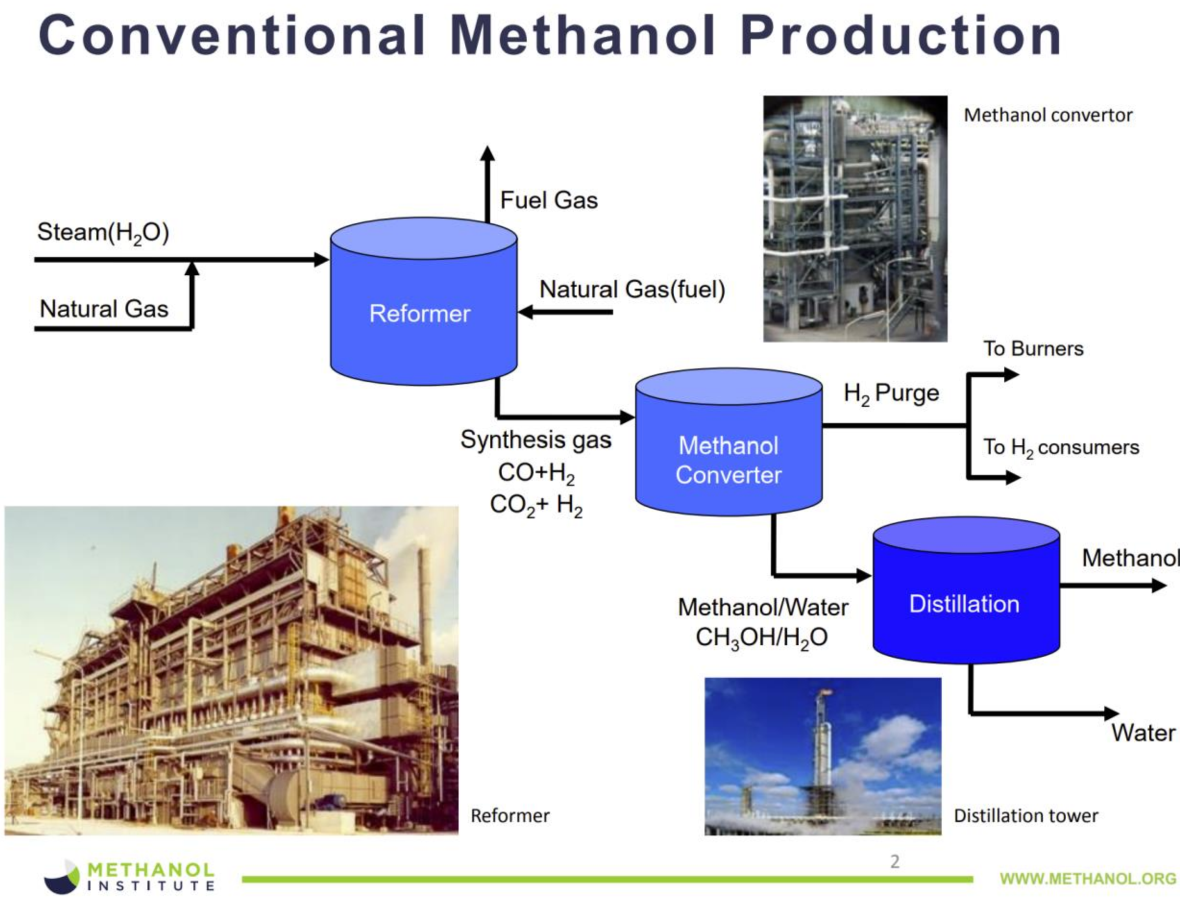
Production quantity in MASDP assumed based on Gas Taskforce Table: 1.6 Mtpa of methanol

7.5.1 How Is Methanol Produced?

Methanol refineries convert natural gas into methanol. The typical process involves syngas reformation, methanol conversion, and distillation. The process requires large amounts of natural gas as a heat source and as a feedstock.

[76] US Chemical Safety Board. (2016). West Fertilizer Explosion and Fire. Available here https://www.csb.gov/west-fertilizer-explosion-and-fire-/

Figure 28. Conventional methanol production process.[77]



Methanol is a chemical building block for hundreds of everyday products, including plastics, paints, car parts and construction materials.

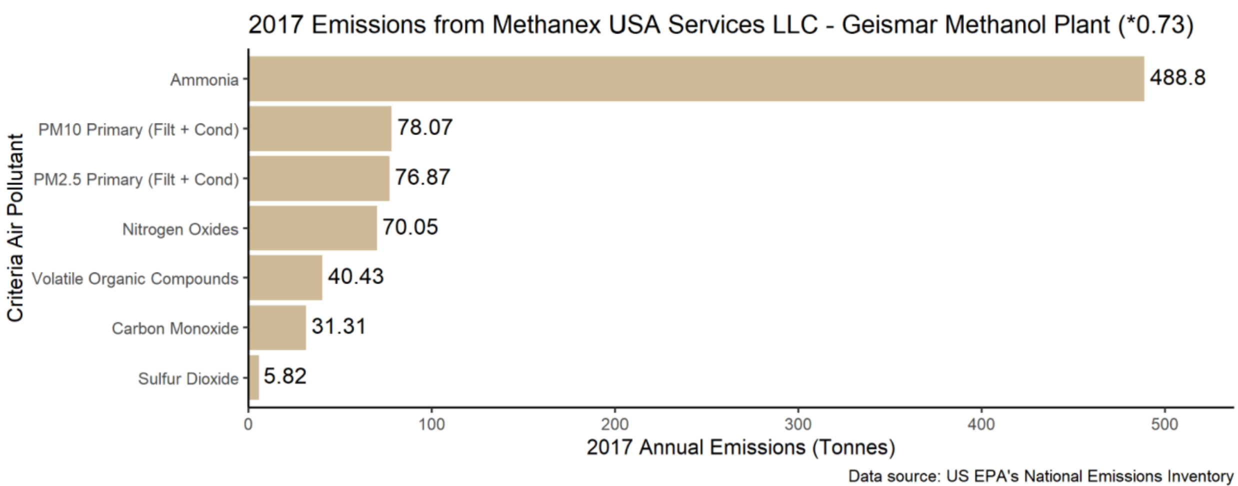
7.5.2 Comparable Facilities

The proposed methanol output of the MASDP development scenario facility is 1.6 mtpa. A slightly larger methanol facility, known as Methanex, went online in 2015 in Geismar, Louisiana, USA (see footprint of the facility in Figure 29). 2017 emissions from the Methanex site, scaled down by a factor of .73 serve to represent the possible emissions from the planned facility at the MASDP. Figure 30 shows the results of this scaling, the emissions estimated from the MASDP methanol facility.

77 https://www.methanol.org/wp-content/uploads/2016/06/MI-Combined-Slide-Deck-MDC-slides-Revised.pdf

Figure 29. The two methanol production units and storage tanks of Methanex, Geismar.[78]

Figure 30. Projected emissions from the MASDP methanol production plant estimated by scaling the Geismar facility.



7.5.3 Accidents

Accidents involving the production, transfer, and storage of methanol are rare compared to accidents in the oil and gas sector,but they do happen and the consequences are severe. Figure 31 shows an example of the kind of fire and emissions that can result from methanol plant explosions. A 2014 study reviewed multiple incidents across the global supply chain, noting that "Methanol's hazardous properties can easily go unrecognized and result in incidents with substantial human and material

[78] Mosbrucker, K. (April 1st, 2020). Methanex hits pause button on third Geismar plant for the next 18 months. The Advocate. Available here https://www.theadvocate.com/acadiana/news/business/article_b3459cae-7424-11ea-8269-4f80a334f56a.html

impacts" and that "hazards inherent in the use, storage and transportation of methanol can result in serious and catastrophic events."[79]

Figure 31. Image of an explosion and fire fueled by methanol which killed 19 people and injured 12 at a Sichuan plant in 2018.[80]

7.6 Ethylene Cracker and Polyethylene Production

Production quantity in MASDP assumed based on Gas Taskforce Table: 400 ktpa ethylene

7.6.1 How Is Ethylene Produced?

The MASDP projects the installation of a facility to produce ethylene and derivatives. Due to the presence of natural gas and natural gas liquids (NGL) at the site, presumably the MASDP facility would produce ethylene by steam cracking wet gas and NGLs from the Beetaloo Basin and Barossa gas field. Although no downstream plastics or resin manufacturing have been proposed in the Gas Taskforce table, later stage manufacturing operations are, as noted earlier, included in the general outline presented in the draft development plan.

Ethylene is a vital intermediate for products including food packaging, film, toys, food containers, bottles, pipes, antifreeze, carpets, insulation, housewares, etc. Chemicals that are made from ethylene to produce these end products are polyethylene, ethylene dichloride, ethylene oxide, ethylbenzene, and vinyl acetate, just to name a few.[81]

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[79] Medina, E. (2014). Methanol Hazards & Safeguards: Lessons Learned from the Global Supply Chain. Professional Safety, 59(06), 67-74. Available here https://aeasseincludes.assp.org/professionalsafety/pastissues/059/06/F3Medina_0614.pdf

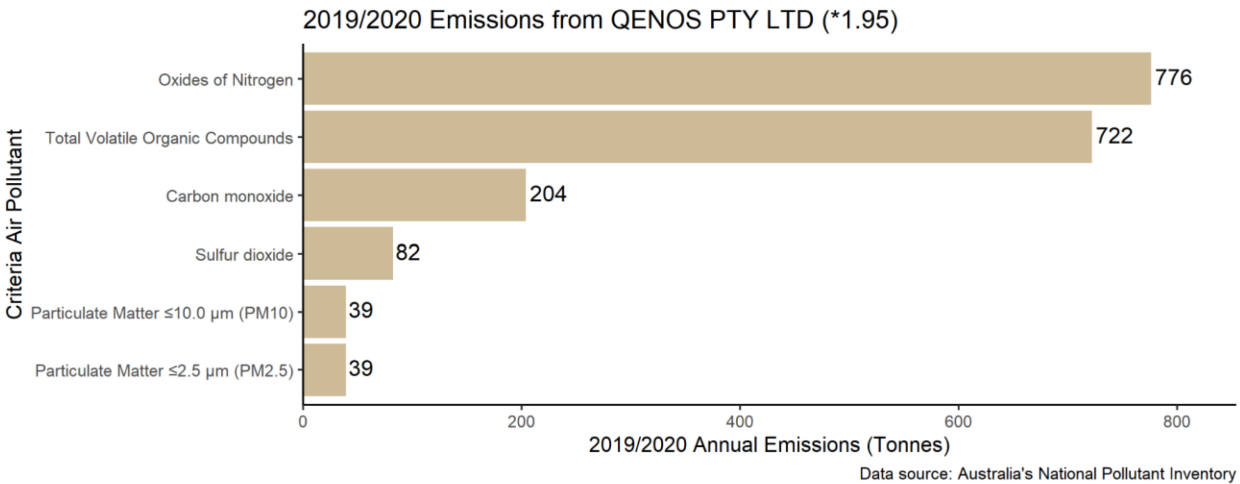
[80] Buckley, C. (July 13, 2018). Chinese Chemical Plant Explosion Kills at Least 19. *The New York Times*. Available at https://www.nytimes.com/2018/07/13/world/asia/china-chemical-plant-explosion-.html

[81] Emerson Process Management. (2010). Chemical Sourcebook Chapter 1 - Ethylene Production. Fisher Controls International. Available here https://www.emerson.com/documents/automation/manuals-guides-chemical-sourcebook-chapter-1-2-ethylene-production-polysilicone-production-fisher-en-138242.pdf

7.6.2 Comparable Facility

The QENOS PTY LTD, Altona, Victoria facility has the capacity of 205 kT of ethylene per year.[82] Emissions from the plant are based on the 2020/2021 NPI report which describes the main activities at the plant being "production of polyethylene" and "[s]team cracking of ethane and LPG".[83] To meet the proposed capacity of the MASDP facility, QENOS PTY LTD emissions are multiplied by a factor of 1.95.

Figure 32. Projected emissions from a MASDP ethylene plant based on Qenos Pty Altona.



7.6.3 Accidents

High pressure equipment, heat, and flammable materials present significant accident risk at ethylene production facilities. An explosion occurred at an ethane cracker in 2013 killing two workers and injuring 167. Residents within a 3km radius were ordered by authorities to remain indoors for hours to avoid the smoke plume.[84] Additional incidents have occurred in Pasadena and Deer Park TX.[85]

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[82] Qenos. (2022). Our Plants. Available at http://www.qenos.com/internet/home.nsf/web/OurPlants

[83] Australian Government Department the Environment and Energy. (2022). 2020/2021 report for QENOS PTY LTD, QENOS PTY LTD - Altona, VIC. National Pollutant Inventory. Available at http://www.npi.gov.au/npidata/action/load/individual-facility-detail/criteria/state/VIC/year/2021/jurisdiction-facility/00004342

[84] Bachman, J. (June 13, 2013). Explosion at Louisiana chemical plant kills 1, injures 73. Reuters. Available here https://www.reuters.com/article/us-chemicals-fire/explosion-at-louisiana-chemical-plant-kills-1-injures-73-idUSBRE95C0P120130613

[85] Minott, J. O. (2014). Health Impact Assessment of the Shell Chemical Appalachia Petrochemical Complex. Clean Air Council. Available here https://www.researchgate.net/profile/Sean-Mccormick-7/publication/279173563_Health_Impact_Assessment_of_the_Shell_Chemical_Appalachia_Petrochemical_Complex/links/558ad58808ae02c9d1f94569/Health-Impact-Assessment-of-the-Shell-Chemical-Appalachia-Petrochemical-Complex.pdf

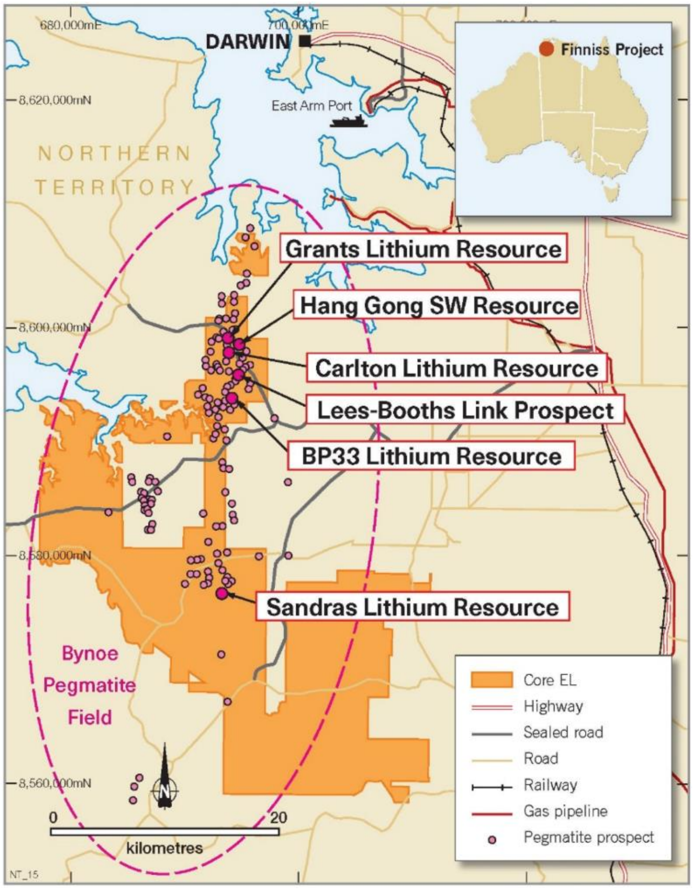
Figure 33. Photos from the June 13, 2013 Williams Olefins Incident in Geismar, LA. The full Chemical Safety Board review of this incident revealed several deficiencies in accident protection measures at the facility that led to this incident.[86]

7.7 Mineral Processing Facility 1: Lithium Hydroxide Refinery

While the proposed development scenario does not specify the type or scale of mineral refineries, I assume that one of the facilities will be a lithium ore refinery. I make this assumption based on the battery and cell phone product symbols in the "typical uses" column of the Gas Taskforce table as well as the nearby lithium ore reserves indicated by the map in Figure 34.

[86] U.S. Chemical Safety and Hazard Investigation Board. (June 13, 2013). Williams Geismar Olefins Plant – Reboiler Rupture and Fire Geismar, Louisiana. Available here https://www.csb.gov/file.aspx?DocumentId=6004

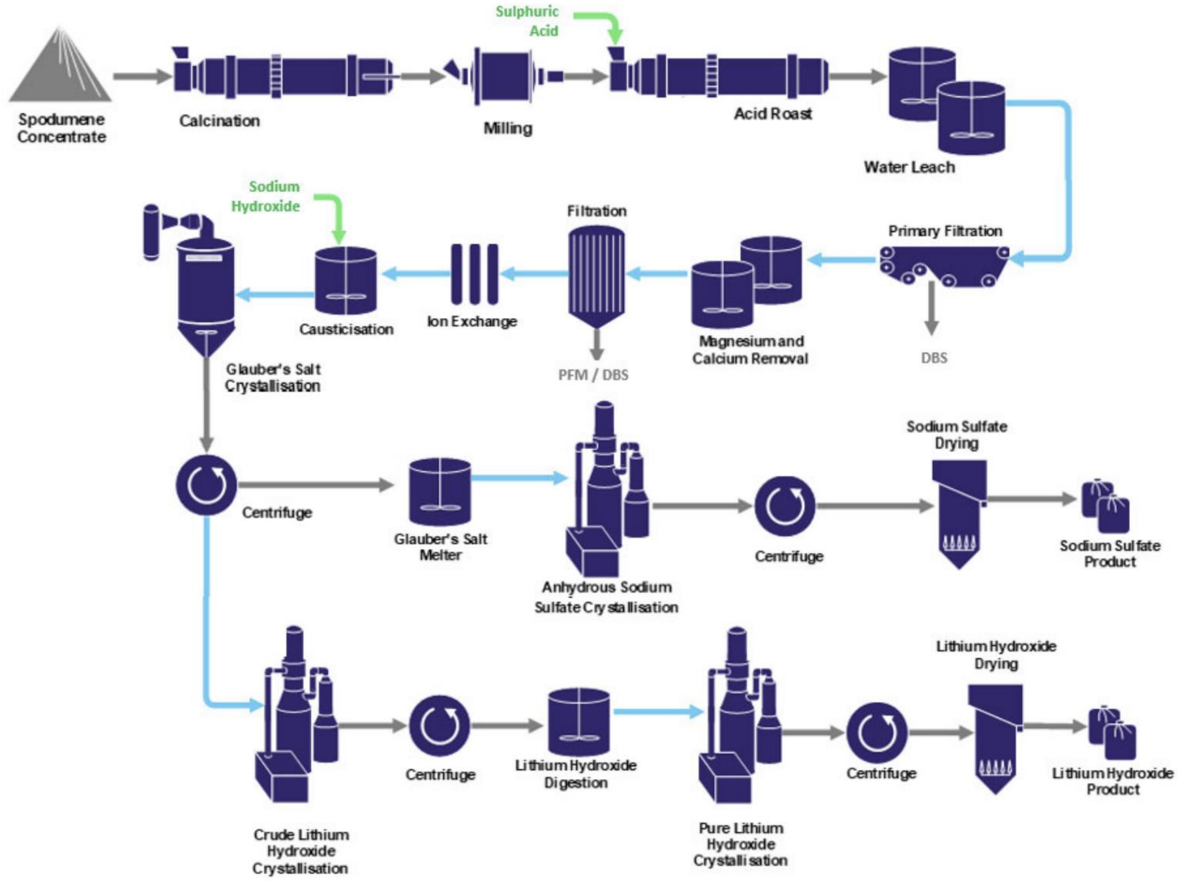
Figure 34. Spodumene concentrate production facilities in Western Australia.[87]



While there are multiple and evolving processes for lithium refinement, I show in Figure 35 what is likely to be a similar lithium refinement method to what would be used in the MASDP, taken from the recent environmental impact assessment of the new Covalent Lithium Pty Ltd Lithium Refinery in Western Australia.

[87] Core Lithium map of spodumene concentrate production facilities in Western Australia. Available here https://corelithium.com.au/finniss-lithium-project

Figure 35. Spodumene to Lithium Hydroxide (LIOH) process at Covalent.[88]



The process for converting spodumene into LIOH includes four different emissions source types including calcination stacks, ball mill stacks, acid roaster stacks, steam boiler stacks and sodium sulfate stacks.

7.7.1 Comparable Facility

Estimating the operating emissions from a LIOH refinery is difficult because there are not yet any reported emissions from operating facilities in Australia's National Pollutant Inventory or the USA's National Emissions Inventory (at least that I could identify for this report). Therefore emissions have been calculated using rates taken from the Covalent facility for a limited number of chemicals. Notably the emissions estimates do not include fine particulate matter. The facility is assumed to run 365 days per year for 24 hours per day because operational timelines could not be located, and this analysis is taking a precautionary approach.

The table below presents a yearly estimate of emissions from a facility similar to Covalent Lithium.

[88] GHD. (September 2020). Covalent Lithium Refinery Approvals – Air Quality Impact Assessment. Available here https://www.epa.wa.gov.au/sites/default/files/Referral_Documentation/Appendix%20D%20-%2012511788_Rep-1_Covalent_Air%20Quality.pdf

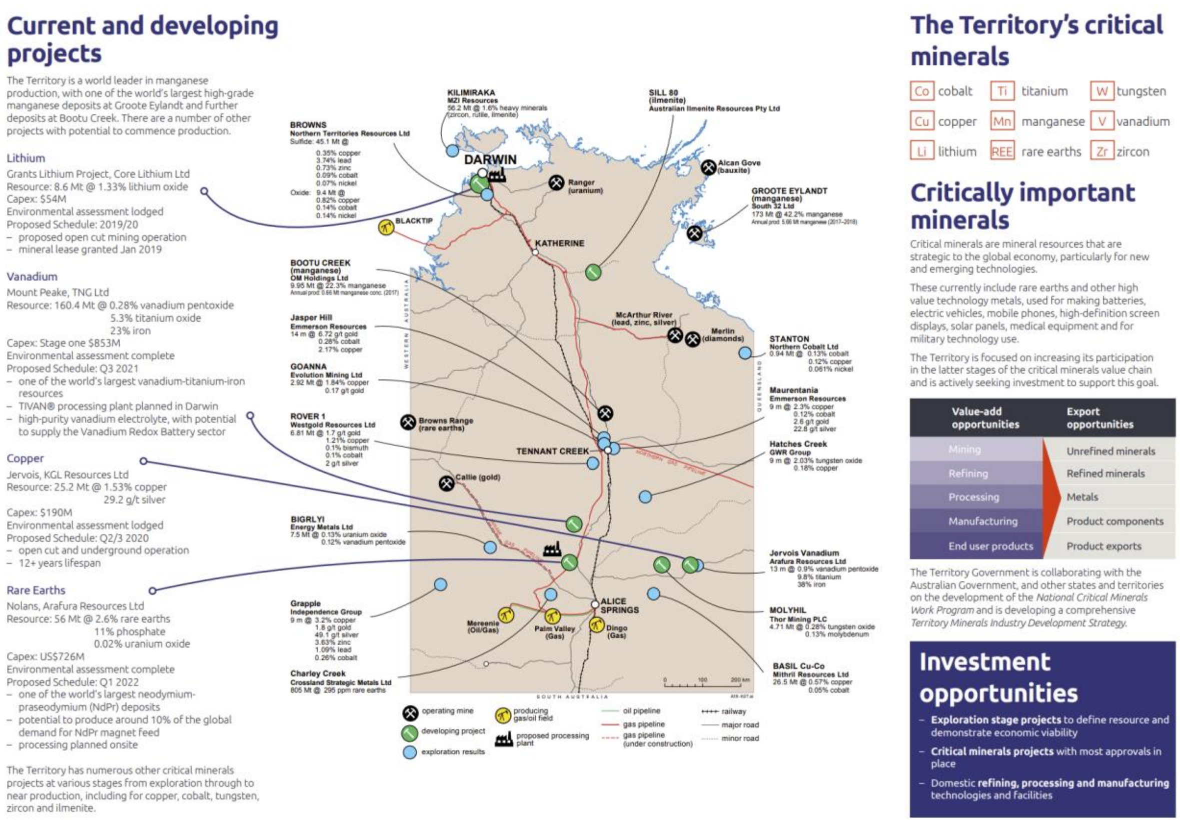
Table 3. Projected air pollution from MASDP lithium refinery based on Covalent Lithium.

Lithium Refinery Air Pollutant	Oxides of Nitrogen	Sulphur Dioxide	Carbon Monoxide	PM10
Projected Annual Emissions (Tonnes)	**39.79**	**51.91**	**114.79**	**14.63**

7.8 Minerals Processing Facility 2: Manganese Refinery

One option for the second minerals processing facility listed in the Gas Taskforce table is a manganese refinery. Manganese fits both product symbols in the ‘typical uses’ column of the table, which show animal feed supplements, and fertilizer. Manganese is an essential component in animal feeds and fertilizer as it is a trace mineral that is a dietary essential for animals and crops. The ore is also used in steel making, battery production, and other industrial applications. While several other mineral processing and refining operations are possible at Middle Arm. The NT is a ‘world leader in manganese production’ and is well suited for a refinery.

Figure 36. Manganese is one of the Territories main critical minerals.[89]



[89] Northern Territory Government Strategic Infrastructure and Projects. The Territory Critical Minerals Plan. Available here https://industry.nt.gov.au/__data/assets/pdf_file/0009/681174/nt-critical-minerals-plan.pdf

7.8.1 Comparable Facility

Unable to locate a comparable manganese refinery operating in Australia, I have selected the only operating manganese refinery in the United States as a comparison facility. Eramet Manganese of Marietta Ohio USA operates a 70-year-old manganese alloy refinery processing 120,000 tons of manganese each year via electric furnace.[90]

Figure 37. Google maps of the Erament, Marietta, OH facility. The NT's massive yearly manganese ore production of 6.7 million tonnes and the land available on the Middle Arm could easily support a facility of this size.[91]

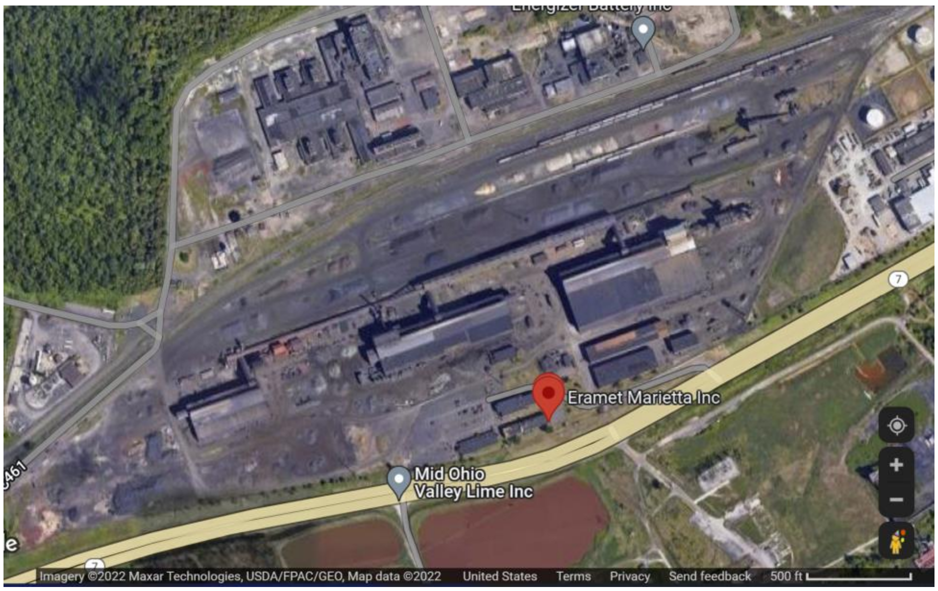
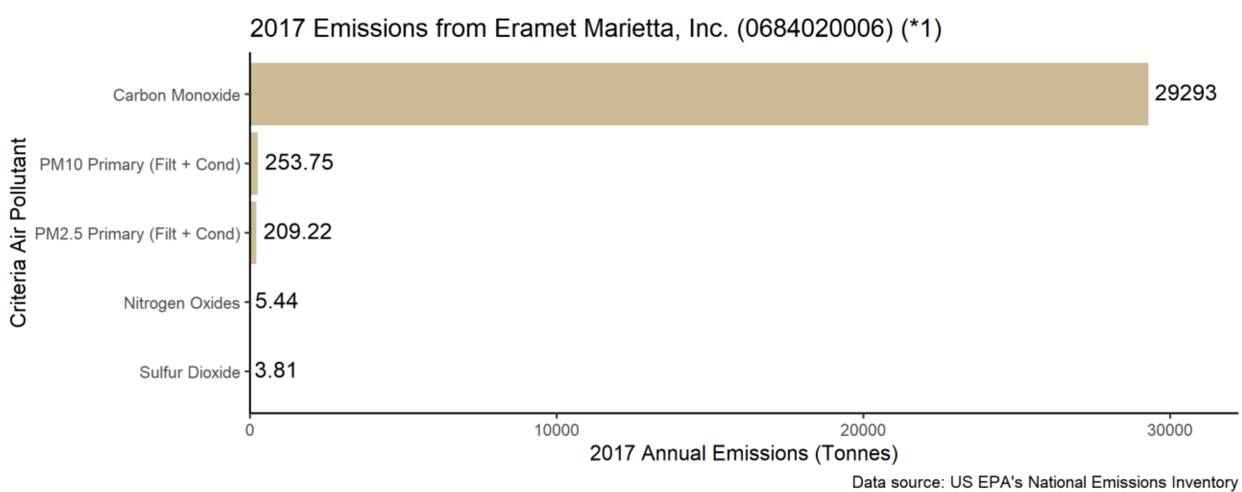


Figure 40. Projected emissions from an MASDP manganese refinery based on Eramet emissions.



[90] Eramet Marietta Website. Available here https://erametmarietta.com/

[91] Northern Territory Government. RESOURCING THE TERRITORY. Manganese. Available here https://resourcingtheterritory.nt.gov.au/minerals/mineral-commodities/manganese

8 Estimated Total Annual Air Emissions

8.1 Criteria Air Pollutants

Based on emissions from comparison facilities grounded in the Gas Taskforce table's development scenario, I estimate the MASDP will drastically change the industrial air pollution landscape of the Greater Darwin Region. The table below shows the criteria air pollutants that may be emitted from these facilities and their combined total potential emissions.

Table 3. Criteria air pollutant annual release potential from one development scenario of the MASDP.

Criteria air pollutant annual release potential from one development scenario of the MASDP	Carbon Monoxide (Tonnes)	Nitrogen Oxides (Tonnes)	PM2.5 Primary (Tonnes)	PM10 Primary (Tonnes)	Sulfur Dioxide (Tonnes)	Volatile Organic Compounds (Tonnes)
LNG (5 Mtpa)	1923.85	1002.484	51.8935	51.907	648.957	2400.689
GTL (36.5 mmbblspa)	2810.5	2292.2	211.7		481.8	1419.85
Hydrogen (600 Tpd)	49.72657	416.8808	17.53849	30.75762	2.214284	126.8564
Ammonia (1 Mtpa) & Urea (2.1 Mtpa)	343.8305	249.7535	26.61576	33.49995	2.092562	44.08218
Methanol (1.6 Mtpa)	31.31473	70.05059	76.87444	78.07336	5.819349	40.42967
Ethylene (400 Ktpa)	203.9591	776.2919	39.21019	39.21031	82.21998	721.8906
Lithium Refinery (50,000 Tpa)	114.79	39.79		14.63	51.91	
Manganese Refinery (~120,000 Tpa)	29293	5.44311	209.2204	253.7541	3.810177	
Total	34770.97	4852.894	633.0527	501.8323	1278.823	4753.798

For comparison, Table 4 shows a list of the criteria air pollutants emitted from industrial sources within 50km of the project in the 2020/2021 National Pollutant Inventory reporting year.

Table 4. Criteria air pollutants reported to the NPI by industry sector within 50km of the MASDP (10-year annual average).

Criteria air pollutants reported to the NPI by industry sector within 50km of the MASDP (10-year annual average)	Carbon Monoxide (Tonnes)	Nitrogen Oxides (Tonnes)	$PM_{2.5}$ Primary (Tonnes)	PM10 Primary (Tonnes)	Sulfur Dioxide (Tonnes)	Volatile Organic Compounds (Tonnes)
Cement and Lime Manufacturing	1.20	3.59	0.29	10.12	0.00	0.44
Fossil Fuel Electricity Generation	672.81	2758.77	42.54	44.11	6.46	30.84
Gas Supply						2.61
Hospitals (Except Psychiatric Hospitals)	0.81	3.65	0.07	0.18	0.02	0.04
Industrial Gas Manufacturing						27.71
Oil and Gas Extraction	4226.53	2491.65	107.07	107.08	873.02	3228.81
Other Electricity Generation	8.39	3.72	0.49	0.49	0.84	0.30
Other Warehousing and Storage Services						258.82
Petroleum Product Wholesaling						5.10
Port and Water Transport Terminal Operations	2.57	8.68	0.70	7.75	0.01	1.06
Rail Freight Transport						1.01
Waste Treatment and Disposal Services	18.43	22.24	1.53	1.61	0.66	4.75

Water Freight Transport	4.56	10.74	0.64	1.00	0.00	1.19
Total	4935.30	5303.05	153.32	172.33	881.03	3562.68

8.2 Air Toxics

Some air toxics are regulated under Australia's National Environment Protection (Air Toxics) Measure.[92] Additional air toxics are recorded in the National Pollutant Inventory (NPI). Here I quantify the potential changes in some Air Toxics that might occur if the MASDP scenario is completed. To do this, air toxics have been matched by name from the USA National Emissions Inventory (NEI) and the Australian National Pollutant Inventory. Once chemicals were matched, emissions of air toxics reported in the NPI or the NEI were converted to kilograms then toxicity weighted by multiplying the total air emissions by toxicity weights that are based on the relative cancer related toxicity of each compound. Additional air toxics may be released by the MASDP which are not represented here either because they were not reported by comparable facilities, or because the chemicals have not been shown to be carcinogens.

[92] National Environment Protection Council. National Environment Protection (Air Toxics) Measure. Available here http://www.nepc.gov.au/nepms/air-toxics

Table 5. Estimated MASDP Cancer-Causing Air Toxics Emissions by Chemical and Facility.

Estimated MASDP Cancer-Causing Air Toxics Emissions by Chemical and Facility	LNG (5 Mtpa)	GTL (36.5 mmbblspa)	Ammonia (1 Mtpa) & Urea (2.1 Mtpa)	Methanol (1.6 Mtpa)	Ethylene (400 Ktpa)	Manganese Refinery	MASDP Total (kg)	IUR ToxWeight	Inhale Unit Risk (IUR)	MASDP Cancer Inhalation Hazard by Chemical (kg*IUR ToxWeight)
Formaldehyde		77015.00	259.51	0.04			77274.54	46000.00	0.013	3554629055.54
Acetaldehyde		433875.50	0.02	0.02			433875.54	7900.00	0.002	3427616780.12
Polycyclic Aromatic Compounds	0.77	51.10	0.00	0.00	1.55	2651.70	2705.12	390000.00	0.600	1054997269.91
Benzene	5643.52	693.50	0.14	0.03	3091.29		9428.48	28000.00	0.008	263997445.75
Chromium (IV) + Chromium (unspecified) Total	0.00	3.29	0.02	0.00	1.02	0.00	4.32	43000000.00	12.000	185721412.48
Nickel	0.25	73.00	0.68		5.08	28.12	107.12	930000.00	0.260	99625034.04
Arsenic	0.03	4.38	0.06		0.48		4.95	15000000.00	4.300	74300934.12
1,3-Butadiene					663.33		663.33	110000.00	0.030	72966465.00
Cadmium	0.13		0.36		2.66		3.15	6400000.00	1.800	20147020.86
Ethyl Benzene	583.63	58.40			14.31		656.34	890.00	0.003	584138.33
Cobalt			0.03				0.03	17000000.00	4.800	462368.66
Beryllium	0.00				0.00		0.00	8600000.00	2.400	26359.00
Fluoranthene			0.00	0.00			0.00	390000.00	0.600	481.50
Naphthalene			0.04	0.00			0.04	12000.00	0.034	474.71
Chrysene				0.00			0.00	390000.00	0.600	4.38
Total Cancer Inhalation Hazard by Facility	160274205	7284550426	17069611.42	2763.622025	232861579.5	1060316659				**8755075244.41**

Table 6. 10 Year Average Cancer-Causing Air Toxics Toxicity Weighted Emissions within 50km of the MASDP by Chemical and Source Type

10 Year Average Cancer-Causing Air Toxics Toxicity Weighted Emissions within 50km of the MASDP by Chemical and Source Type	Fossil Fuel + Other Electricity Generation	Hospitals (Except Psychiatric Hospitals)	Oil and Gas Extraction	Other Warehousing and Storage Services	Petroleum Product Wholesaling + Cement and Lime Manufacturing	Port and Water Transport Terminal Operations + Water Freight Transport + Waste Treatment and Disposal Services	IUR ToxWeight	Existing Average Cancer Inhalation Hazard by Chemical (kg*IUR ToxWeight)
Polycyclic aromatic hydrocarbons (B[a]Peq)	5948398	35897269	634402	1382940000	65910	260559	390000	1425746539
Arsenic & compounds	3114465	468135027	1100000			34882789	15000000	507232282
Benzene	39915	15224	428199417	50686720	1953120	676788	28000	481571185
Beryllium & compounds	3552	201298062	4214				8600000	201305828
Cadmium & compounds	1769395	149803209	2538667				6400000	154111270
Chromium (VI) compounds	46307945	1317786	27233				43000000	47652964
Ethylbenzene	204	112	1526237	438788	51999	45278	890	2062618
Nickel & compounds	3312509	21768279	700600			786338	930000	26567725
Acetaldehyde	0	3123				3759	7900	6882
1,3-Butadiene (vinyl ethylene)	0	2141				8952	110000	11093
Cobalt & compounds	0	12645731				6608532	17000000	19254263
Formaldehyde (methyl aldehyde)	0	26576				755042	46000	781618
Chloroform (trichloromethane)	5092					67821	82000	72914
Dichloromethane	4					1840	36	1844
Tetrachloroethylene	101					30633	930	30734
Trichloroethylene	1242					159674	15000	160916
Vinyl Chloride Monomer	2086					269204	31000	271290
Acrylonitrile (2-propenenitrile)	0					7714942	240000	7714942
1,2-Dichloroethane	0					102660	93000	102660
1,1,2-Trichloroethane	0					11756	5700	11756
Total Average Cancer Inhalation Hazard by Industry Group	60504907	890912537	434730771	1434065508	2071029	43326734		**2874671322**

8.3 Comparing Emissions

Under the Gas Taskforce development scenario I have considered, industrial emissions from the MASDP will increase dramatically compared to the levels seen in the Darwin area over the past decade. Annual fine particulate emissions may quadruple, and carbon monoxide emissions may increase by 705%.

Table 7. Criteria air pollutant emissions comparison.

Criteria Air Pollutant Emissions	Carbon Monoxide (Tonnes)	Nitrogen Oxides (Tonnes)	PM2.5 Primary (Tonnes)	PM10 Primary (Tonnes)	Sulfur Dioxide (Tonnes)	Volatile Organic Compounds (Tonnes)	Cancer Hazard from Air Toxics (Unitless)
MASDP Scenario Total	34770.97	4852.89	633.05	501.83	1278.82	4753.8	8755075244
Region Average	4935.29	5303.05	153.32	172.33	881.03	3562.66	2874671322
Average + MASDP Scenario	39706.26	10155.94	786.37	674.16	2159.85	8316.46	11629746566
Percent Increase	**805%**	**192%**	**513%**	**391%**	**245%**	**233%**	**405%**

8.4 Assessing the Economic Human Health Impacts of Air Quality Changes

With potential emissions from the simulated group of major MASDP facilities, some components of a prospective human health impacts assessment can be performed. This will be a limited 'cumulative' screening assessment as it does not include supporting industry, shipping, trucking, or rail emissions. This limited assessment does, however, provide opportunities to conceptualize the largest emitters and their potential impacts as a group.

Human exposure to NOX[93], SO2[94], PM2.5[95], and ozone, has been linked to increased risk of respiratory and cardiovascular symptoms, and to increased mortality rates.

Adapting a framework for valuing PM2.5 metrics from the UK Department of Environment, a consulting company prepared a particle emissions valuation methodology for the NSW Environment Protection Authority.[96] The method fits a regression model to calculate costs of emissions as a function of:

- population density,
- a PM2.5 concentration response function from Pope and colleagues where a 10-µg/m3 increase in average annual concentration results in a 4% increase in all-cause mortality rate[97],

[93] National Center for Environmental Assessment-RTP Division, Office of Research and Development. Integrated science assessment for oxides of nitrogen - health criteria. 2008; EPA/600/R-08/071

[94] National Center for Environmental Assessment-RTP Division, Office of Research and Development. Integrated science assessment for sulfur oxides - health criteria. 2008; EPA/600/R-08/047A

[95] National Center for Environmental Assessment-RTP Division, Office of Research and Development. Integrated science assessment for particulate matter. 2009; EPA/600/R-08/139F

[96] PAEHolmes. (February, 2013). Methodology for Valuing the Health Impacts of Changes in Particle Emissions – Final Report. Available here https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/air/HealthPartEmiss.ashx

[97] Pope C A III, Burnett R T, Thun M J, Calle E E, Krewski D, Ito K and Thurston G D (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American medical association, 287: 1132 - 1141. Available here https://jamanetwork.com/journals/jama/fullarticle/194704

- and the value of a statistical life year, calculated as $288,911 in 2011 Australian dollars based on a 2012 study by Defra.[98]

The resulting published cost per tonne of fine particulate matter emissions in Darwin is $100,000 in 2011. Relying on this method, I adjust for inflation to a cost of 120,297.15 per tonne in 2021 Australian Dollars[99], then compare it to the Australian value of a statistical life ($5,000,000)[100] to provide one way to put an economic and human cost on the fine particle emissions that would be released by these facilities. The human costs of PM2.5 calculated through this method from each facility in the proposed MASDP complex are given in Table 8.

Table 8. Estimated costs of PM2.5 emissions from each MASDP facility.

Costs of PM2.5	**LNG (5 Mtpa)**	**GTL (36.5 mmbblspa)**	**Hydrogen (600 tpd)**	**Ammonia (1 Mtpa) & Urea (2.1 Mtpa)**	**Methanol (1.6 Mtpa)**	**Ethylene (400 Ktpa)**	**Manganese Refinery**	**Totals**
PM2.5 (Tonnes)	51.89	211.70	17.54	26.62	76.87	39.21	209.22	633.05
Annual Costs (Millions)	$6.24	$25.47	$2.11	$3.20	$9.25	$4.72	$25.17	$76.15
Statistical Lives Taken Annually	1.25	5.09	0.42	0.64	1.85	0.94	5.03	15.23

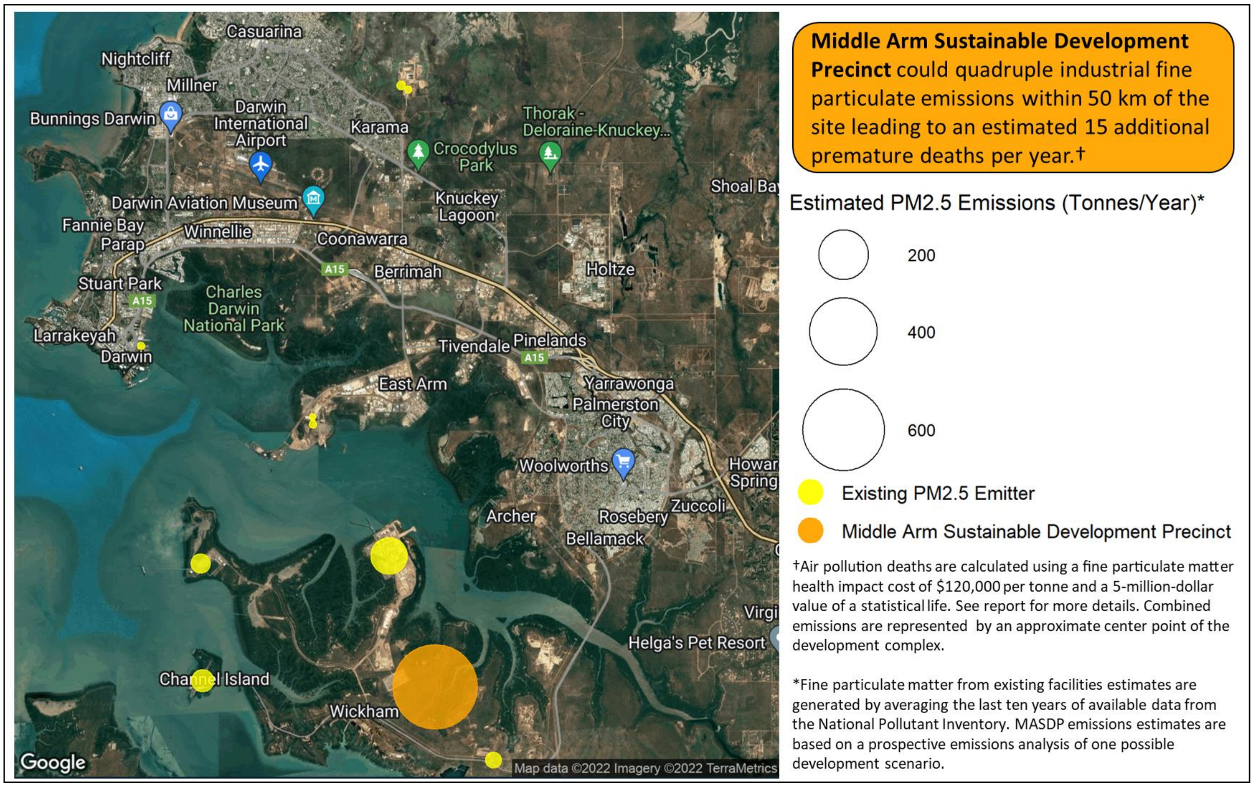
Direct fine particle emissions from these simulated facilities, if emitted in 2021, would have cost the people of Darwin an estimated $76.15 million dollars in premature mortality health costs. That is equivalent to the loss of 15.23 lives annually.

98 Defra (2012). Air Quality Damage Costs. Published by Defra. The current damage cost values are published at: https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance#damage-costs

99 Inflation estimated using the Reserve Bank of Australia Inflation Calculator. Available here https://www.rba.gov.au/calculator/annualDecimal.html

100 Australian Government Office of Best Practice Regulation. (2020). Best Practive Regulation Guidance Note – Valuation of statistical life. Available here https://obpr.pmc.gov.au/sites/default/files/2021-06/value-of-statistical-life-guidance-note-2.pdf

Figure 1. Map of potential fine particulate emissions from the studied MASDP development scenario compared to other emitters. Circles represent the comparative amount of emissions released annually, not the emissions plume.



Premature mortality from direct particulate matter emissions is not the only cost that can be estimated from pollutants emitted by these facilities. Gaseous emissions like NOX and VOCs can form secondary particulate matter through photochemical secondary formation. They can also create ground level ozone and other harmful criteria air pollutants. Due to complex atmospheric conditions, it is difficult to predict the secondary formation of particles from NOX, VOCs and SO2 in the Darwin region, and I was unable to find common cost factors for these secondary pollutants in the NT. For the sake of demonstration purposes only, then, I have produced some estimates based on published cost factors published for the United Kingdom. This would assume a conversion rate of $1.50 Australian dollars per Euro and that the facility was placed in a representative location in the UK.[101]

[101] United Kingdom Department of Environment, Food, and Rural Affairs. (2020). Air Quality Damage Costs. Published by Defra. The current damage cost values are published at: https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance#damage-costs

Figure 39. Emissions cost factors from the United Kingdom Department of Environment, Food, and Rural Affairs.

Pollutant emitted	2020 Damage costs (£/t) National averages (2017 prices) Latest figures
NOx	6,385
SO2	13,206
NH3	7,923
VOC	102
PM2.5	73,403

Table 9. Estimated costs in Australian dollars of criteria air pollutant emissions from each MASDP facility if they were being built in a representative location in the UK.

Hypothetical Emissions costs based on UK estimates	NOX	PM2.5	SO2	VOCS	NH3	Total by Facility (2020 UK damage adjusted by Australian exchange rate)
LNG (5 Mtpa)	$ 9,601,291	$ 5,713,708	$ 12,855,189	$ 367,305	$ -	$ 28,537,493
GTL (36.5 mmbblspa)	$ 21,953,546	$ 23,309,123	$ 9,543,976	$ 217,237	$ -	$ 55,023,881
Hydrogen (600 tpd)	$ 3,992,676	$ 1,931,066	$ 43,863	$ 19,409	$ -	$ 5,987,014
Ammonia (1 Mtpa) & Urea (2.1 Mtpa)	$ 2,392,014	$ 2,930,514	$ 41,452	$ 6,745	$ 1,373,063	$ 6,743,787
Methanol (1.6 Mtpa)	$ 670,910	$ 8,464,222	$ 115,275	$ 6,186	$ 5,809,140	$ 15,065,733
Ethylene (400 Ktpa)	$ 7,434,935	$ 4,317,218	$ 1,628,696	$ 110,449	$ -	$ 13,491,299
Manganese Refinery (~120,000 Tpa)	$ 52,131	$ 23,036,105	$ 75,476	$ -	$ -	$ 23,163,712
Lithium Refinery (50,000 Tpa)	$ 381,089	$ -	$ 1,028,285	$ -	$ -	$ 1,409,374
Total by Chemical	$ 46,478,591	$ 69,701,956	$ 25,332,212	$ 727,331	$ 7,182,203	$ 149,422,293

While I cannot assume that the atmospheric chemistry will create secondary particulate matter in the Northern Territory the same way it is generated in the UK, this hypothetical helps to illustrate how the impacts and costs of PM2.5 and ozone precursors must also be considered within the health impact analysis performed for the SEA.

8.5 Greenhouse Gases and Carbon Capture, Utilization & Storage Facilities

Simulated greenhouse gas emissions were estimated using emissions reported by from comparison facilities that were then scaled in the same manner as criteria pollutants and air toxics.

Table 10. Estimated Potential MASDP Scenario Greenhouse Gas Emissions (in Megatons)

MASDP Scenario Greenhouse Gas Emissions (in Megatons)	Mt/annum CO2e	Plant Size Modifier	MASDP Estimate
LNG (5 Mtpa)	7.62472[102]	0.5	3.81236
GTL (36.5 mmbblspa)	5.90424[103]	1	5.90424
Hydrogen (600 tpd)	0.123065[104]	7.47	0.919296
Ammonia (1 Mtpa) & Urea (2.1 Mtpa)	1.866659[105]	1	1.866659
Methanol (1.6 Mtpa)	0.856186[106]	0.73	0.625016
Ethylene (400 Ktpa)	0.978936[107]	1.95	1.908925
Manganese Refinery (~120,000 Tpa)	0.170561[108]	1	0.170561
Lithium Refinery (50,000 Tpa)	0.317449[109]	1	0.317449
Total			15.52451

Based on recent emissions from simulated facilities fit to match the development scenario, the MASDP may release 15.52 megatons of CO2e per year when completed. Applying a 2019 estimate of the full Territory's emissions - 20.7 Mt CO2-e[110] --this would increase the Territory's emissions by 75%. Using a

[102] Australian Government Clean Energy Regulator. 2019/2020. INPEX HOLDINGS AUSTRALIA PTY LTD Scope 1 + 2. Available here Link.

[103]Canada Gas-to-Liquids Project. (May 2013). Volume 2 Environmental Impact Assessment. Table 3-5, pdf pare 89. Available here https://open.alberta.ca/dataset/f31e6946-ac74-44cf-90e9-2fec83808ab7/resource/ac81aa0f-9047-4e82-a43a-5e8fb075a547/download/sasol-gtl-project-volume-2-environmental-impact-assessment.pdf.

[104] US EPA Greenhouse Gas Reporting Program (GHGRP). (2020). AIR PRODUCTS AND CHEMICALS INC - CATLETTSBURG HYDROGEN PLANT. Available here https://ghgdata.epa.gov/ghgp/service/html/2020?id=1005809&et=undefined.

[105] US EPA Greenhouse Gas Reporting Program (GHGRP). (2020). Iowa Fertilizer Company. Available here https://ghgdata.epa.gov/ghgp/service/html/2020?id=1012918&et=undefined.

[106] US EPA Greenhouse Gas Reporting Program (GHGRP). (2020). Methanex USA, LLC - Geismar Methanol Plant. Available here https://ghgdata.epa.gov/ghgp/service/html/2020?id=1011799&et=undefined.

[107] Australian Government Clean Energy Regulator. 2019/2020. QENOS PTY LTD Scope 1 + 2. Available here link.

[108]US EPA Greenhouse Gas Reporting Program (GHGRP). (2020). ERAMET MARIETTA INC. Available here https://ghgdata.epa.gov/ghgp/service/html/2020?id=1004376&et=undefined.

[109] Covalent Lithium Hydroxide Refinery Project Greenhouse Gas Management Plan. (2021). Table 8, p. 20. Available here https://static1.squarespace.com/static/5d8c061dd46259208da3638c/t/62413030f173df29069f3a87/1648439348897/Refinery+Greenhouse+Gas+Management+Plan.pdf.

[110] Australian Government Department of Industry, Science, Energy, and Resources. National Greenhouse Accounts 2019. Available here https://www.industry.gov.au/data-and-publications/national-greenhouse-accounts-2019/state-and-territory-greenhouse-gas-inventories-annual-emissions#:~:text=Northern%20Territory%3A,extraction%20and%20stationary%20energy%20emissions.

social cost of carbon of $20 per tonne, this complex alone would generate social costs of some $310 million per year.[111]

With the proposed 12 Mtpa CO2 utilization and storage facility working at full capacity, this cost could be reduced to $70.5 million per year. Based on a study of this carbon capture and technology, the cost to capture, compress, transport, and inject this CO2 is even higher, estimated somewhere in the range of $70 to $90 dollars per tonne.[112] It's difficult to assess the feasibility and success rate of this technology as, if built, it will be one of, if not the, largest systems of its kind. Only two facilities are operating in the United States with 1 Mtpa injection rates or less.[113] The closest comparison operation is the Gorgon Joint Venture which plans to inject 3.3-4 Mtpa in the Dupuy Formation.[114] Planned to operate a full capacity in 2017,[115] Gorgon has run into operational difficulties and in 2021 has only achieved a little over half of its stated capacity.[116]

Operations of a CCS plant at the scale proposed at the MASDP will produce additional criteria pollutants, air toxics, and water pollution due to the additional energy required to capture and transport CO2 as well as materials used to run and service associated equipment. This could result in 15-25% higher energy requirements of all the plants at the MASDP.[117] Pipeline compressors will also likely produce emissions but due to the unknown location of this equipment, these emissions have not been taken into account for the purposes of this study.

9 Discussion of Emissions Results

Based on the studied scenario, the MASDP, which would contain mainly traditional industrial operations, has the potential to substantially increase industrial emissions in the region. This analysis does not include emissions related to the generation of green hydrogen or green ammonia, which I assume will be generated using solar power. Without viable carbon capture and storage, this project, if built as simulated here, will be the single largest contributor to greenhouse gases in the NT. Additional study is needed to further understand the local, state, and global risks associated with a development of this

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[111] Act Government. (October 10, 2021). Considering the 'social cost of carbon'. Available here https://www.cmtedd.act.gov.au/open_government/inform/act_government_media_releases/rattenbury/2021/considering-the-social-cost-of-carbon#:~:text=%E2%80%9CAs%20part%20of%20the%202021,its%20operational%20emissions%20each%20year.

[112] Global CCS Institute. (November, 2020). Carbon Capture and Storage Hub Study Prepared for The Government of The Northern Territory Of Australia. Figure 29, p. 79. Available here https://cmc.nt.gov.au/__data/assets/pdf_file/0006/1052898/q20-0114-gccsi-nt-css-hub-study-final-report.pdf

[113] US EPA. (2022). Class VI Wells Permitted by EPA. Available here https://www.epa.gov/uic/class-vi-wells-permitted-epa

[114] Government of Western Australia. Gorgon carbon dioxide injection project. Available here https://www.dmp.wa.gov.au/Petroleum/Gorgon-CO2-injection-project-1600.aspx.

[115] Trupp, M., Ryan, S., Barranco Mendoza, I., Leon, D., & Scoby-Smith, L. (2021). Developing the world's largest CO2 Injection System–a history of the Gorgon Carbon Dioxide Injection System. Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3815492.

[116] Lewis. J. (February 10, 2022). Chevron's flagship Gorgon CCS project still failing to live up to expectations. Upstream Energy Explored. Available here https://www.upstreamonline.com/energy-transition/chevrons-flagship-gorgon-ccs-project-still-failing-to-live-up-to-expectations/2-1-1166185.

[117] van Harmelen, T., van Horssen, A., Jozwicka, M., Pulles, T., Odeh, N., & Adams, M. (2011). Air pollution impacts from carbon capture and storage (CCS). https://www.eea.europa.eu/publications/carbon-capture-and-storage.

scale. Specifically, expanded local emissions monitoring needs to be combined with sophisticated atmospheric modeling and detailed facility emissions point details to prepare a risk assessment. This screening highlights some of the potential risks of the MASDP that have no reference in the draft TOR and may not be accounted for in the SEA. One of these concerns is cancer-causing air toxics. Methods for performing air pollution risk assessment should be adapted from US EPA's National Air Toxics Assessment for air toxics[118] and the EPAs guidance on performing air quality impact assessments for national ambient air quality standards for fine particulate matter.[119]

The potential release of large amounts of air toxics, specifically formaldehyde, acetaldehyde, and polycyclic aromatic hydrocarbons (PAHs) may present cancer risks to nearby populations. Formaldehyde exposure can lead to nasal and eye irritation, neurological effects, and increased risk of asthma and/or allergy at concentrations between .1 or .5 ppm. Long term exposure to the substance increases the risk of nose and throat cancers.[120] The link between acetaldehyde exposure and cancer is less certain, but epidemiological studies have observed elevated nasal cancers in rodents from prolonged exposure to the substance.[121]

The cancer hazards described here are potentially compounded by several factors, including the presence of nearby populations, some with chronic health conditions, the possibility of cyclones and rising sea levels damaging the facilities. This project presents a significant risk to public health. Positive associations have been reported between ambient polycyclic aromatic hydrocarbons and breast cancer, childhood cancers and lung cancers. A world health organization study recommends that the lowest possible exposure to PAHs/PACs should be aimed at to minimize the risk of cancer development.[122] Further modeling of emissions from potential development scenarios will help determine potential risk to the surrounding areas from MASDP development scenarios.

Additionally, this analysis only includes quantifiable emissions based on reports made by comparable facilities. Additional likely air and water emissions that were not available in reports from these facilities are therefore not assigned emission values in this analysis, including some persistent and bioaccumulating pollutants beyond PAHs/PACs. These include the dioxins (Octachlorodibenzodioxin in

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[118] US EPA. (2022). National Air Toxics Assessment. Available here https://www.epa.gov/national-air-toxics-assessment

[119] US EPA. (2014). Guidance for PM2.s Permit Modeling. Available here https://www.epa.gov/sites/default/files/2015-07/documents/pm25guid2.pdf

[120] Agency for Toxic Substance and Disease Registry. (2022). Formaldehyde and Your Health. Available here https://www.atsdr.cdc.gov/formaldehyde/#:~:text=Exposure%20to%20very%20high%20levels,the%20exposures%20linked%20to%20cancer

[121] US EPA. (2020). Acetaldehyde Hazard Summary. Available here https://www.epa.gov/sites/default/files/2016-09/documents/acetaldehyde.pdf

[122] Sun, K., Song, Y., He, F., Jing, M., Tang, J., & Liu, R. (2021). A review of human and animals exposure to polycyclic aromatic hydrocarbons: Health risk and adverse effects, photo-induced toxicity and regulating effect of microplastics. *Science of The Total Environment,* 773, 145403. Available here https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2021/human-health-effects-of-polycyclic-aromatic-hydrocarbons-as-ambient-air-pollutants-report-of-the-working-group-on-polycyclic-aromatic-hydrocarbons-of-the-joint-task-force-on-the-health-aspects-of-air-pollution-2021

particular) that would result from flaring and the reforming related production processes in the gas-to-liquids facility.[123]

Table 1 of the Referral Report, "Summary table of NT EPA environmental factors and potentially significantly impacted *(sic)* by the strategic proposal" states that it is "Uncertain" whether the MASDP will have a "Potential significant impact" on "Human health".[124] This contrasts to the "Yes" rating applied to all other relevant NT EPA Environmental Factors in the same table, including air quality.[125] The notion promoted here that the emissions of the facility that are indeed having a significant effect on air quality would not reach at minimum Palmerston, a mere 3 km away, is misleading. Though a high-quality dispersion model with excellent data will be needed to assess the full extent of these impacts, the present analysis belies the suggestion in this table that the MASDP could avoid having significant health impacts on nearby communities via its regular toxic emissions and the possibility for accidental spills and releases of toxic material.

10 Evaluation of the MASDP Draft Terms of Reference for Strategic Assessment

Information gaps prevent meaningful public involvement for this development. In order for the public to be able to assess the draft TOR and provide input to the SEA, more details are required about the size and operations of the facilities being proposed. It is my understanding that studies have been commissioned, but no information from them has been made publicly available.[126]

10.1 Assessed Sections of the Terms of Reference

10.1.1 3.5.8 Air Quality

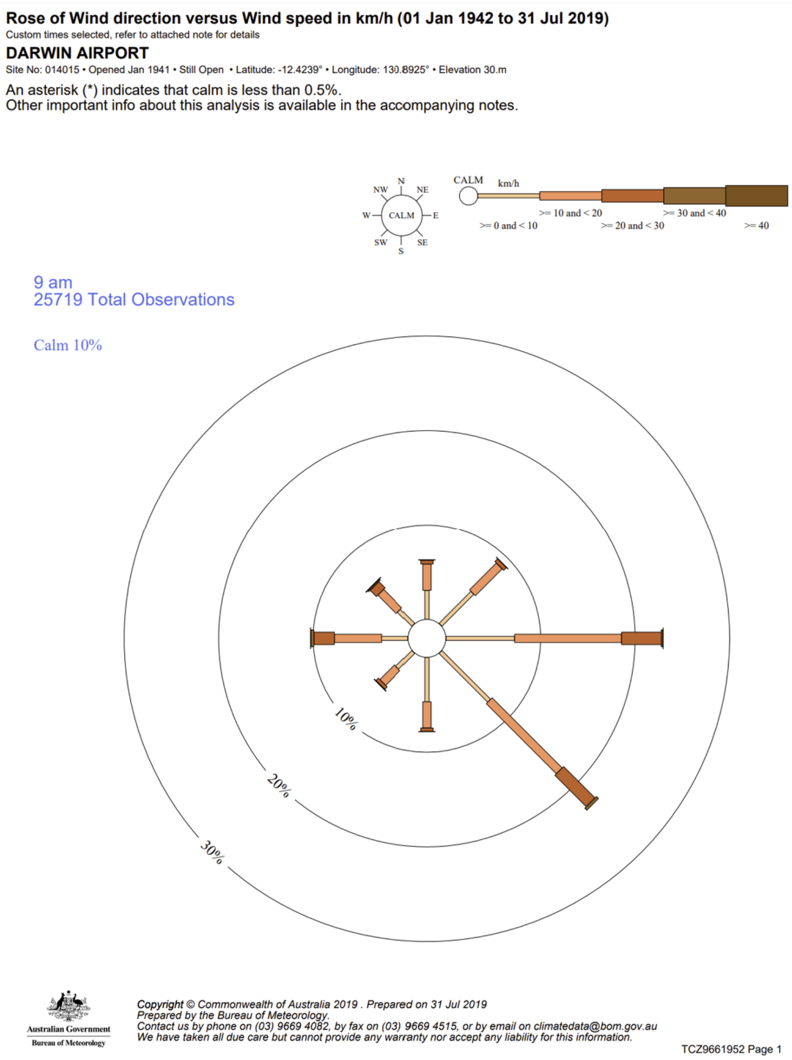
- The exact definition of the Strategic Assessment Area (SAA) must be clarified and a justification for creating boundaries presented within the Terms of Reference must be provided. Fine particulate matter emissions from the development can have far-reaching impacts and "can remain airborne for long periods and travel hundreds of miles".[127] Without an exact definition of the SAA, the strategic assessment will violate the decision-making principle by not providing detailed information for community involvement. It also violates the principle of evidence-based decision-making by allowing the proponent to limit the SAA without justification and not base this critical scoping decision on the best available science.
- The proponent must define the specific information required to develop an airshed model. These include

[123] Canada Gas-to-Liquids Project. (May 2013). Volume 2 Environmental Impact Assessment. Table 13-1, pdf p. 575. Available here https://open.alberta.ca/dataset/f31e6946-ac74-44cf-90e9-2fec83808ab7/resource/ac81aa0f-9047-4e82-a43a-5e8fb075a547/download/sasol-gtl-project-volume-2-environmental-impact-assessment.pdf.
[124] Middle Arm Sustainable Development Precinct Referral Report (January 2022). p. xii. https://ntepa.nt.gov.au/__data/assets/pdf_file/0009/1092465/masdp-referral-report.pdf .
[125] *Ibid.*
[126] Northern Territory Government. (2020). Darwin - Consultancy - Middle Arm Industry Development- Provision of Environmental Studies for a Period of 12 Months. Available here https://tendersonline.nt.gov.au/Tender/AwardedDetails/17965.
[127] US Environmental Protection Agency. (2018). Particulate Matter Emissions. Available here https://cfpub.epa.gov/roe/indicator_pdf.cfm?i=19.

    - What sources are being considered?
    - What airborne contaminants are being evaluated?
    - How will the airshed model treat gaps in available data using the precautionary principle?
- The TOR must address the specific information requirements for a cumulative impact assessment. Questions to be answered include:
    - Will the assessment include the vulnerability of populations?
    - Will it perform a toxicity weighted screening on potential emissions?
    - How will emissions with different biophysical damage endpoints be combined in the assessment?
- The development of the airshed model and airshed survey are reliant on the methods of the proposed cumulative assessment. These details are critical for public involvement, and accurate evaluation of the assessment. This process cannot be allowed to move forward without community input. The fact that a survey has been designed and disseminated[128] without the chance for public comment is indication that the decision-making principle of ecologically sustainable development has already been violated for this project.
- Methods should be considered for estimating air pollution deposition rates and exposures.
- Figure 40 displays a wind rose representing the data taken from the Darwin airport from 1942-2016. SEA procedures should specify how they will utilize more than one year of historic meteorological data and how they will account for differences between the Darwin Airport and Middle Arm locations.

[128] NT Government. (May 11, 2022). Ensuring Environmental Sustainability for Middle Arm Sustainable Development Precinct. Available at https://www.miragenews.com/ensuring-environmental-sustainability-for-779415/.

Figure 40. Historical wind direction and speed recording at the Darwin Airport.[129]



10.1.2 3.5.9 Atmospheric Processes

- Greenhouse Gas (GHG) emissions from all shipping related to the project should be included in the specific information requirements. Ship emissions can be quite significant and harmful at port industrial facilities of this type.
- The proponent must, in the SEA, include proof that any and all proposed GHG mitigation, capture, storage, or reuse technology, as well as all other forms of pollution mitigation technology, is viable and guarantee its use at the proposed scale for the entire life of the facility.

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[129] Australian Government Bureau of Meteorology. (2022). Win Speed and Direction Rose, Darwin Airport. Available here http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/windrose_selector.cgi?period=Annual&type=9&location=14015

10.1.3 3.5.10 Community and Economy

- The potential impacts and opportunities section of the TOR should include specific language on the negative economic impacts related to health damages from emissions, not just point to ab "alteration of amenities."[130] This current phrasing allows the proponent to understate the economic health consequences of the development.
- Impacts of light pollution and light trespass, light emitted by a luminaire that shines beyond the boundaries of the property on which the luminaire is located, should be added to the "alteration of amenities" section as operations may have significant effects on skyglow and nighttime views from Charles Darwin National Park. See Section 5 of the Sasol GTL Alberta Environmental Assessment for more guidance on these requirements.[131]

Figure 41. Example of a large industrial light source.[132]

10.1.4 3.5.11 Health Impact Assessment (HIA)

- It must be reiterated that the SAA needs to be specified beyond what is included in the TOR as the "Strategic Assessment Area," namely "The geographic area covered by the strategic environmental assessment that has the potential to be directly and indirectly impacted by the proposal, which includes the Middle Arm Peninsula, Darwin Harbour and surrounding areas".[133] This is a grossly vague definition for a project of this magnitude. Relevant areas must be defined and justified using evidence before the SEA can commence. The guiding principles of an HIA demands this as the health risks the facility poses are involuntary. To commence a strategic assessment without defining the people who may be impacted threatens the democratic integrity, transparency, and rigor of the strategic assessment process.
- This section must include an assessment of psychological health risk, requiring a survey of residents in the SAA to communicate to them potential worst case accident scenarios and the probabilities of these occurring, as well as to develop an understanding of the psychological impacts these risks will have on the community and ways to mitigate these risks.
- The draft TOR is leaving out necessary HIA requirements for the strategic assessment that should be included in the minimum information requirements, including assessment of
    - How health inequities will be affected by the development

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[130] Terms of Reference, p. 33.

[131] Canada Gas-to-Liquids Project. (May 2013). Volume 2 Environmental Impact Assessment. Section 5, pdf p. 229. Available here https://open.alberta.ca/dataset/f31e6946-ac74-44cf-90e9-2fec83808ab7/resource/ac81aa0f-9047-4e82-a43a-5e8fb075a547/download/sasol-gtl-project-volume-2-environmental-impact-assessment.pdf.

[132] Canada Gas-to-Liquids Project. (May 2013). Volume 2 Environmental Impact Assessment. Section 5, pdf p. 236. Available here https://open.alberta.ca/dataset/f31e6946-ac74-44cf-90e9-2fec83808ab7/resource/ac81aa0f-9047-4e82-a43a-5e8fb075a547/download/sasol-gtl-project-volume-2-environmental-impact-assessment.pdf.

[133] Terms of Reference, p. 1 footnote.

- How current populations with pre-existing conditions (e.g., asthma, heart disease, high blood pressure) might be affected and how they will be identified and accounted for in the strategic assessment
- The potential of the project to affect population migration (e.g., movement to areas closer or further from the development) and the ensuring effects on infrastructure and health risks.
- Injuries to workers, contractors, and first responders from acute hazards
- The influence of climate change on all of the human health risks presented by this coastal facility
- Socio-economic impacts which may have an impact on health
- How health impacts will be monitored over time, what parameters will be monitored, what protocols will be used, how will funding be ensured for continued monitoring, how will results be interpreted, evaluated, and incorporated in adaptive risk management.
- How adaptive capacity to new health risks will be assessed and If community health monitoring may be required to mitigate the potential impacts
- How project risks, and the uncertainty in evaluating them, will be communicated effectively to the general public. Health consequence scales should be required (see HIA Guidelines p. 35-6).[134]

11 Resources

For the sake of transparency, I have produced a password protected resource folder which contains the datasets, some downloaded studies, additional materials I have reviewed, as well as the procedures developed to perform and communicate the analysis.

Original charts and maps produced for this analysis were created in the R within RStudio[135] using the following packages.

- tidyverse[136]
- ggmap[137]
- sf[138]

The folder is available upon request. Please send inquiries to mdpeton@syr.edu or call 1-860-716-2768.

[134] Australia Department of Health. (2017). Health Impact Assessment Guidelines. Available at https://www1.health.gov.au/internet/main/publishing.nsf/content/A12B57E41EC9F326CA257BF0001F9E7D/$File/Health-Impact-Assessment-Guidelines.pdf

[135] RStudio Team (2021). RStudio: Integrated Development Environment for R. RStudio, PBC Boston, MA URL http://www.rstudio.com/

[136] Wickham et al., (2019). Welcome to the tidyverse. Journal of Open Source Software, 4(43), 1686, available at https://doi.org/10.21105/joss.01686

[137] D. Kahle and H. Wickham. ggmap: Spatial Visualization with ggplot2. The R Journal, 5(1), 144-161. Available here http://journal.r-project.org/archive/2013-1/kahle-wickham.pdf

[138] Pebesma, E., 2018. Simple Features for R: Standardized Support for Spatial Vector Data. The R Journal 10 (1), 439-446, available here https://doi.org/10.32614/RJ-2018-009

13 Curriculum Vitae

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EDUCATION

BA, St. Lawrence University - 2012
MPA, Syracuse University - 2016
MS, State University of New York College of Environmental Science and Forestry (Environmental Science)
PhD, State University of New York College of Environmental Science and Forestry (Environmental and Natural Resources Policy)

PEER REVIEWED PUBLICATIONS

Petroni, M., Howard, S., Howell, I.B., Collins, M.B. (2021). NYenviroScreen: An Open-Source Data Driven Method for Identifying Potential Environmental Justice Communities in New York State. *Environmental Science and Policy*. https://doi.org/10.1016/j.envsci.2021.07.004

Hill, D.T., Petroni, M., Collins, M.B. (2021). United States Federal Contracting and Pollution Prevention: How Award Type and Facility Characteristics Affects Adoption of Source Reduction Techniques in Four Manufacturing Sectors. *Environmental Research: Infrastructure and Sustainability, 1*(2), 025006. https://doi.org/10.1088/2634-4505/ac1161

Hill, D., Petroni, M., Larsen, D.A., Bendinskas, K., Heffernan, K., Atallah-Yunes, N., Parsons, P.J., Palmer, C.D., MacKenzie, J.A., Collins, M.B., & Gump, B.B. (2021). Linking metal (Pb, Hg, Cd) industrial air pollution risk to blood metal levels and cardiovascular functioning and structure among children in Syracuse, NY. *Environmental Research.* 193. 110557. https://doi.org/10.1016/j.envres.2020.110557

Petroni, M., Hill, D., Younes, L., Barkman, L., Howard, S., Howell, I.B., Mirowsky, J., & Collins, M.B. (2020). Hazardous air pollutant exposure as a contributing factor to COVID-19 mortality in the United States. *Environmental Research Letters*. *15*(9), 0940a9. https://doi.org/10.1088/1748-9326/abaf86

Petroni, M. Brown, T. Collins, M. Teron, L. (2022). Population Health and Energy Justice Based Prioritization of Fossil Fuel Power Plant Displacement in the Low Carbon Energy Transition. Applied Energy (under review)

OTHER PUBLICATIONS AND REPORTS

Petroni, M. (2020, October 30) Studies link COVID-19 deaths to air pollution, raising questions about EPA's 'acceptable risk'. *The Conversation*. Available at https://theconversation.com/studies-link-covid-19-deaths-to-air-pollution-raising-questions-about-epas-acceptable-risk-148081

Younes L., Shaw, A. Petroni, M. (2019, October 30). How We Found Chemical Plants Are Being Built in South Louisiana's Most Polluted Areas. *ProPublica*. Available at https://www.propublica.org/article/how-we-found-new-chemical-plants-are-being-built-in-south-louisianas-most-polluted-areas

Hamlin, M., Huang, Y., Kelley, J., Kurtz, M., Petroni, M., Wilcoxen, P. (2016). LED Street Lighting Assessment for the City of Syracuse. Delivered to the City of Syracuse June 2016.

AWARDS

Fellowship. Center for Environmental Medicine and Informatics. SUNY Discovery Challenge 2019-2021.
Society of Environmental Journalists Nina Mason Pulliam Award for Outstanding Environmental Reporting for "Polluter's Paradise". Awarded 2020.
Microsoft Azure AI for Earth competition. Awarded July 2018 to SUNY-ESF.
U.S. Environmental Protection Agency 2017 TRI University Challenge. Awarded to SUNY-ESF.
Joan Donovan Speech Competition. Awarded 2012.
St. Lawrence University B.A. Cum Laude.

RELEVANT SPEAKING ENGAGEMENTS

Petroni, M. (October 20, 2021). Using TRI's Risk Screening and Environmental Indicators Model to Communicate the Relative Risk of Proposed Petrochemical Development. Toxics Release Inventory Data Users Presentation.

Petroni, M. (November 15, 2021). Population Health and Environmental Justice Based Prioritization of Electric Generating Unit Displacement in the Carbon Neutral Energy Transition. Invited Speaker at the 2021 Eastern Analytical Symposium. Environmental Challenges in 2021.

Petroni, M. (July 28, 2021). How Cumulative Risk & Environmental Justice Screening Tools Enable Informed Decision Making in Environmental Health. Dissertation Capstone Presentation.

Collins, M. B., Petroni, M., and Hill, D. (Nov. 17, 2020). Invited Panelists, Johns Hopkins University GIS Week: GIS and Spatial Analysis in Environmental Health.

Terrell, K., Petroni., M., Howard, S. (June 27, 28, 2020). Communicating Environmental Health Science: A Workshop on Accessing and Utilizing Pollution Risk Data for Spatial Health Research. University Network for Human Rights.

Petroni, M. (June 13, 2019). Uncovering Green Chemistry Pollution Prevention Success Stories Using the Toxics Release Inventory. America Chemical Society Green Chemistry Institute 23rd Annual

Green Chemistry & Engineering Conference and 9th International Conference on Green and Sustainable Chemistry. Session on Sustainability Success Stories in Industrial Chemical Processing.

Petroni, M. (November 8, 2018) TRI-CoLAB a Pollutant Release and Transfer Registry [PRTR] tool for identifying potential impacts and pollution prevention opportunities using risk screening score and facility commonality matching. Third Global Round Table on PRTRs. Geneva, Switzerland.

Petroni, M. & Hill, D. TRI-CoLAB a Multistakeholder Information Tool for Identifying Pollution Prevention Opportunities. (September 13, 2018). US EPA Headquarters, Washington, D.C. USA

Petroni, M., Hill, D. & Collins, M.B. (April 2018). 595 Chemicals Upstream. Poster presenter at SUNY-ESF Spotlight on Student Research. Syracuse, NY.

Professional and Expert Services

Reviewer, *Environmental Research Letters*
Reviewer, *Environmental Research Communications*
Reviewer, ProPublica's *Sacrifice Zone* series
Expert, Cooper Crouse Hinds v City of Syracuse
Expert Reviewer, Louisiana Air Monitoring Program