SCHOOL OF PUBLIC POLICY
CENTER FOR GLOBAL SUSTAINABILITY

Maryland Department of the Environment

Emissions Reductions and the Economic Impacts on Maryland's Manufacturing Sector

Aug 23th, 2022

Report Outline

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4. Other Manufacturing Sectors
   a. Emissions reduction strategies and scenarios
   b. Social and economic impacts
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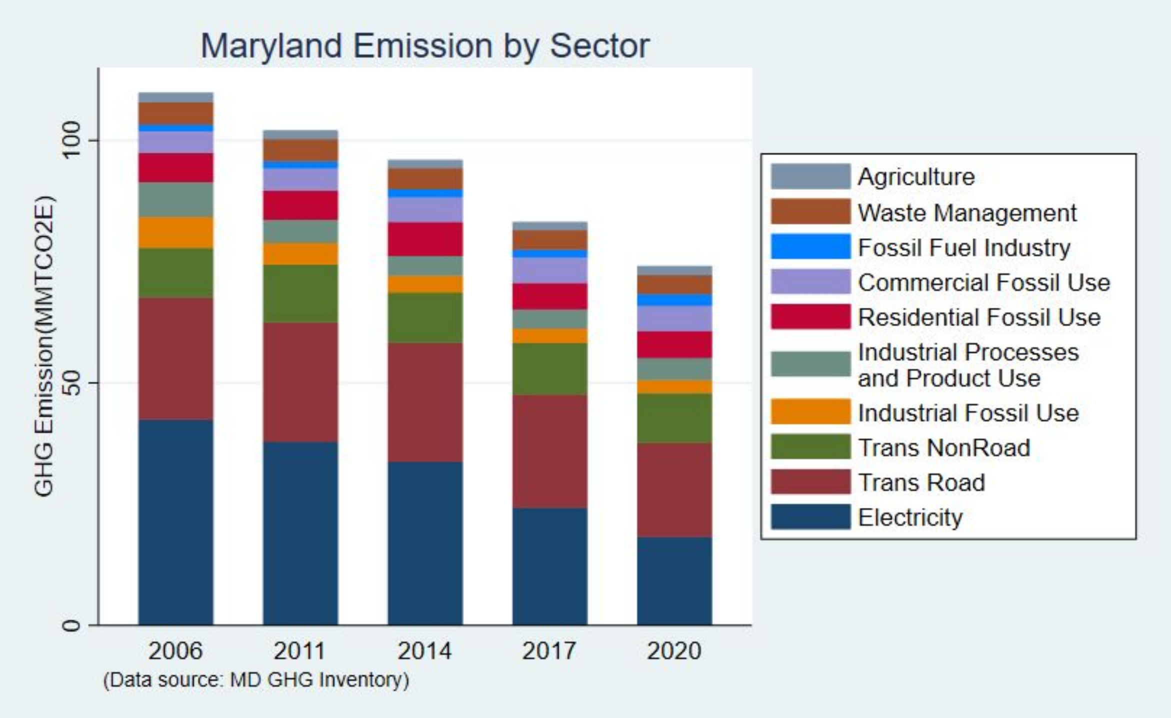
1. Introduction

Maryland's manufacturing sector is a critical element in delivering the State's ambitious climate targets

- The Maryland Climate Solutions Now Act of 2022 sets the most ambitious state climate targets in the U.S. with the goals of a 60% reduction in statewide emissions from 2006 levels by 2031 and achieving net-zero by 2045.
- The manufacturing sector in Maryland presents unique challenges for these goals due to difficult-to-decarbonize process emissions and the potential cost increases and employment impacts to the sector.
- To support enhanced climate actions in Maryland's manufacturing sector, this study assesses different emissions reduction strategies, quantifies the associated social and economic impacts, and discusses policy options to help achieve emissions reductions with lower costs to the sector.

Maryland's total emissions have been declining, mainly from electricity

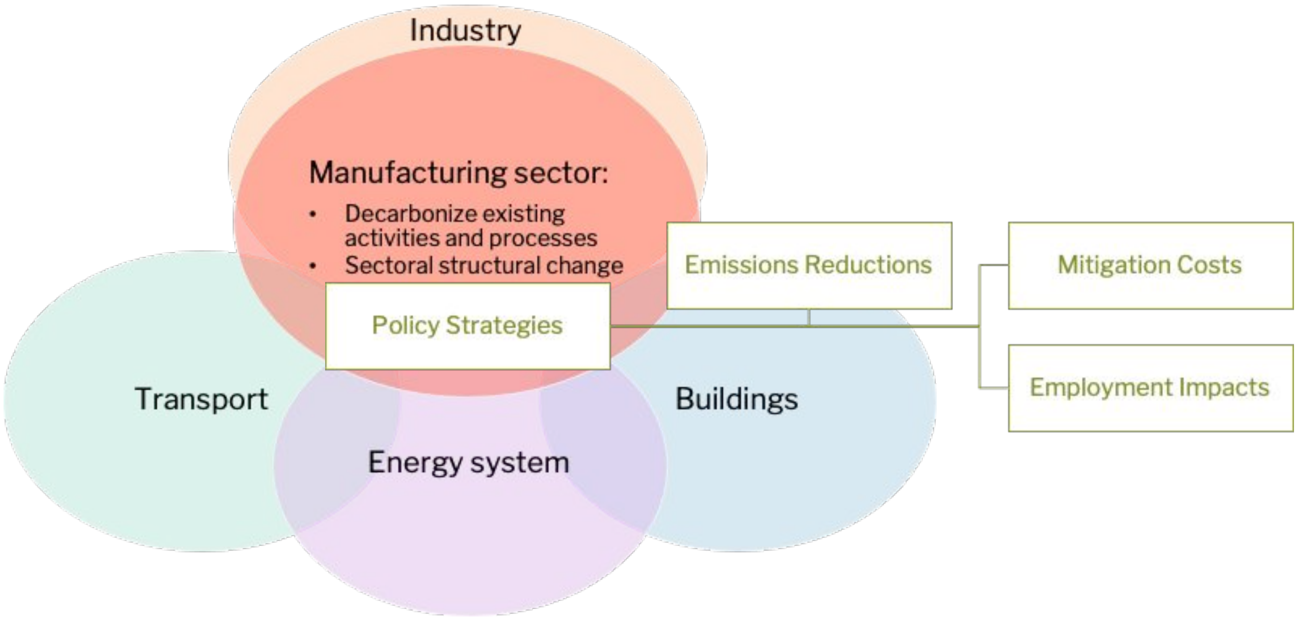


- Gross GHG emissions in MD have declined by 32% from 109 MtCO2e in 2006 to 74 MtCO2e in 2020.
- Main reductions have come from electricity (-24 MtCO2e), road transport (-5.8 MtCO2e), and industrial fossil use (-3.7 MtCO2e).
- Ind. Processes + Ind. Fossil Use together account for about 9.7% of total MD emissions in 2020, slightly declined from 2006.

* some industrial process data for 2020 was supplemented from a 2019 SIT dataset. 2020 numbers are preliminary.

Preliminary Results, Not for Distribution

This study mainly focuses on the manufacturing sector itself, but emissions are also affected by the rest of the system



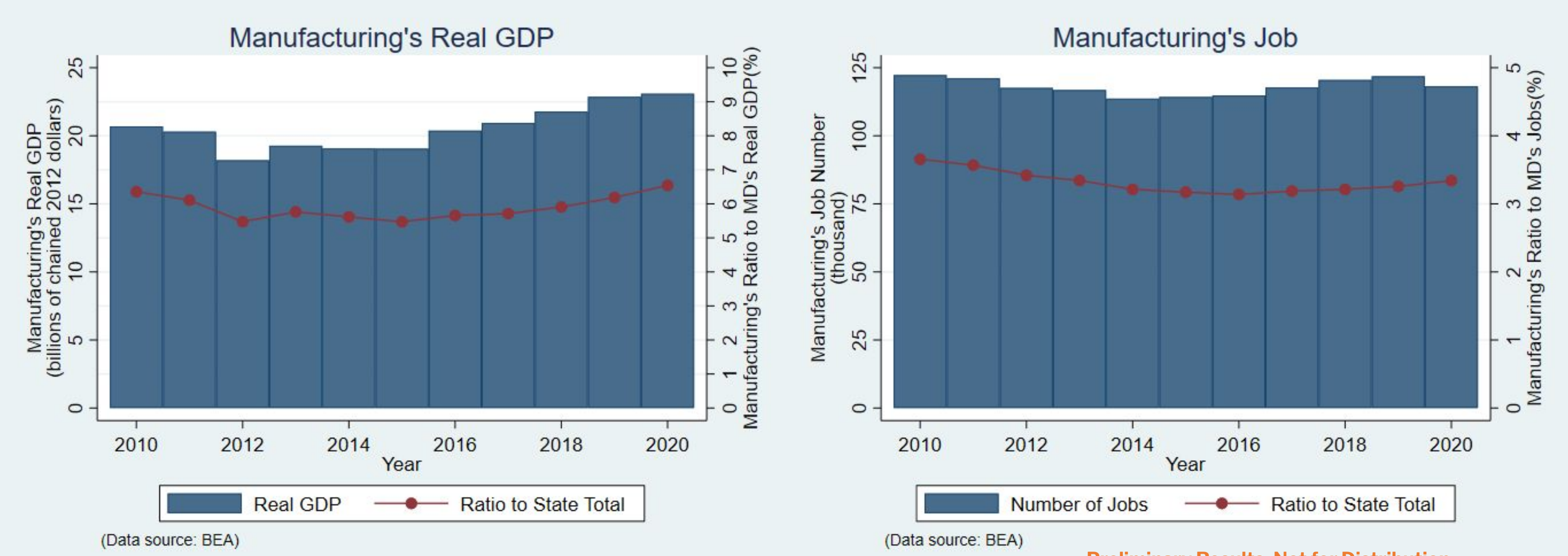
Our research approach and steps:

- Data Collection + Collaborative Policy Platform Development
- Scenario Construction
- Emissions Reductions Analysis
- Costs and Jobs Impact Analysis

2. Manufacturing Sector Overview

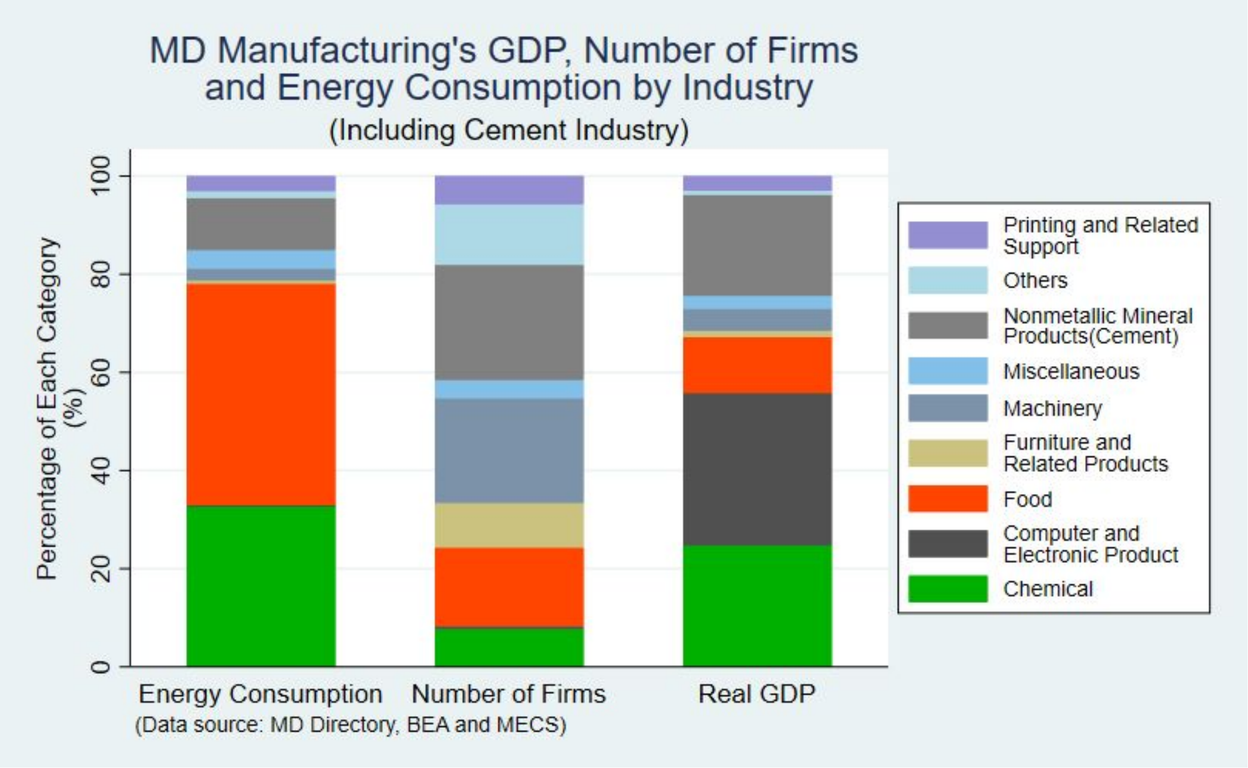
Manufacturing sector contributes to about 7% of State's GDP and over 3% of total employment in 2020

- Both economic output as measured by GDP and manufacturing jobs have remained fairly constant since 2010, with GDP increasing slightly



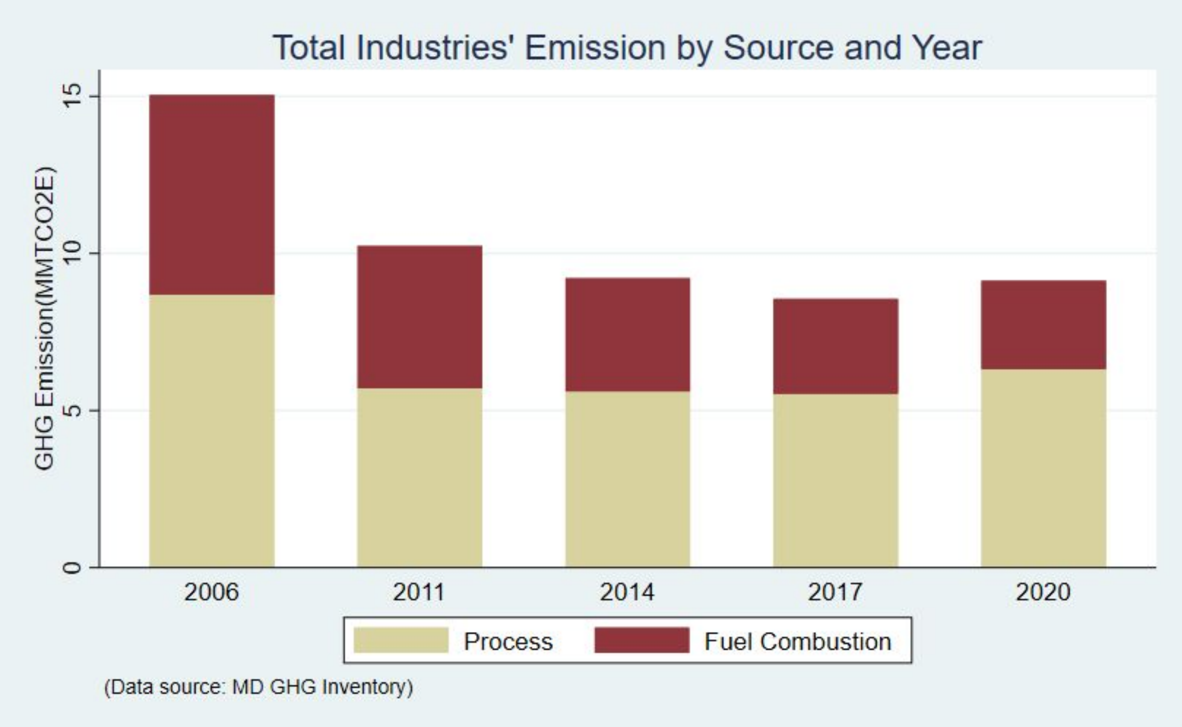
Preliminary Results, Not for Distribution

Food and chemical sectors consume a lot of energy but contribute to a smaller share of GDP



- GDP and energy are not proportional across NAICS categories
- Emissions are also not proportional - e.g. food industry primarily uses natural gas and electricity, which has lower emissions than heavy industry coal use

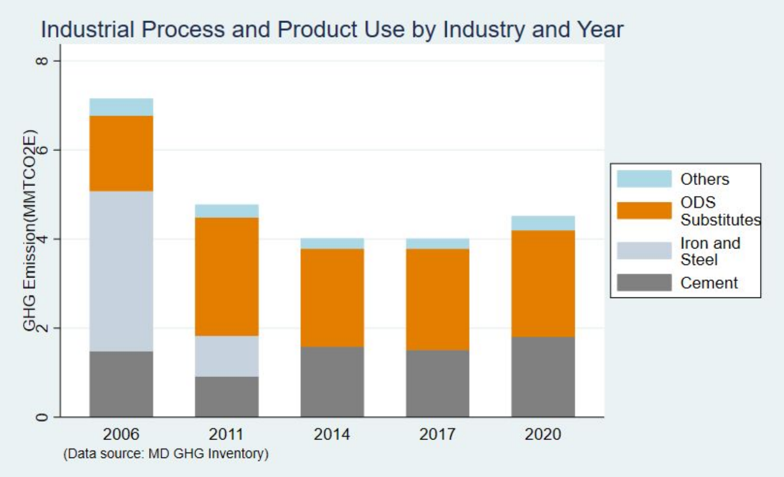
Total industrial emissions decline by over 30% from 2006 to 2020, mainly from fuel combustion



- Emissions from fuel combustion fell significantly (by 29%) after 2011 closure of RG Steel
- Process and product use emissions have been increasing since 2017, accounting for 69% of total industrial emissions in 2020

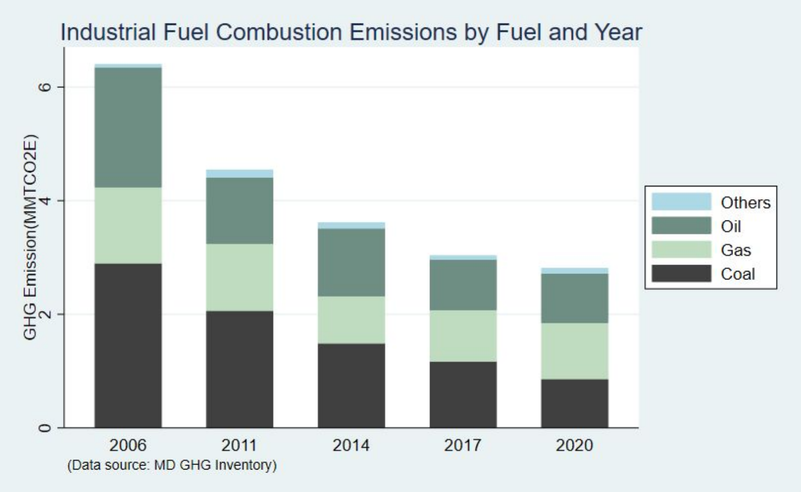
* 2020 numbers are preliminary

Industrial process and product use emissions decline by over 25% from 2006 to 2020, fuel emissions decline by over 55%



- Process emissions from Cement (+21% 2006-2020), and Ozone-Depleting Substance (ODS) Substitutes (+42%) are increasing over time
- Iron and Steel emissions eliminated due to 2011 closure of RG Steel

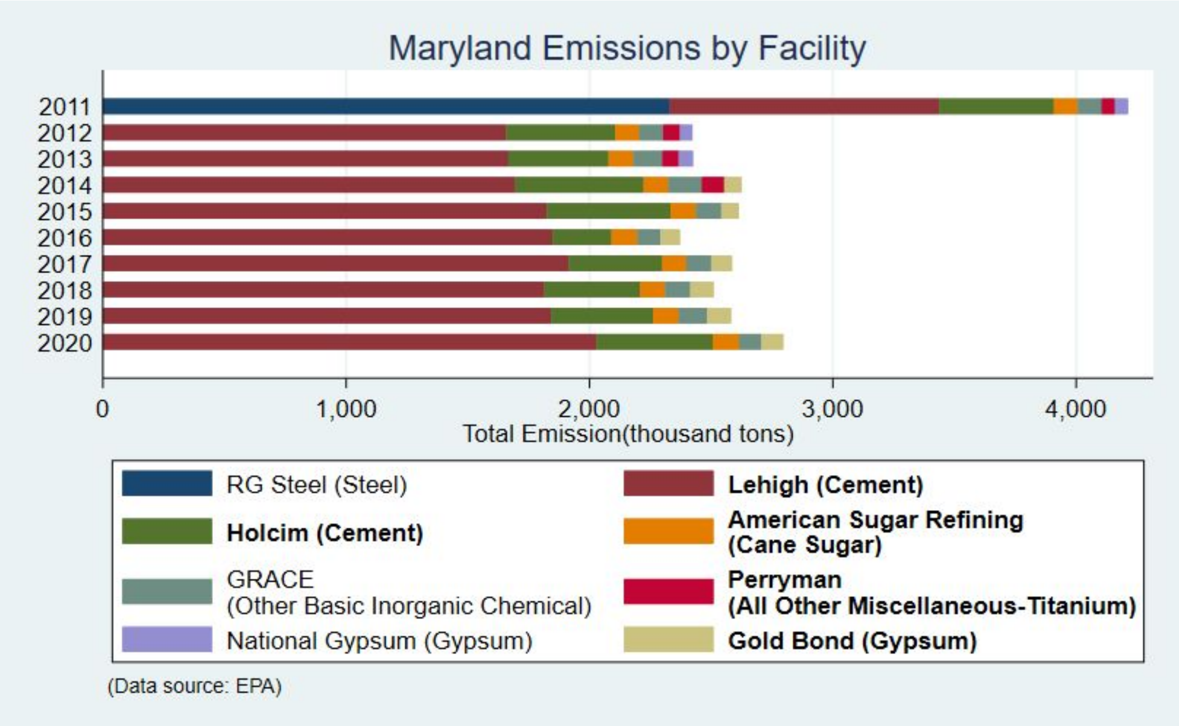
- Emissions from fuel use trending downward over time
- Significant drop after 2011, which could be due to closure of RG Steel
- We see coal-to-gas switching from 2014 to 2020:
  - Coal emissions from 41% to 30% of the total
  - Gas emissions from 23% to 35% of the total



* 2020 numbers are preliminary

Preliminary Results, Not for Distribution

There are five major manufacturing emitters, where cement facilities' emissions dominate and increase over time

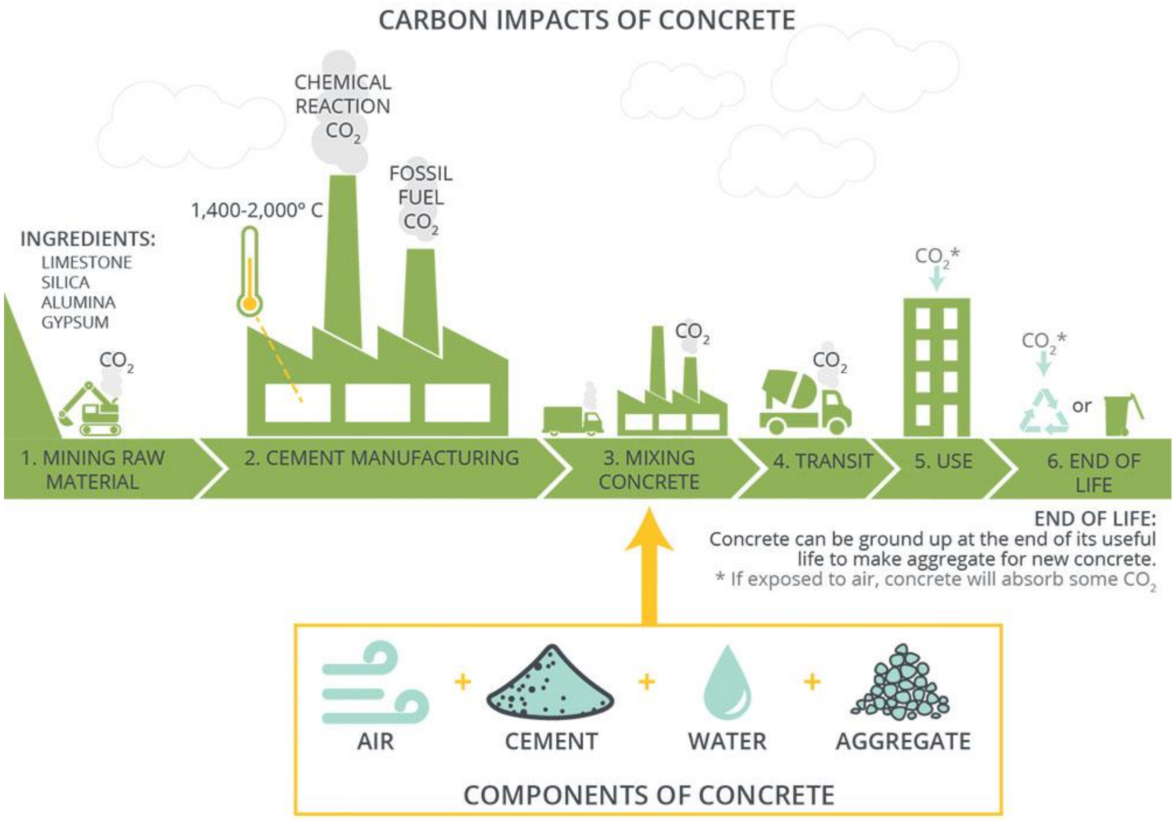


- Lehigh is the highest emitter by far and Lehigh's emissions are increasing over time
- Cement facilities (Lehigh's Union Bridge and Holcim's Hagerstown) emit significantly more than non-cement facilities

Preliminary Results, Not for Distribution

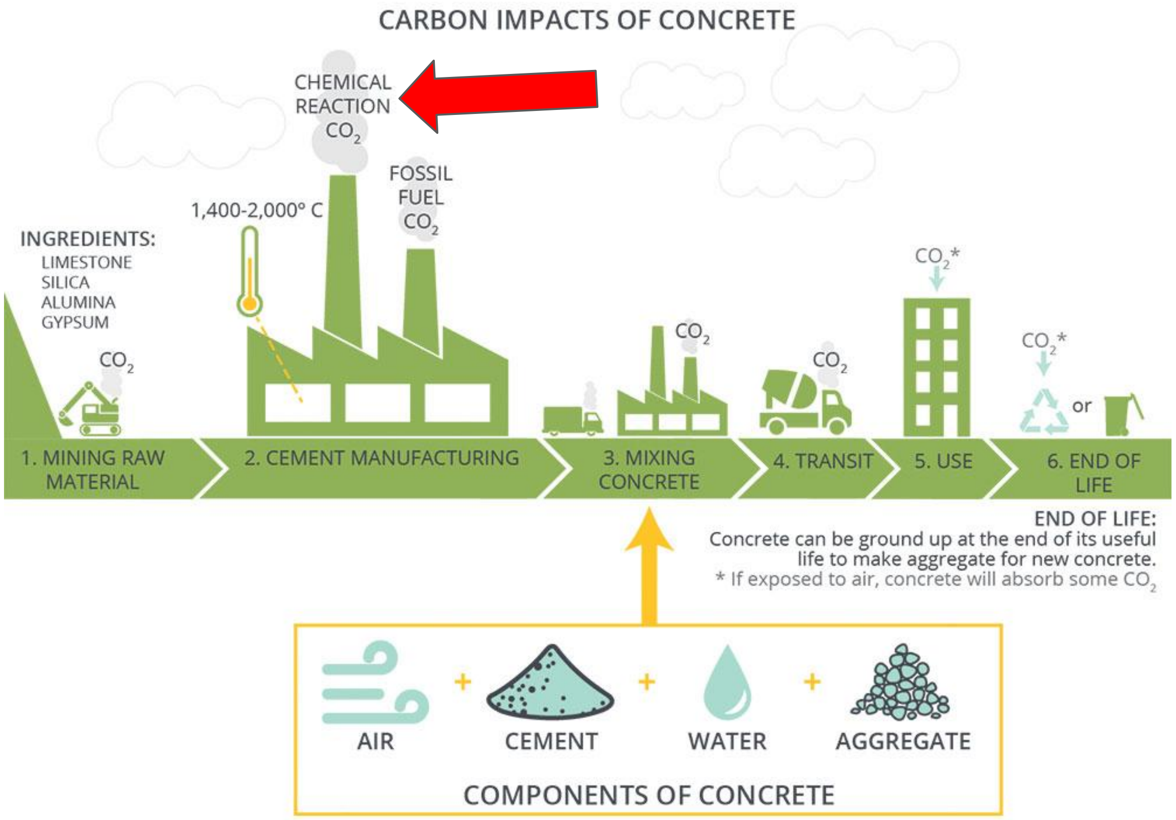
3. Emissions Reduction Strategies and Economic Impacts in Cement

Emissions occur throughout the cement manufacturing process



1. Quarried raw materials are crushed into a fine powder.
2. Raw materials are mixed using either wet or dry method.
3. Mix is fired in a rotary kiln to form clinker.
4. Clinker is ground into powder and mixed with gypsum to create cement.
5. Cement is mixed with water and aggregate to create concrete

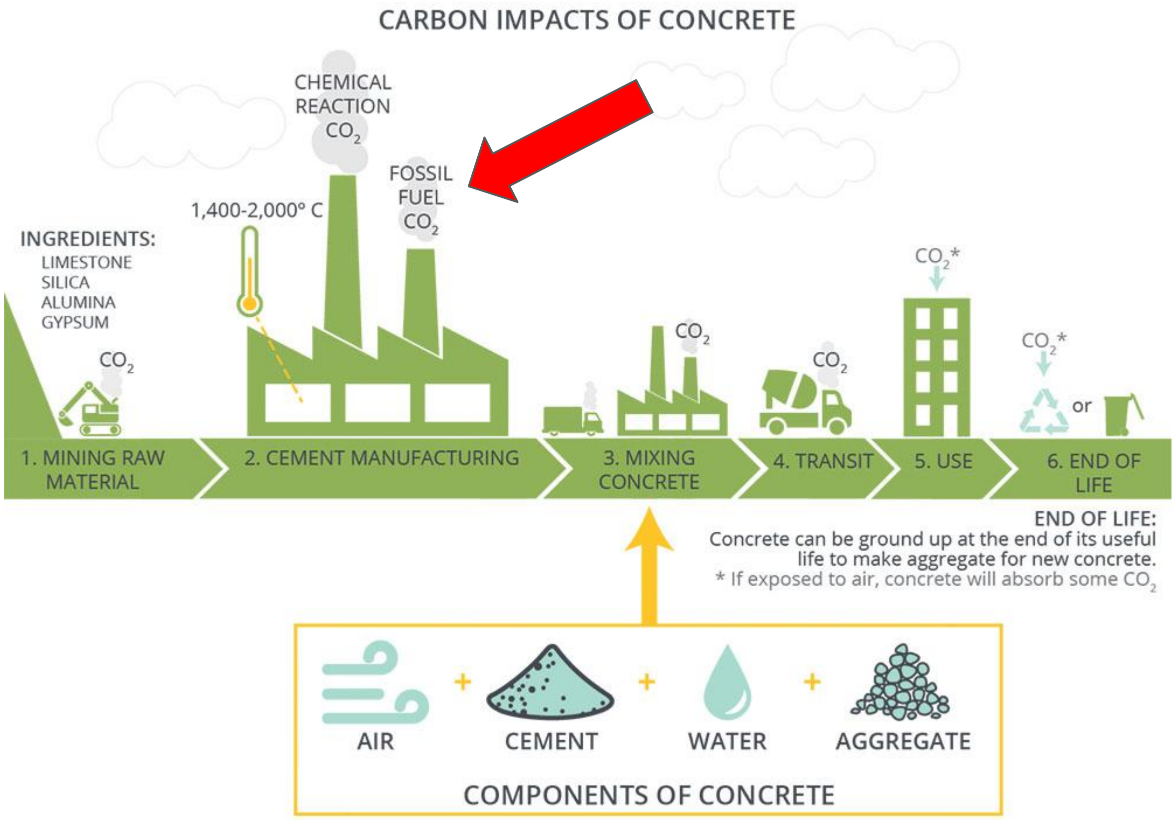
Substituting clinker reduces process emissions



Use of Decarbonated Materials

- Clinker is the active ingredient in cement and is the primary source of process CO_2 emissions generated in cement manufacturing
- Substituting high-carbon clinker for low-carbon alternatives reduces process emissions
- Portland Limestone Cement (PLC) substitutes 5% to 10% more clinker with low-carbon limestone, resulting in an equivalent reduction in CO_2 emissions

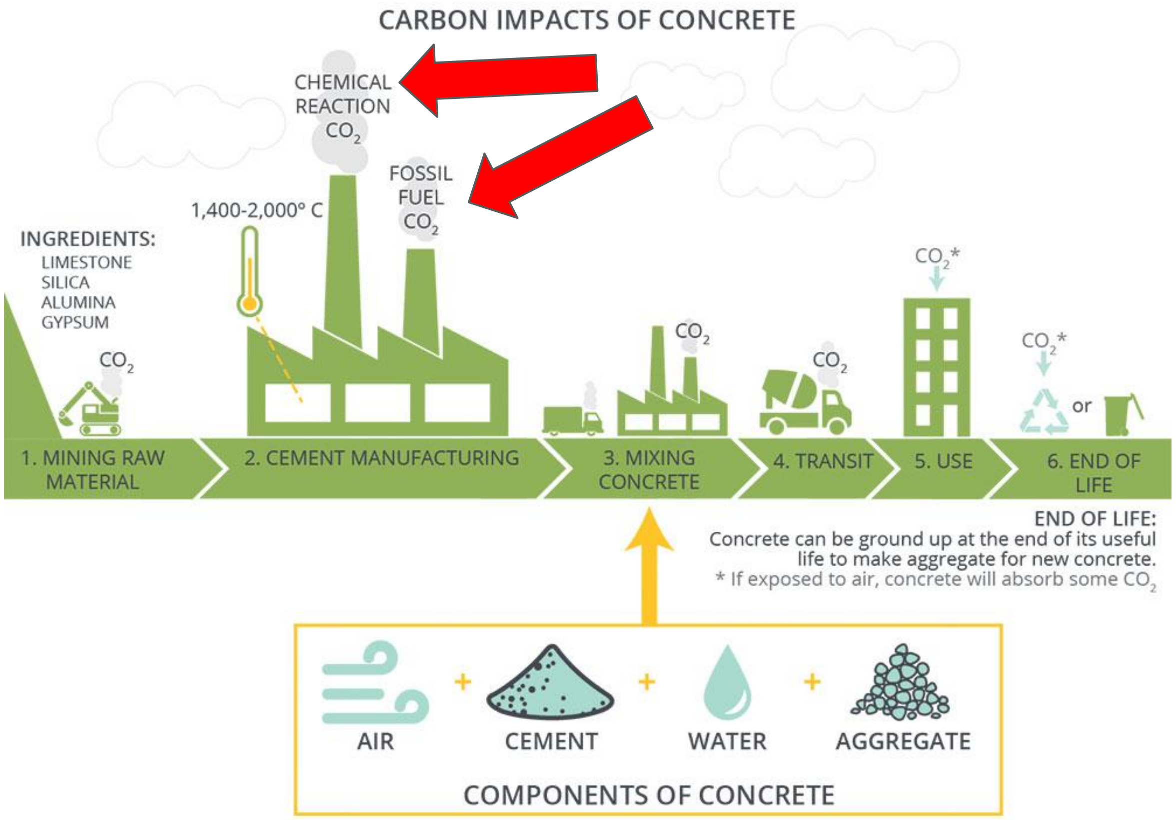
A spectrum of options exists to replace coal as primary fuel



Fuel Switching

- Coal is the primary fuel used in cement manufacturing. Coal is inexpensive but carbon intensive.
- Natural gas (NG) is more expensive than coal and requires pipeline infrastructure, but is less carbon intensive.
- Refuse-derived fuels (RDF) are an inexpensive low-carbon alternative fuel. Use is limited by EPA regulations.
- Hydrogen is most promising alternative fuel for reaching net-zero, but requires further research.

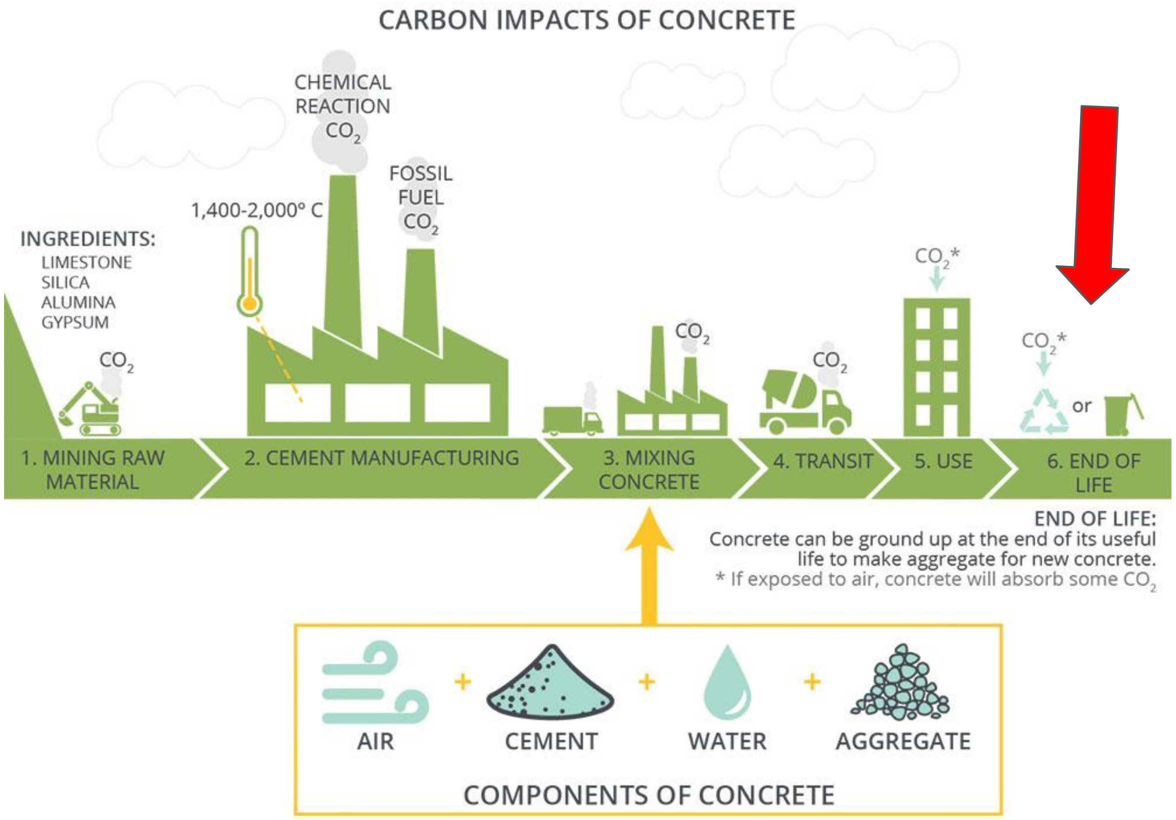
CCUS is essential to reduce unavoidable process emissions



Carbon Capture Utilization and Storage (CCUS)

- Process emissions from cement manufacturing are unavoidable - CCUS is the most promising option to substantially reduce process emissions
- Requires substantial investment and infrastructure
- Likely to be a job creator

Concrete carbonation is a significant carbon sink

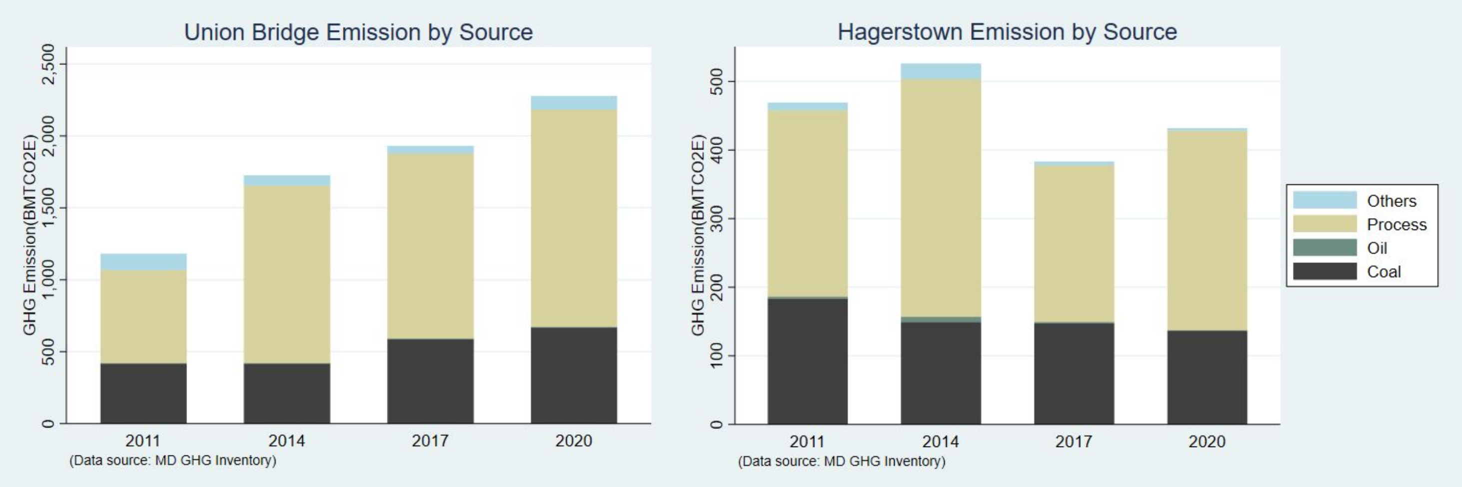


Recognize the unique CO_2 absorption properties of concrete

- Concrete is a mixture of aggregates and cement paste
- Concrete reabsorbs 10% to 30% of its own associated CO_2 emissions over the course of its lifetime through carbonation
- Developing methods to include carbonation in state GHG inventories would more accurately reflect net CO_2 emissions from the cement industry

Process emissions dominate in cement facilities, with Lehigh as the largest emitter and continuing to grow

- Process emissions are the largest source of emissions for both plants
- Union Bridge's emissions have been growing due to increased production
- Hagerstown's emissions reduced after a $96 million plant modernization in 2016
- Emissions intensity are estimated to be ~720 kg CO_2/mt cement at Union Bridge and ~1000 kg CO_2/mt cement at Hagerstown, compared to an industry average of 776 kg CO_2/mt cement in the USA

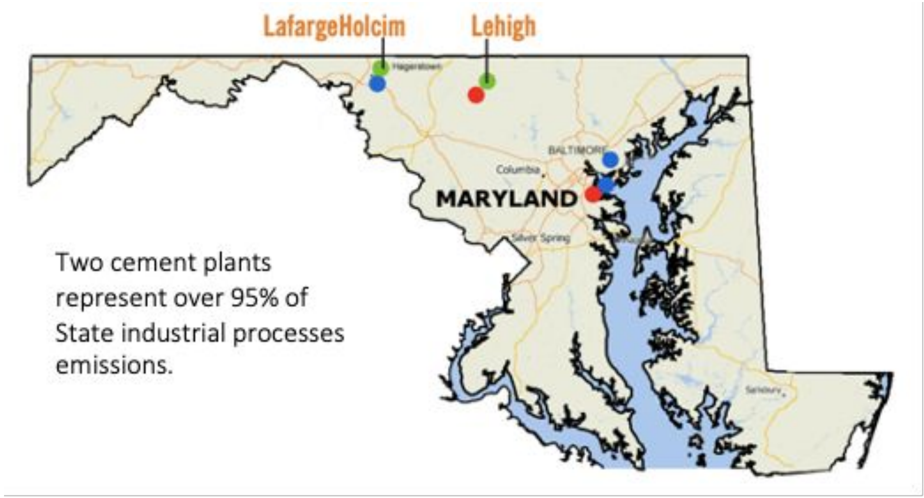


* Significant difference in scale between Lehigh and Holcim charts. Intensity estimates provided by the facilities. 2020 numbers are preliminary.
Source: https://www.concreteconstruction.net/business/producers/holcim-us-hagerstown-cement-plant-completes-96-million-modernization_o

Both cement facilities have taken actions to reduce emissions and have plans to reach net-zero

Lehigh (Union Bridge):

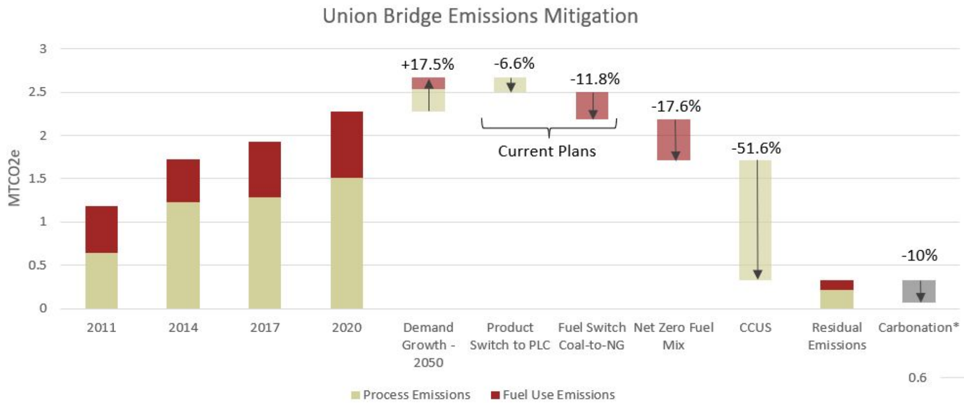
- Plans to increase production overall
- Product switch to 100% Portland Limestone Cement (PLC) by January 2023
- Fuel switch from coal to natural gas by 2028
- Invested $12 million across 11 facilities to reduce NO_x and SO_2 emissions
- Parent company committed to reducing emissions per ton of cement by 22% relative to a 2016 base year by 2030, and to be net-zero by 2050 - verified by Science Based Targets initiative (SBTi)



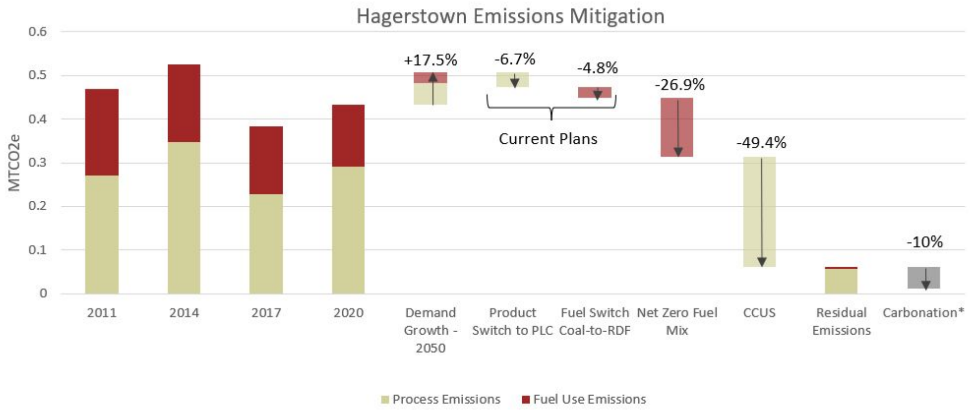
Holcim (Hagerstown):

- Invested $96 million to switch to a more efficient vertical kiln with preheater tower
- On-site solar array provides ~25% of facility power needs, operating since 2020
- Planned introduction of non-recyclable polymers as a low-carbon fuel over 3 years
- Product switch to PLC planned after new equipment installation
- Parent company committed to reducing emissions per ton of cement by 21% relative to a 2018 base year by 2030, and to be net zero by 2050 - verified by SBTi

Current plans could achieve notable reductions at both facilities, but more action is needed



- Current plans by Lehigh could reduce emissions at Union Bridge by ~18%
- Current plans by Holcim could reduce emissions at Hagerstown by ~11%



- All other measures taken first, then CCUS must be used for final ~50% of emissions
- Residual emissions must be offset in other sectors or through other methods

* More research needed to verify amount of carbonation, 10% estimate shown here as a lower bound.
2020 numbers are preliminary.

Preliminary Results, Not for Distribution

Costs to abate cement manufacturing emissions are uncertain

Abatement Technology	Cost ($/tCO2e)
Product switching to Portland Limestone Cement (PLC)	-$10 to -$30*
Fuel switch from coal to natural gas	$22 to $29
Fuel switch from coal to RDF mix	$0 to $100*
Fuel switch to net zero mix	RDF: $0 to $100* Green Hydrogen: $448 to $560 Biomass: $20 to $50*
Carbon Capture Utilization and Storage	$40 to $200* to capture + $50 to sequester
*Total Abatement***	$82 to $829

- Product switch to PLC saves on both emissions and cost to manufacture
  - Both Union Bridge and Hagerstown to produce 100% PLC in 2023
- Pipeline infrastructure required for fuel switch to NG is very expensive to build and NG is more expensive than coal
  - NG pipeline construction at Union Bridge may be a major job creator
- Fuel switching to RDF mix can be low-cost relative to other alternative fuels
  - Holcim’s subsidiary Geocycle to provide RDF mix to Hagerstown
- Cost to fuel switch to net-zero fuel mix is uncertain, but will fall over time (i.e. hydrogen)
- CCUS is expensive to build but is necessary to reduce process emissions
  - CCUS construction likely to be major job creator. Will also create 20-30 long-term plant positions at each facility.

Supportive policy approaches can facilitate cement mitigation

Policy Approach	Description	Connection to Mitigation Strategy	Federal Action
Market-based policies	Carbon pricing Carbon border leakage protection Creation of investment frameworks Incentives for net zero fuels in heavy industry	Carbon pricing can help net-zero and low-carbon fuels reach cost parity, and create incentive for CCUS Carbon border leakage protection keeps clean manufacturers competitive Providing incentives to switch to net zero fuels helps them reach cost parity with traditional fuels	$5.8 billion assistance to install advanced industrial technology at manufacturing facilities, $500 million for industrial efficiency demonstration projects
Circular economy and procurement policies	Demand reduction incentives Utilization of waste streams “Buy Clean” programs	Waste can be utilized in RDF mixes and as clinker substitutes State procurement can catalyze demand for low-carbon products as a first adopter market, building off of EPA programs with labeling and EPD’s	$4.15 billion for low-carbon materials procurement, $250 million for Environmental Product Declarations (EPDs) for manufactured products, $100 million for labeling program for construction material EPDs
Supportive policies	Coalition building Streamline regulation, siting, and permitting	Coalitions can build demand for low-carbon products in commercial markets, and build knowledge and acceptance of circular economy principles	-

Summary of key findings and policy implications for cement manufacturing

- Both cement facilities have taken actions to reduce emissions and set targets to reach net-zero by 2050.
- The estimates of abatement costs for mitigation technologies have a wide range due to uncertainties in both technology costs and mitigation pathways.
- Mitigation strategies have limited impacts on direct jobs onsite but can generate many indirect jobs along the supply chain
- About half of cement emissions will need to be removed through CCUS, which is likely to be pursued after exhausting other strategies to minimize operating costs.
- State legislators should:
  - Promote **low-carbon product procurement** and **streamline regulation, siting, and permitting practices** to support near-term actions in switching to PLC products and fuel switching to RDF
  - Adopt **market-based policies**, such as carbon pricing and net-zero fuel incentives, to help lower the costs of long-term technology options like hydrogen and CCUS.

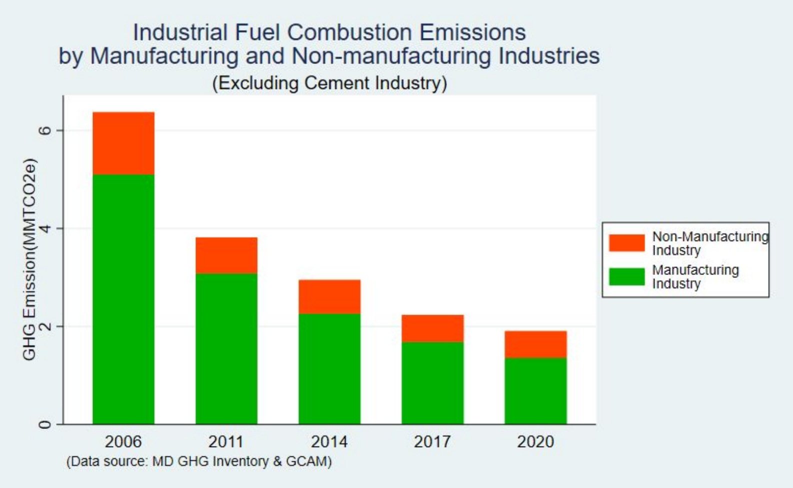
4. Emissions Reduction Strategies and Economic Impacts in the Rest of Manufacturing Sector

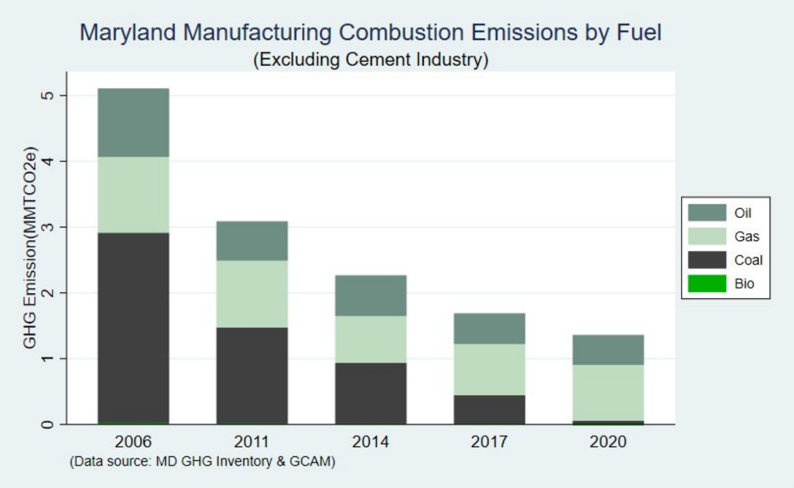
4.1 Industrial Fuel Usage
4.2 Steel
4.3 F-gas emissions (ODS Substitutes)

4.1 Industrial Fuel Usage

Fuel combustion-related emissions from the rest manufacturing sectors have been declining

- Manufacturing sectors account for the majority of industrial fuel use emissions.
- Coal emissions declined to nearly zero in 2020, while gas emissions has increased since 2014.
- Main non-cement manufacturing sectors include chemicals, pulp, paper, and wood, food processing, and other nonmetallic minerals.



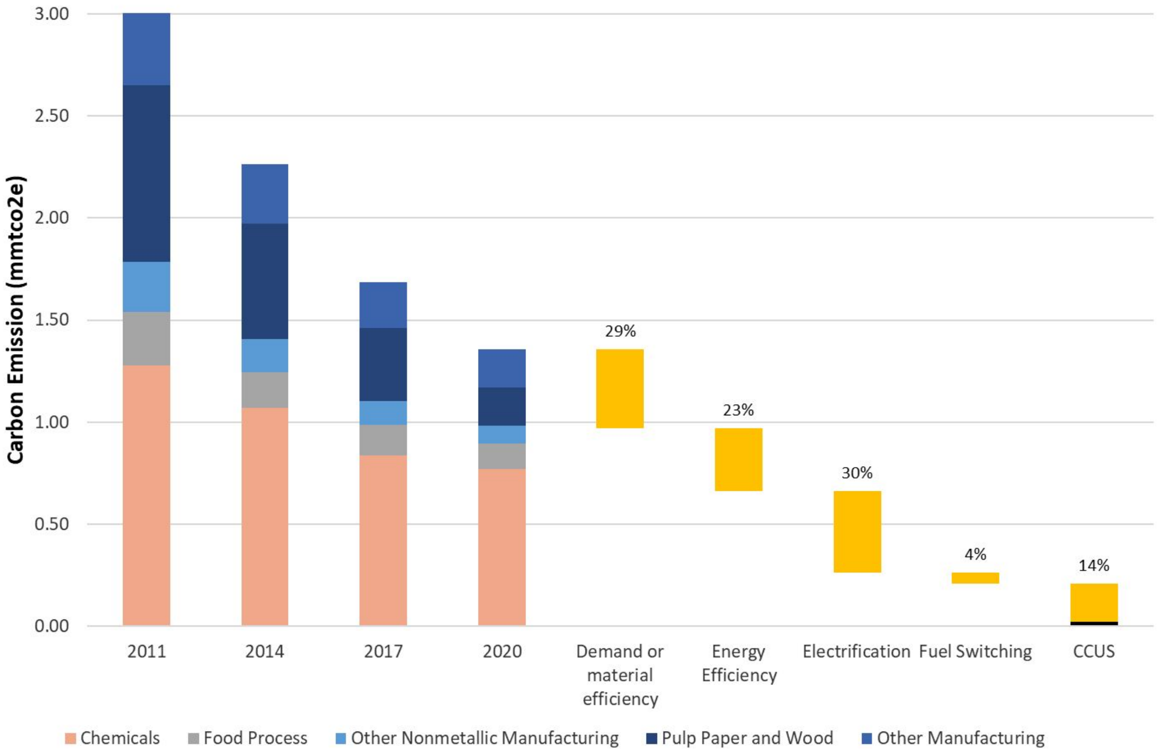


* 2020 numbers are preliminary

Mitigation strategies for other sectors (potentials)

Sector	Energy efficiency	Demand or material efficiency	Electrification	Fuel switching	CCUS
Pulp, paper, and wood	High	High (Increased use of recycled material)	High (low-temp heat)	n.a.	n.a.
Food processing	Medium	High (Reduce food waste)	High (low-temp heat)	n.a.	n.a.
Chemicals	Medium	Medium (Increased use of recycled material)	Low (high-temp heat)	Medium (to biomass or hydrogen)	Likely needed
Other nonmetallic minerals (gypsum, glass, etc.)	Medium	Medium (Increased use of recycled material)	High (low-to-medium temp heat)	n.a.	n.a.

Emissions reductions by strategy for non-cement manufacturing sectors



- Electrification contributes to the largest emissions reductions (30% from 2020).
- Sustainable demand growth through waste reduction and material efficiency can make a similar contribution (29%), followed by energy efficiency measures (23%).
- For chemicals, majority of the remaining emissions will need to be removed through CCUS.

Abatement costs for other sectors

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Abatement Strategy	Cost ($/tCO2e)	Total Emissions Reductions (MtCO2e)	Total Cost ($)
Demand or Material Efficiency	-$10[2]	386,327	-$3,093,080
Energy Efficiency	-$132.17 to $153.07[1]	309,308	-$-40,881,259 to $47,345,799
Electrification	$170[3]	398,218	$67,697,070
Fuel Switching	$0.00 to $121.66[1]	52,697	$0 to $6,411,077
Carbon Capture Utilization and Storage	$91.96 to $263.78[1]	189,708	$17,445,553 to $50,041,191

[1] GHG abatement costs for selected measures of the Sustainable Recovery Plan – Charts – Data & Statistics - IEA
[2] Levelized Cost of Carbon Abatement: An Improved Cost-Assessment Methodology for a Net-Zero Emissions World, using waste recycling number
[3] Carbonomics - The Economics of Net Zero

Job impacts of abatement strategies for other sectors

Abatement strategy	Direct jobs created	Direct jobs replaced	Indirect jobs created
Energy Efficiency	EE, energy, and facility management jobs	N\A	EE manufacturing, supply and contractor jobs
Demand or Material Efficiency	Operations management jobs	N\A	Recycling jobs
Fuel Switching	RE management and operation jobs	Traditional energy operations jobs	RE manufacturing, supply and contractor jobs
Electrification	Electrification management and operation jobs	Traditional energy operations jobs	Electrification equipment manufacturing and contractor jobs
Carbon Capture Utilization and Storage	On-site operation jobs	N\A	Hundreds of construction jobs per CCUS site

https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate (exhibit 4)

https://ec.europa.eu/social/BlobServlet?docId=21417&langId=en

4.2 Steel

Manufacturing sector structural change expected due to emergence of offshore wind turbine manufacturing

Significant growth expected in offshore wind turbine manufacturing.

Sparrow's Point Steel Facility (US Wind):

- Company estimates facility will create 530 jobs at full capacity
- Consume 110,000 tons of steel plate for monopile construction each year

Crystal Steel - Federalsburg (Ørsted):

- Company estimates 50 new jobs will be created due to wind turbine demand
- 20,000 tons of structural steel per year, making turbine foundation parts such as platform railings

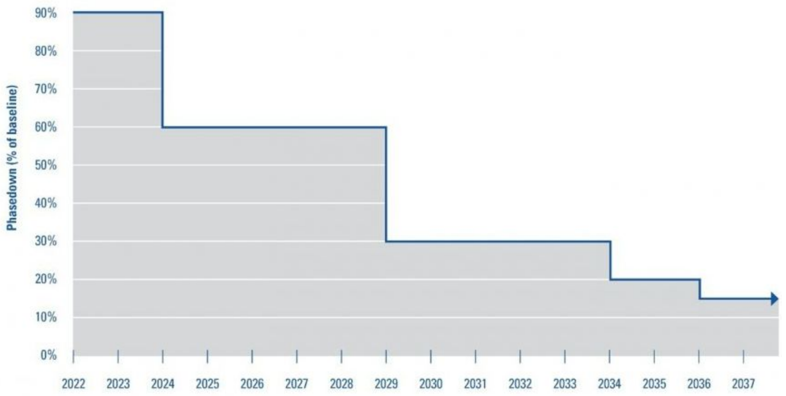
Seeking verification of expected activities, but currently expect relatively small emissions increases from fabrication processes such as cold rolling and welding. Similar mitigation measures apply as seen in other non-cement sectors including efficiency and electrification.

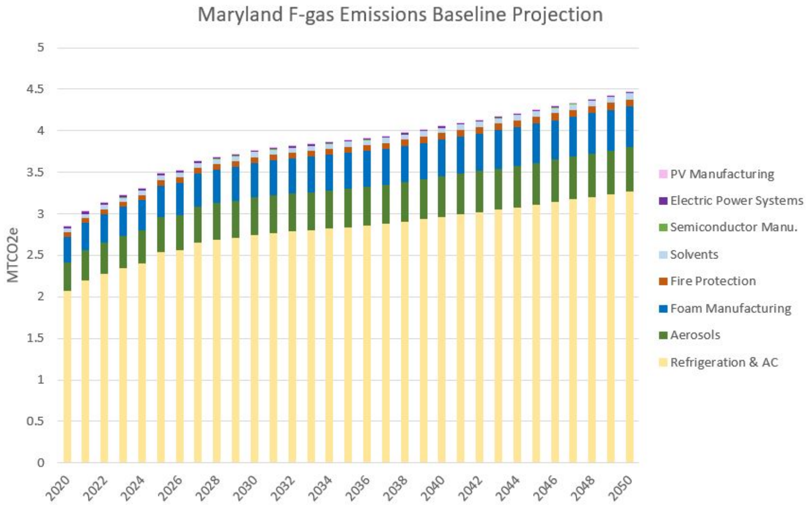
Sources: https://uswindinc.com/momentumwind/
https://www.crystalsteel.com/2012-10-08-15-19-16/crystal-steel-federalsburg.html

4.3 F-Gas Emissions (ODS Substitutes)

Substitutes for ozone-depleting substances (ODS) in refrigeration and air conditioning dominate F-gas emissions

- ODS substitutes replace CFCs, which were harmful to the ozone layer, but are themselves potent greenhouse gases
- Includes HFCs, PFCs, SF_6, etc.
- Emissions primarily come from product use through leaks, servicing, and disposal rather than manufacturing
- EPA analysis provides state-level projections for future emissions and mitigation potential



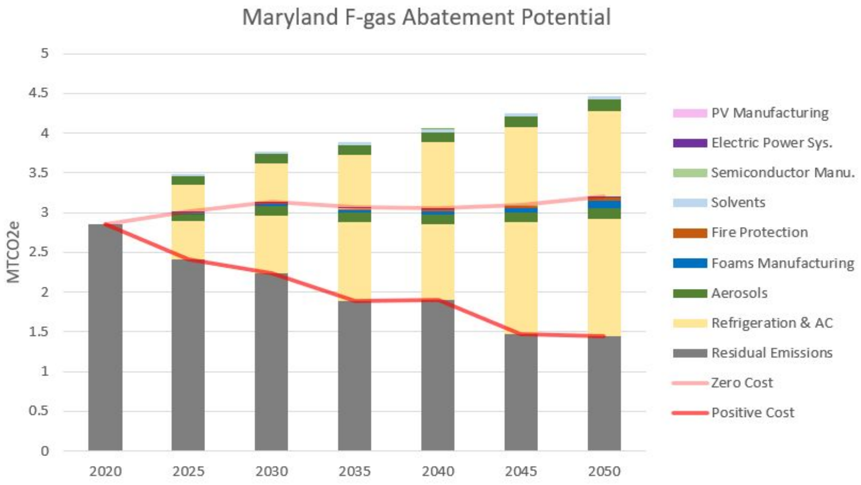


- ***Federal action:*** The American Innovation and Manufacturing (AIM) Act established a goal of phasing down HFCs by 85% over the next 15 years
- The EPA has established an allowance allocation and trading program with the pictured timeline, starting from a 2020 baseline

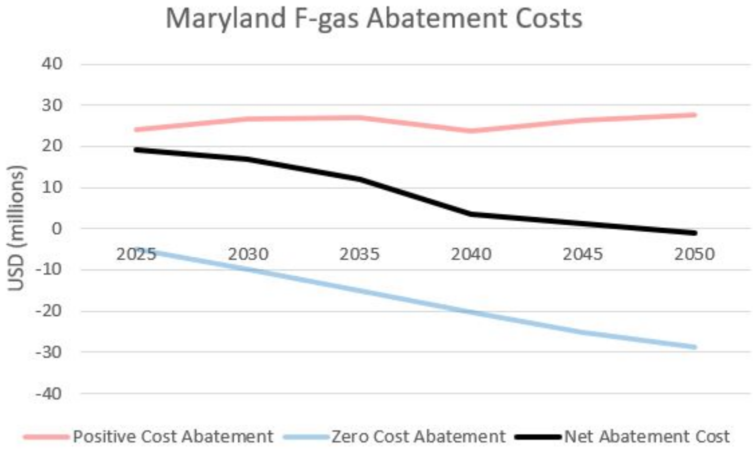
* EPA historical data does not match MD GHG inventory exactly due to different downscaling methods and categorizations

Data source: U.S. State-level non-CO_2 GHG Mitigation Report by the EPA

Substantial reductions relative to baseline can be achieved at zero cost



- Refrigeration and air conditioning are the largest potential source of abatement
- Leak repair, reuse of substances, and material substitutions can provide substantial reductions with cost savings
- Additional innovation is needed to achieve further mitigation



- Cost savings potential from F-gas abatement is expected to increase over time
- Abatement costs range from -45.75 to 436.80 $/t$CO_2$e
- Refrigeration and AC abatement offer biggest cost savings
- Pharmaceutical use of aerosols is the most expensive to abate

Data source: U.S. State-level non-CO_2 GHG Mitigation Report by the EPA

Key messages and policy implications for non-cement manufacturing sectors

Federal action:

- $27 billion for Green Banks, $7 billion earmarked for states/cities/nonprofits (IRA)
- $5.8 billion in financial assistance to install advanced industrial technology at manufacturing facilities (IRA)
- $500 million for industrial efficiency demonstration projects (IIJA)
- $4.15 billion for procurement of low-carbon materials (IRA)
- $250 million for the EPA to develop Environmental Product Declarations (EPDs) for manufactured products, $100 million for labeling program for EPDs (IRA)
- EPA allowance and trading program to phase down HFCs by 85% over the next 15 years (AIM + IRA)

Paths for additional state action:

- Pursue federal funds to expand the Maryland Clean Energy Center, making explicit provision for some funds to be used to support cost-saving efficiency measures that also reduce emissions in manufacturing facilities
- Develop state procurement guidelines that build off of the EPA labeling and EPD programs to “Buy Clean” and support demand for low carbon products
- Use convening power to build coalitions around circular economy principles along the value chain, both within manufacturing and with end users
- Provide incentives and capacity building to facilitate electrification in light industry processes and building operations

5. Conclusions and Policy Implications

Summary of key findings

- The Maryland manufacturing sector includes several difficult-to-abate categories of emissions, including cement process emissions and F-gases
- There are strategies to reduce emissions, and key facilities are already taking action and developing future plans to reach net-zero
- Current costs for some net-zero measures are expensive, and a small amount of residual emissions may need to be offset outside the sector; but minimal impacts are expected on onsite jobs, while many indirect jobs can be created
- To achieve emissions reductions compatible with ambitious state goals, supportive policies will be needed such as:
    - State procurement policies to accelerate the switch to clean products
    - Circular economy incentives and regulations to reduce excessive demand and utilize waste streams
    - Market-based policies to lower the cost burden of reaching net-zero emissions
- Recent federal actions provide substantial funding opportunities for the state and individual manufacturers to pursue more ambitious emissions reductions, making this an opportune time to address these difficult emissions

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Thank you!

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Appendix

Data sources

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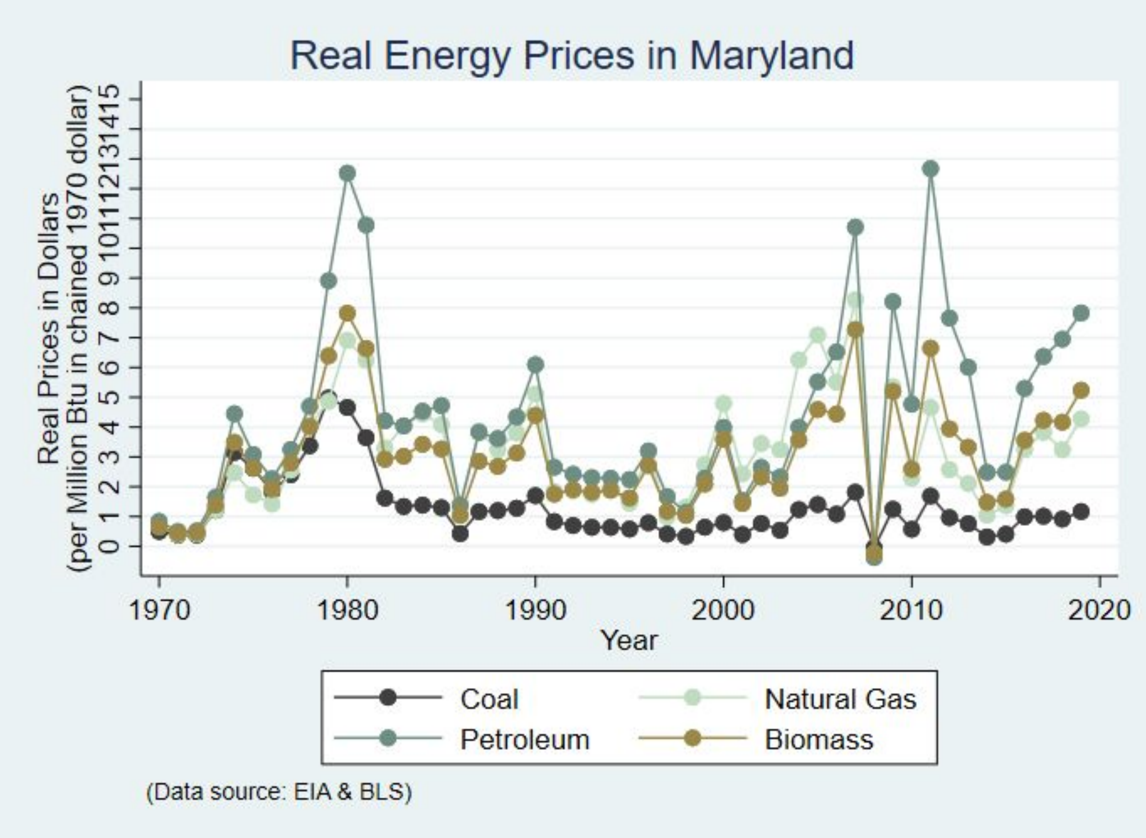
Backup slides

Energy prices in Maryland vary widely over past decades, with consistent upward trend since 2015



- Coal is consistently the least expensive fuel and petroleum is consistently the most expensive
- Real prices of all fuels trending upwards since 2015
- Coal and gas were close in price in 2015, which may have led to the coal-to-gas switching we do see, then subsequent gas increases limited future switching

There is uncertainty in abatement costs at cement facilities

Abatement Technology	**Cost ($/tCO2e)**	**Total Annual Emissions Reductions (MtCO2e)**		**Annualized Cost ($/year)**	
		Union Bridge	*Hagerstown*	*Union Bridge*	*Hagerstown*
Product switching to Portland Limestone Cement (PLC)	-$10 to -$30*	150,962	29,073	$1,509,620 to $4,528,860 in savings	$290,730 to $872,190 in savings
Fuel switch from coal to natural gas	$22 to $29	267,545	N/A	$3,597,682 in fuel + 4,166,666 to 2,272,727 in annualized infrastructure cost	N/A
Fuel switch from coal to RDF mix	$0 to $100*	N/A	20,590	N/A	$0 to $2,059,000
Fuel switch to net zero mix	RDF: $0 to $100* Green Hydrogen: $448 to $560 Biomass: $20 to $50*	401,318	116,221	$0 to $224,738,080 depending on the percentages used in fuel mix	$0 to 65,083,760 depending on the percentages used in fuel mix
Carbon Capture Utilization and Storage	$40 to $200* to capture + $50 to sequester	1,175,825	213,281	$105,824,250 to $293,956,250	$19,195,290 to $53.320,250
*Total Abatement***	$82 to $829	1,995,650	379,165	$163,643,300 to $1,654,393,850	$22,749,900 to $310,915,300

*Estimated range from McKinsey report on zero carbon cement **Not all costs are necessarily concurrent

Preliminary Results, Not for Distribution

Limited impacts are expected for on-site jobs at facilities, but many indirect jobs can be generated along the supply chain

Abatement technology	**Direct jobs** *Union Bridge*	*Hagerstown*	**Indirect jobs** *Union Bridge*	*Hagerstown*
Product switching to Portland Limestone Cement (PLC)	No impact expected		No impact expected	
Fuel switch from coal to natural gas	No impact expected	N/A	Construction of ~30 mile pipeline with estimated 58 jobs per mile of pipeline (1,740 jobs), pipeline maintenance	N/A
Fuel switch from coal to RDF mix	N/A	No impact expected	N/A	RDF manufacturing and transportation
Fuel switch to net zero mix	No impact expected		RDF/Hydrogen/Bio manufacturing and transportation of fuel mix	
Carbon Capture Utilization and Storage	Approximately 20 to 30 long term positions at each facility		Hundreds of construction jobs	

Preliminary Results, Not for Distribution