A Meaningfully Just Transition for Mossmorran

The Case for a Site-Specific Just Transition Process

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Summary

The Mossmorran natural gas liquids processing plants face an uncertain future, with significant vulnerabilities due to the climate and environmental emergency. External factors contributing to these vulnerabilities include (i) a decrease in the availability of raw material inputs as a result of ambitions to limit oil and gas extraction in line with the Paris Agreement, and (ii) a decrease in demand for ethylene (Mossmorran's main output) due to international efforts to curb plastic waste.

If countries limit their extraction of oil and gas in line with the IPCC's 50:50 chance of a Paris-compliant 1.5-degree warming scenario, the availability of Mossmorran's main input (natural gas liquids) will decline by between 25% - 74% by 2030.

The Mossmorran sites are responsible for nearly 10% of large industrial site emissions in Scotland and are hard to decarbonise. Any plan for industrial decarbonisation in Scotland must tackle emissions at Mossmorran. All decarbonisation options carry risks and trade-offs. This includes relying on CCS technology, which faces constraints around costs, geological uncertainties, and competition for limited storage infrastructure.

Historic examples of successful transitions show that strong sectoral negotiations between unions, industry, and government, informed by site-specific worker discussions, are crucial.

The two Mossmorran plants directly employ approximately 250 workers, and periodically many more through short-term maintenance contracts. Pay, benefits, health and safety, and other conditions for staff on site are protected by robust agreements. Existing experiences with renewable energy jobs (or lack thereof) make many unionised workers sceptical of the prospects of decarbonisation and whether a just transition will be delivered.

Far stronger worker representation in decision-making, alongside adequate financing for industrial retooling, is necessary to support a just transition at Mossmorran.

Possible future pathways to a decarbonised Mossmorran

Decarbonising Mossmorran could take a range of pathways, addressing both the feedstock and the fuel source challenges. Continued ethylene production is possible with two options for feedstock: natural gas liquids (as current) or biological feedstock. There are four primary options for fuel sources: methane (as current), blue hydrogen, green hydrogen, or electrified processes.

Our analysis examined these options to identify 5 alternative core pathways to decarbonisation[1]:

1. Natural gas liquids as feedstock, methane as fuel. Full reliance on CCS (at St Fergus, at NGL plant and at ethylene plant).
2. Natural gas liquids as feedstock, blue hydrogen as fuel. CCS required at St Fergus and at blue hydrogen production site.
3. Natural gas liquids as feedstock, green hydrogen as fuel. CCS required at St Fergus.
4. Bio-ethanol use as feedstock, electrified process as fuel. No CCS.
5. Alternative industrial uses, i.e. diversification or conversion to a different zero carbon production process.

All decarbonisation options have risks and trade-offs, and should be explored in more detail, backed by workforce engagement and sufficient investment.

Next steps for the Scottish Government to take

Planning for change at Mossmorran

1. Make a clear commitment that the Mossmorran plants will need to decarbonise in line with a 1.5 degree future, and that livelihoods and job quality will be protected with nobody left behind.
2. Urgently engage with trade unions, Shell, and ExxonMobil to understand in detail the needs of workers at both plants at Mossmorran, and commit to ensuring that collective agreements are adhered to for all employees, contractors and subcontractors.
3. Partner with trade unions to facilitate worker-led planning to develop options for production changes on site, with the potential to link up such planning across the Scottish Cluster.
4. In line with worker-led planning and community engagement, identify funding to investigate the full range of technology pathways to 100% full lifecycle decarbonisation - covering feedstock, processes and outputs, including options without CCS dependence.
5. An independent recognised national group, such as the Just Transition Commission, should facilitate negotiations between Unite, GMB, Fife Council, local civil society, Shell, ExxonMobil, and the Scottish Government to create a decision-making process for Mossmorran's future that balances power and rights amongst the different actors as much as possible.

[1] Note that there are other possible combinations of feedstock and fuel. E.g., It is possible to also use bio-ethanol as a feedstock, and green hydrogen as the fuel, or natural gas liquids as the feedstock, with an electrified process as the fuel. However, the pathways illustrated here were used as core pathways to explore the potential and the challenges.

Investing into a Just Transition for Mossmorran

1. Pro-active public investment should drive decarbonisation of high carbon industrial sectors including Mossmorran, where this is technologically feasible within the urgent timelines - as laid out by the UK government's Green Jobs Taskforce.[2] To achieve that, the Scottish Government should expand its Scottish Industrial Energy Transformation Fund (SIETF) from £34 million until 2026 to at least £250 million,[3] and involve trade unions within the process.
    a. The expanded SIETF should include a specific funding sub-stream supporting high carbon industries to become early adopters and developers of zero carbon processes and technologies to develop a global competitive edge.
    b. Trade unions should be given a formal role within the process.
2. All government support to existing high carbon emitters, including those at Mossmorran, should require formal industry commitment to retrain existing workers and redeploy them. Support should also include an obligation to negotiate with unions over just transition agreements to ensure job quality and numbers are protected through the transition.
3. The Fife communities around Mossmorran need a Community Just Transition Fund to support economic diversification and develop alternative industries - to prepare for the last-resort scenario where all Mossmorran operations wind down with no industrial conversion or replacement. Such place-based financial support should be accountable to regional or local transition bodies. This should learn from the experiences of the EU's Just Transition Fund.
4. Identify opportunities for further UK Government and Scottish Government funding to factor in oil and gas infrastructure and employment across Scotland, including Mossmorran and Grangemouth, beyond the existing £500 million Just Transition Fund for North East and Moray.

Making national processes that affect the Mossmorran transition just

1. The Scottish Government should coordinate with unions to ensure that Fair Work policy can be better implemented to support sectoral industrial agreements.
2. Make government support for transition boards like the Grangemouth Future Industries board conditional on relevant union representation amongst board members.
3. Use levers such as offshore wind licensing rounds and procurement of waste management facilities to improve the quality of work in green industries in general, e.g. by requiring operating

[2] UK Government, Green Jobs Taskforce, https://www.gov.uk/government/publications/green-jobs-taskforce-report
[3] Estimate on public investment into refineries decarbonisation by Transition Economics for the STUC (https://stuc.org.uk/files/Policy/STUC_Green_Jobs.pdf), applied proportion

firms' adherence to sectoral collective agreements, and Fair Work as a minimum where these are not applicable.

4. Work with the Just Transition Commission to clarify how the climate transition will balance power and rights amongst those impacted, and the role of local-level transition processes at sites like Mossmorran.

Recommendations to Employers (ExxonMobil and Shell)

1. Deliver greater transparency over existing employment numbers and conditions
2. A Just Transition Agreement negotiated with the trade unions that protects job quality and skills, as recommended by the UK government's Green Jobs Taskforce.
3. Commit to respecting existing collective agreements going forward, and ensuring that all contractors and subcontractors do.
4. Committing to a full life-cycle decarbonisation of the Mossmorran plants, on a timeline that is 1.5 degree compliant.
5. Transparency over future pathways and business decisions regarding decarbonisation, including the option where North Sea oil and gas extraction declines on a managed pathway that is 1.5 degree compliant
6. Commitment to exploring a range of options for Mossmorran's zero carbon future (not relying solely on CCS) and consultation with worker representatives on these.
7. Take responsibility for all workers at the plant - both directly employed and contractors - as EDF did at Cottam coal power station[4].

[4] More information available here: https://www.unionlearn.org.uk/case-studies/prospect-helps-energy-workers-transfer-skills

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Introduction

The Mossmorran NGL plants

The petrochemical plants at Mossmorran - Shell's Natural Gas Liquids plant and ExxonMobil's Ethylene plant - are located near the former mining village of Cowdenbeath. The plants have operated since the 1980s and have formed a valuable source of jobs in an area ravaged by the closure of coal mines.

Local controversy around the plants has increasingly focused on the flaring of gas on site.[5] This has led to regulatory action and commitments to investment to reduce flaring[6]. Calls to close the plant have been followed with calls for a Just Transition board, in keeping with other national initiatives. At the time, the Scottish Government did not agree to set up a Just Transition Board for the site, citing ongoing consideration of legal proceedings against ExxonMobil[7].

Research questions

1. How will the Mossmorran site be affected by pressures on feedstock and outputs in line with environmental and climate concerns?
2. How do direct emissions need to be reduced to be in line with net zero commitments?
3. What needs to be put in place to ensure a just transition for the Mossmorran workforce?

Methodology and limitations

This report uses publicly available information (government published data, reports by international bodies, academic studies) to assess the likely future pressures on production at Mossmorran, as well as emissions onsite and decarbonisation pathway options. Job numbers, quality, and issues facing workers onsite were evaluated using publicly available information, supplemented and guided by three interviews with key union and worker actors, with a focus on engineering construction contractors.

This report begins to consider possible decarbonisation pathways for Mossmorran, as well as their implications for jobs onside, but the scope of the project has important limitations. Within this research

[5] More information available: https://www.thecourier.co.uk/fp/business-environment/environment/2683911/gas-flaring-mossmorran-fife/
[6] For example: https://media.sepa.org.uk/media-releases/2021/clear-pathway-to-compliance-for-mossmorran-as-watchdog-strengthens-regulation-monitoring-of-fife-sites.aspx
[7] More information available: https://www.parliament.scot/chamber-and-committees/official-report/what-was-said-in-parliament/meeting-of-parliament-29-09-2020?meeting=12853&iob=116207

it has not been possible to consult representatives of the directly employed workforce at Mossmorran (which is much smaller than the outsourced contractor workforce).

Due to resource constraints, this report cannot cover the impacts of the war in Ukraine, the gas price crisis, and the resulting debate on oil and gas reliance on future availability of natural gas liquids, are beyond the scope of this report, but merits further investigation.

The report also does *not* begin to consider potential options for diversification or alternative industrial uses for the Mossmorran site. Considering these should be an essential part of the process for working out a Just Transition plan for Mossmorran.

Structure of this report

Section 1 looks at how environmental commitments could reduce the supply of the site's primary input (natural gas liquids) or reduce demand for its key output (ethylene). Section 2 considers direct greenhouse gas emissions from the Mossmorran site and how these can be phased out. And Section 3 considers the numbers and quality of jobs onsite, as well as workers' broader concerns in the context of the necessary changes.

1. Pressures on Mossmorran's inputs and outputs

Key findings

- **The outlook for demand for Mossmorran's main output, ethylene, is uncertain, due to international efforts to curb plastic waste.** Ethylene is predominantly used to make polyethylene, a substantial proportion of which is used for packaging. The market for ethylene is expected to grow rapidly up to 2030, but the growth of policies limiting single-use plastics will chip away at demand.
- **If countries limit their extraction of oil and gas in line with the IPCC's 50:50 chance of a Paris-compliant 1.5-degree warming scenario, the availability of Mossmorran's main input (natural gas liquids) will decline by between 25% - 74% by 2030.**

Background: what is produced at Mossmorran

The site at Mossmorran comprises the Shell Natural Gas Liquids (NGL) processing plant and Exxon's Fife Ethylene Plant. Its primary function is to receive natural gas liquids, a byproduct of producing the largely methane mixture that goes into the National Transmission Service and powers UK homes and businesses. The Shell NGL plant processes this into various light hydrocarbon fuels and crucially, ethane. This is then passed to the ExxonMobil plant, which converts the ethane to ethylene using a process of high-temperature steam cracking and purifies the output using fractionation. The ethylene is liquified and exported to chemical manufacturers, where it is used in a large variety of petrochemical processes, predominantly to manufacture the widely used plastic polyethylene.

The future of ethylene demand

Ethylene is a valuable precursor to other petrochemicals and a key building block for plastics, including PVA and PVC, synthetic rubbers, high impact polystyrene, PEO, Low Density Polyethylene and High-Density Polyethylene[8]. These plastics are used throughout all sectors, from construction to manufacturing to food and agriculture[9]. Due to its importance, ethylene production accounted for 40% of petrochemical revenues in 2020, with a global market valued by different analysts as $101 billion[10] in

[8] https://www.climaterealityproject.org/blog/ethane-cracker-plants-what-are-they
[9] https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-1.2.2
[10] https://www.polarismarketresearch.com/industry-analysis/ethylene-market

2020 and $134.2 billion in 2021[11]. The biggest end use for ethylene is polyethylene, accounting for 54% of end use share[12].

Multiple forecasts give high levels of growth in the sector, with illustrative global compound annual growth rates of 3.4% from 2021 to 2028 for plastics[13], 6.4% in terms of revenue from 2021 to 2028 for petrochemicals[14] and of 6% between 2022 and 2030 for ethylene production specifically[15]. These analysts identified increased demand from construction and the move towards using plastics to build lighter, more fuel-efficient cars, particularly in middle income countries. This echoes the picture painted by the industry of plastic use in 'automotive, high-tech and high-spec industries'[16], where plastics are crucial for reaching sustainability goals, especially for renewable energy[17].

However, the majority of forecast growth in plastics and ethylene revenues derives from their use in consumer packaging. Packaging accounted for over a third of all plastics revenue in 2020[18] and was found to be 'largest industry in terms of revenue generation' in forecasts of ethylene markets[19].

This large share of the market means that demand for ethylene is exposed to action on plastic packaging needed to deal with consumer waste. Alarm at the large quantities of microplastics in our oceans, ecosystems and human bodies has broadened out to include all plastic, with multiple regions and countries introducing bans on consumables such as plastic straws and bags. The UK government recently introduced a new, albeit limited, tax on plastic packaging that contains less than 30% recycled materials. The European Commission has established a Circular Economy Action Plan, with restricting single-use items and countering obsolescence of products as one of its aims.[20] The Scottish Government intends to legislate for a circular economy in Scotland, including proposals to introduce charging for single-use plastic items, and to use public sector procurement frameworks to maximise reuse and recycling of materials.[21]

[11] Market Research Future (Feb 2021). Ethylene Market Research Report. https://www.marketresearchfuture.com/reports/ethylene-market-931
[12] Polaris Market Research (Nov 2021). Ethylene Market Share, Size, Trends, Industry Analysis Report https://www.polarismarketresearch.com/industry-analysis/ethylene-market
[13] https://www.grandviewresearch.com/industry-analysis/petrochemical-market
[14] https://www.grandviewresearch.com/industry-analysis/petrochemical-market
[15] https://www.marketresearchfuture.com/reports/ethylene-market-931
[16] INEOS
[17] https://www.bpf.co.uk/sdgs/energy.aspx
[18] https://ihsmarkit.com/research-analysis/ethylene-market-outlook-considering-the-impact-of-covid19.html
[19] https://www.marketresearchfuture.com/reports/ethylene-market-931
[20] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN
[21] https://consult.gov.scot/environment-forestry/circular-economy-proposals-for-legislation/

ExxonMobil's annual report has acknowledged that environmental regulation on plastics represent a business risk to their petrochemical activities[22]. The economic impact of consumer concern on plastic packaging, alongside a move away from manufacturing, has led to a decoupling of demand for plastic from GDP in high income countries. High costs of shipping and fragmentation of global supply chains also mean that Asian markets have become oversupplied, with the potential that demand could continue to be largely satisfied locally[23].

Policy is increasingly taking a broader look at the intertwined nature of the fossil fuel industry and plastic waste. Environmental movements have long made the argument that unsustainable plastic use is driven by fossil fuel subsidies[24]. The subsidising and extraction of natural gas in larger volumes, however, is limited by 2050 net zero targets.

The future of natural gas liquids supply

Current operations at Mossmorran depend on the availability of large volumes of natural gas liquids. In the UK North Sea, natural gas liquids are extracted alongside fossil gas. As a result, the availability of gas liquids is tied to the availability of gas.

Limits on fossil fuel extraction

In order to stay within safe climate limits - i.e., the 'carbon budget' associated with a reasonable likelihood of meeting a 1.5 degree warming scenario - the world's, and the UK's, rates of oil and gas extraction must decline in coming decades. The need for a managed phaseout of fossil fuel burning and extraction is well established.[25] The UK Government has introduced a Climate Compatibility Checkpoint as part of its oil and gas licencing process, creating the possibility of a phase-out of licencing new fields, though the way this mechanism will be used in practice remains to be seen.[26]

If and when countries constrain their oil and gas output in line with their Paris Agreement commitments, the available volumes of gas will shrink, as will the availability of natural gas liquids. In this analysis, we assume that the availability of natural gas liquids (Mossmorran feedstock) is correlated to that of natural gas, and that the UK and other countries implement a managed decline at a similar pace.

[22] https://corporate.exxonmobil.com/-/media/Global/Files/investor-relations/annual-meeting-materials/annual-report-summaries/2020-Annual-Report.pdf
[23] https://www.icis.com/asian-chemical-connections/2022/02/ten-drivers-of-global-polyethylene-demand-in-2022/
[24] https://enb.iisd.org/articles/subsidies-under-radar-or-moving-spotlight
[25] https://www.iea.org/reports/net-zero-by-2050
[26] https://www.gov.uk/government/consultations/designing-a-climate-compatibility-checkpoint-for-future-oil-and-gas-licensing-in-the-uk-continental-shelf

Note that this analysis does not take into account commitments and policies made in relation to the gas price crisis and the war in Ukraine. It only queries what rates of extraction are considered compatible with keeping within safe climate limits.

Imported or domestic feedstock

Mossmorran has a commercial agreement to receive some imported feedstock - ethane imported by INEOS from the USA.[27] The UK also imports a significant proportion of its gas (as opposed to natural gas liquids) - up to half of what it uses in the winter months[28] - with 90% of the UK's gas imports coming from Norway, Qatar, the USA and the Netherlands.

In the three scenarios identified below for a 1.5 degree world, oil and gas extraction in these countries would need to phase down in line with the UK's North Sea extraction. Therefore, this analysis assumes that declining gas output affects the Mossmorran plants regardless of the origin of the gas.

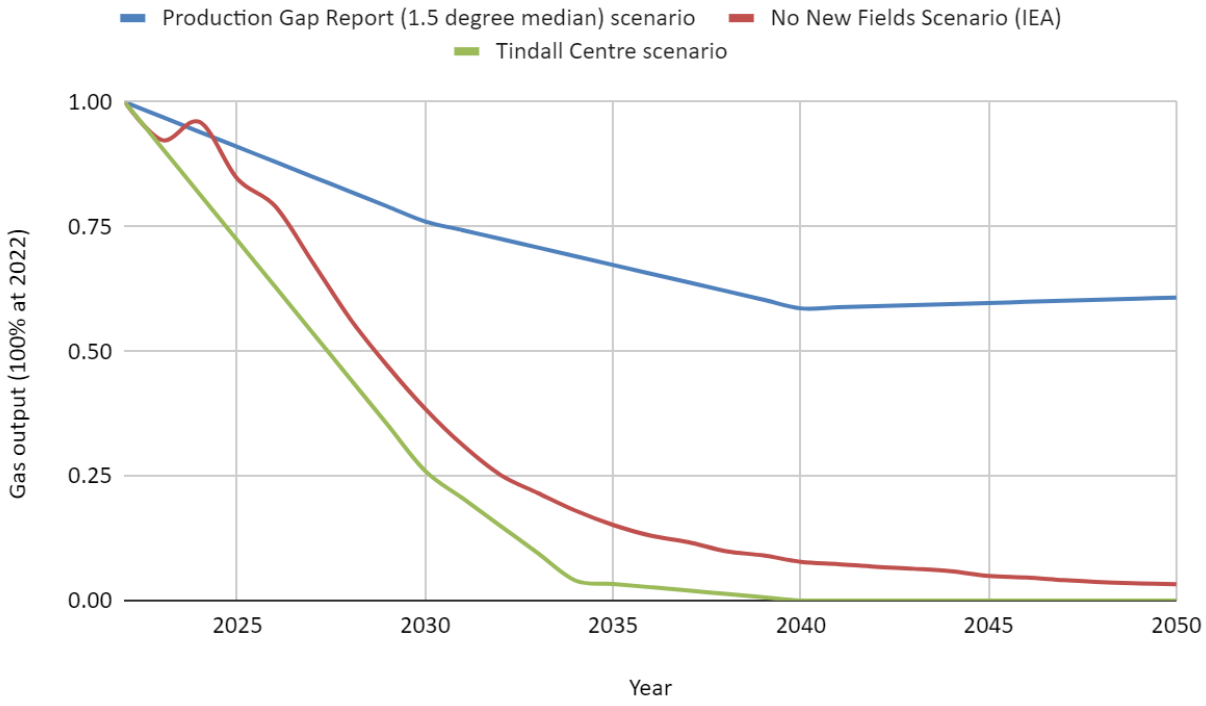
Scenarios

How will the availability of feedstock change, in line with a managed decline of gas output in a 1.5-degree warming world? The IPCC's headline carbon budget for a 50:50 chance of 1.5°C places very tight constraints on the production of oil and gas.

Graph 1 below demonstrates the range of scenarios for how the UK North Sea's rate of gas output might change, in line with meeting Paris Agreement commitments. As outlined above, we suggest that the availability of feedstock for Mossmorran will change similarly.

[27] https://www.ineos.com/news/ineos-group/ineos-signs-agreement-with-exxonmobil-chemical-limited-and-shell-chemicals-europe-bv/
[28] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1086781/Energy_Trends_June_2022.pdf

Graph 1. Changing availability of Natural Gas Liquids under Paris Agreement compliant scenarios



Scenario descriptions follow.

1. **International Energy Agency: no new oil and gas fields**

In May 2021, the IEA published its "Net Zero by 2050" roadmap, concluding that opening any new oil and gas fields was inconsistent with decarbonisation targets: "Beyond projects already committed as of 2021, there are no new oil and gas fields approved for development in our pathway".[29] The report assumed that "the net zero pathway results in a sharp decline in fossil fuel demand, meaning that the focus for oil and gas producers switches entirely to output – and emissions reductions – from the operation of existing assets."[30]

As modelled in the report *Sea Change*[31]*,* this pathway would result in a 60% reduction in the UK's North Sea gas output by 2030, and a more than 90% reduction by 2040.

2. **UNEP Production Gap Report**

[29] https://www.iea.org/reports/net-zero-by-2050
[30] https://www.iea.org/reports/net-zero-by-2050
[31] https://platformlondon.org/p-publications/sea-change-climate-emergency-jobs-north-sea-oil/

The Production Gap Report, published annually by the UN Environment Programme, provides estimates of the gap between oil and gas extraction that is consistent with a 1.5-degree warming pathway, and actual plans for oil and gas extraction on the other. The Production Gap Report's projection of gas extraction in a 'median' 1.5-degree scenario requires actual gas extraction to be 25% less than planned by 2030 and 40% less by 2040.[32]

The rates of decline projected by the Production Gap Report are less steep in comparison to the IEA, because it estimates a steeper decline in oil use and more of a consistent role for gas use over the next 30 years.

3. Tyndall Centre: Production Pathways within Paris-compliant carbon budgets

The Tyndall Centre for Climate Change Research published a report in March 2022 that identifies Phaseout Pathways for Fossil Fuel Production that are in line with carbon budgets derived from the Paris Agreement.[33]

The report incorporates the UN's equity framing of 'common but differentiated responsibility', that requires wealthier nations with economies less dependent on oil and gas revenues to lead the way with high rates of closure and early phase-out dates. Poorer nations have more leeway, with both slower rates of closure and slightly later phase out dates. For the poorest group with lowest capacity, a 14% cut is required by 2030, with all production ended by 2050.

However, for the wealthiest group of high emitting 'producer nations', with the highest capacity to achieve a 'just transition', output of oil and gas needs to be cut by 74% by 2030, approaching complete phase out by 2034. This group includes the UK, as well as Norway, Netherlands, the US, and Qatar (i.e., the sources of most UK gas imports).

[32] https://www.unep.org/resources/report/production-gap-report-2021
[33] Calverley, D. and Anderson, K. (2022), Phaseout pathways for fossil fuel production within Paris-compliant carbon budgets. Tyndall Centre, University of Manchester.
https://www.research.manchester.ac.uk/portal/files/213256008/Tyndall_Production_Phaseout_Report_final_text_3_.pdf

2. Tackling direct greenhouse gas emissions at Mossmorran

Key findings

- **The Mossmorran plants represent a substantial proportion of industrial emissions in Scotland.** They represent 9.4% of the carbon dioxide, nitrous oxide and methane emitted by all Scottish large sites regulated by SEPA and are the 3rd and 10th top industrial emitters in the country. Any credible plans to reach net zero emissions cannot afford to leave Mossmorran out.
- Ethylene production is hard to decarbonise, with the majority of emissions coming from burning fossil fuels to power high-temperature ethane cracking furnaces to split out ethylene and other products.
- Current proposals from Scottish and UK governments and industry focus on either capturing and storing such industrial carbon emissions (CCS) or using hydrogen as fuel.
- **CCS technology cannot be considered a sole solution to decarbonisation at Mossmorran, due to several risks**: seismic data uncertainties, planning processes, likely high costs for CCS technology for combustion processes, and competition from other industrial sites for limited storage facilities. Whilst Grangemouth has a clear role in existing plans for a CCS-based Scottish industrial cluster, no mention is made of either of the plants at Mossmorran.
- **This analysis identifies five core pathways to decarbonisation at Mossmorran, which carry risks and trade-offs. Imaginative and detailed planning on the future of the site needs to begin as quickly as possible.**

Understanding Mossmorran's emissions

The Scottish Environmental Protection Agency (SEPA) provides data on pollutants emitted by large industrial plants like those at Mossmorran[34]. Greenhouse gases are defined in the Kyoto Protocol and can be expressed in terms of an equivalent amount of carbon dioxide based on how much they contribute to global warming. Although greenhouse gas emissions at both plants are largely driven by carbon dioxide,

[34] Scottish Environment Protection Agency (2019). Scottish Pollution Release Inventory. [Dataset] https://informatics.sepa.org.uk/SPRI/

the amount of methane and nitrous oxide recorded for them was converted to a CO2 equivalent using factors published by the UK government[35].

Table 1. Greenhouse gas emissions for both the Shell NGL plant and ExxonMobil ethylene plant, according to SEPA regulatory data.

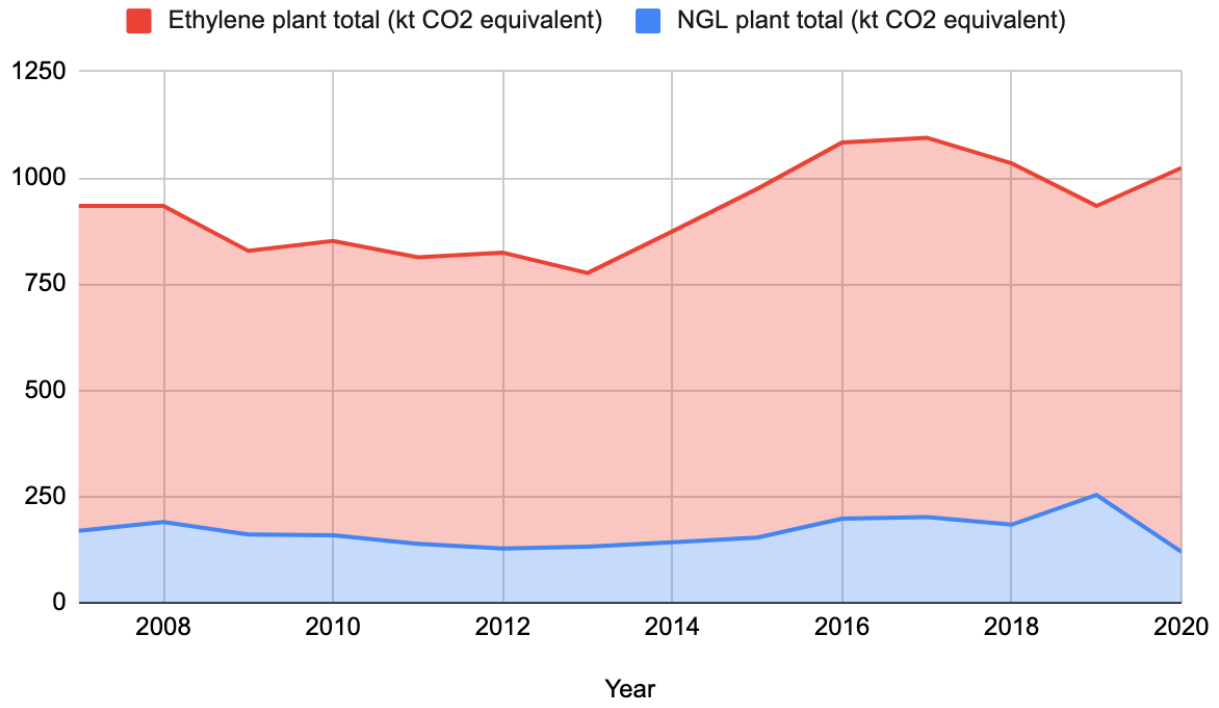
	Fife NGL Plant				Fife Ethylene Plant			
Year	Carbon dioxide (kt)	Methane (kt CO2 equivalent)	Nitrous oxide (kt CO2 equivalent)	NGL plant total (kt CO2 equivalent)	Carbon dioxide (kt)	Methane (kt CO2 equivalent)	Ethylene plant total (kt CO2 equivalent)	Mossmorran Total (ktCO2 equivalent)
2007	163.61	2.09	3.68	169.38	764.08	0.36	764.44	933.82
2008	182.03	3.74	4.2	189.97	743.96	0.33	744.29	934.26
2009	159.73	1.02		160.75	667.65		667.65	828.4
2010	154.19	1.17	3.36	158.72	693.02		693.02	851.74
2011	138.83			138.83	674.27		674.27	813.1
2012	127.48			127.48	696.74		696.74	824.22
2013	132.1			132.1	643.83		643.83	775.93
2014	139.42		3.05	142.47	731.34		731.34	873.81
2015	150.08		3.28	153.36	820.77		820.77	974.13
2016	193.55		4.23	197.78	885.58		885.58	1083.36
2017	197.09		4.34	201.43	892.96		892.96	1094.39
2018	179.75		3.9	183.65	850.7		850.7	1034.35
2019	249.58		4.01	253.59	679.83	0.71	680.54	934.13
2020	116.34		3.40	119.74	901.84	1.69	903.53	1023.28

According to this regulatory data, in 2020 120 kt CO2 equivalent was emitted by the NGL plant and 904 kt CO2 equivalent by the ethylene plant. Between 2015 and 2020, the combined emissions of the plant

[35] Department for Business, Energy, and Industrial Strategy (2022). Conversion factors 2021: condensed set (for most users) - revised January 2022. [Dataset]
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1049332/conversion-factors-2021-condensed-set-most-users.xls

consistently hovered at around 1 megatonne of CO2 equivalent greenhouse gases. As can be seen from the Graph 2 below, based on SPRI data from SEPA, emissions have been driven by persistently high levels of CO2.

Graph 2. CO2 equivalent emissions at the Fife NGL and ethylene plants for 2007-2020.



Mossmorran looms large in overall Scottish emissions. The ethylene plant ranks third in Scotland in the National Atmospheric Emissions Inventory (NAEI) of onshore 'large point emitters' and the NGL plant tenth (see Table 2).

The combination of both plants accounts for 9.4% of all the carbon dioxide, methane and nitrous oxide emitted by Scottish onshore sites recorded in the NAEI database (see Table 2 below, based on NAEI data from 2019)[36]. This highlights that any credible plans to reach net zero emissions cannot afford to leave Mossmorran out.

[36] National Atmospheric Emissions Inventory (2019). Emissions from NAEI large point sources. [Dataset] https://naei.beis.gov.uk/data/map-large-source. Carbon dioxide mass calculated by multiplying by the ratio of molecular mass of CO2 to carbon, 44/12, which gives agreement with the SPRI data. Other gases calculated using UK government conversion factors.

Table 2. Scotland's largest industrial greenhouse gas emitter sites.

Plant name	Operator	Co2 equivalent kt
Peterhead Power Station	SSE Generation Limited	1580
Grangemouth Refinery	Petroineos Manufacturing Scotland Limited	1343
Fife Ethylene Plant	ExxonMobil Chemical Limited	680
Grangemouth CHP	Grangemouth CHP Limited	640
Dunbar Works	Tarmac Cement and Lime Limited	566
Grangemouth Olefins	INEOS Chemicals Grangemouth Limited	523
Grangemouth Power Station	Ineos Infrastructure (Grangemouth) Limited	440
Kinneil Terminal	BP EXPLORATION OPERATING COMPANY LIMITED	370
St Fergus	SHELL U.K. LIMITED	327
Fife NGL Plant	SHELL U.K. LIMITED	264

Ethylene production and the path to Net Zero

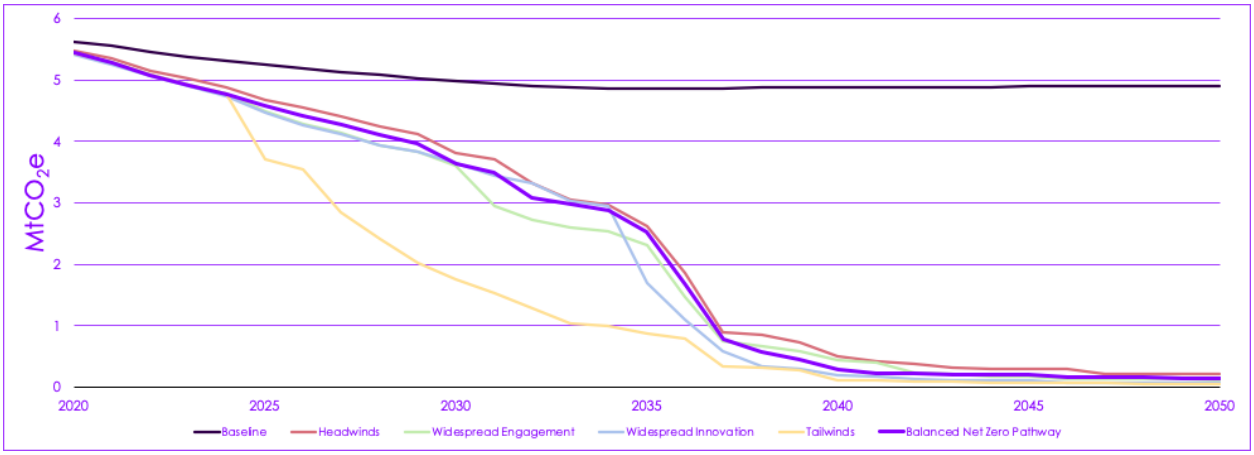
In 2019, the Scottish Government legally committed to achieving net zero greenhouse gas emissions by 2045, a more ambitious target than the UK Government's[37]. In terms of industry specifically, there are additional targets to increase energy productivity by 30% and decrease emissions intensity by 30% by 2032[38]. As part of the pathway to net zero by 2050, the UK Government has launched the UK Emissions Trading Scheme (UK ETS), which is due to introduce caps on emissions for energy intensive industrial sectors 'aligned with a net zero consistent trajectory' by January 2024 at the latest[39].

The rate at which emissions are reduced across the country and across industry depends on multiple factors, such as technological development in each sector, investment and choices surrounding policy levers such as funding, taxation, and regulation.

[37] Scottish Government (2021, 5 February). *Reaching net zero*. https://www.gov.scot/news/reaching-net-zero-1/
[38] Scottish Government. Energy and Climate Change Directorate (2020). *Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update. Annex B: Monitoring Framework*. https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/pages/16/
[39] UK Government. Department for Business, Energy & Industrial Strategy (2021). *Net Zero Strategy: Build Back Greener:* 121 https://www.gov.uk/government/publications/net-zero-strategy

The Climate Change Committee's Sixth Carbon Budget included modelling of different emission reduction pathways for the Scottish manufacturing and construction industry. Their 'balanced' pathway, taking into account both tailwinds and headwinds facing emissions reduction in the sector, involves a gradual decline of around 45% between 2020 and 2035, followed by a sharp reduction of around the same scale between 2035 and 2040. In the CCC's scenario (see Graph 3, from the Sixth Carbon Budget), emissions reduction in manufacturing and construction is largely driven by the electrification of processes and the use of hydrogen in sectors where this is more challenging.

Graph 3. Emissions reduction pathways for the Scottish manufacturing and construction industry



Additional modelling by Element Energy for the CCC shows how deep industrial decarbonisation may be more challenging in petrochemical manufacturing and especially so in ethylene production[40]. This analysis shows that whilst resource efficiency, energy efficiency and actions in other sectors could reduce sector emissions by 47%, this is largely as a result of reduced demand for petroleum products causing a contraction in refining. This implies that in a net zero pathway, the propane, butane, and other outputs produced at the Shell NGL plant alongside ethane will also be impacted by this reduced demand.

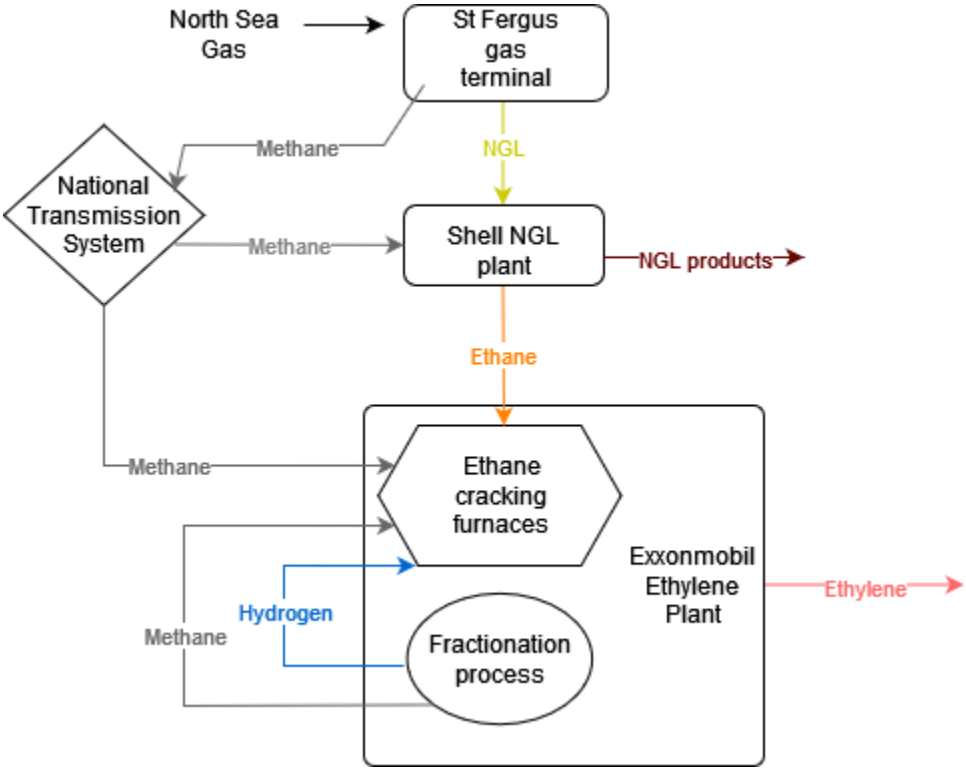
As identified by Element Energy, reducing emissions by making the production of ethylene more efficient is challenging, as the process is already optimised by recycling byproducts to fuel the production process itself. In the case of the ethane cracking method used at Mossmorran, hydrogen and methane separated out in the fractionation towers are recycled to fuel the ethane cracking furnaces (see Figure 1). Whilst the process at the Fife Ethylene Plant does recycle heated steam from cracking to power turbines elsewhere in the plant, a study found that for a typical petrochemical plant 60% of the energy comes from fuel, 35% from steam and the remaining 5% from the power grid[41].

[40] Element Energy (2020). *Deep-Decarbonisation Pathways for UK Industry*. Climate Change Committee. https://www.theccc.org.uk/publication/deep-decarbonisation-pathways-for-uk-industry-element-energy/

[41] Benchaita, T. (2013). *Greenhouse Gas Emissions from New Petrochemical Plants: Background Information Paper for the Elaboration of Technical Notes and Guidelines for IDB Projects* (IDB - TN - 562): 15. Inter-American Development Bank.

Figure 1 is a simplified representation of the industrial process at Mossmorran. North Sea Gas arrives at the St Fergus gas terminal and is fed through the National Transmission System as methane. The Shell NGL plant uses Natural Gas Liquids from the St Fergus terminal and methane from the National Transmission system to make NGL products and ethane. The ExxonMobil ethylene plant uses ethane from the Shell NGL plant and methane from the National Transmission system, processing it in ethane cracking furnaces to produce ethylene and other products. Methane and hydrogen that are byproducts at the ethylene plant are reused in the furnaces as fuel.

Figure 1. Mossmorran industrial processes



The largest part of emissions in ethylene production processes like those at Mossmorran comes from the burning of fossil fuels to power the cracking furnaces. For example, chemical company Dow estimates 50% of their ethylene production emissions come from heat sources for cracker furnaces and as a result

https://publications.iadb.org/publications/english/document/Greenhouse-Gas-Emissions-from-New-Petrochemical-Plants-Background-Information-Paper-for-the-Elaboration-of-Technical-Notes-and-Guidelines-for-IDB-Projects.pdf

are trying to electrify cracking furnaces to meet net zero goals[42]. Recent life-cycle modelling of various ethylene production methods found that the actual cracking process contributed over 54%[43].

The recycling of feedstock to fuel furnaces means that cracking ethane and other NGLs produces much lower emissions than using other fossil fuels as feedstock because NGLs contain lower amounts of carbon. For example, one study found that naphtha crackers emit 73% more CO2 per tonne of ethylene than ethane crackers[44], whilst another analysis showed that ethane steam cracking produces around 1 tonne of CO2 per tonne of product, compared to 5 to 8 tonnes for coal-based feedstock[45]. A 'cradle to gate' life-cycle analysis showed that using naphtha, ethane and corn-ethanol as feedstocks has a 'similar environmental impact' if natural gas is used as the source of energy production, as this accounted for around 85% of the environmental impact in their model for all three cases[46]. This means that in terms of emissions, what powers the ethane production process is critical.

Viability of carbon capture at Mossmorran

Considering the importance placed by government and industry on CCS technology for industrial decarbonisation in general and decarbonisation at Mossmorran specifically, it is worth looking in depth at the prospects for the site's ability to use CCS infrastructure.

Acorn

Shell has been extensively involved in multiple rounds of research on re-purposing depleted oil fields, nearby existing geological formations and current infrastructure for Carbon Capture and Storage (CCS). Recently, this has focused on the Acorn project joint venture, composed of Shell along with partners Storegga (formerly Pale Blue Dot Energy) and Harbour Energy. The concept involves storing CO2 emissions in the 'Acorn CO2 site', or the sandstone Captain Aquifer[47], located 100km off the coast of St Fergus gas terminal and 2.5km underneath the North Sea. Plans currently involve transporting liquified CO2 from St Fergus to the storage site via the repurposing of the pre-existing Goldeneye and Atlantic pipelines. Later

[42] Tullo, A.H. (2021). The search for greener ethylene. *Chemical & Engineering News, 99*(9). https://cen.acs.org/business/petrochemicals/search-greener-ethylene/99/i9

[43] Zhao, Z.; Chong, K.; Jiang, J.; Wilson, K.; Zhang, X.; Wang, F. (2018). Low-carbon roadmap of chemical production: A case study of ethylene in China. *Renewable and Sustainable Energy Reviews, 97(), 580–591.* doi:10.1016/j.rser.2018.08.008

[44] Benchaita, *Greenhouse Gas Emissions from New Petrochemical Plants*.

[45] Ren, T.; Patel, M.K. (2009). Basic petrochemicals from natural gas, coal, and biomass: Energy use and CO2 emissions. *Resources, Conservation and Recycling*, 53(9), 513–528. doi:10.1016/j.resconrec.2009.04.005

[46] Ghanta, M., Fahey, D. & Subramaniam, B. (2014). Environmental impacts of ethylene production from diverse feedstocks and energy sources. *Appl Petrochem Res,* 4**,** 167–179 . https://doi.org/10.1007/s13203-013-0029-7. NB they assume catalytic dehydration of ethanol - energy requirements are 1.6 MJ/kg ethanol whereas '13.7 and 0.2 MJ/kg' for 'fuel and power…respectively' for ethane cracking.

[47] *Acorn:Project Details* (2021). The University of Edinburgh. https://www.geos.ed.ac.uk/sccs/project-info/2081

phases of the project aim to use this storage infrastructure to enable the production of hydrogen from natural gas at St Fergus, store CO2 from other countries imported into the port at Peterhead and store CO2 from industrial sources primarily located at Grangemouth transported via existing pipelines[48]. This latter phase, including agreements to store CO2 from the power station at Peterhead, formed the basis of the Scottish Industrial Cluster bid for funding from the UK-wide £1 billion Carbon Capture and Storage Infrastructure Fund (CIF)[49].

Much of the plans to store CO2 in the North Sea rest on the idea that there is ample understanding of and data on the geological structures that could be used as storage facilities due to the long history of oil and gas exploration and extraction in the area[50]. Earlier carbon capture projects, for example in Norway, used injection and storage of CO2 to increase extraction of hydrocarbons from ageing oil and gas fields[51].

Geological uncertainties around CCS potential

Mossmorran's future ability to rely on CCS infrastructure is subject to significant geological uncertainties. 'Open' aquifers like Captain and Sleipner which have received much of the attention for initial storage of CO2 present complex challenges, as sequestering CO2 depends on not only physically trapping gas but on chemical reactions fixing carbon in water and minerals over the long term. In open aquifers, CO2 plumes can leak out of the structures before these longer-term effects have a chance to kick in. The ability to safely store a given amount of CO2 then depends on how fast the plume of injected gas will flow through the structure, which in term limits when and how much gas can be injected before it risks escaping[52].
The Sleipner CCS project, operated by Norwegian state-controlled company Equinor, has captured and stored around 1Mt of CO2 a year since 1996 off the coast of Norway. Although CO2 has not escaped at

[48] Acorn (n.d.) https://theacornproject.uk/about/
[49] UK Government. Department for Business, Energy, and Industrial Strategy (2021). *The Carbon Capture and Storage Infrastructure Fund: an update on its design*. https://www.gov.uk/government/publications/design-of-the-carbon-capture-and-storage-ccs-infrastructure-fund/the-carbon-capture-and-storage-infrastructure-fund-an-update-on-its-design-accessible-webpage
[50] Scottish Carbon Capture & Storage (2015). *Optimising CO2 storage in geological formations: a case study offshore Scotland*. University of Edinburgh. https://www.sccs.org.uk/images/expertise/reports/co2multistore/SCCS-CO2-MULTISTORE-Report.pdf
[51] Stephens J. and Van Der Zwaan B. (2005). The Case for Carbon Capture and Storage. *Issues in Science and Technology 22*(1). https://issues.org/stephens/
[52] Ghanbari, S., Mackay, E. J., Heinemann, N., Alcalde, J., James, A., & Allen, M. J. (2020). Impact of CO2 mixing with trapped hydrocarbons on CO2 storage capacity and security: A case study from the Captain aquifer (North Sea). *Applied Energy*, *278*, 115634. DOI:10.1016/j.apenergy.2020.115634

Sleipner and the site is judged to be a success[53], the plume of gas spread much faster than anticipated,[54] limiting the project's storage capacity.

There is a consistent trajectory of initial enthusiasm over potentially large storage CCS volumes being tempered by later detailed considerations of geological uncertainties. This has been borne out through a series of scoping projects on CO2 storage in the Captain Aquifer in the Central North Sea over the last six years. CO2 can be injected into the Captain Aquifer either through the Goldeneye depleted gas field or Site X, both of which have an existing pipeline suitable for re-use to transport CO2.

- Scottish Carbon Capture and Storage in 2015 estimated Captain Aquifer to have a storage capacity of 360MT of CO2, at a rate of 6 to 12 MT a year.[55]
- A 2016 UK Government funded analysis estimated the Goldeneye section to have a capacity of 20MT of CO2, with injection happening at 1MT per annum, [56] and Site X, 180MT over 40 years. Uncertainty about where the CO2 plume may flow after being injected at the site produced a predicted capacity for storage to 60MT over 20 years.[57]

Additional research highlighted the Captain aquifer's open nature combined with faults that breach the seal of the aquifer and rise to the seabed increase the risk of seabed leakage - suggesting that its use as a

[53] Furre, A. K., Eiken, O., Alnes, H., Vevatne, J. N., & Kiær, A. F. (2017). 20 years of monitoring CO2-injection at Sleipner. *Energy procedia*, *114*, 3916-3926. https://doi.org/10.1016/j.egypro.2017.03.1523

[54] Haszeldine R.S. and Cavanagh A.J. (2014). The Sleipner storage site: Capillary flow modeling of a layered CO2 plume requires fractured shale barriers within the Utsira Formation. *International Journal of Greenhouse Gas Control*, *21*, 101-112. https://doi.org/10.1016/j.ijggc.2013.11.017

[55] This model assumed two drilling sites, and the authors flagged that 'Storage of CO2 at more than one injection site will create widespread interacting pressure changes within the storage formation, which will determine the total amount of CO2 that can be stored', including interactions with existing hydrocarbon drilling and emphasised the need for more detailed modelling and careful monitoring of pressure changes.

[56] Peterhead CCS Project (2016). *FEED Summary Report for Full CCS Chain* (PCCS-00-MM-AA-7180-00001). Shell U.K.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/531394/11.133_-_FEED_Summary_Report_for_Full_CCS_Chain.pdf
This was despite the volume of extracted hydrocarbons implying space for 47MT of CO2, due to uncertainties around the geology of the field itself, the dynamics of CO2 injection and uncertainties around potential overspill into the surrounding Captain saline aquifer meant that their models constrained overall

[57] Pale Blue Dot Energy, Axis Well Technology, Costain (2016). *Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource: A Summary of Results from the Strategic UK CO 2 Storage Appraisal Project*: 34
https://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal
The authors highlighted that the ability of CO2 to move laterally through the upper layer of sandstone represented 'both the main opportunity and the main challenge at Captain X' by increasing both the potential storable volume and uncertainty around leakage. They also highlighted concerns over abandoned hydrocarbon wells, especially those plugged with concrete, that may provide an additional escape route for CO2 if the injected plume migrates towards them.

site for CO2 storage remains unproven.[58] More recent modelling of the Captain aquifer has suggested that the mixing of CO2 with lighter hydrocarbon residues may make the CO2 plume migrate faster and reduce storage capacity[59].

Timescale uncertainty

Given the complexity and uncertainty surrounding storage in the aquifer as a whole, it is perhaps unsurprising that 'Phase 1' of the Acorn project (funded by BEIS, the EU, and private investors)[60] is focused on the more modest goal of capturing 345 kt CO2/year from the flues at St Fergus and storing it in the depleted Goldeneye gas field[61]. As of January 2020, this initial stage was described as being in the 'Concept Select phase' during which 'technical options will be evaluated'[62].

Pale Blue Dot, now Storegga, was awarded the first 'initial term' Carbon Storage Licence by the UK Oil and Gas Authority (OGA) in 2018, due to run out in 2022[63]. This only grants 'authorisation for offshore exploration for the purposes of selecting a site for CO2 storage', and the 'the company would need to submit and be awarded a Storage Permit before CO2 injection could begin'[64], apparently contradicting Acorn claims that 'the Acorn CO_2 Storage Licence…grants regulatory approval for the storage of CO_2 in the proposed location'[65]. Actual approval is likely to be a more involved process, as it would involve the OGA signing off on the detailed information on operational requirements during the development process that would be included in the Storage Permit.

The project was dealt a blow when the UK Government designated the Scottish Industrial Cluster as a 'reserve' and not a 'Track 1' project in the allocation of the CIF[66]. This is confirmed in the more recently published British Energy Security Strategy.[67] The Scottish Government, however, has pledged £80 million

[58] Guariguata-Rojas, G. J.; Underhill, J. R. (2017). Implications of Early Cenozoic uplift and fault reactivation for carbon storage in the Moray Firth Basin. *Interpretation*, *5*(4), SS1-SS21. https://doi.org/10.1190/INT-2017-0009.1
[59] Ghanbari, S. et al. *Impact of CO2 mixing with trapped hydrocarbons on CO2 storage capacity and security*
[60] Perry, J. (2020) Letter to Tully, E. 28th January. https://theacornproject.uk/wp-content/uploads/2020/08/Screening-letter-for-Aberdeen-Council-280120.pdf
[61] Acorn (n.d.). Townhall - Technical. *The Acorn Project*. https://theacornproject.uk/townhall-technical/
[62] Ibid, pg. 2
[63] *Carbon Capture Storage Licence Awarded* (2018). Oil and Gas Authority. https://www.nstauthority.co.uk/news-publications/news/2018/carbon-capture-storage-licence-awarded/
[64] Ibid.
[65] Acorn, *Townhall - Technical*.
[66] UK government. Department for Business Energy and Industrial Strategy (2021). *October 2021 update: Track-1 clusters confirmed*. https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-deployment-phase-1-expressions-of-interest/october-2021-update-track-1-clusters-confirmed
[67] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy#oil-and-gas

of funding for the cluster if the UK Government clarifies the priority of the cluster in its investment decisions[68].

The lack of alternative planning to reduce emissions has been recognised as a key risk to Scotland meeting its emissions targets. In their 2021 Progress Report, the Climate Change Committee argued that the lack of UK government support for CCS in Scotland necessitates 'clear contingency plans'[69] in the event that CCS is not delivered at the required scale in time for 2030 targets to be met, and that these should be implemented by 2023 at the latest if this is indeed the case.

Competition for CCS capacity

Assuming the ambitious predictions for CO2 storage at the Acorn site are achieved, there is a question mark over whether Shell and Exxon's combined CO2 emissions of 1 Mt per year could be included in storage plans. The 'Scottish Industrial Cluster' project anticipated using Acorn infrastructure to capture and store 6.7 Mt of CO2 per annum by 2030, of which20% would come from industry, and 39% from blue hydrogen production from natural gas[70]. At this capacity, storing Mossmorran's 1 MT per annum emissions would take up two thirds of Acorn's expected capacity for capturing industrial emissions.
Although ExxonMobil signed an Expression of Interest to look at using Acorn infrastructure to store emissions from the Fife Ethylene Plant in 2021[71], the plants at Mossmorran are not explicitly named in publicly available material associated with the Scottish Cluster. Instead, publicity mentions '1 million tonnes of CO2 per year from the INEOS and Petroineos sites at Grangemouth' being captured by 2027[72], leaving very little room (under 0.34 MT per year) for emissions from other industrial sites in current plans. This could not cover Mossmorran's current emissions. Moreover, if injection rates are closer to previous more conservative modelling of the Captain X and Goldeneye sites, yearly capacity for carbon storage could amount to 3Mt and 1Mt of CO2 a year respectively; this is a total of 4Mt of CO2 per annum, or a 40% reduction on current Acorn predictions, putting further pressure on competing demands for storage.

[68] Scottish government (2022). *Scottish Cluster support*. https://www.gov.scot/news/scottish-cluster-support/
[69] Climate Change Committee (2021). *Progress in reducing emissions in Scotland: 2021 Report to Parliament*: 12. Climate Change Committee. https://www.theccc.org.uk/wp-content/uploads/2021/12/Progress-reducing-emissions-in-Scotland-2021-Report-to-Parliament-1.pdf
[70] Element Energy (2021). *Economic impact assessment for the Scottish Cluster: Public summary*. The Scottish Cluster. https://uploads-ssl.webflow.com/60939cc3116ed76a8a306170/60f7df4941614b0e6c8c2476_210707%20-%20Element%20Energy%20-%20Scottish%20cluster%20economic%20impact%20-%20public_summary%20report_ISSUED_KL.pdf
[71] Penman, H. (2021, 6th October). Study to explore using Acorn to bag emissions from ExxonMobil's Mossmorran site. *Energy Voice.* https://www.energyvoice.com/renewables-energy-transition/ccs/354525/exxonmobil-mossmorran-acorn/
[72] The Scottish Cluster (n.d.). The Scottish Cluster Supply Chain. *The Scottish Cluster*. https://www.thescottishcluster.co.uk/the-scottish-cluster-supply-chain

Costs of CCS for combustion processes

Upstream uncertainties in relying on CCS to decarbonise Mossmorran are also accompanied by uncertainties surrounding carbon capture at the plant itself. Modelling by Element Energy found that carbon capture technology is more costly at ethylene plants than at ammonia plants or refineries, estimated at £110 per ton of CO2 equivalent compared to less than £50[73]. This is because it is more expensive to abate emissions from combustion than higher purity process emissions and the former make up most of the greenhouse gases emitted at Mossmorran.

In conclusion, the viability of CCS for use in capturing emissions at Mossmorran is subject to several risks: seismic data uncertainties, planning processes, and competition from other industrial sites for limited storage facilities. While CCS is the main option considered by the Scottish Government and industry for decarbonising refining processes, consideration of these risks suggests that it is also worth following the CCC's advice to develop "clear contingency plans" to reach 2030 targets. This should include investigating other options for decarbonisation at Mossmorran, including the use of green hydrogen as fuel (which is less reliant on CCS), or diversification or conversion at the site.

Mapping abatement options in ethylene production

To understand the complex uncertainties surrounding different options for reducing emissions at Mossmorran whilst producing ethylene, different approaches to reducing or abating combustion emissions are considered. Particular attention has been paid to technologies named in plans advanced by the Scottish Industrial Cluster and the Scottish government, namely CCS and burning hydrogen produced from fossil fuels (blue hydrogen) or hydrogen produced through renewable-powered electrolysis of water (green hydrogen). A simplified mapping of flows of different fuels and outputs along the SEGAL production process, beginning at St Fergus, was used. This helped to understand the level of reliance on CCS for each option. It also clarified the role of by-product gases from the fractionation process under each option, which would normally contribute to powering cracking furnaces. In addition, the role of changing the feedstock from NGL derived ethane to bio-ethanol was considered.

Table 3 summarises the options for decarbonisation and their exposure to risks. The following sections explore the options in more detail (including references).

[73] Element Energy, *Deep-Decarbonisation Pathways for UK Industry*.

Table 3. Core pathways to decarbonisation for Mossmorran and their exposure to risks

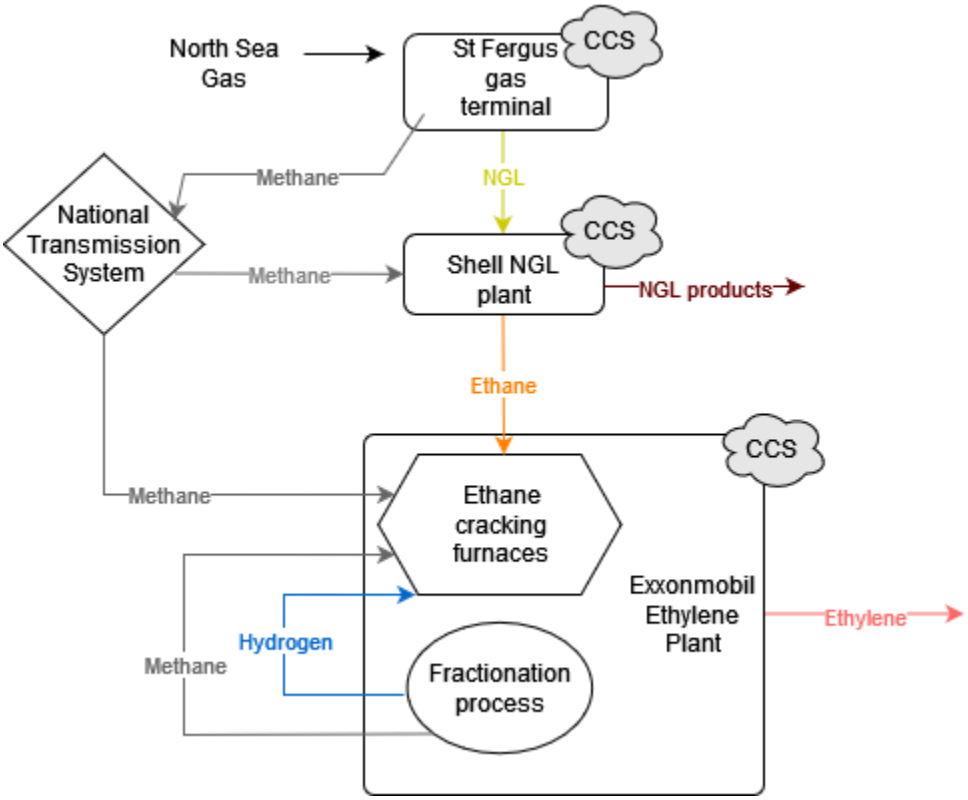
Option	Vulnerable to decline in oil & gas output	Vulnerable to declining ethylene demand	Needs on-site CCS	Needs CCS upstream	Challenges and Positives	Research and investment required
#1: NGL feedstock, methane as fuel source (figure 2)	Yes	Yes	Yes	Yes	Cons - high levels of CCS required at Mossmorran. Pros - Can burn both byproducts from fractionation.	Yes - Carbon capture onsite, CCUS upstream
#2: NGL feedstock, blue hydrogen fuel source (figure 3)	Yes	Yes	No	Yes - at St Fergus and blue hydrogen production site. Could be higher than Option 1 CCS requirements.	Cons - methane byproduct leftover. Question whether could be recycled back into blue hydrogen production. Pros - Can burn hydrogen byproduct.	Yes - modification of furnaces, upstream blue hydrogen hydrogen production, upstream CCUS upstream
#3: NGL feedstock, green hydrogen fuel source (figure 4)	Yes, but reduced	Yes	No	Yes. - but only at St Fergus	Cons - methane byproduct leftover. Pros - Can burn hydrogen byproduct.	Yes - modification of furnaces, upstream green hydrogen production, upstream CCUS upstream
#4: Bio-ethanol feedstock, electrified process as fuel source	No	Yes	No	No	Cons - Energy demand for dehydration of ethanol to ethylene higher. Question over sourcing of sufficient bio-ethanol. Pros - Co-production of ethanol	Yes - installation/adaptation of plants, securing of feedstock, electrification of process

					could help produce electricity for the site.	
#5: Alternative industrial uses: diversification or conversion	No	No	No	No	Cons - Unspecific. Depending on process of conversion and new industrial use, greater precarity for current workers due to deeper transformation and potentially likely different skills requirements. Pros - Can be thoroughly future-proofed in terms of zero carbon processes and production outputs with long-term demand	Yes - investment into new manufacturing plant

Option #1: Continued use of natural gas liquids as feedstock and methane as fuel. Upstream and onsite CCS as primary pathway to decarbonisation

Figure 2 below shows a simplified diagram of how CCS could be applied to abate the main GHG emissions associated with the current cracking of ethane using natural gas-fuelled furnaces. Carbon would need to be captured upstream at the St Fergus terminals that produce NGLs as well as on-site at both the Shell NGL plant and the ExxonMobil ethylene plant. If conditions were similar to those that produced 2020 greenhouse emissions, this could amount to around 1 Mt a year[74]. The need to use potentially more expensive CCS technology on furnace combustion emissions also increases the risks around this option. Efficiency continues to be driven by methane and hydrogen byproducts being used as fuel.

Figure 2. Option 1 Emissions abatement at Mossmorran: CCS only



[74] National Atmospheric Emissions Inventory, *Emissions from NAEI large point sources*, 2019 data .

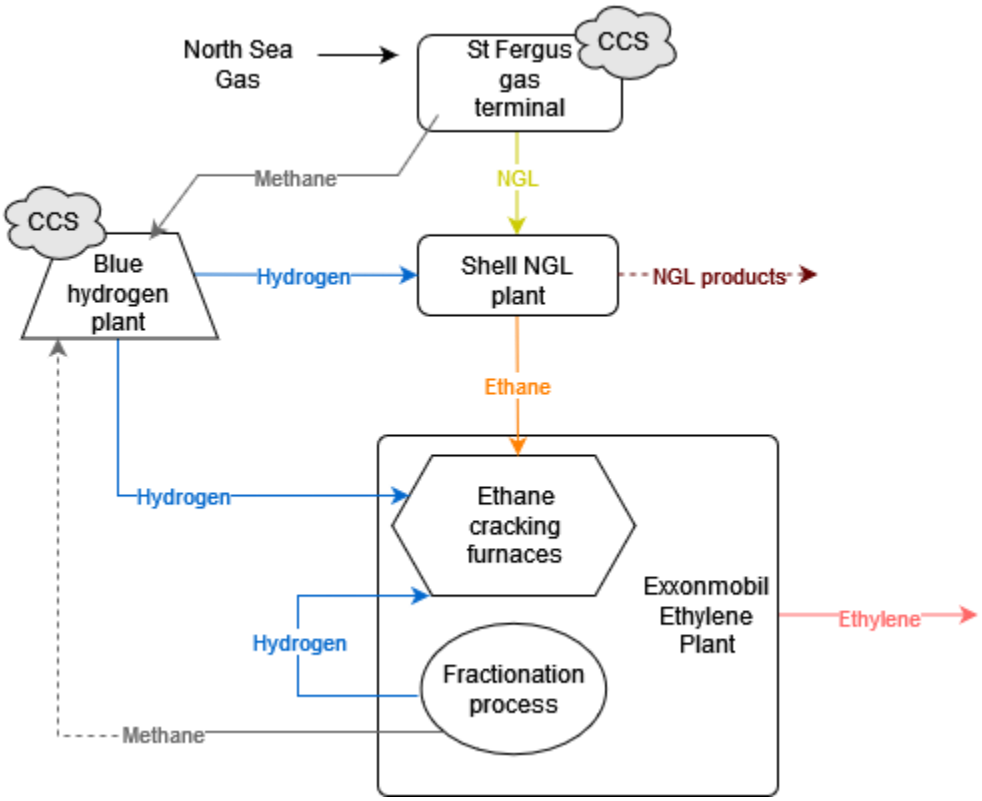
Option #2: Methane as feedstock and blue hydrogen as fuel. CCS required upstream at St Fergus and to produce blue hydrogen

Figure 3 maps out the use of blue hydrogen to fuel the ethane steam cracker at the ethylene plant. Burning hydrogen means that carbon dioxide no longer needs to be captured from combustion emissions at either plant. As the fractionation process at Shell does not produce CO2 as an output, it is assumed that the majority of its emissions also come from combustion of fossil fuels for energy and that this would also be substituted for by hydrogen[75]. In this simple model, this could save over 900 kt of CO2 but would necessitate new carbon capture upstream involved in the production of blue hydrogen. In addition, if the methane byproduct from fractionation is no longer burned in the cracking furnaces it could in theory be recycled back into blue hydrogen production further upstream.

How much CCS capacity would be required upstream in this scenario? Previous analysis by Pale Blue Dot Energy estimated that blue hydrogen production would produce 0.25Mt of CO2 for every TWh of energy fuelled by blue hydrogen[76]. Assuming the lowest bound of estimates for energy use in ethane cracking of 17MJ per kg of ethylene[77] and current production of 800,000 tonnes of ethylene per year[78], the ethylene plant alone could require 3.8TWh of energy a year. Under the same assumptions used by Element Energy, this is equivalent to 0.9 Mt of CO2 needing to be captured and stored per year, substantially higher than the 0.12 Mt emitted by the plant in 2020.

[75] Congressional Research Service (2018). *Natural Gas Liquids: The Unknown Hydrocarbons*. EveryCRSreport.com. https://www.everycrsreport.com/reports/R45398.html#_Toc529449714
[76] Element Energy (2020). *Hydrogen In Scotland: The Role of Acorn Hydrogen in Enabling UK Net Zero*, 46. The Acorn Project. https://theacornproject.uk/wp-content/uploads/2020/09/Hydrogen-in-Scotland-The-role-of-Acorn-Hydrogen-in-Enabling-UK-Net-Zero.pdf
[77] Yao, Y.; Graziano, D. J.; Riddle, M.; Cresko, J.; Masanet, E. (2015). Understanding variability to reduce the energy and GHG footprints of US ethylene production. *Environmental Science & Technology*, *49*(24), 14704-14716. https://doi.org/10.1021/acs.est.5b03851
[78] ExxonMobil (n.d.). *Our Operations*. https://www.exxonmobil.co.uk/Company/Overview/UK-operations/Fife-operations/Our-Operations#WhatWeDo [Accessed 16th April 2022]

Figure 3. Emissions abatement at Mossmorran: Blue Hydrogen + CCS

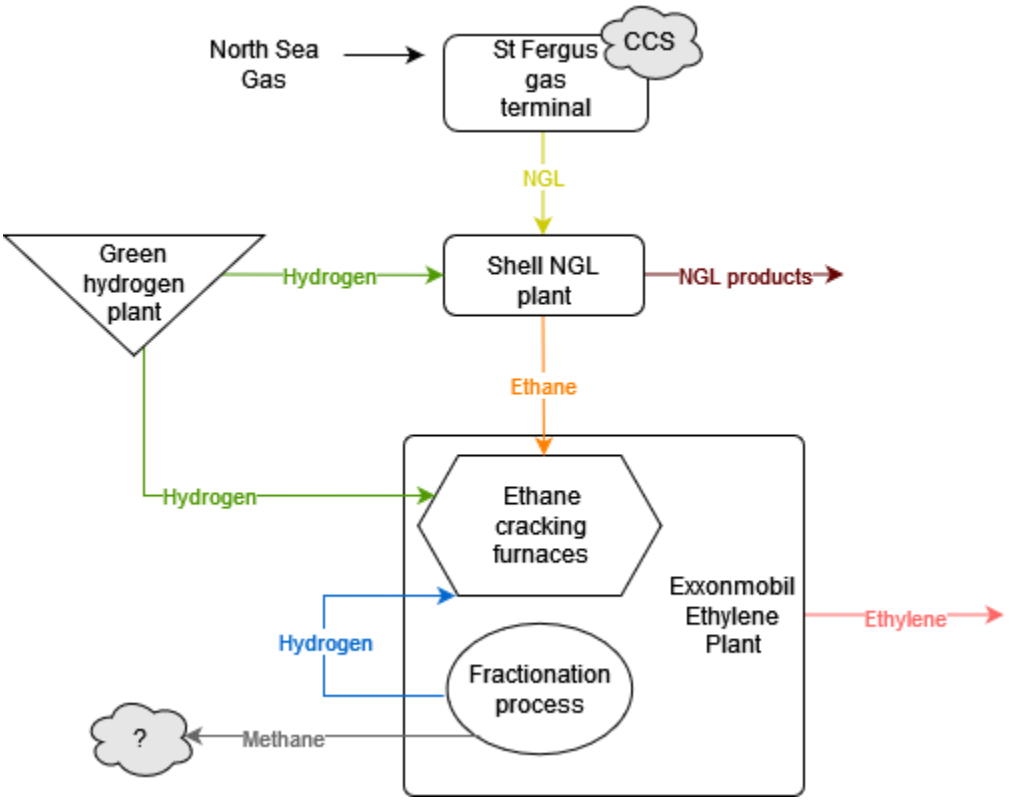


Option #3: Green hydrogen + CCS

Hydrogen can also be produced via 'green' methods, using electrolysis to split water molecules into hydrogen and water, powered by renewable sources[79]. A simplified mapping of how green hydrogen could be used to power production at Mossmorran is shown in Figure 4 below. The use of NGLs as a feedstock means that CCS is still needed upstream at St Fergus, however if emissions are comparable to 2020 this would involve up to 0.4 MT of CCS per year. Crucially, CCS at St Fergus is the first phase of development within the Acorn project and hence the most likely part to be delivered in a timely fashion. In this scenario, however, methane produced during fractionation would not have an obvious destination for recycling.

[79] Oliveira, A. M., Beswick, R. R., & Yan, Y. (2021). A green hydrogen economy for a renewable energy society. *Current Opinion in Chemical Engineering*, *33*, 100701. https://doi.org/10.1016/j.coche.2021.100701

Figure 4. Emissions abatement at Mossmorran: Green Hydrogen + CCS



Option #4: Biological feedstocks

An alternative to using NGLs as a feedstock is making ethylene from biological feedstocks. These include using bio-ethanol produced by fermenting crops such as corn and sugarcane, a feedstock used by plants in Brazil and India that currently produce up to 200,000 tonnes of ethylene a year[80].

Whilst biological feedstocks contribute to net zero emissions by naturally sequestering CO2 from the air as they grow, careful analysis across the lifecycle of production is necessary to understand their true environmental impact. A recent life-cycle analysis showed that using biomass as feedstock could result in emissions ranging from -0.6 to -1.3 tons of CO2 per ton of ethylene[81]. The study also found that growing and processing biomass emits more CO2 than extracting and processing natural gas feedstocks, but this is more than compensated by biomass feedstocks fixing carbon from the atmosphere. It is important to note, however, that this analysis assumes that both types of feedstocks are obtained and processed using

[80] IEA-ETSAP and IRENA (2013). *Production of Bio-ethylene: Technology Brief* (I13). IEA-ETSAP and IRENA. https://irena.org/-/media/Files/IRENA/Agency/Publication/2013/IRENA-ETSAP-Tech-Brief-I13-Production_of_Bio-ethylene.pdf

[81] Zhao Z. et al, *Low-carbon roadmap of chemical production*.

fossil fuels for power. Again, how power is generated through the whole lifecycle of ethylene is crucial - different lifecycle modelling found that 2-3 tons of CO2 per ton of hydrocarbon product can be offset produced by 'co-generating' electricity for the plant[82]. This is even more important because producing ethylene by dehydrating biomass-derived alcohols consumes more energy[83].

Summary of Risks to Production at Mossmorran

The identified risks to production associated with the technologies currently dominating the policy landscape, alongside producing ethylene from bio feedstocks, are summarised in Table 3. These are risks from declining inputs and demand for outputs, reliance on CCS both onsite and further upstream, further details on efficiencies or inefficiencies in relation to how power is generated and risks from the level of research and investment needed to realise the production process. Whilst all scenarios assume that greenhouse gas emissions are reduced to net zero, these don't include other risks to the environment, jobs, or community.

All scenarios for ethylene production are vulnerable to previously identified policy risks to plastics demand and all require substantial amounts of investment, planning and research. Relying on CCS to capture all emissions at the site and upstream poses the biggest exposure to the risk that Mossmorran will not be able to store this level of CO2. Using hydrogen removes the necessity to install CCS on site but requires CCS upstream. In the case of blue hydrogen, the amount of upstream CCS needed may be larger than current onsite emissions. Moreover, all options that use NGLs as a feedstock are exposed to the decline in oil and gas output necessitated by a commitment to 1.5 degrees, if oil and gas extraction is phased out in line with national and global climate targets as explained in section 1. Alternative feedstocks produced from biological origins would not carry this risk but careful modelling across the lifecycle is necessary to understand their environmental impact.

[82] Ren, T.; Patel, M.K., *Basic petrochemicals from natural gas, coal, and biomass*.
[83] Zhao Z. et al, *Low-carbon roadmap of chemical production*.

3. A Just Transition for the workforce

Key findings

- The two plants directly employ approximately 250 workers, according to Shell and ExxonMobil. Short-term maintenance projects employ more workers, sometimes vastly outnumbering direct jobs, though some of these workers are hired in from other parts of Scotland, or further afield.
- **Pay, benefits, health and safety, and other conditions for contract staff on site are protected by robust agreements.**
- **Existing experiences with renewable energy jobs (or lack thereof) make unionised workers sceptical of the prospects of decarbonisation**. Reasons cited include the use of exploited foreign labour at waste to energy plants to dodge collective bargaining agreements, the lack of renewable energy jobs and in particular, the collapse of nearby BiFab fabrication yards due to not being able to win contracts from wind power companies operating in Scottish seas.
- Other than the Just Transition Commission (JTC), publicly-supported UK and Scottish bodies shaping the transition have no or minimal worker representation. The mechanism for allocating government funding for Just Transition, such as the £500m Just Transition Fund for the North East and Moray, is unclear.
- **Historic examples of successful transitions suggest strong sectoral negotiations between unions, industry, and government, informed by site-specific worker discussions are crucial**. Lessons can be learned from the industry-union negotiating forum for engineering and construction, the National Joint Council for the Engineering Construction Industry (NJC), on how to facilitate this.
- Workers in different sectors are increasingly formulating plans for transition in their workplace in the face of plant and factory closures. Industrial planning with genuine worker participation could help ensure Mossmorran's transition is fair to workers and mitigate against the longer-term risks identified in this report.

A portrait of work at Mossmorran

Numbers of jobs

Permanent jobs at both the Mossmorran plants are largely made up of a core team of scientists, engineers, technicians, and support staff who oversee the day-to-day running of the plants. But the majority of work at the plants - primarily maintenance and upgrades - is outsourced to engineering construction contractors, whose workforce onsite often significantly outnumbers directly employed workers.

Historically, Cowdenbeath and the area surrounding Mossmorran have experienced high levels of unemployment since the decline of coal. When the plants were initially established, it was suggested that 1,600 permanent jobs could be created if the full chain of plastics production was realised. Surveys in 1993 and 1996, however, revealed residents' anger at the promise of a 'jobs bonanza' not being fulfilled[84].

It is difficult to access detailed information on employment at both plants. Information available publicly or through our interviews does not allow us to trace how the number of direct or outsourced roles has changed over time.

Shell says the NGL plant 'typically has a workforce of more than 250 people'[85] and ExxonMobil claims 'a team of around 250' made up of 'scientists, chemical, mechanical and environmental engineers, catering, cleaning, maintenance, technicians, analysts, planners and support staff', employing contractors 'in addition'[86].

To understand both the experience and context of workers at both plants better, interviews with three relevant union and worker sources were utilised to supplement publicly available sources. Most of the insight given was in relation to the experiences of repair and maintenance workers on site. This report doesn't encapsulate the full experience, skills and needs of all workers at both plants; further research and interviews with workers on both sites would be needed to achieve this. However, it provides an indication of unionised workers' experiences at the Mossmorran site.

The majority of repair and maintenance work at Mossmorran is now outsourced to engineering and construction contractor companies, in keeping with industry trends beginning in the 1980s in response to falls in oil prices[87]. It is this outsourced construction and engineering work that can cause large fluctuations in the total number of people working on site. For example, in 2019 ExxonMobil stated that their £140m investment into noise-reduction flare tips and an enclosed ground flare at the ethylene plant would bring 850 temporary construction jobs[88]. Similarly, Shell stated that work upgrading the

[84] Breakwell, G. and Barnett J. (2001). Amplification of risk: The citing and development of NGL facility. In *The impact of social amplification of risk on risk communication* (pp 178-214). https://www.hse.gov.uk/research/crr_pdf/2001/crr01332.pdf

[85] Shell (n.d.). *About the Fife NGL Plant at Mossmorran*. https://www.shell.co.uk/about-us/what-we-do/shell-fife-ngl/about-fife.html [Accessed 17th April 2022]

[86] ExxonMobil (n.d.). *Our People*. https://www.exxonmobil.co.uk/Company/Overview/UK-operations/Fife-operations/Our-People#WhoworksatFEP [Accessed 17th April 2022]

[87] Clarke, L., and Fitzgerald, I. (2020). The changing nature of labour regulation: the distinctiveness of the National Agreement for the Engineering Construction Industry. *Industrial Relations Journal*, *51*(1-2), 58-74. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/irj.12280

[88] Robertson, A. (2019, 17th September). Mossmorran investment: £140 million upgrade will bring 850 temporary jobs. *The Courier*.

inlet to the Fife NGL plant from the main pipe coming in from St Fergus would employ 60 contractors in April 2021[89]. As well as large capital expenditure jobs, contractors are used for ongoing maintenance and repair work, with four active repair and maintenance contractors employing 175 people in the Fife Ethylene Plant as of February 2022.[90]

Project-based construction work features heavily at both plants. Recent work at ExxonMobil illustrates how construction projects can last anywhere from a couple of months to several years. For example, the installation of noise-reduction tips commenced in April 2021 and finished in July[91], whilst groundwork for the new ground-enclosed flare started in July 2021 and is projected to be completed in December 2022[92]. At Shell, there was a large programme of renovation work that provided considerably longer-term work than is common for the sector. This finished in 2020, resulting in layoffs, the number of which was disputed. In October 2020, Unite claimed 63 out of 77 contractor jobs were to be cut, however Shell said 15 contract jobs across St Fergus and Mossmorran were to go and the core maintenance team would be reduced from 125 to 110, made up of staff and contractors[93].

Interviews with trade union sources suggested that as of early 2022, the core maintenance team who were directly employed by Shell could be as low as 30 people.

This cutting of core repairs and maintenance jobs and reliance on project-based work means that former workers on both sites are now more exposed to the unstable nature of engineering and construction contracting. The UK-wide nature of large contractors like Bilfinger means that local labour isn't necessarily used for projects and tradespeople often have to travel across the country for work. This has very human consequences, with people often spending large amounts of time away from their families. One interviewee said he could count on one hand the number of his son's birthdays that he'd been able to be present for.

https://www.thecourier.co.uk/fp/news/fife/980563/mossmorran-investment-140-million-upgrade-will-bring-850-temporary-jobs/

[89] Williams, I. (2021, 6th April). Mossmorran: Flaring plans revealed by ExxonMobil and Shell. *Dunfermline Press*. https://www.dunfermlinepress.com/news/19212595.mossmorran-flaring-plans-revealed-exxonmobil-shell/

[90] National Joint Council (2022). *Cat 2 Repair & Maintenance monthly reports: March 2022*. https://www.njceci.org.uk/download/category-2-rm-sites-monthly-report-february-2022/?wpdmdl=1866&refresh=6241a88c671681648470156

[91] McRoberts, A. (2021, 22nd July). Mossmorran: ExxonMobil re-start plant after £140m upgrade. *Central Fife Times*. https://www.centralfifetimes.com/news/19459611.mossmorran-exxonmobil-re-start-plant-140m-upgrade/

[92] ExxonMobil (2022). *Fife Ethylene Plant - Enclosed Ground Flare Project (EGF) Community Update : February 2022*. https://www.exxonmobil.co.uk/-/media/UnitedKingdom/Files/Fife/EGF-Updates/FEP-EGF-Community-Update-SEPAFebruary.pdf

[93] Robertson, A. (2020, 21st October). Shell's plans to slash maintenance staff at Mossmorran would put lives at risk warns union. *The Courier*. https://www.thecourier.co.uk/fp/news/fife/1664911/shells-plans-to-slash-maintenance-staff-at-mossmorran-would-put-lives-at-risk-warns-union/

Interviews with trade unions highlighted that there had been discussion through the National Joint Council for the Engineering Construction Industry (NJC) about hiring local labour for energy plants in Scotland, however this was scuppered by energy procurement companies using cheaper non-UK based contractors.

Training and skills

Interviewees expressed pride in the high level of skill and standards of work found in the engineering and construction workforce at Mossmorran. Two interviewees highlighted that the Mossmorran roles involved in repair and maintenance, such as welding, pipefitting, scaffolding and electrical work, are fairly flexible and applicable to all large construction projects. For example, a pipefitter working at Mossmorran could transition into a role that installs new boiler and heating systems at large institutions (e.g. hospitals).

This is in stark contrast to work in the offshore oil and gas sector, where the mismatch between training standards required by oil and gas industries bodies on the one hand, and renewables on the other, has led to calls for the creation of training passports to facilitate workers moving between industries.[94]

We were unable to ascertain whether the skills of the (smaller) directly employed workforce at Mossmorran, such as chemical engineers or technicians, are as transferable.

Interviewees were also concerned that the Mossmorran workforce's current high level of skills and expertise in engineering and construction could be lost due to inadequate training standards. In particular, they expressed reservations that apprentices were not receiving enough hands-on training and opportunities to plan and carry out work as independently as possible. In the engineering and construction industry, nearly 40% of the workforce is over 50 years old and only 14% is under the age of 29[95], making the passing down of skills between generations of workers even more vital for the sector.

Pay and conditions of work

Employee bargaining over pay and work conditions operates substantially differently for direct employees of Shell and ExxonMobil and for employees of their contractors. According to one trade union interviewee, although wages at petrochemical sites like Mossmorran still carry a premium over other engineering and construction work, this has shrunk considerably over the years.

[94] https://foe.scot/resource/offshore-oil-and-gas-workers-views/

[95] Blumenthal, F. and Fantini, A. (2021). *ECITB Workforce Census 2021: Overview of the Engineering Construction Industry*. Engineering Construction Industry Training Board. https://www.ecitb.org.uk/blog/2021/09/15/ecitb-census-points-to-industry-jobs-recovery-by-2023/

For directly employed staff, ExxonMobil operates a 'Services Information and Consultation Council' for employees on all of its sites to 'engage with management on a broad range of topics,[96] but we were not able to find out the detail of this arrangement. However, engineering and construction contractors at both sites are covered by a robust and transparent agreement over pay and conditions, in the form of the sector-level National Agreement for the Engineering and Construction Industry (NAECI)[97].

In 1997, ExxonMobil agreed to use contractors under a new 'supplementary agreement' that applied the NAECI to maintenance and repair at their plant. Scholars have suggested that this was a way for both the contractors and the petrochemical firms contracting them to gain legitimacy[98]. Although Shell formally utilised the NAECI for large projects at Mossmorran in the 1990s, it has not been applied since[99]. However, according to our interviews, workers in the Shell plant have a site-specific agreement that contains some elements of the NAECI with tweaks such as changes to rest periods.

The history of the NAECI illustrates how union militancy, government action and commercial concerns over attracting skilled workers and maintaining industrial stability lead to an enduring national 'gold standard' on pay and conditions. As one interviewee described, the process had its roots in different workers from a range of trades employed by specialised companies comparing rates of pay and conducting wild cat strikes to equalise them. As a result, NAECI was developed to ensure large capital expenditure projects were not disrupted or slowed down by prolonged negotiations between unions and employers.[100]

Agreements under NAECI are complex and robust, covering all issues surrounding work on a construction site. This includes pay and working conditions across different ways of working, like bonuses associated with different trades, payments covering travel and accommodation, working hours, sick pay, holidays, and dispute resolution. There is also protection of pay during training and times when work is not possible due to poor weather or on-site emergencies[101]. Crucially, the agreement is based on the understanding that contractors employ workers directly, avoiding the spurious 'self-employed'

[96] Exxon Mobil Chemical Ltd full accounts 21 Dec 2021, pg. 7 https://find-and-update.company-information.service.gov.uk/company/00867162/filing-history
[97] NJCECI (n.d.). *National Agreement for the Engineering Construction Industry 2022-2023*. https://www.njceci.org.uk/national-agreement/
[98] Ritson, N.H. et al., *Trade union recognition by MNCs*.
[99] NJCECI (n.d.). *NJC Completed Category 1 Projects Since 1981*. https://www.njceci.org.uk/download/completed-category-1-projects-since-1981/?wpdmdl=155&refresh=6241aa278b9061648470567 [Accessed 17th April 2022]
[100] Ritson, N.H.; Wilson, M.J.; Maclean, G. (2015). Trade union recognition by MNCs: evidence of an underlying rationale in UK petrochemicals. *Labor History*, *56*(4), 499-520. https://doi.org/10.1080/0023656X.2016.1086561
[101] NJC (n.d.). *National Agreement for the Engineering Construction Industry, 2022-2023*. https://www.njceci.org.uk/download/naeci-2022-2023/?wpdmdl=2138&refresh=61bc80080299c1639743496

status that has been common in other sectors such as offshore work[102]. Indeed, offshore contractors and operators have only just reached a sector-wide agreement with Unite, GMB and RMT in 2021[103].

NAECI agreements are administered by the National Joint Council, a body of unions (Unite and GMB) and employers (ECIA, Select and TICA) that rules on disputes and agrees special purpose agreements (SPAs) for each site. Clients and contractors register work as long as it is 'in scope' and for major capital works, a largely client-funded auditor makes sure pay is in keeping with these agreements. In addition, the Engineering Construction Industry Training Board (ECITB) facilitates training on-site for both shop stewards and management[104]. The union infrastructure supporting the NAECI is democratically accountable to its membership, including through the NAECI National Shop Stewards Forum, established in 2003. The forum provides a way for site-level shop stewards to both feed in to the national-level negotiations and organise collectively to maintain their rights[105].

Trade union interviewees expressed confidence that although 'pay-offs' and being employed by different contractors was a feature of fluctuating construction and engineering work at Mossmorran, a combination of the standard set by the NAECI agreement and Transfer of Undertakings (Protection of Employment) regulations (TUPE) meant that pay and conditions at large established plants like Shell and ExxonMobil were well protected. For example, 55 maintenance employees at Exxon were transferred over to Bilfinger under continuing contracts using TUPE in 2019[106].

Interviewees also believed that although firms like Shell and ExxonMobil might switch contractors, they would be unable to find workers or may face industrial action if they switched to contractors not operating under the NAECI.

[102] UK government. HMRC (2013). *Offshore Employment Intermediaries*: *Summary of Responses*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/249786/Summary_of_Responses_Offshore_Employment_Intermediaries.pdf

[103] Unite (2021, 4th February). New collective bargaining structure for North Sea gains support. *Unite the Union*. https://www.unitetheunion.org/news-events/news/2021/february/new-collective-bargaining-structure-for-north-sea-gains-support/

[104] *Frequently Asked Questions* (n.d.). NJCECI. https://www.njceci.org.uk/faq/ [Accessed 17th April 2022]

[105] Clarke, L. and Fitzgerald, I. (2020). The changing nature of labour regulation: the distinctiveness of the National Agreement for the Engineering Construction Industry. *Industrial Relations Journal*, *51*(1-2), 58-74. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1111/irj.12280

[106] Bilfinger to Provide Maintenance at ExxonMobil Fife Ethylene Plant (2019). *Millbank*. https://www.millbank.com/blog/bilfinger-provide-maintenance-exxonmobil-fife-ethylene-plant

Safety issues

Both the Mossmorran NGL and ethylene plants were commissioned in 1985[107] and require regular repair and maintenance work to be operated safely. Both plants are regularly inspected by the Health and Safety Executive (HSE) and SEPA under Control of Major Accident Hazards[108] regulations.

Between 2015-2017, the Health and Safety Executive raised multiple concerns over the failure of Shell to replace a leaky gas seal and Exxon's failure to comply with 11 out of 12 safety recommendations made by the regulator. Shell responded that it had since made substantial investments, as was confirmed by one interviewee.[109]

Since then, despite some alarms raised on under-staffing and a notice served in 2017 over inadequate accommodation for contractors[110], concerns raised with regard to the Shell plant by both HSE[111] and unions[112] have diminished.

The ExxonMobil ethylene plant, on the other hand, has continued to be plagued by HSE notices of a more structural nature.

- In May and June of 2019, HSE served notices that the plant continued to operate with a known ethane leak due to corrosion[113] and failed to put measures in place to inspect and repair

[107] Irish Environmental Protection Agency (2021). *Peer review of SEPA's Regulation of the PPC Permit for the ExxonMobil Chemical Ltd Fife Ethylene Installation*. SEPA. https://www.sepa.org.uk/media/559063/sepa-irish-epa-peer-review.pdf
[108] Control of major accident hazards (COMAH) (n.d.). *SEPA*. https://www.sepa.org.uk/regulations/control-of-major-accident-hazards-comah/ [Accessed 17th April 2022]
[109] Edwards, R. (2018, 8th July). Oil giants under fire for safety failings at Fife plant. *The Herald*. https://www.heraldscotland.com/news/16340335.oil-giants-fire-safety-failings-fife-plant/
[110] Health and Safety Executive (HSE) (n.d.). *Notice 308403744 served against Shell U.K. Limited on 28/09/2017*. https://resources.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=308403744 [Accessed 17th April 2022]
[111] Edwards, R. (2018, 9th July). Shell and ExxonMobil accused of 'putting profit before safety' in Fife. *The Ferret*. https://theferret.scot/shell-exxonmobil-profit-safety-fife/
[112] Robertson, *Shell's plans to slash maintenance staff at Mossmorran would put lives at risk warns union*.
[113] HSE (n.d.) *Notice 309915835 served against ExxonMobil Chemical Limited on 28/05/2019.* https://resources.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=309915835 [Accessed 17th April 2022]

potential leaks underneath damaged insulation[114] [115]. HSE sought prosecution of ExxonMobil in May 2021 over hydrocarbon leaks from pipes[116].

- In July 2019, HSE issued notices over a lack of measures to reduce the risk of firebox explosions in the furnaces at the ethylene plant[117].
- Two explosions in two separate incidents occurred in August 2019, one of which reportedly had a blast radius of over 20m[118] and the plant was shut down for five months[119]. An HSE investigation into the explosions was launched in October 2019[120], which appears to be ongoing.
- In the same month the plant reopened, around 100 repair and maintenance contractors staged a walk-out, with a GMB union spokesman citing ongoing safety concerns[121]. Work subsequently resumed, with reassurances given that conditions would be brought up to NAECI standards.
- A HSE notice served in July 2020 over systems for inspecting potentially corroded pipework was only complied with in October 2021[122].

ExxonMobil has recently invested £140m in an improvement programme for the ethylene plant, including installing noise-reducing flare tips and a ground flare[123], but the extent to which this will address infrastructural issues is unclear.

[114] HSE (n.d.). *Notice 309947168 served against ExxonMobil Chemical Limited on 27/06/2019*. https://resources.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=309947168 [Accessed 17th April 2022]
[115] HSE(n.d.) *Notice 309947111 served against ExxonMobil Chemical Limited on 27/06/2019.* https://resources.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=309947111 [Accessed 17th April 2022]
[116] Brown, A. (2021, 24th May). Mossmorran: Safety watchdog seeks chemical plant prosecution. *BBC*. https://www.bbc.co.uk/news/uk-scotland-edinburgh-east-fife-57232845
[117] HSE (n.d.). *Notice 310065815 served against ExxonMobil Chemical Limited on 04/07/2019*. https://resources.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=310065815
[118] Smith, C. (2019, 12th October). Probe launched into two 'explosions' at Fife chemical plant. *The Courier*. https://www.thecourier.co.uk/fp/news/fife/997425/probe-launched-into-two-explosions-at-fife-chemical-plant/
[119] Warrender, C. (2020, 21st February). ExxonMobil restarts normal production at Mossmorran plant. *The Courier*. https://www.thecourier.co.uk/fp/news/fife/1156744/exxonmobil-restarts-normal-production-at-mossmorran-plant/
[120] Brown, A. (2019, 11th October). Mossmorran: Probe into boiler explosions at ExxonMobil plant. *BBC*. https://www.bbc.co.uk/news/uk-scotland-edinburgh-east-fife-50019712
[121] PA News Agency (2020, 19th February). Mossmorran chemical plant workers walk out after 'intense flaring'. *Darlington and Stockton Times*. https://www.darlingtonandstocktontimes.co.uk/news/national/18246720.mossmorran-chemical-plant-workers-walk-intense-flaring/
[122] HSE (n.d.). *Notice 310542304 served against ExxonMobil Chemical Limited on 18/03/2020*. https://resources.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=310542304 [Accessed 17th April 2022]
[123] Clifford, F. (2021, 27th April). Mossmorran's new boss 'sorry for years of unplanned flaring'. *STV News*. https://news.stv.tv/east-central/mossmorrans-new-boss-sorry-for-years-of-unplanned-flaring

The history of HSE action related to Mossmorran appears to suggest a disparity in the level of investment between the NGL and ethylene plants and the implied length of time each can continue to run safely. However, it is important to note that it is not possible to confirm this from publicly available information.

Increased transparency over the condition of both plants and planned investment is crucial to understand the future of the site and what is needed to guarantee safe working conditions.

Challenges for a just transition at Mossmorran

All trade union interviewees indicated there is a lack of trust amongst the workforce in the promise of 'green jobs' made by governments and employers.

Two interviewees mentioned the case of BiFab, a fabrication yard operator that went into administration in 2020 despite receiving government support to keep it open, largely due to not being able to secure contracts related to large Scottish offshore wind projects[124]. The situation prompted the chair of the Just Transmission Commission to write a letter to Scottish cabinet secretaries[125] urging them to address the social and economic damage at BiFab and prevent similar situations from arising in the future. Interviewees expressed frustration that although the BiFab yard has since won some work to produce eight wind turbine jackets, the bulk of components for Scottish wind farms are still being imported from as far afield as Indonesia[126].

Despite promises that new green infrastructure would create quality construction jobs, workers at Mossmorran are aware that engineering and construction contractors in new sectors touted as 'green', like Energy from Waste plants, have repeatedly bypassed industry job quality standards:

- Contractor Hitachi Zosen Inova (HZI) is trying to avoid applying the NAECI agreement to the construction of a waste-to-energy plant in Skelton Grange in Leeds in 2022[127].

[124] Walker, P.A. (2021, 22nd January). Scottish Parliament publishes BiFab report, raising serious concerns. *Insider*. https://www.insider.co.uk/news/scottish-parliament-publishes-bifab-report-23366802
[125] Skea, J. (2020). *Government support for the renewable supply chain: letter to Ministers from Professor Jim Skea*. Energy and Climate Change Directorate. https://www.webarchive.org.uk/wayback/archive/20201103132424/http://www.gov.scot/publications/government-support-for-the-renewable-supply-chain-letter-to-ministers-from-professor-jim-skea/
[126] Scottish secretary: UK should be 'better' at producing turbines (2020,12th February). *BBC*. https://www.bbc.co.uk/news/uk-scotland-scotland-politics-51474725
[127] Construction unions fight for correct pay at energy-to-waste plant (2022). *GMB*. https://www.gmb.org.uk/news/construction-unions-fight-correct-pay-energy-waste-plant

- A Rotherham waste plant being built by Danish contractor Babcock & Wilcox Vølund subcontracted work to Croatian contractor Duro Dakovic, who paid Croatian workers £7.20 an hour compared to NAECI rates of £16.97 an hour[128].
- Unite called on the Scottish Government to investigate allegations that sub-contractors were ignoring the NAECI national agreement and excluding local workers from accessing 250 skilled jobs at the Oxwellmains facility in Dunbar.[129]
- Workers at a waste management plant in Glasgow took industrial action in April 2016 over a subcontractor paying some construction workers up to £5 an hour less than workers under NAECI rates[130]. The subcontractor was later implicated in a lock out of 60 workers[131].

These examples underscore why unionised construction workers may be concerned about the prospect of industrial transition, where existing experiences of green industries involve employers undermining established terms.

Interviewees also warned that implementation of the Fair Work criteria used in public procurement in Scotland can be limited to a 'tick box' approval of the Real Living Wage - which in practice may be used to bring standards in pay down rather than up. In 2022, the Real Living Wage stood at £9.90 per hour,[132] compared to NAECI rates of up to £19.42 depending on the level of a worker's skill[133]. In order to protect conditions for construction and engineering workers, procurement criteria should prioritise collective bargaining agreements, in addition to the Real Living Wage threshold.

Manufacturing lay-offs during the Covid-19 pandemic has also eroded trust and confidence amongst Mossmorran workers that the climate transition will be well-managed.

One interviewee pointed to the cuts at the Inchinnan Rolls Royce Aerospace factory, which resulted in the loss of 700 highly-skilled jobs. Unite commissioned a survey of 172 of the Rolls Royce workers that were made redundant and found that 82% of respondents reported a significant drop in income, with

[128] Unions challenge migrant labour exploitation (2017, 11th April). *The Construction Index*. https://www.theconstructionindex.co.uk/news/view/unions-challenge-migrant-labour-exploitation
[129] Union urges minister to investigate employment claims (2015, 13th August). *Construction News*. https://www.constructionnews.co.uk/news/financial-news/union-urges-minister-to-investigate-employment-claims-13-08-2015/
[130] Simpson, J. (2016, 25th April). Workers strike at Interserve EfW plant. *Construction News*. https://www.constructionnews.co.uk/archive/workers-strike-at-interserve-efw-plant-25-04-2016/
[131] Unite union to meet waste firm management over lockout (2016, 9th December). *BBC*. https://www.bbc.co.uk/news/uk-scotland-scotland-business-38267392
[132] Living Wage Scotland (n.d.). https://scottishlivingwage.org/ [Accessed 17th April 2022]
[133] NJCECI (n.d.). *National Agreement for the Engineering Construction Industry 2022-2023*.

24% experiencing a reduction of £20,000 or more and 28% reporting no current income at all. Only 12% reported an equivalent or increased use of their skills since being made redundant[134].

The prospect of a Just Transition at Mossmorran

Lessons for Mossmorran from international experiences

The term 'Just Transition' was first used in the 1990s by organisers in the US labour movement, to refer to protecting the livelihoods and rights of workers whose jobs are displaced by urgent environmental protections. In turn, this argument had its conceptual origins in trade unionists using the post-World War II G.I. Bill of Rights, which guaranteed a living wage and funded training for veterans, as an example of how to transition away from an arms-race fuelled Cold War economy.

As international commitments to tackle climate change became more serious, reference to the resulting social and employment impacts appeared in the COP15 negotiating texts at Copenhagen in 2009 and the preamble to the Paris Agreement in 2015[135]. In 2015 the International Labour Organisation (ILO), a UN agency mandated to advance social and economic justice by setting international labour standards, published guidelines for how to formulate policies that would enable a just transition to environmentally sustainable policies.

The ILO guidelines on just transition call for sustainable social security to protect displaced workers, investment to stimulate decent sustainable jobs along the supply chain and the protection of fundamental rights at work such as health and safety and the right to organise. Substantial attention was also given to the principle of 'social dialogue' between unions, government, and industry, with guidelines pointing out how this could support effective training programmes, technology transfer and the sharing of best practice. The guidelines envision a robust role for government. This includes creating a formal mechanism for social dialogue, leveraging public procurement to enable high quality sustainable work, and using job guarantees and public employment to match workers to new demand. Fundamental to this is planning for transition far in advance and compiling detailed information on the affected work forces[136].

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[134]New research finds vast majority of Rolls Royce workers at Inchinnan have not found re-employment as Unite demands government support (2021). *Unite the Union*. https://www.unitetheunion.org/news-events/news/2021/september/new-research-finds-vast-majority-of-rolls-royce-workers-at-inchinnan-have-not-found-re-employment-as-unite-demands-government-support/

[135] Labour Network for Sustainability, Strategic Practice (2016). *Just Transition - Just What is it?: An Analysis of Language, Strategies, and Projects*. Labour Network for Sustainability. https://www.labor4sustainability.org/uncategorized/just-transition-just-what-is-it/

[136] International Labour Organization (2015). *Guidelines for a just transition towards environmentally sustainable economies and societies for all.* https://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_432859.pdf

Various arguments have been made for Just Transition to incorporate procedural justice and restorative justice alongside distributional justice. Darren McCauley and Raphael Heffron (2018) describe procedural justice as designing decision-making processes in a just manner, that leads to better access to information that informs plans, more buy-in from all the affected stakeholders and more effective addressing of a deeper and wider range of distributional issues.[137] Restorative justice - i.e. repairing harms done - in Mossmorran's context may include considering how transition planning can help repair the devastation to communities wrought by coal mine closures in Fife.[138]

Important lessons can be drawn for a Just Transition at Mossmorran and in Fife from the move away from coal in Canada, Denmark, and Germany. The Task Force on Just Transition for Canadian Coal Power Workers and Communities led to the Canadian government allocating $26 million for worker transition centres and a $113 million infrastructure fund in the 2019 budget, to support the transition away from coal power[139]. In Denmark, social dialogue created to coordinate industrial policy is credited with not only transitioning away from coal but delivering a strong wind power industry that in 2015 employed 31,251 people and delivered 42% of Denmark's electricity[140].

The closure of underground mines in the Saarland and Ruhr valleys in Germany was managed with wage-safeguarding for those close to retirement age and vocational training centres that achieved a placement rate of 80%[141]. Jobs were preserved not only by a phased shut down of mines enabling the redeployment of workers, but also investment in universities and technical colleges in the region, redeployment of workers into the labour-intensive ecological rehabilitation of mining sites, and repurposing of existing expertise in manufacturing and logistics towards renewable energy[142].

The strength of tripartite (employer - government - unions) relations in German and Scandinavian industrial models is credited with these successes. It is characterised by 'highly-centralised collective bargaining system with large employers' associations, regular participation of unions in political and

[137] McCauley, D. and Heffron, R.(2018). Just transition: Integrating climate, energy, and environmental justice. *Energy Policy, 119, 1–7.* doi:10.1016/j.enpol.2018.04.014
[138] Scott, J.; Thomson, K.; Canavan, D.; Murdoch, J. (2020). *INDEPENDENT REVIEW – Impact on communities of the policing of the miners' strike 1984-85*. Cabinet Secretary for Justice and Veterans. https://www.gov.scot/publications/independent-review-impact-communities-policing-miners-strike-1984-85/pages/9/
[139] Canada: National Task Force on Just Transition for Coal Power Workers and Communities (2021). *World Resources Institute*. https://www.wri.org/update/canada-national-task-force-just-transition-coal-power-workers-and-communities
[140] Rosemburg, A. (2017). *Strengthening Just Transition Policies in International Climate Governance*. The Stanley Foundation. https://stanleycenter.org/publications/pab/RosembergPABStrengtheningJustTransition417.pdf
[141] Rosemburg, *Strengthening Just Transition Policies in International Climate Governance*.
[142] Sheldon, P.; Junankar, R.; De Rosa, A. (2018). *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities*. CFMMEU. https://www.ituc-csi.org/IMG/pdf/ruhrorappalachia_report_final.pdf

economic decision-making, state support for union activities, cooperation between unions and employers in pursuit of mutual interests, and a high degree of rank and file participation in organising'[143]. Of key importance in Germany was the willingness to strike and protest on the part of the negotiating union IG BCE and a dual approach of national collective and site-specific bargaining.

It is important to note, however, that there are some criticisms of this model, including by environmental groups for excluding their influence, and some actors critique it as discouraging more militant action on the part of workers[144]. There is also criticism that whilst early retirement and generous pensions have safeguarded existing hard coal miners from hardship, the lack of focus on smaller companies and in some cases active blocking of new uses of land by larger companies means there is an entrenched disparity in opportunity for younger workers in the northern Ruhr area[145]. Some critics argue that support for affected workers has largely benefited those with more stable employment conditions, with more precarious workers left out[146].

Climate resilience scholars argue that transition process design must involve questions of who has a right to be involved and who has a responsibility to contribute because of particular capabilities or resources. Simply including civil society actors may not 'trickle down' to the most vulnerable affected people or address power imbalances between them and those with control over policy[147]. Transition planning needs to find a way to genuinely involve those most affected.

Possibilities and limitations from Scottish policy for Mossmorran

In Scotland both a commitment to reaching net zero greenhouse gas emissions by 2045 and achieving this via a just transition is enshrined in law[148]. This national level commitment was supported via the establishment in 2019 of a Just Transition Commission to advise the Scottish Government on how to do

[143] Abraham, J. (2017). Just Transitions for the Miners: Labor Environmentalism in the Ruhr and Appalachian Coalfields. *New Political Science, 39(*2*),* 218–240*.* https://doi.org/10.1080/07393148.2017.1301313
[144] Abraham, *Just Transitions for the Miners*.
[145] Dahlbeck, E. and Gärtner, S. (2019). *Just transition for regions and generations: Experiences from structural change in the Ruhr area*. WWF Germany. https://regionsbeyondcoal.eu/wp-content/uploads/2019/02/2019_01_15_Just-Transition-for-regions-and-generations.pdf
[146] Pinker, A. (2020). *Just Transitions: a comparative perspective*. Just Transition Commission. https://www.webarchive.org.uk/wayback/archive/20200908110713/http://www.gov.scot/publications/transitions-comparative-perspective/pages/4/
[147] Orleans Reed, S., Friend, R., Toan, V. C., Thinphanga, P., Sutarto, R., & Singh, D. (2013). "Shared learning" for building urban climate resilience–experiences from Asian cities. *Environment and Urbanization*, *25*(2), 393-412. https://doi.org/10.1177/0956247813501136
[148] Scottish Government. Energy and Climate Change Directorate (n.d.). *Reducing greenhouse gas emissions*. https://www.gov.scot/policies/climate-change/reducing-emissions/

this[149], made up of academics, industry, environmental groups, and national level union officers[150]. An initial report highlighting just transition principles identified the need for longer term strategies, addressing distributional and procedural justice and using transition plans as an opportunity to 'redress systemic injustices'[151]. The report also made clear that planning for transition requires time and resources and observed that regional planning around the world was more advanced than in Scotland[152].

Following additional research, including 'town hall' meetings and site visits, the first commission published their finalised advice in 2020[153]. As well as generally urging participatory planning for transition start as soon as possible, this recognised that jobs were already being lost in the oil and gas sector and recommended swift action to support workers to transition into jobs likely to be available in the short-to-medium term such as decommissioning[154]. The Scottish Government responded to this by publishing a National Just Transition Planning Framework[155], committing to developing sectoral Transition Plans and establishing a second Just Transition Commission to work with them, monitor and hold them to account on this[156].

Current policy faces two crucial questions:

1) Who is involved in decision making and how is power balanced among them? The planning framework recognises the importance of 'placing those most likely to be negatively impacted by the transition at the heart of [the] process'[157] and commits to ensuring plans are co-designed and co-delivered. But it does not detail how this will happen beyond gathering evidence directly

[149] *Just Transition Commission* (2021). Scottish Government. https://www.webarchive.org.uk/wayback/archive/20210111123819/https://www.gov.scot/groups/just-transition-commission/
[150] *Just Transition Commission: member profiles* (2019). Energy and Climate Change Directorate. https://www.webarchive.org.uk/wayback/archive/20210111130820/https://www.gov.scot/publications/just-transition-commission-member-profiles/
[151] Pinker, Just *Transitions: a comparative perspective*.
[152] Pinker, Just *Transitions: a comparative perspective*.
[153] Just Transition Commission (2020). *Just Transition Commission: advice for a green recovery*. Energy and Climate Change Directorate https://www.webarchive.org.uk/wayback/archive/20200730180449/https://www.gov.scot/publications/transition-commission-advice-green-recovery/
[154] Just Transition Commission, *Just Transition Commission: advice for a green recovery*.
[155] *Just Transition - A Fairer, Greener Scotland: Scottish Government response* (2021). Minister for Just Transition, Employment and Fair Work. https://www.gov.scot/publications/transition-fairer-greener-scotland/pages/5/
[156] Just Transition Commission (n.d.). *Overview*. https://www.gov.scot/groups/just-transition-commission/ [Accessed 17th April 2022]
[157] Minister for Just Transition, Employment and Fair Work, *Just Transition - A Fairer, Greener Scotland: Scottish Government response*.

from stakeholders and responding to a similar evidence-gathering process from the Just Transition Commission.

2) How can sufficient investment be secured to develop new industries or future-proof existing ones? The Commission's report recognises the need for public investment for innovation as seed-funding,[158] but so far the levels of public finance for greening industry available in Scotland and elsewhere in the UK are far below what some other European governments have provided.

For comparison, Transition Economics research for the Scottish Trade Union Congress found that a public investment of between £1.1 - £3.75 billion (with private co-investment on a similar scale) would be needed to future-proof some of Scotland's high-carbon industries including hydrogen-based chemical manufacturing at Grangemouth, a new Electric Arc Furnace based steel plant and three bio-refineries. These estimates do not include investment for Mossmorran, but they help demonstrate that future-proofing industry requires a significant scaling-up of government investment.

Lack of worker voice in existing transition plans within the sector

Existing sector initiatives that are likely to directly impact Mossmorran lack worker voice in governance.

While the overall Just Transition Commission has members from a range of backgrounds, the commissioners appointed specifically to develop the transition plan for the energy sector are heavily weighted towards business - three out of the four represent businesses or business-dominated bodies.[159] The sub-group has no union representation specifically covering downstream energy, or community representation.

Other flagship Scottish Government-backed projects for industrial transition lack worker or other civil society representation in governance:

- North East CCUS, an industry-led body, received a start-up grant of £300,000 from the Scottish Government to produce a Net Zero Roadmap for industrial sites and subsequently £800,000 from the UK Industrial Decarbonisation Challenge Fund to finish it[160]. North East CCUS has no membership from unions, community groups or environmental groups[161].
- The £100m Green Jobs Fund delivered through enterprise agencies, £34 million Scottish Industry Energy Transformation Fund seeking match-funding from the private sector to create business

[158] https://www.gov.scot/publications/transition-commission-national-mission-fairer-greener-scotland/pages/5/
[159] *Ensuring a fair journey to net zero* (2021). Scottish Government. https://www.gov.scot/news/ensuring-a-fair-journey-to-net-zero/
[160] *Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update* (2020). Scottish Government. https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/pages/10/
[161] *Partners* (n.d.). NECCUS. https://www.neccus.co.uk/partners/ [Accessed 17th April 2022]

cases ready for investment, and the £26m Low Carbon Manufacturing Challenge Fund are all focused on public-private partnership delivery with no worker representation [162].

The UK-level North Sea Transition Deal between companies and the UK Government has committed to £14-16 billion of investment in new energy technologies by 2030 and the delivery of a business model that enables the deployment of CCUS and hydrogen at scale. The governance of the deal will be chaired by an industry representative of the North Sea Transition Forum (NSTF) and a representative from BEIS[163]. The NSTF claims meetings were attended by 'ministers and officials from both the UK and Scottish governments, trade unions, regulators and senior representatives from the upstream oil and gas industry'[164]. Although the STUC raised the issue of workforce representation on boards in 2015[165], neither the NSTF steering group[166] nor any of the task forces' boards appear to have any union members or other worker representation.

A lack of worker representation in the governance of institutions involved in the deal is reflected in lacklustre commitments to previously voiced concerns over keeping jobs throughout the supply chain in the UK and supporting working conditions. The oil and gas industry made a voluntary commitment of '50% local UK content' across the lifecycle of energy transition projects, including decommissioning, by 2030. This is lower than the widely criticised 60% UK content target for offshore wind, and financial services (i.e. capital borrowed in the UK) can be used towards the local content targets - with negligible local economic benefit. Another voluntary commitment has been made of 30% 'locally sourced technology', however the businesses involved reserve the right to adjust these targets after mapping the UK supply chain. The lack of clear commitments to distributional and procedural justice in this important forum is particularly concerning given that Greg Hands, the UK Minister of State for Business Energy and Clean Growth, has described the North Sea Transition Deal as 'the Bible going forward'[167].

[162] Scottish Government, *Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update.*
[163] *The North Sea Transition Deal is progressing well, working across the industry, BEIS and other key stakeholders* (2021). North Sea Transition Authority. https://www.nstauthority.co.uk/media/7915/december-2021-nstd-update-one-pager.pdf
[164] *North Sea Transition Forum & Task Forces* (n.d.). North Sea Transition Authority. https://www.nstauthority.co.uk/about-us/north-sea-transition-forum-task-forces/ [Accessed 31st March 2022]
[165] North Sea Transition Authority (2015, 17th December). *Note of MER UK Forum discussion*. https://www.nstauthority.co.uk/media/1089/mer_uk_forum_meeting_-_december_2015.pdf
[166] *North Sea Transition Steering group* (n.d.). North Sea Transition Authority. https://www.nstauthority.co.uk/about-us/north-sea-transition-forum-task-forces/north-sea-transition-steering-group/ [Accessed 31st March 2022]
[167] North Sea Transition Authority (2021, 29th November). *North Sea Transition Forum (NSTF) Meeting.* https://www.nstauthority.co.uk/media/7914/north-sea-transition-forum29nov2021.pdf

Lessons for Mossmorran from existing transition processes at Grangemouth and Longannet

Looking towards transition initiatives at other industrial sites provides some lessons, including on the importance of formally involving workers, as well as creating mechanisms for community and civil society involvement (such as town hall meetings and joint task forces).

Local MSPs have pointed to the Grangemouth Future Industries board as an example of a process that could be replicated on the Mossmorran site[168]. The Grangemouth Future Industries board is solely comprised of Scottish national and local government bodies, with a key function being to 'strengthen engagement between key businesses and the relevant public sector organisations'[169].

Despite its work plan specifically referencing the scoping of projects that would create jobs in line with a 'Just Transition' and the development of a 'regulatory hub', including questions relating to land use and the environment[170], there are no formal channels for engagement with either unions or community or environmental groups.

A question over community involvement was raised in 2021 and the Scottish Government responded that officials from the board had met with Grangemouth Community Council and would inform them of ways to become involved[171], however, there is no formal process surrounding this. The focus of the Grangemouth board on aligning public and private interests represents a missed opportunity to engage workers in a procedurally just process. This is particularly important given the history of industrial dispute at INEOS, the company controlling the site, including the locking out of workers during a dispute in 2013[172] and an attempted derecognition of the union in 2017[173].

A different approach was taken in the form of the Longannet Task Force. This ran between 2015 and 2018 to help to manage the closing of the last coal power plant in Scotland, also based in Fife, where

[168] https://www.centralfifetimes.com/news/18791256.court-action-stops-talks-mossmorran-just-transition-board/
[169] https://www.gov.scot/publications/grangemouth-future-industry-board-12-month-priorities/
[170] https://www.gov.scot/binaries/content/documents/govscot/publications/factsheet/2021/02/grangemouth-future-industry-board-12-month-priorities/documents/grangemouth-future-industry-board-12-month-priorities/grangemouth-future-industry-board-12-month-priorities/govscot%3Adocument/GFIB%2B-%2B12%2BMonth%2BPriorities.pdf
[171] https://www.parliament.scot/chamber-and-committees/written-questions-and-answers/question?ref=S5W-35870
[172] https://www.theguardian.com/uk-news/2013/oct/16/grangemouth-refinery-closes-dispute-ineos-unite
[173] https://www.heraldscotland.com/news/15270899.grangemouth-owners-ineos-threatened-legal-action-unite-union/

236 people were directly employed and 800 indirectly in supply chain jobs[174]. It was a reactive initiative, largely focused on mitigating the impact of the closure on the workers, businesses and community that was directly affected. It was chaired by the Scottish Business Minister and leader of Fife Council and crucially brought together relevant public sector organisations and businesses with unions and community groups. This led to positive outcomes for workers, with 99% of the staff and contractors who accessed training support finding work elsewhere and 50 contractors working on the demolition of the station[175]. It is important to note, however, these jobs were largely at the Grangemouth refinery[176], reflecting the lack of an environmental transition remit in the task force and a view to the longer-term risk to these jobs.

The Longannet Task Force developed an Economic Recovery Plan that addressed development in the region more broadly and additional funds of £2.7 million were made available to Fife Council, some of which went to a skills and enterprise hub established by the Coalfields Regeneration Trust in Kincardine. Despite this, many residents in the wider community, especially in the smaller towns such as Kincardine and villages, felt that they had not been protected from economic decline triggered by the plant closing[177].

The delivery of the Longannet Economic Recovery Plan passed into the hands of the business-lead Fife Economy Partnership, with the current focus being largely on the former power station site being used to manufacture trains by Spanish company Talgo. Plans for a factory that the firm claimed could create up to 1,000 jobs became substantially more uncertain, however, when they failed to win a contract to build trains for HS2[178]. This shows the risk involved in taking an approach to longer-term economic planning that is focused on attracting a single large investment dependent on outside actors.

Involving the affected community can generate ideas that could have more of an impact on a shorter timeframe or provide useful 'Plan Bs' if private or public investment does not materialise. In Kincardine, the Coalfields Regeneration Trust worked in partnership with local community groups to produce the Coalfields Longannet Initiative, which highlighted how improving public transport, accessible training facilities and funding for small and medium businesses could boost the local economy. The initiative also

[174] https://www.gov.scot/binaries/content/documents/govscot/publications/minutes/2019/05/just-transition-commission-meeting-papers-april-2019/documents/just-transition-commission-meeting-2-longannet-taskforce-paper-2.2/just-transition-commission-meeting-2-longannet-taskforce-paper-2.2/govscot%3Adocument/Just%2BTransition%2BCommission%2B-%2BMeeting%2B2%2B-%2BLongannet%2BTask%2BForce%2Bpaper%2B-%2Bpaper%2B2_2.pdf
[175] Ibid
[176] http://files.nesc.ie/nesc_research_series/Research_Series_Paper_15_TTCaseStudies.pdf
[177] https://www.alloaadvertiser.com/news/18297794.longannet-task-force-missed-opportunity-finds-report/
[178] https://www.bbc.co.uk/news/uk-scotland-scotland-business-59775943

highlighted the need for the community to be involved in the discussions over the future of the site and included imaginative alternative suggestions such as a heritage museum and art gallery[179].

The potential for a worker-led transition plan for Mossmorran

Worker-led, site-specific planning can help lead to innovative and sustainable transitions at industrial sites like Mossmorran. There is increased activity within trade unions and amongst shop floor unionised workers to develop decarbonisation and industrial conversion plans that protect jobs going forward.

Inspiration is drawn from the 'Lucas Plan', a detailed alternative corporate plan formulated by the shop stewards committee in response to job cuts at Lucas Aerospace in the 1970s[180]. The plan was put together by a Combine that brought together staff from across Lucas sites, including scientists, engineers, shop stewards and machine operatives. This enabled the Combine to put together a detailed inventory of the equipment and skills available across sites and to crowd-source ideas on how these could be applied to 'socially useful products'. This led to innovative solutions for what the factories could produce that demonstrated extraordinary far-sightedness, for example wind turbines, hybrid engines and novel heat and power systems.[181]

Worker-led planning has multiple advantages:

- 'Competence is collective:'[182] ideas generated by a diverse group of people go beyond what any one specialist can devise.
- Using existing organising structures can facilitate a rapid turnaround when required, as demonstrated by the involvement of union organisers in repurposing an Airbus facility in Wales to make ventilator parts during the first weeks of the Covid-19 pandemic[183].
- Trusting workers to make decisions has been found to lead to higher morale and better process, in a study at an oil refinery.[184]

Worker-led plans in response to job cuts meet with varying levels of resistance from companies. At Rolls Royce in Renfrewshire, Lancashire and Coventry, industrial action led to a deal between unions and Rolls Royce to keep factories open for five to ten years. The deal also guarantees no compulsory redundancies for two years, a training school at the Lancashire site to support the development of green technology and ensures collaboration between management, unions, and government to secure new work across

[179] https://www.coalfields-regen.org.uk/scotland_support/coalfields-longannet-initiative/
[180] https://lucasplan.org.uk/more-about-the-lucas-plan/
[181] https://magazine.scienceforthepeople.org/vol22-2/the-new-lucas-plan/
[182] Boreham, N. (2011). Competence as collective process. In *Vocational learning* (pp. 77-91). Springer, Dordrecht.
[183] https://www.redpepper.org.uk/swords-into-ploughshares/
[184] Boreham, N. (2008). Organisational learning as structuration: an analysis of worker-led organisational enquiries in an oil refinery. In *The learning potential of the workplace* (pp. 225-240). Brill Sense.

the sites[185]. Inspired by the Lucas plan, union convenors designed combine workshops that could draw on workers' skills and ideas across the three factories to produce a 'Green New Deal' for the factories. A trial of these workshops at Coventry generated plans for how the factory could diversify into producing wind turbine gearboxes. Management at the sites, however, have been "pretty lukewarm" and as of late 2021 had yet to respond to the project[186], demonstrating a reluctance to support worker-led initiatives despite an agreement to cooperate. As previously mentioned, 700 jobs were lost at the factory in Renfrewshire[187].

In response to the proposed closure of the GKN drivetrain plant in Erdington, Birmingham, workers put together a 90-page plan to convert production processes to making new components for electric vehicles in a way that would save the company money[188]. The company refused to engage with the plan and decided to move manufacturing to Poland, resulting in the loss of over 500 jobs[189]. This was despite GKN Automotive receiving £8 million pounds in research funding from the UK Government to develop new propulsion systems for electric cars[190]. GKN had previously been subject to a 'hostile takeover' by asset-stripping firm Melrose in 2018, which attracted condemnation from unions and MPs.[191] The GKN experience highlights how worker-led initiatives may need support through levers available to governments (e.g. conditionality of financial support to business; protection from opportunistic capital).

In addition, a trade union interviewee highlighted that these often detailed plans were formulated voluntarily and on shop stewards' own time. The interviewee put forward the possibility of having an officer responsible for coordinating worker-led transition planning across different sites. In Mossmorran's case this could, for example, facilitate coordination across the Shell NGL and Exxon ethylene plants and include workers throughout an expanded 'Scottish Cluster', including St Fergus and Grangemouth.

This would, however, require not only funding but clear, Scottish and UK government-backed pathways for how worker-led planning would influence and shape decision-making in current structures such as the North Sea Transition Forum.

[185] https://www.tuc.org.uk/sites/default/files/2021-11/FINAL%20Net%20Zero-report.pdf
[186] https://www.tuc.org.uk/blogs/pushing-green-new-deal-rolls-royce
[187] https://www.unitetheunion.org/news-events/news/2021/september/new-research-finds-vast-majority-of-rolls-royce-workers-at-inchinnan-have-not-found-re-employment-as-unite-demands-government-support/
[188] https://www.theguardian.com/commentisfree/2021/sep/20/green-jobs-car-factory-strike-industry-offshoring
[189] https://www.birminghammail.co.uk/news/midlands-news/hammer-blow-more-500-jobs-22065826
[190] https://www.gknautomotive.com/en/company/media-centre/news-releases/2019/a-milestone-in-electric-mobility/
[191] https://www.theguardian.com/business/2018/mar/29/whats-the-controversy-over-melroses-hostile-takeover-of-gkn

Supporting factors and barriers to a just transition at Mossmorran

Table 4 provides a summary of the barriers and supporting factors for a just transition at Mossmorran reviewed throughout this section.

Table 4. Barriers and supporting factors for a just transition at Mossmorran

Factors supporting a distributionally and procedurally just process	Barriers to a distributionally and procedurally just process
● Highly skilled and experienced workforce ● Large numbers of contractor jobs at Mossmorran associated with highly transferable construction and maintenance skills ● Positive example of industry and union body that has delivered good pay, conditions, and standards in the form of the NJC for the Construction Engineering Industry and the NAECI ● National forums for positive dialogue and coordination at the national level between unions and environmental groups in the form of the Just Transition Partnership ● A national level Just Transition Commission bringing together industry, national level union officers and civil society that specifically acknowledges the importance of procedural and distributional justice and has a mandate to hold the Scottish Government to account on this ● Existing example of the Coalfields Regeneration Trust working with local communities in Fife on local economic planning ● Scottish Government's multiple public commitments to 'co-design' ● Unions active at Mossmorran have interest in and recent experience attempting to organise worker-led plans to transition specific sites	● Lack of transparency on number and skills mix of staff at Mossmorran ● Lack of a structure to begin advance planning that is specific to Mossmorran and focused on balancing power, rights, and responsibilities amongst stakeholders ● Decisions around management and investment that would affect both sites taken separately by two different companies ● Differences in how core staff and contractors work and organise, including instability of contractor work force at a site level ● Separate working and organising of workers at the Shell NGL plant and the ExxonMobil plant ● Energy Sector Plan commissioners skewed towards business ● Lack of worker or community representation on influential sector- or regional-level boards, including potentially equivalent Grangemouth Future Industries board. ● Failure to date to use licensing and procurement powers to ensure relevant supply chains stay or grow in Scotland ● Private ownership by Exxon and Shell prioritising business over labour and community interests ● Risk of national labour policies undermining sectoral collective bargaining ● Lack of sufficient investment commitments at required scale from

	public or private sector ● Action on the part of the Scottish Government limited by UK Government policy

It is currently unclear how planning for a transition at Mossmorran fits into national or sectoral transition plans. Calls for a just transition board specific to the site in 2020 were deemed not appropriate by Scottish Government because of ongoing investigations and legal action on the part of SEPA [192]. It is imperative that planning - with representation from and accountability to trade unions and people who live and work in Mossmorran - begins as soon as possible.

[192] https://www.parliament.scot/chamber-and-committees/official-report/what-was-said-in-parliament/meeting-of-parliament-29-09-2020?meeting=12853&iob=116207

Conclusion

The future of the Mossmorran ethylene and NGL plants faces a number of challenges, including diminishing availability of natural gas liquids feedstock, reduced demand for ethylene for plastics, and the need to drastically reduce greenhouse gas emissions. The decarbonisation technology options we reviewed - including the use of CCS, blue or green hydrogen, or biological feedstock - all carry risks and trade-offs. These include the continued exposure to the risk of shrinking demand for ethanol, and the specific risks associated with CCS (incl. geological and competition uncertainties, as well as potentially high ongoing costs).

The Mossmorran ethylene and NGL plants provide approximately 250 stable direct jobs, as well as a fluctuating and sometimes far higher number of engineering contractor jobs. Pay, benefits, and safety at these roles is protected by robust agreements, and the engineering contractor workforce has a varied and transferable skills base. These same workers are also well-organised in bargaining structures that could help facilitate detailed planning and cooperation with industry on a site and national level, with unions involved that have recently supported worker-led planning at factories around the country.

A planning process that considers the technological options, alongside options for diversification or industrial conversion at the site, should begin as soon as possible and involve Mossmorran workers and the local community at its heart. The history of collective bargaining in the engineering and construction sector represents a real opportunity in terms of the institutional infrastructure needed to understand and plan for the change that needs to happen now.

There are substantial barriers to overcome. Public investment available for industrial decarbonisation so far is not at the scale that will be required. There is the lack of transparency over the numbers and skill mixes of staff and the state of infrastructure and equipment on site. There is mistrust amongst unions and workers around the promises of quality green jobs not materialising and the lived experiences of undermining local labour conditions. Unfortunately, despite the urgent need for coordination, Mossmorran does not currently feature prominently in sectoral plans, which are dominated by business interests. Sectoral plans are also too narrowly focused on technologies such as CCS and blue hydrogen, without sufficient consideration to diversification options.

Technocratic and top-down decision making will not fix this. It risks missing the opportunity for innovative choices that would be better for workers, the wider community, and longer-term environmental goals.

On a national level, there is an acceptance by the Scottish Government of recommendations by the Just Transition Commission that transition plans must be distributionally and procedurally just and the new Commission has a remit to hold them to account on this. Policy needs to be both considerably more

coherent on a national level and meaningfully involve workers and local communities on the site level. Otherwise, the community connected to the Mossmorran plants risk being left behind once again.