Pennsylvania Climate Pollution Reduction Grant: Industrial Decarbonization Funding Recommendations

Prepared for the Ohio River Valley Institute

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Background

The Environmental Protection Agency's Climate Pollution Reduction Grants (CPRG) program provides $5 billion in grants to states, local governments, tribes, and territories to develop and implement ambitious plans for reducing greenhouse gas emissions and other harmful air pollution. The goals of the CPRG implementation grants are to:

1. Implement ambitious measures that will achieve significant cumulative GHG reductions by 2030 and beyond;
2. Pursue measures that will achieve substantial community benefits (such as reduction of criteria air pollutants (CAPs) and hazardous air pollutants (HAPs)), particularly in low-income and disadvantaged communities;
3. Complement other funding sources to maximize these GHG reductions and community benefits; and,
4. Pursue innovative policies and programs that are replicable and can be "scaled up" across multiple jurisdictions.

The CPRG program is divided into two segments – planning grants and implementation grants. The PA DEP has already received a CPRG planning grant to develop a climate, energy, or sustainability plan for Pennsylvania by March 1, 2024. Following the development of this plan, Pennsylvania has the opportunity to receive an implementation grant totaling up to $500 million from the EPA to support the deployment of investment-ready policies, programs, and projects to reduce greenhouse gas emissions. The significant amount of funding available from the CPRG presents a critical opportunity for Pennsylvania to kickstart in-state industrial decarbonization efforts and position the commonwealth for long-term decarbonization.

Objective

This analysis aims to identify how Pennsylvania can optimally invest potential CPRG funds to maximize the achievement of programmatic goals. Strategen has designed a scoring matrix to determine which decarbonization levers and, where applicable, which industrial subsectors should be targeted for investment to achieve significant GHG reductions cost-effectively.

Methodology

Analysis of Decarbonization Levers

Strategen evaluated the role that several key levers can play in reducing industrial emissions and their applicability for CPRG funding. These decarbonization levers include (alphabetically):

+ Carbon Capture and Storage
+ Clean Hydrogen
+ Electrification
+ Energy Efficiency
+ Material Efficiency
+ Technology Upgrades

The technology upgrades lever specifically accounts for methane leak-reducing upgrades in the fossil fuel extraction and delivery subsector. It should be noted that additional emergent levers may play a role in industrial decarbonization, particularly for unique processes within certain subsectors, such as new production methods in industries like steel and cement that have high process emissions, but these solutions are still nascent. Noting that CPRG scoring is heavily weighted towards near-term emissions reductions, Strategen excluded such levers.

Strategen evaluated the included decarbonization levers based on stated CPRG criteria to provide a high-level estimate of potential grant scoring. It was determined that the selection of a decarbonization lever would minimally influence the following CPRG scoring criteria, and these criteria were therefore excluded from Strategen's analysis:

+ Overall Project Summary and Approach
    - Description of GHG Reduction Measures (20 points)
    - Demonstration of Funding Need (10 points)
    - Transformative Impact (15 points)
+ Impact of GHG Reduction Measures
    - Documentation of GHG Reduction Assumptions (15 points)
+ Environmental Results – Outputs, Outcomes, and Performance Measures
    - Expected Outputs and Outcomes (10 points)
    - Performance Measures and Plan (10 points)
    - Authorities, Implementation Timeline, and Milestones (10 points)
+ Low-Income and Disadvantaged Communities
    - Community Engagement (10 points)
+ Programmatic Capability and Past Performance
    - Past Performance (10 points)
    - Reporting Requirements (10 points)
    - Staff Expertise (10 points)
+ Budget and Timely Expenditure of Grant Funds
    - Budget Detail (20 points)
    - Expenditure of Awarded Funds (15 points)
    - Reasonableness of Cost (10 points)

Below is a description of the four applicable CPRG scoring criteria and Strategen's prioritization methodology utilized in this analysis. These criteria were weighted based on the proportion of the criteria's points compared to the total CPRG points from the four criteria.

+ Cost Effectiveness of GHG Reductions
    - **Description:** The cost to enable emissions reductions.
    - **Measurement Methodology:** Quantitative measure of $/metric ton of abated CO_2 equivalent (CO_2e) based on the estimated capital expenditures (CapEx) for equipment replacement, excluding incentives. This category also excludes the costs of supportive infrastructure needs.[1]
    - **CPRG Points:** 15
+ Job Quality
    - **Description:** An evaluation of the potential creation of quality, family-sustaining jobs.
    - **Measurement Methodology:** Quantitative assessment of comparative job multipliers.

[1] For example, regarding the cost effectiveness of clean hydrogen, the reported cost is only based on the CapEx of a hydrogen boiler. This excludes the cost for clean hydrogen production, delivery, and storage infrastructure.

- CPRG Points: 5

+ Magnitude of GHG Reductions 2025-2030
    - **Description:** An estimation of cumulative metric tons of CO_2e emissions reductions resulting from the measure between 2025 and 2030.
    - **Measurement Methodology:** Quantitative valuation based on Strategen's Pennsylvania Industrial Decarbonization Roadmap and the expected durability of the technology.
    - **CPRG Points:** 20
+ Magnitude of GHG Reductions 2025-2050
    - **Description:** An estimation of cumulative metric tons of CO_2e emissions reductions resulting from the measure between 2025 and 2050.
    - **Measurement Methodology:** Quantitative valuation based on Strategen's Pennsylvania Industrial Decarbonization Roadmap.
    - **CPRG Points:** 10

Table 1. Summary of Criteria Weights

Criteria	CPRG Point Total	Weight
Cost Effectiveness	15	30%
Job Quality	5	10%
GHG Reductions 2025-2030	20	40%
GHG Reductions 2025-2050	10	20%
TOTAL	**50**	**100%**

Community benefits are a high-priority scoring criteria in the CPRG guidance but were excluded from Strategen's decarbonization lever scoring matrix due to the complexities of attempting to score this category on a lever-by-lever basis and this criteria's specific geographic focus. In the CPRG guidance, the community benefits criteria notes that "Applications should discuss and quantify, where possible, direct and indirect benefits and potential disbenefits to low-income and disadvantaged communities," as identified through the Inflation Reduction Act. Community benefits are discussed at a high level by lever in Table 2 and by industrial subsector in Table 4.

Analysis of Industrial Levers

Analysis was also performed on an industrial subsector basis to identify differences in decarbonization lever applicability across subsectors, highlight the subsectors with the highest potential for near-term decarbonization, and describe potential community benefits resulting from variations in facility locations. Based on these data, industrial subsectors were not necessarily prioritized or scored because Strategen is not recommending that any industrial subsectors be excluded from funding eligibility. Instead, the data collected on a subsector basis are meant to provide insights on high-priority opportunities that could strengthen PA DEP's application for CPRG implementation funding.

Results

Analysis of Decarbonization Levers

Table 2. Decarbonization Lever Analysis Inputs

	Community Benefits	Cost Effectiveness	Job Quality	Magnitude of GHG Reductions 2025-2030		Magnitude of GHG Reductions 2025-2050
	Description	**\$/metric ton of CO_2e abated in 2030 (CapEx, no incentives)**	**Direct Impacts (Full Time Jobs/ \$million)[2]**	**Annual Metric tons of CO_2e[3]**	**Durability (years)**	**Annual Metric tons of CO_2e[4]**
Carbon Capture	+ Uncertain air quality benefits for surrounding communities, as more research is needed. + Higher potential for disbenefits due to carbon transport and storage infrastructure and perpetuated extraction/use of fossil fuels.	\$344 – 598[5]	0.3[6]	250,000	25[7]	5,750,000

[2] Strategen's analysis of job impacts is focused on direct impacts. Direct impacts are defined as the impacts within the industry where the initial economic activity occurs. This analysis does not account for the direct impacts from upstream production. For example, decarbonization via electrolytic hydrogen or electric boilers will require installation of additional renewable capacity, but the extent of renewable buildout necessary per project can vary greatly, so this was not included.

[3] Goodenbery, J. et al., *A Roadmap for Industrial Decarbonization in Pennsylvania*, Strategen Consulting, 2023 (Hereafter "A Roadmap for Industrial Decarbonization in Pennsylvania").

[4] A Roadmap for Industrial Decarbonization in Pennsylvania.

[5] Strategen analysis based on data from *Turning CCS projects into heavy industry & power into blue chip financial investments*, Energy Futures Initiative, 2023. https://efifoundation.org/wp-content/uploads/sites/3/2023/02/20230212-CCS-Final_Full-copy.pdf. This is inclusive of carbon transportation and storage costs.

[6] *Jobs and Economic Impact of Carbon Capture Deployment Midcontinent Region*, Regional Carbon Capture Deployment Initiative, 2020. https://carboncaptureready.betterenergy.org/wp-content/uploads/2020/10/Midcontinent_Jobs.pdf

[7] Fahs, R. et al., *Pathways to Commercial Liftoff: Carbon Management*, DOE, 2023. https://liftoff.energy.gov/wp-content/uploads/2023/04/20230424-Liftoff-Carbon-Management-vPUB_update.pdf

Clean Hydrogen	+ Benefits and disbenefits in part depend on the type of hydrogen. If blue, there is a higher potential for disbenefits due to perpetuated extraction/use of fossil fuels and air pollutants created in the steam methane reforming process. + All types of hydrogen have the potential for disbenefits due to hydrogen production, transport, and storage infrastructure. + All types of hydrogen will reduce air pollutants from fossil fuel combustion, but NOx emissions remain a concern.	$135-$313[8]	1.4[9]	380,000	25[10]	5,130,000
Electrification	+ High air quality benefits for communities near industrial sites due to the complete elimination of fossil fuel combustion emissions. + If using fossil electricity may result in disbenefits by exacerbating air quality issues in communities near fossil fuel extraction and power plant sites. + Expanding infrastructure to support electrification (e.g., transmission) could be a disbenefit.	$501 - $1,861[11]	1.4[12]	3,700,000	15[13]	30,300,000

[8] Strategen analysis based on data from "Industrial Boilers," Arup, 2022. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1123264/External_research_study_hydrogen-ready_industrial_boilers.pdf

[9] Strategen analysis in IMPLAN.

[10] The durability figure is based on that of an industrial hydrogen boiler which is consistent with that of a hydrogen kiln. "H2 Industrial Boiler Technology Factsheet," Energy.nl, 2020. https://energy.nl/wp-content/uploads/h2industrialboiler_28092020_upd-7.pdf; "Hydrogen for the Ceramic Industry," Gausine, 2021. https://www.gasunie.nl/nieuws/vooraankondiging-publicatie-rapport-h2-voor-de-keramische-industrie-in-september/$4422

[11] Strategen analysis based on data from *Industrial Heat Pumps: Electrifying Industry's Process Heat Supply*, ACEEE, 2022. https://www.aceee.org/sites/default/files/pdfs/ie2201.pdf; "Electrification of Boilers in Manufacturing," Lawrence Berkeley National Laboratory, 2021. https://escholarship.org/content/qt98r4r9r5/qt98r4r9r5_noSplash_016278e60333f3f05ce150b89cc9f28f.pdf. The low end of the range represents the cost of a low-temperature industrial heat pump and the range maximum represents the cost of an electric boiler. The cost of a high-temperature industrial heat pump falls within this range.

[12] Strategen analysis in IMPLAN.

[13] The durability figure is based on that of an industrial heat pump, but this value may be lower for subsectors that utilize differing electric technology such as electric melting technology in the glass subsector. Khan, U. et al., *Life cycle cost analysis (LCCA) of Stirling-cycle-based heat pumps vs. conventional boilers*, Cleaner Environmental Systems Volume 8, March 2023. https://www.sciencedirect.com/science/article/pii/S2666789422000368; *All Electric Melting Technology*, Fives Group, 2019. https://glassmanevents.com/content-images/main/Fives.pdf

Energy Efficiency	+ High air quality benefits by reducing the need for fossil fuel combustion and electricity use at industrial sites. + Creates upstream benefits by reducing the need for fossil fuel extraction and electricity production. + No identified disbenefits.	$160[14]	4.8[15]	2,800,000	7[16]	8,720,000
Material Efficiency	+ If material efficiency results in less industrial production, it may create air quality benefits for surrounding communities, but the impact is difficult to characterize. + No identified disbenefits.	$0[17]	0	45,000	25[18]	120,000
Technology Upgrades	+ Air quality benefits for communities surrounding natural gas extraction and transport infrastructure through leak detection and repair. + Reduced methane losses may result in a lesser need for new extraction, creating additional benefits. + Disbenefits may arise if technology upgrades encourage prolonging the life of natural gas extraction.	$9-25[19]	2.1[20]	485,000	4[21] – 20[22]	5,900,000

[14] Strategen analysis based on data from *Pathways to Commercial Liftoff: Industrial Decarbonization*, United States Department of Energy, 2023. https://liftoff.energy.gov/wp-content/uploads/2023/10/LIFTOFF_DOE_Industrial-Decarbonization_v8.pdf
[15] Strategen analysis in IMPLAN.
[16] *Industrial O&M Persistence Study Program Years 2010-17*, Energy Trust of Oregon, 2020. https://www.energytrust.org/wp-content/uploads/2020/04/DNVGL_2019_Persistence_Study_Report_FINAL-w-SR.pdf
[17] Assumes that equipment upgrades or replacements are not needed as only material inputs are being substituted or recycled.
[18] As equipment upgrades are not needed, this value is based on average industrial equipment lifetimes for technologies such as burners, boilers, and kilns. This assumes that industrial equipment would be replaced on a typical as-needed basis.
[19] Strategen analysis based on data from *Global Methane Assessment*, United Nations Environment Programme, 2021. https://www.ccacoalition.org/sites/default/files/resources//2021_Global-Methane_Assessment_full_0.pdf.
[20] Strategen analysis in IMPLAN.
[21] There is a range of solutions that fall into the technology upgrades category. These can range from replacing values or seals to installing new instrument air systems. A range of durability values was provided to represent this solution range. *Lessons Learned from Natural Gas STAR Partners: Convert Gas Pneumatic Controls to Instrument Air*, United States Environmental Protection Agency, 2021. https://19january2021snapshot.epa.gov/sites/static/files/2016-06/documents/ll_instrument_air.pdf ; *How Long Will a Mechanical Seal Last?* Fluid Sealing Association, Pumps and Systems. https://www.pumpsandsystems.com/how-long-will-mechanical-seal-last
[22] Global Methane Tracker, International Energy Agency, 2023. https://iea.blob.core.windows.net/assets/48ea967f-ff56-40c6-a85d-29294357d1f1/GlobalMethaneTracker_Documentation.pdf

Table 3. Decarbonization Lever Ranking Matrix

	Cost Effectiveness	Job Quality	Magnitude of GHG Reductions 2025-2030	Magnitude of GHG Reductions 2025-2050	Overall Prioritization
Carbon Capture (CCS)	Low	Low	Medium	Medium	Low
Clean Hydrogen	Low[23]	Medium	Medium	Medium	Medium
Electrification	Medium	Medium	High	High	High
Energy Efficiency	High	High	High	Medium	High
Material Efficiency	High	Low	Low	Low	Low
Technology Upgrades	High	Medium	Medium	Low	Medium

[23] Although the $/metric ton CapEx cost of clean hydrogen is on par with that of other decarbonization levers in Table 2, the OpEx of clean hydrogen is significantly higher than that of the other decarbonization levers which was a differentiator in this analysis. While the OpEx of electrification ranges from 1%-3% of its CapEx (*Industrial Heat Pumps: Electrifying Industry's Process Heat Supply*, ACEEE, 2022; *Electrification of Boilers in Manufacturing, Lawrence Berkeley National Laboratory*, 2021) and the OpEx of CCS ranges from 5%-7% of its CapEx (*Turning CCS projects into heavy industry & power into blue chip financial investments*, Energy Futures Initiative, 2023) that of clean hydrogen is 13-40% of its CapEx (Industrial Boilers, Arup, 2022; Fahs, R. et al., *Pathways to Commercial Liftoff: Carbon Management*, DOE, 2023).

Based on Strategen's scoring matrix, energy efficiency and electrification have been identified as the highest-priority decarbonization levers for the industrial sector. Technology upgrades and clean hydrogen fall into the second tier of decarbonization levers. In designing a program to provide funding for these levers, however, it is also critical to consider whether currently available solutions may already be required. For example, in Pennsylvania, oil and gas companies will be required to adopt a "reasonably available control technology (RACT)" to limit emissions from conventional and unconventional sources of volatile organic compound emissions in alignment with federal rules.[24] Providing funding to subsidize such technologies would, therefore, not be recommended.

Energy Efficiency

Energy efficiency solutions have been implemented across multiple sectors for decades, making this one of the industrial sector's most technologically mature and "shovel-ready" decarbonization levers. Further, most energy efficiency measures result in cost savings to consumers, lowering energy bills and helping cushion the effects of unexpected price spikes.[25] This innate cost-effectiveness is a critical differentiator between energy efficiency and other decarbonization levers, which might require tax credits, grants, and other government financing support to be economical. This approach is particularly salient for the industrial sector, where nearly two-thirds of energy input is lost before reaching its intended purpose.[26] Given that the industrial sector accounts for about a third of Pennsylvania's total energy consumption and a typical industrial plant spends 30-50% of its operating budget on energy, it is critical to focus on industrial energy efficiency to reduce energy loss and emissions as soon as possible cost-effectively.[27] Energy efficiency also received a maximum score for job quality. It should be noted that investments in energy efficiency offer advantages for *local* job creation in a way that differentiates this lever from others. Most efficiency improvements, such as upgrades in lighting, insulation, doors and windows, or heating and cooling systems, can be performed by the local workforce, supporting jobs for contractors and suppliers within the region. In contrast, industries such as natural gas extraction have often relied heavily on workers and suppliers from out of state.[28]

Electrification

Similar to energy efficiency, in many cases, electrification can begin immediately, given existing technology, and thus, near-term emissions reductions are significant. Further, as the grid becomes cleaner over time, investments in electrification will continue to lead to additional, incremental decarbonization, resulting in the possibility for about 30 million metric tons of annual GHG emissions reductions in the industrial sector by 2050. The incremental manufacturing, sales, and installation of electric equipment is also expected to generate job growth similar to that of technology upgrades and clean hydrogen.

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[24] See *Control of VOC Emissions from Conventional Oil and Natural Gas Sources and Control of VOC Emissions from Unconventional Oil and Natural Gas Sources*, available at: https://www.dep.pa.gov/Business/Air/pages/methane-reduction-strategy.aspx. Limited emissions sources include natural gas-driven continuous bleed pneumatic controllers, natural gas-driven diaphragm pumps, reciprocating compressors, centrifugal compressors, fugitive emissions components and storage vessels installed at unconventional well sites, gathering and boosting stations and natural gas processing plants, as well as storage vessels in the natural gas transmission and storage segment.

[25] Howarth, N. et al., Energy Efficiency, IEA. https://www.iea.org/energy-system/energy-efficiency-and-demand/energy-efficiency

[26] Emerson, "Industrial Energy Efficiency Comes of Age Through Digital Transformation," Reuters. https://www.reuters.com/plus/roadmap-to-industrial-sustainability/industrial-energy-efficiency-comes-of-age-through-digital-transformation

[27] Ibid.

[28] For example, it was reported that initially 70% of Marcellus workers came from out of state. See: Marcellus Shale Education & Training Center, 2011. Pennsylvania Marcellus Shale Economic Impact Study.

Technology Upgrades

While technology upgrades are low-cost and relatively straightforward to implement, their applicability to only the fossil fuel extraction and delivery subsector means that a universal solution, such as energy efficiency or electrification, will result in more significant emissions reductions in the near- and long-term. However, it is essential to note that the fossil fuel extraction sector is the largest industrial subsector in Pennsylvania, and technology upgrades will be incredibly important to realize emissions reductions in this subsector.

Clean Hydrogen

Clean hydrogen has the potential to reduce high-heat temperature emissions across industrial subsectors but is not expected to be deployed at a commercial scale until post-2030, leading to decreased potential for near-term emissions reductions. Further, the high cost of clean hydrogen fuel and the costly nature of retrofitting equipment to run on 100% clean hydrogen have been identified as notable barriers. Finally, clean hydrogen already has dedicated federal and state-level incentives, so it may be more prudent to utilize CPRG funding elsewhere.

Material Efficiency

As with energy efficiency, material efficiency provides a low-cost opportunity to lower emissions while minimizing the need for other decarbonization technologies; however, it offers limited opportunity for job growth because equipment upgrades are not likely to be needed. Further, the low technical potential and limited applicability of material efficiency result in lower potential emissions reductions in the near- and long-term as compared to the other identified decarbonization levers.

Carbon Capture

Similar to clean hydrogen, carbon capture and storage is constrained by high costs and limited commercial availability at present, which limit its near-term deployment potential. Additionally, the buildout of carbon capture infrastructure has yet to be identified to produce a significant number of full-time jobs compared to the other decarbonization levers.

Analysis of Industrial Subsectors

The industrial sector is wide-ranging and includes a diverse set of economic activities, such as the manufacture of goods (e.g., pulp and paper products), production of materials (e.g., cement, iron, steel, petrochemicals), and extraction and processing of fossil fuel products (e.g., coal mining, petroleum and gas systems, refining). Table 4 below summarizes the industrial subsectors present in Pennsylvania, associated decarbonization levers, and emissions reduction potential by 2030 and 2050.

Table 4. Industrial Subsector Analysis Overview

	Cement & Lime	Chemical Manufacturing	Glass	Food Processing	Fossil Fuel Extraction & Delivery	Iron & Steel	Other Metals	Pulp & Paper	Refining
Magnitude of Existing Emissions in 2022 (million metric tons)	5,172	5,870	817	1,187	29,452	9,447	1,316	2,688	3,622
Share of Industrial Emissions (2019)[29]	5.9%	3.4%[30]	0.9%	1.4%	34.1%	10.9%	1.1%	3.1%	4.2%
Relevant Decarbonization Levers	Carbon Capture for Process Emissions Clean Hydrogen Kilns Electric Boilers Energy Efficiency Material Efficiency	Clean Hydrogen Burners Clean Hydrogen Input Material Electric Boilers and Compressors Energy Efficiency	Carbon Capture for Process Emissions Clean Hydrogen Burners Electric Melting Energy Efficiency Material Efficiency	Clean Hydrogen Ovens Electric Boilers and Ovens Energy Efficiency	Demand Reduction/Retirement Electric Compressors Energy Efficiency Technology Upgrades (ex., leak detection, vapor recovery)	Clean Hydrogen Burners DRI-EAF with Clean Hydrogen or CCS Energy Efficiency Material Efficiency	Clean Hydrogen Burners Electric Heaters Energy Efficiency	Clean Hydrogen Ovens Electric Boilers and Heat Pumps Energy Efficiency	Carbon Capture for Process Emissions Clean Hydrogen Burners Clean Hydrogen Input Material Electric Boilers and Heat Pumps Energy Efficiency

[29] A Roadmap for Industrial Decarbonization in Pennsylvania.
[30] This value does not include the Shell Ethylene Cracker which came online in 2021. Inclusive of this asset, the chemical manufacturing subsector represents 6.6% of industrial subsector emissions.

Emissions Reduction Potential by 2030 compared to 2019[31]	9%	5%	13%	11%	42%	19%	12%	14.5%	15%
Emissions Reduction Potential by 2050 compared to 2019[32]	94%	100%	99%	100%	82%	92%	92%	100%	98%
Share of Total Industrial Emissions Reductions Possible by 2030 compared to 2019[33]	0.6%	0.2%	0.1%	0.2%	1.2%	1.5%	0.2%	0.5%	0.6%
Share of Total Industrial Emissions Reductions Possible by 2050 compared to 2019[34]	8%	4%	1%	2%	10%	11%	2%	3%	4%

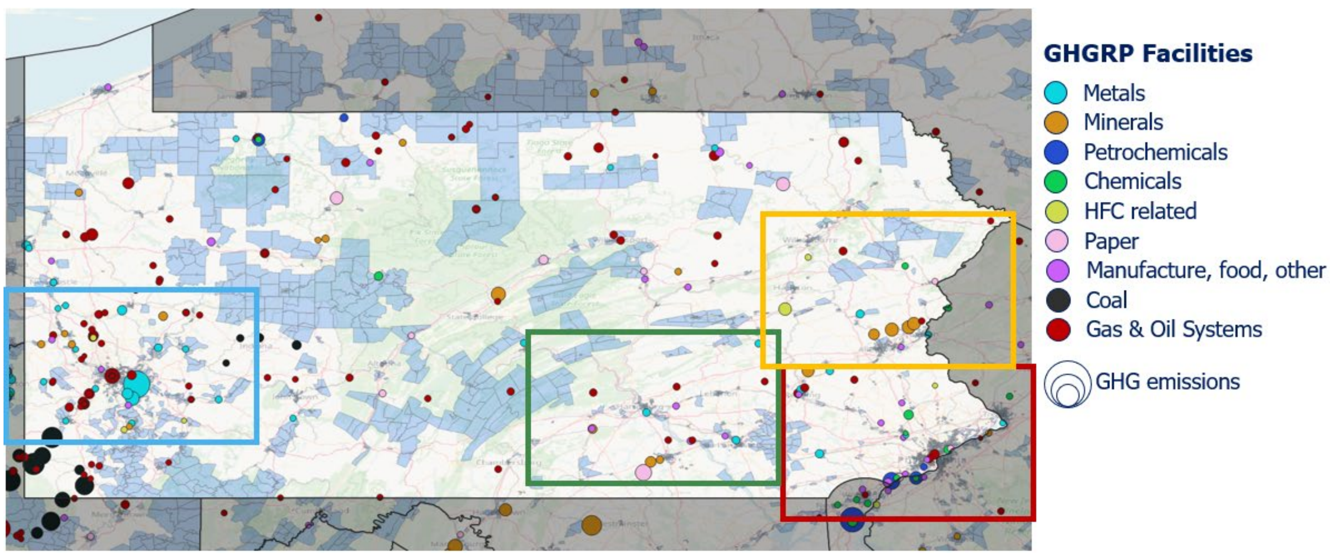
There are opportunities across the industrial sector to achieve emissions reductions in the near- and long-term. Of particular note, there are overlapping technological opportunities that include the deployment of energy efficiency measures, electric boilers, electric compressors, electric ovens, industrial-scale heat pumps, and clean hydrogen burners or boilers.

[31] Based on Strategen analysis in A Roadmap for Industrial Decarbonization in Pennsylvania.
[32] Ibid.
[33] Ibid.
[34] Ibid.

Subsector Mapping and Discussion of Community Benefits

The CPRG application requires that applicants discuss the community benefits that may result from CPRG implementation funding. This section of the application and its related scoring apply only to benefits delivered to certain geographic areas (those qualifying as low-income or disadvantaged communities as defined in the Inflation Reduction Act). Absent direct outreach, Strategen's assessment does not include a full community benefits analysis for each subsector or lever, given uncertainty about specific locations to which CPRG funding will ultimately be deployed. As a proxy, Strategen conducted a cursory mapping exercise that overlayed Pennsylvania's largest industrial facilities (those reporting to EPA's GHGRP) with the low-income and disadvantaged areas in the state that could be targeted through the grant program. Strategen then used this mapping to identify subsectors that may be a priority to address from a community benefits perspective. If a subsector appears to have a high concentration of facilities in or near these areas, then it would offer a higher potential for benefits to accrue to those communities. This mapping exercise is intended to be illustrative only and should not be considered comprehensive.

Figure 1. Mapping of Pennsylvania's Industrial Subsector



Overall, 21% of large industrial facilities are within a disadvantaged community, while an additional 15% and 16% of facilities, respectively, are within 1 mile and 3 miles from a disadvantaged community. This means that 52% of large industrial facilities are sited 3 miles or less from a disadvantaged community. These facilities are responsible for 71% of carbon emissions, with those directly within disadvantaged communities accounting for 32% of carbon emissions, while those within 1 mile are responsible for 23% of carbon emissions, and those within 3 miles are responsible for 16%. Notably, all emissions from large facilities in the metals and refining subsectors are within 3 miles of disadvantaged communities. Within the other industrial subsectors – minerals, chemicals, pulp and paper, petroleum and gas systems, and other – 47% to 70% of emissions are within 3 miles of a disadvantaged community.

Figure 2. Pittsburgh Area Mapping

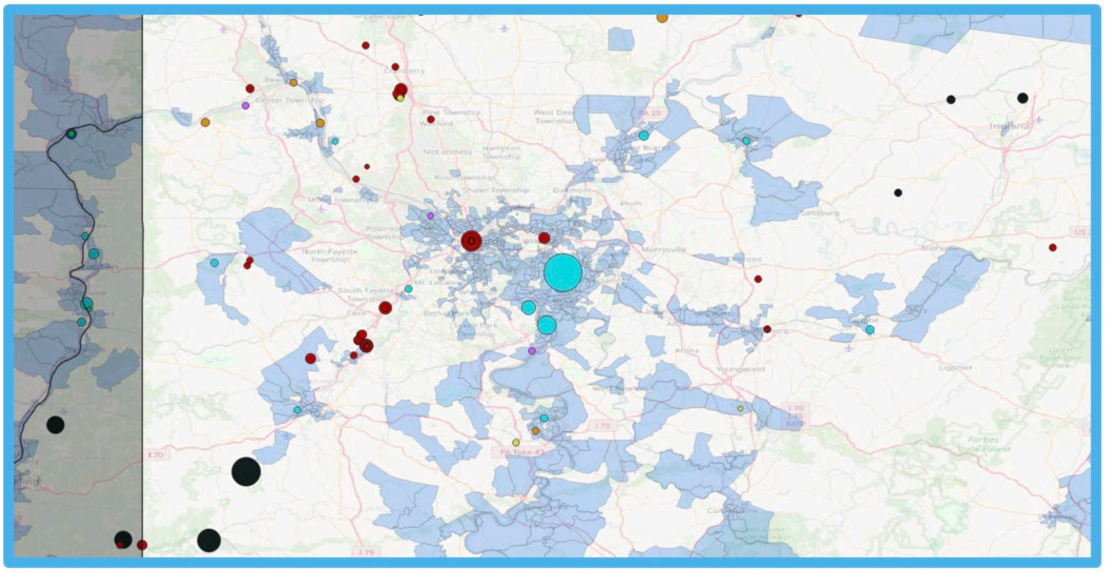


Figure 3. Philadelphia Area Mapping

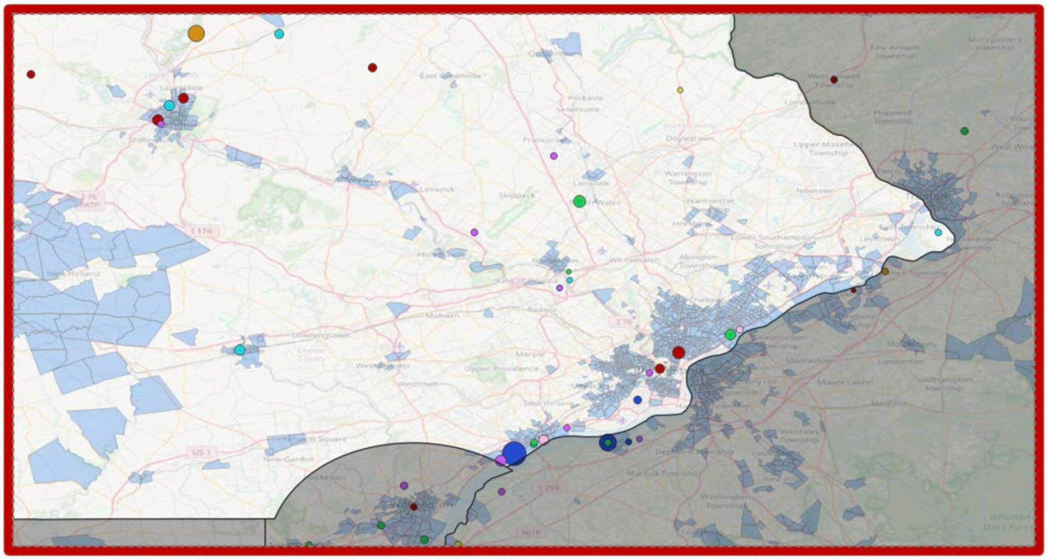


Figure 4. Lehigh Valley Area Mapping

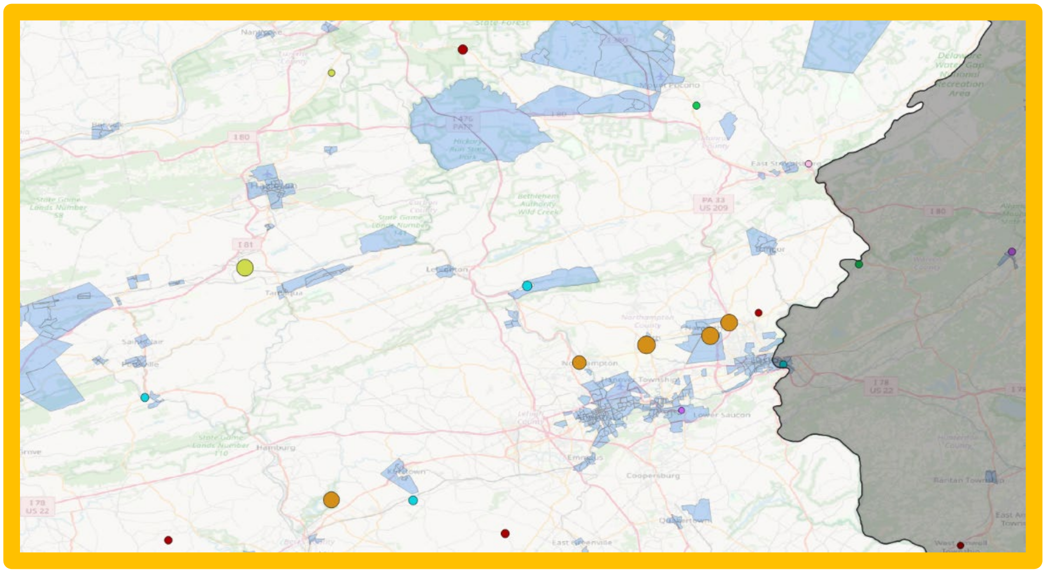
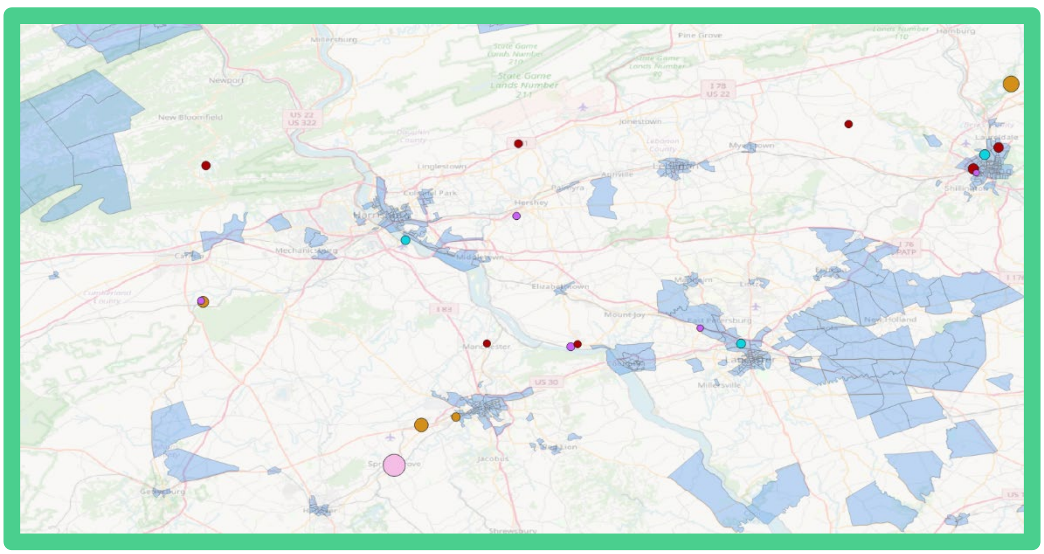


Figure 5. Harrisburg Area Mapping



The table below summarizes the community benefit considerations for decarbonization interventions across each industrial subsector. This summary considers the geographic proximity of each subsector to target communities (based on Strategen's mapping exercise above), the air quality and health improvements that may accrue to target communities as a result of decarbonization, and the potential disbenefits that may occur concurrently (e.g., the buildout of new infrastructure to facilitate decarbonization). This analysis is underpinned by the subsector decarbonization pathways outlined in Strategen's Pennsylvania Industrial Decarbonization Roadmap and the lever-specific community benefits considerations summarized in Table 2.

Table 5. Community Benefits by Industrial Subsector

	Potential Community Benefits or Disbenefits
Cement & Lime	+ Moderate potential for benefits based on geographic analysis. Distribution of facilities shows most are not in target areas. + Decarbonization of the subsector would result in mixed benefits due to the heavy need for CCS and fuel switching.
Chemical Manufacturing	+ Moderate to high potential for benefits – one large facility (Shell cracker) creates major air quality impacts but was not included in the mapping exercise because it is not included in the GHGRP dataset. Other chemical facilities do not appear to be concentrated in target communities. + Decarbonization of the subsector would result in mixed benefits due to the need for both efficiency and electrification (positive benefits) and fuel switching to hydrogen (mixed benefits).
Glass	+ Moderate potential for benefits based on geographic analysis. Distribution of facilities shows a mix of those in and outside target areas. + The major role of electrification and efficiency in the decarbonization pathway results in the potential for air quality benefits. Minimal use of CCS and hydrogen may create some disbenefits.
Food Processing & Other Manufacturing	+ Moderate potential for benefits. Nearly all decarbonization is attributed to energy efficiency and electrification, which offer substantial air quality gains. But these sectors are unlikely to be significant sources of air pollution compared to heavier industry. + Distribution of facilities shows roughly even numbers in target areas and outside target areas.
Fossil Fuel Extraction & Delivery	+ There is high potential for benefits, given the large concentration of facilities in target communities across the state and the heavy health impacts from this industry at present. + Technology upgrades can create benefits by reducing the need for new extraction (via methane leak prevention). + Decarbonization investments in this subsector may have a perverse impact of extending its lifespan, which would create continued disbenefits for surrounding communities.
Iron & Steel	+ High potential for benefits, given the heavy concentration of facilities in target communities across the state and the heavy air quality impacts of the subsector at present. + Efficiency and electrification (switch to EAFs/DRI-EAF) offer the most significant benefit potential. Hydrogen and CCS use are likely to have mixed impacts.
Other Metals	+ Moderate potential for benefits. Facilities appear to be concentrated in or near target communities, but uncertain air quality impacts of subsector processes (due to the diversity of metals businesses in the state) means overall benefits are highly facility-specific. + Contributions of efficiency and electrification to decarbonization create benefits, but decarbonization will also require fuel switching to hydrogen, which brings mixed benefits.
Pulp & Paper	+ High potential for benefits given facilities appear concentrated in target areas (although not densely populated areas). + The decarbonization pathway creates a high potential for benefits, given that nearly all emissions reductions are attributed to energy efficiency and electrification.
Refining	+ High potential for benefits given the proximity of facilities to (or in) target areas (specifically Philadelphia). + Decarbonization of the subsector would result in mixed benefits due to the need for fuel switching and CCS. + Decarbonization investments in this subsector may have a perverse impact of extending its lifespan/perpetuating fossil fuels, which would create continued disbenefits for surrounding and upstream communities.

Complementary Funding Available in Pennsylvania

Pennsylvania has existing government loan, grant, and tax credit programs that may be leveraged in a complementary manner with CPRG funding. Although the majority of industrial incentives in the state focus on job increases or construction equipment deployment rather than decarbonization, these dollars can still be creatively leveraged to promote decarbonization. The following list of ongoing Pennsylvania programs has been identified as relevant for industrial decarbonization. Several of these incentives also highlight Pennsylvania's commitment to creating quality jobs, providing employees with growth and training opportunities, and promoting investment and community development in distressed areas.

- **Keystone Innovation Zone Tax Credit:** Provides a credit to be applied against tax liability to promote the growth of for-profit companies less than eight years old operating within specific targeted industries – advanced materials/diversified manufacturing, business services, life sciences, high technology – within the boundaries of a Keystone Innovation Zone.
- **Regional Clean Hydrogen Hub Tax Credit:** Provides a tax credit for the use of clean hydrogen at a manufacturing facility that is designated as part of a federally funded Regional Clean Hydrogen Hub, provided the company makes a capital investment of $500 million in that facility and creates at least 800 jobs.
- **Tax Exempt Bond Program:** Provides tax exempt bonds to finance land, building, equipment, working capital and refinancing.
- **PIDA Low-Interest Loans:** Provides low-interest loans and lines of credit for construction costs, renovation costs, and machinery and equipment purchases.
- **Taxable Bond Program:** Provides taxable bonds to finance land, buildings, equipment, working capital, and refinancing.
- **Small Business Advantage Grant:** Provides grants for small businesses to improve energy efficiency or reduce pollution or waste by upgrading or replacing equipment or supplies, improving processes, or reducing runoff into affected waterways.
- **Manufacturing Tax Credit:** Provides a tax credit for companies that increase payroll by at least $1 million through full-time job creation.
- Industrial Resource Center Program: Provides funding for the state's seven Industrial Resource Centers to serve as technical resources for technology implementation and manufacturing competitiveness.
- **PennTAP:** Provides free technical assistance across a range of topics, including energy efficiency and technology commercialization.
- **WEDnetPA:** Provides qualified employers with training funds for new and existing employees.
- **PA First:** Provides grants, loans, or loan guarantees for various activities including job training and purchase or equipment upgrades.
- **Neighborhood Assistance Program:** Provides a tax credit for investments in distressed areas that promote community development.

Incentives for new-build construction that do not mention clean energy, such as the Local Resource Manufacturing Tax Credit and the Milk Processing Tax Credit, have been excluded.

Stakeholder Mapping

To determine potential partners for implementing CPRG funding, Strategen conducted an initial stakeholder mapping exercise focused on the companies contributing the most to industrial sector climate pollution in Pennsylvania and the enabling organizations that might be key partners in engaging companies in decarbonization efforts. This work will be expanded upon in more detail in the next phase of this project.

The table below summarizes the top-emitting companies in Pennsylvania (those emitting more than 500,000 metric tons of CO_2e in 2022), according to the EPA GHGRP. To characterize companies' potential willingness to engage in decarbonization efforts, Strategen analyzed their existing decarbonization commitments or efforts, summarizing them with the following high-level categorization system:

- *Nonexistent:* No climate target or specific decarbonization efforts could be identified.
- *Low:* The company has no formal target but has stated informal progress toward decarbonization.
- *Low-moderate:* The company has set a target that focuses only on the short term or only on the company's emissions intensity, not total emissions.
- *Moderate:* The company has set a net-zero target that excludes scope 3 emissions, does not include interim deadlines, or lacks specificity on the pathway to achievement.
- *Moderate-high:* The company has set a net-zero target for scopes 1 and 2 and made partial progress toward full scope 3 decarbonization.
- *High:* The company has made credible and ambitious climate commitments that fully decarbonize scopes 1, 2, and 3 and contain interim deadlines and specific details for achievement.

Additional detail or conversations with these companies would be necessary to validate this categorization.

Table 5. Companies with 500,000+ Metric Tons CO_2e Emissions/Year

Name	Sector	Emissions (metric tons CO_2e)	Decarbonization commitments or efforts	Existing relationship or contact
Consol Energy	Fossil fuel extraction and delivery – Coal	5,591,000	Nonexistent	No
US Steel	Iron and steel	4,126,000	Moderate	Indirect
Shell	Chemicals	2,248,000	Low-moderate	Yes
Iron Senergy	Fossil fuel extraction and delivery – Coal	1,503,000	Nonexistent	No
Delta Airlines	Refining	1,270,000	Moderate	Indirect
Heidelberg Materials	Cement and lime	1,115,000	Moderate	No
Graymont	Cement and lime	768,000	Moderate	No
Procter & Gamble	Pulp and paper	706,000	High	Indirect
Cleveland-Cliffs	Iron and steel	645,000	Low-moderate	No
Enbridge	Fossil fuel extraction and delivery – Oil & gas	642,000	Moderate	Yes

Keystone Cement	Cement and lime	633,000	Nonexistent	No
Air Products	Chemicals	618,000	Moderate-high	Yes
Buzzi Unicem USA	Cement and lime	552,000	Low	No
Williams Co.	Fossil fuel extraction and delivery – Oil & gas	503,000	Moderate	Indirect

In addition to the above, Strategen also examined other organizations that can be important enablers of industrial decarbonization efforts due to their work with industrial companies. These include membership-based organizations (e.g., trade associations), technical assistance providers, and nonprofit or economic development organizations with close relationships with industrial players. These stakeholder groups can help reach a broad spectrum of industrial companies in outreach efforts and provide insight into some of the decarbonization challenges or opportunities across the sector. The most promising organizations for outreach are summarized below.

Table 6. Enabling Organizations for Company Engagement

Name	Type	Relevant levers / Levers of focus	Geographic scope	Strategen existing relationship or contact
PA Chamber of Business and Industry	Association	All	Statewide	No
Keystone Energy Efficiency Alliance	Association	Energy efficiency	Statewide	Yes
Industrial Energy Consumers of Pennsylvania (IECPA)	Association	All	Statewide	No
DVIRC	Industrial Resource Center	Energy efficiency, material efficiency	Southeast PA	No
Manufacturers' Research Center	Industrial Resource Center	Energy efficiency, material efficiency	Eastern PA (Lehigh Valley)	No
MANTEC	Industrial Resource Center	Energy efficiency, material efficiency	South Central PA	No
Innovative Manufacturers' Center	Industrial Resource Center	Energy efficiency, material efficiency	Central PA	No
Northeastern Pennsylvania Industrial Resource Center	Industrial Resource Center	Energy efficiency, material efficiency	Northeast PA	No
NW IRC	Industrial Resource Center	Energy efficiency, material efficiency	Northwest PA	No

Catalyst Connection	Industrial Resource Center	Energy efficiency, material efficiency	Southwest PA	No
Penn State Regional Onsite Energy Technical Assistance Provider	Technical assistance provider – DOE-funded	Energy efficiency	Statewide	No
Lehigh University Regional IAC Center of Excellence	Technical assistance provider – DOE-funded	Energy efficiency	Statewide	No
In-2-Market	Convener	Energy efficiency, material efficiency, hydrogen, CCS	Southwest PA	Yes
Allegheny Conference on Community Development	Convener	Hydrogen, CCS	Southwest PA	Yes
Team Pennsylvania Foundation	Convener	Hydrogen, CCS	Statewide	Yes

Industrial Decarbonization Programs in Other States

Several states have established grant and financial incentive programs to drive emissions reductions at industrial facilities. The table below summarizes programs that may offer a model for PA DEP in implementing CPRG funding. Note that most of these programs are geared toward energy efficiency, with some also supporting industrial electrification or onsite renewable energy generation. Programs that explicitly support fuel switching and carbon capture have thus far been less common.

Program	State	Lever(s)	Type	Funding details	Description
C&I Carbon Challenge	New York (NYSERDA)	Electrification Carbon capture Low-carbon fuels Process emissions reductions	Grant Technical assistance	$500,000 - $5 million/proposal Up to $15 million available	For large, non-residential energy users (paying $1M+ annually on energy). Challenge winners work 1-1 with NYSERDA on refining and implementing projects. Projects last for 3 years.
C&I Accelerated Efficiency	New York (NYSERDA)	Energy efficiency Electrification	Grant	$500,000 - $5 million/proposal (cap of 50% of private investment amount) Up to $10 million available	For facilities with $500,000+ in annual energy costs. Supported energy reduction and electrification projects installed

					by the end of 2025. Projects last for 3 years.
Large Energy Users Program	New Jersey	Energy efficiency	Grant	$100,000 - $4 million/project Incentives capped at $/kWh or $/therm amount, or 75% of total project cost (whichever is lesser)	For facilities with $5M+ in annual energy costs. Applicants can submit up to 3 energy plans for funding.
Energy Efficiency Investment Fund	Delaware	Energy efficiency Electrification	Grant	Up to $250,000/facility calendar year (unless written approval) Up to 60% of energy efficiency-related costs Different $/kWh, $/therm, or $/kW incentives apply depending on grant type	Specifically for retirement and replacement of inefficient equipment. Particular focus on helping minority, women, veteran-owned, and small businesses. Several grant categories, one supporting prescriptive EE projects, another for more comprehensive projects (which includes a fuel switching bonus), and one supporting combined heat and power systems.
C&I Custom Program	Maine	Energy efficiency Distributed generation Behind-the-meter storage Beneficial electrification Heat recovery	Grant	$10,000 - $1 million/customer Each grant type (differentiated by lever) has differing incentive levels and maximum amounts	Custom projects are those not covered through Maine's C&I Prescriptive Program and include all levers mentioned to the left.
Industrial Energy Efficiency Program	Mississippi	Energy efficiency	Grant	$15,000 - $50,000 Up to 50% of total project costs	Must submit an energy audit along with a grant application. They offer assistance to

					offset energy audit costs.
C&I Solar Incentive Program	New Hampshire	Solar thermal Solar PV	Rebate	Up to 25% of the total project cost, or a $/watt incentive payment (whichever is lesser)	Differing incentive levels for solar PV and solar thermal
Low-Interest Commercial Loan Program	Delaware	Energy efficiency Renewable energy technology	Loan	$30,000 - $2 million/project with low-interest rates (determined by loan committee)	Loans up to 20 years. Terms require prevailing wage and other workforce-related requirements.
Energy Efficiency Revolving Loan Fund	Mississippi	Energy efficiency Renewable energy technology	Loan	Up to $500,000 with low-interest rates	Two categories of projects. One supports retrofits for equipment not used in manufacturing (e.g., HVAC, lighting). The other supports energy efficient process equipment (e.g., kilns, boilers). Must support demonstrated commercially feasible technologies.

Conclusions and Takeaways

The following takeaways are based on the insights from Strategen's analysis and include recommendations on how PA DEP can maximize both the competitiveness of its CPRG funding application and the effectiveness of program spending:

- **Energy efficiency and electrification investments across all industrial subsectors are identified as top priorities for CPRG funding.**
  - These levers offer the greatest near-term emissions reductions (through 2030), a high priority for CPRG.
  - Both of these levers offer considerable potential for localized job growth.
  - These levers are also anticipated to result in strong community benefits via air quality improvements, with minimal disbenefits identified.
- **Fuel switching to clean hydrogen and technology upgrades in the natural gas sector are second-tier priorities for CPRG funding.**
- **In general, Strategen does not recommend that PA DEP focus its funding on particular subsectors prior to completing direct outreach to industrial actors due to uncertainty about levels of interest from various industrial companies in those subsectors.** Creating broader programs (to which any subsector may apply) will likely be the most strategic use of CPRG implementation funding.
  - The exception is the natural gas subsector, which likely warrants a unique approach due to its large contribution to emissions and the specificity of decarbonization solutions in that subsector.
  - PA DEP may, however, choose to create programs that are tailored by facility size. Many other states have taken this approach, offering funding unique to large energy users or small manufacturers.
- **Attention should be paid to the solutions that PA DEP may deem eligible for program funding.** Although including a diverse range of solutions can help enable flexibility in achieving emissions reductions, improvements to subsidize solutions that industrial actors should have reasonably already implemented based on economics and/or future requirements will not yield the most optimal emissions outcomes.
- **To be competitive for CPRG funding, DEP will need to intentionally build strong community benefit and job quality considerations into decarbonization planning and proposals.** Creating funding carveouts for projects in specific geographies or offering funding bonuses to projects that integrate community benefits and job quality considerations (e.g., offering localized job training programs or commitments to use local labor and pay competitive wages) are two potential avenues for strengthening program design.
- **Based on an initial qualitative analysis, energy efficiency, and electrification have the highest potential for community benefits due to strong air quality improvements and fewer identified disbenefits.**
  - Clean hydrogen and carbon capture offer mixed benefits. Their air quality impacts warrant further study, and both are likely to result in substantive disbenefits due to a large need for enabling infrastructure.
  - On a subsector basis, investments in iron and steel, other metals, natural gas extraction/delivery, and refining are likely to yield the greatest benefits due to these

subsectors' heavy concentration in target areas and high existing air quality impacts.

- More than half of the large industrial facilities in Pennsylvania, accounting for 71% of emissions, are located within 3 miles of a disadvantaged community. This indicates that many of the facilities that may participate in a program supported through CPRG funding would have the potential to offer community benefits through environmental improvements. On a subsector level, all of the emissions from large facilities in the metals and refining sectors originate within 3 miles of a disadvantaged community, while the oil and gas and minerals subsectors within 3 of disadvantaged communities account for nearly 70% of their respective sectoral emissions.