SOLVING THE CLIMATE CRISIS: REDUCING INDUSTRIAL EMISSIONS THROUGH U.S. INNOVATION

HEARING

BEFORE THE

SELECT COMMITTEE ON THE CLIMATE CRISIS HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

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SOLVING THE CLIMATE CRISIS: REDUCING INDUSTRIAL EMISSIONS THROUGH U.S. INNOVATION

THURSDAY, SEPTEMBER 26, 2019

HOUSE OF REPRESENTATIVES,
SELECT COMMITTEE ON THE CLIMATE CRISIS,
Washington, DC.

The committee met, pursuant to call, at 2:07 p.m., in Room HVC–210, Capitol Visitor Center, Hon. Kathy Castor [chairwoman of the committee] presiding.

Present: Representatives Castor, Bonamici, Brownley, Casten, Neguse, Graves, Griffith, Palmer, Carter, Miller, and Armstrong.

Ms. CASTOR. The committee will come to order.

Without objection, the chair is authorized to declare a recess of the committee at any time.

Welcome to our witnesses. Today we will discuss reducing emissions in the industrial sector. Welcome to the—one of the most exciting hearings on the Hill today. We will focus on the technological opportunities and the policies needed to spur American innovation in addressing this global challenge.

I now recognize myself for 5 minutes for an opening statement.

I would like to start off by just acknowledging that it has been a very busy week for climate action. Kicking things off last Friday, young people and adults all across the world united for the Global Climate Strike. And here in Washington, D.C., and in the communities we represent back home, we were humbled to witness our own American student activists lead the March for Climate Action.

And starting earlier this week, world leaders gathered in New York City for the Climate Action Summit to call for urgent action to reduce carbon pollution and meet the goals of the International Paris Climate Agreement.

President Trump was, unfortunately, absent from the Climate Action Summit.

But while I was there for just a day or two, I saw American businesses, local community leaders and representatives, and a whole host of folks representing our country and working towards the goals of the Paris Agreement.

And I view our job on this committee as trying to fill the policy void left at the national level by the President.

To meet the goals of the Paris Agreement, to limit warming as much as we can, to 1.5 degrees Celsius, we will have to reduce emissions from every sector in the economy. Our committee has heard from experts on how to reduce pollution from the power and transportation sectors, both of which have received the most attention from policymakers at the State and Federal levels.

But today we are here to tackle the industrial sector. This is the sector we count on to make raw materials, like steel and cement, for our buildings and infrastructure. It is the sector that makes fertilizer to grow our food, and the metals, plastics, and chemicals that go into the products we use every day. It is responsible for more than $3 trillion of U.S. GDP and almost 20 million jobs.

Industry also contributes nearly 30 percent of U.S. greenhouse gas emissions.

Many industrial processes use large amounts of energy and require high temperature process heat that cannot be electrified. Some industries release carbon dioxide from chemical reactions in the production process, which cannot be avoided. This makes industry one of the most difficult sectors to decarbonize.

Difficult, but not impossible.

As our panelists today will share, we already have tools at our disposal to reduce emissions from this sector and others are promising. Industrial efficiency technologies, like combined heat and power and waste heat to power, are already commercially available but require high upfront capital costs to implement.

Carbon capture of industrial carbon dioxide streams is being demonstrated around the world but is far from being widely deployed. Technologies like low-carbon cement and concrete and renewable hydrogen for industrial energy and feedstocks have great potential but need further development to be cost effective.

To reach the scale of deployment at the speed to limit warming to 1.5 degrees, we must put policies in place to incentivize all stages of research, development, demonstration, and deployment of these technologies.

And that is where we come in. As we craft policies for this sector, we must consider any potential impacts on production and on employment. Many industrial products are globally traded commodities, which means they are very sensitive to cost increases.

Well-designed policies can reduce emissions while maintaining U.S. competitiveness and preventing offshoring of family-sustaining industrial jobs in the United States. We do not have to choose between reducing emissions and maintaining a robust industrial sector. I am confident that American innovation, coupled with smart policies, will be the key.

At this time, I would recognize the ranking member, Mr. Graves, for 5 minutes.

[The statement of Ms. Castor follows:]

Opening Statement (As Prepared for Delivery)

Chair Kathy Castor

Select Committee on the Climate Crisis

Hearing on "Solving the Climate Crisis: Reducing Industrial Emissions Through U.S. Innovation"

September 26, 2019

It's been a busy week for climate action. Kicking things off last Friday, young people and adults around the world united for the global climate strike. Here in DC, I was humbled to witness our own young activists lead the march for climate action.

On Monday, world leaders gathered in New York to call for urgent action to reduce carbon pollution and meet the goals of the Paris Climate Agreement. President Trump was notably absent from the lineup.

Our job on this committee is to try to fill the policy void left at the national level by the president.

To meet the goals of the Paris Agreement to limit warming as much as we can to 1.5 degrees Celsius, we will have to reduce emissions from every sector of the economy. Our committee has heard from experts on how to reduce pollution from the power and transportation sectors, both of which have received the most attention from policymakers at the state and federal levels.

Today, we're here to tackle the industrial sector. This is the sector we count on to make raw materials—like steel and cement—for our buildings and infrastructure. It's the sector that makes the fertilizer to grow our food and the metals, plastics, and chemicals that go into the products we use every day. It's responsible for more than $3 trillion of U.S. GDP and almost 20 million jobs.

Industry also contributes nearly 30% of U.S. greenhouse gas emissions. Many industrial processes use large amounts of energy and require high temperature process heat that cannot be electrified. Some industries release carbon dioxide from chemical reactions in the production process, which cannot be avoided. This makes industry one of the most difficult sectors to decarbonize.

Difficult, but not impossible.

As our panelists today will share, we already have tools at our disposal to reduce emissions from this sector, and others are promising. Industrial efficiency technologies, like combined heat and power and waste heat to power, are already commercially available but require high upfront capital costs to implement. Carbon capture of industrial carbon dioxide streams is being demonstrated around the world but is far from being widely deployed. Technologies like low-carbon cement and concrete and renewable hydrogen for industrial energy and feedstocks have great potential but need further development to be cost effective.

To reach the scale of deployment at the speed needed to limit warming to 1.5 degrees, we must put policies in place to incentivize all stages of research, development, demonstration, and deployment of these technologies. That's where we come in.

As we craft policies for this sector, we must consider any potential impacts on production and employment. Many industrial products are globally-traded commodities, which means they are very sensitive to cost increases. Well-designed policies can reduce emissions while maintaining U.S. competitiveness and preventing off-shoring of family-sustaining industrial jobs in the United States.

We do not have to choose between reducing emissions and maintaining a robust industrial sector. I am confident that American innovation, coupled with smart policies, will be the key.

Mr. GRAVES. Thank you, Madam Chair.

This whole time I sit here, I have been talking. I don't think you listened to anything I say. But you just said some great words in there. I want to make note that you talked about the role of incentives, you talked about considering employment impacts and economic impacts.

And importantly, and perhaps most importantly, you discussed how the wrong policies could result in offshoring or leakage of emissions to other countries. And I do very much appreciate your recognition. I think those are important, very important factors that we need to be working together on as we move forward.

Thank you for holding this hearing today.

And I want to thank all of the witnesses for being here. Looking forward to your testimony.

Madam Chair, as we look back over the last several years in the United States and the emissions reduction profile that we have been able to experience in the United States, it has resulted in, in some cases, in emissions increases by other countries.

As we have discussed, if we squeeze the balloon in the United States, sometimes that pops out in other areas and you see greater global emissions, greater global emissions, not a reduction, as a result of inappropriate policies in the United States that are not smart, that are not well thought out, are not considering the global environment that we are operating in.

I have mentioned numerous times in this committee, and I am going to say it every single time: For every one ton of emissions we have had in the United States, China has increased their emissions by four tons. That is not a global win. It is not.

And for us to continue to look only myopically, only in a vacuum at the United States, that is not a global greenhouse gas emissions strategy, that is not a global climate change strategy. It is one that will have very little impact, if any, on the United States and on the globe, because it will result in greater greenhouse gas emissions for the globe, which doesn't turn that trend, bend that curve that we are all seeking to bend or change.

Madam Chair, I want to ask, submit for the record, this is an August 27 document that Bill Gates wrote. And here is a question you should ask about every climate change plan, and I am going to read one line he has here at the end where he says, "I am optimistic about all these areas of innovation, especially if we couple progress in these areas with smart public policies."

Companies need the right incentives—you see that, Bill Gates is quoting you—incentives to phase out old polluting factories and adopt these new approaches.

I think it is a really good, really good—I don't know if this is an op-ed or what this was—but it is a very good document. Again, I ask that this be included in the record.

Ms. CASTOR. Without objection.

[The information follows:]

Submission for the Record

Representative Garret Graves

Select Committee on the Climate Crisis

September 26, 2019

HERE'S A QUESTION YOU SHOULD ASK ABOUT EVERY CLIMATE CHANGE PLAN

(By Bill Gates,[1] August 27, 2019)

I get to learn about lots of different plans for dealing with climate change. It's part of my job—climate change is the focus of my work with the investment fund Breakthrough Energy Ventures[2]—but it's just as likely to come up over dinner with

[1] https://www.gatesnotes.com/Books/Sustainable-Materials-With-Both-Eyes-Open.
[2] http://www.b-t.energy/ventures/.

friends or at a backyard barbecue. (In Seattle, we get outside as often as we can during the summer, since we know how often it'll be raining once fall comes.)

Whenever I hear an idea for what we can do to keep global warming in check—whether it's over a conference table or a cheeseburger—I always ask this question: "What's your plan for steel?"

I know it sounds like an odd thing to say, but it opens the door to an important subject that deserves a lot more attention in any conversation about climate change. Making steel and other materials—such as cement, plastic, glass, aluminum, and paper—is the third biggest contributor of greenhouse gases, behind agriculture [3] and making electricity [4]. It's responsible for a fifth of all emissions. And these emissions will be some of the hardest to get rid of: these materials are everywhere in our lives, and we don't yet have any proven breakthroughs that will give us affordable zero-carbon versions of them. If we're going to get to zero carbon emissions overall[5], we have a lot of inventing to do.

This video features one company with an idea about how to make steel without coal. (I'm an investor in Breakthrough Energy Ventures[6], which in turn has invested in this company.)

Steel, cement, and plastic are so pervasive in modern life that it can be easy to take them for granted. The first two are the main reason our buildings and bridges are so sturdy and last so long. Steel—cheap, strong, and infinitely recyclable—also goes into shingles, household appliances, canned goods, and computers. Concrete—rust-resistant, rot-proof, and non-flammable—can be made dense enough to absorb radiation or light enough to float on water.

The 520 floating bridge [7] near my house sits on 77 concrete pontoons, each weighing thousands of pounds. In his book Making the Modern World[8], Vaclav Smil estimates that America's interstate highway system contains about 730 million tons of concrete in the driving lanes alone. (People sometimes use the terms cement and concrete interchangeably, but they're not the same thing. You make cement first, and then you mix it with sand, water, and gravel to make concrete.)

As for plastics, they have a bad reputation these days—and it's true that the amount piling up in the oceans is problematic. But they also do a lot of good. For example, you can thank plastics for making that fuel-efficient car you drive so light; they account for as much as half of the car's total volume, but only 10 percent of its weight!

So how do we cut down on emissions from all the steel, cement, and plastic we're making? One way is to use less of all these materials. There are definitely steps we should take to use less by recycling more and increasing efficiency. But that won't be enough to offset the fact that the world's population is growing and getting richer; as the middle class expands, so will our use of materials.

In a sense, that's good news, because it means more people will be living in sturdy houses and apartment buildings and driving on paved roads. But it's bad news for the climate. Take Africa, for example: Its emissions from making concrete are projected to quadruple by 2050. Emissions from steel could go up even more, because the continent uses so little now.

If using less isn't really a viable option, could we make things without emitting carbon in the first place? That is, in fact, what we'll need to do—but there are several challenges. First, these industries require a lot of electricity, which today is often generated using fossil fuels. Second, the processes also require a lot of heat (as in thousands of degrees Fahrenheit) and fossil fuels are often the cheapest way to create that heat.

Finally—and this might be the toughest challenge of all—manufacturing some of these products involves chemical reactions that emit greenhouse gases. For example, to make cement, you start with limestone, which contains calcium, carbon, and oxygen. You only want the calcium, so you burn the limestone in a furnace along with some other materials. You end up with the calcium you want, plus a byproduct you don't want: carbon dioxide. It's a chemical reaction, and there's no way around it.

All three are tough challenges, but don't despair. Scientists and entrepreneurs are trying to solve these problems and help make zero-carbon materials that will be affordable around the world. Here are a few of the innovative approaches that I'm especially excited about (note that I have investments in two of these companies, Boston Metal and TerraPower):

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[3] https://www.gatesnotes.com/Energy/We-should-discuss-soil-as-much-as-coal.
[4] https://www.gatesnotes.com/Energy/A-critical-step-to-reduce-climate-change.
[5] https://www.gatesnotes.com/Energy/My-plan-for-fighting-climate-change.
[6] http://www.b-t.energy/ventures/.
[7] https://en.wikipedia.org/wiki/Evergreen_Point_Floating_Bridge.
[8] https://www.gatesnotes.com/Books/Making-the-Modern-World.

• Carbon capture. The idea here is to suck greenhouse gases out of the air. I think this is probably the approach we'll have to take with cement; rather than making it without emissions, we'll remove the emissions before they can do any damage. There are two basic approaches: One is to grab the greenhouse gases right where they're created, such as at a cement plant (that's called carbon capture); the other is to pull them from the atmosphere, after they've dispersed. That's called direct-air capture, and it's a big technical challenge that various companies are trying to solve. Mosaic Materials[9], for example, is developing new nano-materials that could make direct-air capture much more efficient and cost-effective. And government policies that create financial incentives to use carbon-removal technology—like federal tax credits that were passed in 2018—will help us deploy it faster.

• Electrification. We may be able to replace fossil fuels with electricity in some industrial processes. For example, as you saw if you watched the video above, Boston Metal[10] is working on a way to make steel using electricity instead of coal, and to make it just as strong and cheap. Of course, electrification only helps reduce emissions if it uses clean power, which is another reason why it's so important to get zero-carbon electricity[11].

• Fuel switching. Some industrial processes can't easily be electrified because they require too much heat. One possible alternative is to get the heat from a next-generation nuclear plant. (As I've mentioned before, a company that I helped start, TerraPower[12], uses an approach called a traveling wave reactor that is safe, prevents proliferation, and creates very little waste.) We also might be able to get the heat using hydrogen fuels, which can be made using clean electricity and don't emit any carbon when they're burned. Hydrogen fuels exist today, but they're expensive to make and transport, so companies are trying to drive the cost down and make hydrogen fuels available at scale. The Swedish steelmaker SSAB plans to build the world's first fossil fuel-free steel plant powered by hydrogen[13], which will be running as a pilot project next year. ThyssenKrupp[14] and ArcelorMittal[15] also recently announced projects in this area.

• Recycling. On its own, recycling steel, cement, and plastic won't be nearly enough to eliminate greenhouse gas emissions, but it will help. The best book I've read on recycling—yes, I've read more than one!—is called Sustainable Materials With Both Eyes Open, and I highly recommend it[16].

I'm optimistic about all these areas of innovation—especially if we couple progress in these areas with smart public policies. Companies need the right incentives to phase out old polluting factories and adopt these new approaches. If all of these pieces come together, we will have a climate-friendly plan for steel, as well as cement, plastic, and the other materials that make modern life possible.

Mr. GRAVES. Thank you.

And it is a very, very practical approach. He talks specifically about concrete, about plastics, and other sectors.

But there is no question that cement plays a very important role in our infrastructure and the resiliency of this Nation. It is going to continue to. You can look at the emissions profile as we import all of this cement from other countries, particularly China, and look at the emissions profile there versus in the United States.

We need to continue making investments in carbon capture, storage, utilization, and other technologies that complement—in fact, I believe as Bill Gates notes in his letter—that complement some of the domestic resources that we have in the United States in industries, because simply offshoring these industries to other countries does not provide a global solution.

9 http://mosaicmaterials.com/.
10 https://www.bostonmetal.com/.
11 https://www.gatesnotes.com/Energy/A-critical-step-to-reduce-climate-change.
12 https://terrapower.com/.
13 https://www.economist.com/technology-quarterly/2018/11/29/how-to-get-the-carbon-out-of-industry.
14 https://www.thyssenkrupp-steel.com/en/newsroom/press-releases/press-release-110080.html.
15 https://corporate.arcelormittal.com/news-and-media/news/2019/mar/28-03-2019.
16 https://www.gatesnotes.com/Books/Sustainable-Materials-With-Both-Eyes-Open.

So with that, I want to thank you again for hosting the hearing. And looking forward to hearing from you all. And thanks for being here.

Yield back.

Ms. CASTOR. Thank you.

Well, without objection, members who wish to enter opening statements into the record may have 5 business days to do so.

Now I want to welcome our witnesses.

David Gardiner is president of his own environmental consulting firm, David Gardiner and Associates, which focuses on climate change and clean energy issues. The firm coordinates the Combined Heat and Power Alliance and the Renewable Thermal Collaborative.

Prior to founding DGA, Mr. Gardiner served in the Clinton administration as executive director of the White House Climate Change Task Force and as assistant administrator for policy at the Environmental Protection Agency.

Dr. Jeremy Gregory is executive director of the MIT Concrete Sustainability Hub. Dr. Gregory is an engineer who studies the economic and environmental implications of materials, their recycling and recovery systems. The CSHub at MIT was established with grants from the Portland Cement Association.

Brad Crabtree is vice president of the Carbon Management Program at the Great Plains Institute and director of the Carbon Capture Coalition. The coalition is a national partnership of more than 70 companies, labor unions, and environmental, clean energy, and agricultural organizations that support the adoption and deployment of carbon capture technologies.

And Ms. Cate Hight is a principal at Rocky Mountain Institute where she leads the institute's efforts to reduce methane emissions from the global oil and gas industry. Before joining RMI, Ms. Hight spent 10 years at the Environmental Protection Agency, where she managed the oil and gas program of the Global Methane Initiative.

Welcome to all of you.

Without objection, the witnesses' written testimony will be made part of the record.

With that, Mr. Gardiner, you are recognized for 5 minutes.

STATEMENTS OF MR. DAVID GARDINER, PRESIDENT, DAVID GARDINER AND ASSOCIATES; DR. JEREMY GREGORY, EXECUTIVE DIRECTOR, MIT CONCRETE SUSTAINABILITY HUB, ON BEHALF OF PORTLAND CEMENT ASSOCIATION; MR. BRAD CRABTREE, VICE PRESIDENT, CARBON MANAGEMENT, GREAT PLAINS INSTITUTE, ON BEHALF OF THE CARBON CAPTURE COALITION; AND MS. CATE HIGHT, PRINCIPAL, INDUSTRY AND HEAVY TRANSPORT, ROCKY MOUNTAIN INSTITUTE

STATEMENT OF DAVID GARDINER

Mr. GARDINER. Thank you, Chair Castor.

And thank you, members of the committee. It is great to be here. I would urge this committee to focus on three key points.

First, as you indicated in your opening remarks, the biggest challenge in reducing industrial emissions comes from the energy to produce heat used in the manufacturing process. Globally, industrial heat makes up two-thirds of industrial energy demand and almost one-fifth of global energy consumption; 90 percent of this heat is produced using carbon-emitting fuels.

Emissions from heat are concentrated in eight energy-intensive basic sectors: steel, chemicals, cement, pulp and paper, aluminum, glass, food, and oil refining. Climate solutions must include approaches to reduce emissions associated with heat production while also making those industries more competitive.

Second, we can and should make America's factories more efficient through the use of efficiency technologies such as combined heat and power, CHP, and waste heat to power, WHP. Because they use heat, which would otherwise be wasted, these technologies can make manufacturers more competitive by reducing energy costs while also cutting emissions.

By harnessing that heat with industrial efficiency, in combination with CHP and WHP, America's manufacturers can cut carbon emissions in an amount equal to that emitted by 46 coal-fired power plants, while saving their own businesses $298 billion between now and 2030.

The Department of Energy has identified nearly 241 gigawatts of remaining CHP technical potential, an amount equal to 480 conventional power plants, with the greatest opportunities in the chemicals, petroleum refining, food, paper, and primary metal sectors.

But CHP and WHP face economic and financial, regulatory and informational barriers to their deployment. To help make manufacturers more competitive, we need a variety of policies to move them forward, many of which already enjoy bipartisan support. These include tax, energy infrastructure, regulatory, information, and industrial efficiency policies.

Third, the committee should recommend policies which accelerate the development and deployment of renewable heat technologies. These technologies have received little attention in discussions of how to reduce emissions and have been called the sleeping giant of renewable energy.

Today, only 10 percent of global heat production is powered with renewable energy. So there is clearly a very large opportunity to scale that up.

Renewable heat sources include renewable natural gas, which is produced from agricultural and food wastes, wastewater treatment plants and landfills, biomass, under the right circumstances, renewable hydrogen and electrification, solar thermal, and geothermal.

In March, the Renewable Thermal Collaborative issued a renewable energy buyers statement calling on market players and policymakers, such as all of you, to accelerate the deployment of cost-effective renewable thermal technologies. Leading industrial companies, such as Cargill, Clif Bar, Chemours, General Motors, HP, L'Oreal, Mars, Proctor and Gamble, and Stonyfield signed the statement.

To meet their own corporate commitments to reduce carbon emissions, they need cost-effective and sustainable renewable thermal technologies. Like combined heat to power and waste heat to power, these technology face supply, market, and policy barriers. The signers believe we should follow a path similar to that of renewable electricity markets where steady technology innovation and improvement have made wind and solar cost effective and the preferred choice in many markets.

The challenge is that few countries, including the United States, have done much. More than 120 countries have policies to promote renewable electricity, but only about 40 have specific policies for renewable heat, most of which are located in the European Union.

So in conclusion, I would just urge the committee to focus real attention on the greenhouse gas emissions associated with producing heat. Step one is to accelerate energy efficient measures like combined heat and power and waste heat to power, and step two is to focus on the innovation of renewable thermal technologies.

There are opportunities to advance these objectives with the support of industry and from Members of both parties, and we should seize them.

Thank you.

[The statement of Mr. Gardiner follows:]

Testimony of David Gardiner, President, David Gardiner and Associates and Executive Director, The Combined Heat and Power Alliance, Before the House Select Committee on the Climate Crisis, Solving the Climate Crisis: Reducing Industrial Emissions Through U.S. Innovation, September 26, 2019

Good morning. I am David Gardiner, President of David Gardiner and Associates, a strategic consulting firm focused on climate, clean energy and sustainability. I am also Executive Director of the Combined Heat and Power Alliance ("the Alliance"), a coalition of business, labor, contractor, and non-profit organizations, who share the vision that Combined Heat and Power (CHP) and Waste Heat to Power (WHP) can make America's manufacturers and other businesses more competitive, reduce energy costs, enhance grid reliability and reduce carbon emissions.[1] Companies like Cargill, GM, Kimberly-Clark, L'Oreal, Mars, P&G, and Stonyfield, are working with my firm, the Center for Climate and Energy Solutions and the World Wildlife Fund to scale up renewable heating and cooling at their facilities as part of the Renewable Thermal Collaborative.

The industrial sector is a large source of carbon dioxide and other greenhouse gas emissions and there is widespread recognition in America's manufacturing sector of the need to reduce their emissions. A 2018 report from the Alliance examined the public clean energy goals of 160 of the nation's largest industrial companies with a combined 2,100 manufacturing facilities in the United States. It found that seventy-nine percent of these manufacturers in the United States have established ambitious public goals to reduce their greenhouse gas emissions. Those companies need our help and support to ensure they can meet those emission reduction targets and become more competitive in global markets.

Much of these industrial emissions result from the energy used to produce heat for the manufacturing production process. Across the globe, industrial heat makes up two-thirds of industrial energy demand and almost one-fifth of total energy consumption. These emissions are concentrated in eight energy-intensive basic material manufacturing sectors—steel, chemicals, cement, pulp and paper, aluminum, glass, food, and oil refining—which produce more than 77 percent of global industrial emissions. Climate solutions must include approaches to reduce emissions associated with heat production, while also making those industries more competitive.

Make Industrial Processes More Efficient with CHP and WHP

The first step in addressing these emissions is to make industrial processes more efficient through the use of technologies such as CHP and WHP. CHP uses a single fuel source to generate both heat and electricity. As a result, it is twice as energy efficient and has half the emissions of the average power plant and it can deliver

[1] Until September 17, 2019, the Combined Heat and Power Alliance was known as the Alliance for Industrial Efficiency.

both the electricity and heat which industrial companies need to power their plants. WHP captures industrial waste heat and uses it to generate electricity with no additional fuel and no incremental emissions.

Because they use heat which would otherwise be wasted, CHP and WHP can make manufacturers more competitive by reducing energy costs while also cutting emissions. Our own analysis shows that by using industrial efficiency and CHP and WHP, manufacturers can cut carbon emissions by 174.5 million short tons in 2030—equal to the emissions from 46 coal-fired power plants—while saving businesses $298 billion from avoided electricity purchases.[2] The top 10 states in which these energy efficiency improvements would produce the greatest total carbon emission reductions and many of the cost savings are Texas, Ohio, Illinois, Indiana, Pennsylvania, Kentucky, Michigan, California, Georgia, and Alabama.

Moreover, CHP can provide overall energy and carbon dioxide savings on par with comparably sized solar photovoltaics (PV), wind, Natural Gas Combined Cycle (NGCC), and at a capital cost that is lower than solar and wind and on par with NGCC, according to the Department of Energy (DOE) and the Environmental Protection Agency (EPA).[3]

CHP systems can also run on renewable fuels, such as biomass (e.g., forest and crop residues, wood waste, food processing residue) or biogas (e.g., manure biogas, wastewater treatment biogas, landfill gas), which can lower GHG emissions even further.

CHP is also accelerating the deployment in microgrids of other renewable technologies, such as solar. A microgrid is a local energy grid that can disconnect from the traditional grid and operate on its own during grid outages. CHP provides 39% of the energy in existing microgrids and offer important reliability benefits when the solar power may not be working.[4]

In addition, because CHP and WHP produce energy onsite at manufacturing facilities, they also can make industrial plants more resilient in the wake of extreme weather events. This ability to come back online, when the electricity grid is not operating, is a significant advantage for industries such as chemicals and petroleum refining, which are highly concentrated on the hurricane-prone Gulf Coast.

Today, CHP produces approximately 9 percent of U.S. electricity, but the potential is much greater. CHP could produce 20 percent of all electricity by 2030, according to DOE's Oak Ridge National Laboratory.[5] DOE has identified nearly 241 GW of remaining CHP technical potential capacity, an amount equal to 480 conventional power plants. The chemicals, petroleum refining, food, paper and primary metals industrial sectors have the greatest potential for CHP installation and to cut emissions while increasing competitiveness, according to DOE.[6]

Unfortunately, CHP and WHP face economic and financial, regulatory and informational barriers to their deployment, according to DOE.[7] CHP requires a significant upfront capital investment, forcing it to compete with other industrial company priorities for limited investment capital. The business model of a utility can reduce its interest in promoting industrial CHP projects. States may adopt policies, such as burdensome standby rates, which discriminate against CHP, or fail to account for its resilience, cost savings and emission reduction benefits. Potential hosts, utilities and policymakers are often unaware of the benefits of CHP and WHP.

Make American Manufacturers Clean and More Competitive with CHP and WHP Policies

To drive the emission reductions and increased competitiveness which CHP and WHP can deliver to America's manufacturers, the Combined Heat and Power Alliance recommends Congress adopt policies which can overcome these barriers. In particular, we urge Congress to enact:

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[2] Alliance for Industrial Efficiency, *State Ranking of Potential Carbon Dioxide Emission Reductions through Industrial Energy Efficiency,* September 2016. https://chpalliance.org/resources/state-industrial-efficiency-ranking/.

[3] U.S. DOE, EPA, *Combined Heat and Power: A Clean Energy Solution,* August 2012 https://www.epa.gov/sites/production/files/2015-07/documents/combined_heat_and_power_a_clean_energy_solution.pdf.

[4] U.S. Department of Energy, Jun. 17, 2014, "How Microgrids Work" (https://bit.ly/2nFsiSP).

[5] Oak Ridge National Laboratory, *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future,* December 2008. https://info.ornl.gov/sites/publications/files/Pub13655.pdf.

[6] U.S. DOE, *Combined Heat and Power Technical Potential in the United States,* March 2016. https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf.

[7] U.S. DOE, barriers report, 2015. https://www.energy.gov/sites/prod/files/2015/06/f23/EXEC-2014-005846_6%20Report_signed_v2.pdf.

- Tax—There are several tax policy measures that would support greater adoption of CHP and WHP, and ensure their contribution to greenhouse gas emission reduction is recognized in the marketplace.
    - (HR 2283 and S 2289) Renewable Energy Extension Act which would extend the section 48 investment tax credit for CHP for five years, and (S.2283) The Waste Heat to Power Investment Tax Credit Act which would add WHP to the section 48 tax credit.
    - (S 1288) Clean Energy for America Act which is a technology neutral clean energy tax credit that accounts for both the thermal and electric energy that CHP systems generate when determining a system's overall greenhouse gas reduction benefit.
    - Finally, Congress should consider boosting the value of the investment tax credit for CHP to incentivize wider adoption, especially in non-traditional markets such as light manufacturing and multifamily housing.
- Energy Infrastructure—(HR 2741) The Leading Infrastructure for Tomorrow's (LIFT) America Act proposes several grid modernization and resiliency programs that encourage the use of onsite energy generation resources like CHP.
    - Section 31101—Authorizes $515 million per year (2020–2024) for a grant program to support state, local, and tribal governments in their efforts to employ "resiliency related technologies," like CHP, to harden their electric grids and protect critical infrastructure.
    - Section 31201—Authorizes $200 million per year (2020–2024) for a financial assistance program to support grid modernization partnership projects and allow greater customer based electric generation.
    - Sections 33301–33304—Establishes several programs to support distributed energy systems, including CHP and WHP. These include the creation of a revolving loan fund to support states, tribes, higher education institutions and utilities distributed energy deployment projects, and a technical assistance and grant program to assist nonprofit and profit entities with site identification, evaluation, engineering, and design of distributed energy systems.
- Regulatory—Regulatory policies promoting clean energy should allow CHP and WHP fair and equal access to energy markets.
    - (HR 2597 and S 1359) Clean Energy Standard Act which credits the greenhouse gas reduction benefits of CHP.
    - Encourage states to establish standby rate and interconnection policies that allow CHP and WHP deployment, and technical assistance grants. The Heat Efficiency through Applied Technology (HEAT) Act introduced by Senator Shaheen in 2017 proposed establishing model best practices states could use to address regulatory barriers to CHP and WHP deployment.
    - Recognize WHP as a renewable energy for purposes of federal electricity purchases (H.R. 8, 114th Congress, sec. 3115).
- Information—(HR 1480 and S 2425) CHP Support Act which would continue to provide information to manufacturers about the benefits of CHP and WHP by reauthorizing the Department of Energy's Technical Assistance Partnerships (TAPs). Congress should continue to provide appropriations for this program.
- Industrial Efficiency Policies—Congress should also enact policies that focus the federal government on broad strategies to encourage energy efficiency in the industrial sector such as the Energy Savings and Industrial Competitiveness Act (H.R. 3962, S. 2137), and Smart Manufacturing Leadership Act (H.R. 1633, S. 715).

Develop Cost-Effective and Sustainable Renewable Thermal Technologies

The second approach to reducing emissions from the energy used to produce heat used in the manufacturing process is to accelerate the development and deployment of renewable heat sources. This is an area which has received little attention in discussions of how to reduce the emissions which cause climate change. Indeed, the International Energy Agency (IEA) has called renewable heating and cooling "the sleeping giant" of renewable energy.[8] IEA has also found that only 10 percent of

[8] International Energy Agency, *Waking the Sleeping Giant*, February 2015, http://iea-retd.org/wp-content/uploads/2015/02/RES-H-NEXT.pdf.

global heat production is powered with renewable energy, with the remaining 90 percent from carbon emitting fuel sources.[9]

Renewable heat sources include Renewable Natural Gas (produced from agricultural and food wastes, wastewater treatment and landfills), biomass (under the right circumstances), renewable hydrogen and electrification, solar thermal, and geothermal.

Over the long term, the Energy Transmission Commission, for example, recommends using three renewable technologies to address industrial emissions, especially for heat production—biomass, electrification, and hydrogen.[10] In the short-term, however, the best approach is to advance a broad range of renewable thermal technologies and let markets determine the best outcomes.

In March, the Renewable Thermal Collaborative issued a Renewable Energy Buyers Statement calling on market players and policy makers to accelerate the deployment of cost-effective renewable thermal technologies. Leading industrial companies such as Cargill, Clif Bar, Chemours, GM, HP, L'Oreal, Mars, Procter & Gamble, and Stonyfield signed the statement.[11] They note that renewable thermal technologies are needed as they meet their own corporate commitments to reduce carbon emissions and that these technologies face many barriers. They believe we should follow a path similar to that of the renewable electricity market, where steady technology innovation and improvement has made wind and solar cost-effective and the preferred choice in many markets. Renewable thermal energy will benefit from a similar approach to develop innovative new technologies and deploy market-ready ones. As they note in their statement, this "may include development of new technologies, innovation and efficiency improvements in existing technologies, and research and deployment support from the national government".

These technologies face supply, market, and policy barriers, as outlined in a 2018 report to the Renewable Thermal Collaborative from my firm.[12] Renewable thermal technologies have few supporting policies, especially when compared to renewable electricity. According to the IEA, more than 120 countries in all world regions have introduced policies designed to promote renewable electricity, whereas only around 40 have specific policies for renewable heat, most of which are within the European Union.[13]

Conclusion

In conclusion, the Committee should focus significant attention on reducing the greenhouse emissions associated with producing heat. The first step is to accelerate energy efficiency measures, such as CHP and WHP, and the second is to focus on innovation of renewable thermal technologies. Many of the approaches to accelerate energy efficiency, CHP and WHP enjoy bipartisan support and Congress should move them forward quickly.

Ms. CASTOR. Thank you very much.

Dr. Gregory, you are recognized for 5 minutes.

STATEMENT OF JEREMY GREGORY

Mr. GREGORY. Good afternoon, Chairwoman Castor, Ranking Member Graves, and members of the Select Committee. I am pleased to be here on behalf of the Massachusetts Institute of Technology's Concrete Sustainability Hub and the Portland Cement Association to talk about concrete's role in a sustainable low carbon economy and how Congress and the cement and concrete industries can work together to achieve this goal.

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[9] International Energy Agency (IEA), 2014, *Heating without Global Warming*, https://bit.ly/2jj4mCy.

[10] Energy Transitions Commission, *Mission Possible: Reaching Net-Zero Carbon Emissions from Harder-To-Abate Sector by Mid-Century*, November 2018. http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf.

[11] Renewable Thermal Buyers Statement, https://www.renewablethermal.org/buyers-statement/.

[12] David Gardiner and Associates, *A Landscape Review of the Global Renewable Heating and Cooling Market*, July 2018, https://www.renewablethermal.org/a-landscape-review-of-the-global-renewable-heating-and-cooling-market/.

[13] International Energy Agency (IEA), 2014, *Heating without Global Warming*, https://bit.ly/2jj4mCy.

I am the executive director of the MIT CSHub, a dedicated interdisciplinary team of researchers working on science, engineering, and economics for the built environment since 2009. PCA is the premier organization serving America's cement manufacturers.

Since the CSHub is jointly funded by the cement and concrete industries by PCA and the Education Foundation for the National Ready Mixed Concrete Association, our research teams regularly interact with companies in this arena and also stakeholders who are involved in decisions related to concrete, such as architects, engineers, and contractors.

In my testimony today, I would like to provide the committee with some key actions related to the cement and concrete industries that will accelerate us on the path to sustainability in the industrial manufacturing sector.

For background, cement is the powdery substance that is mixed with water and aggregates to make concrete. If you didn't realize there was a difference between cement and concrete, you can join my entire extended family in that esteemed club.

Although cement and concrete have different manufacturing processes and emissions profiles, they are inherently linked as an end-use building material whose use impacts other emissions, such as building energy consumption or vehicle fuel consumption on pavements.

In addition, exposed concrete sequesters CO_2 over its lifetime in a naturally occurring chemical process. Thus it is important to consider the embodied emissions for these materials in the context of their full lifecycle and their potential to naturally sequester carbon.

Furthermore, concrete is the most used building material in the world for a reason: It is a relatively low-cost and low-environmental footprint material that provides critical functionality for buildings and infrastructure. It is necessary to meet societal goals for sustainable development.

There are four actions that can be taken to catalyze innovation in low-carbon cement and concrete.

The first action is reducing regulatory barriers to cement plant energy efficiency improvements and use of alternative fuels that are less carbon intensive than conventional fuels, such as biomass and waste materials. New Source Review and the Clean Air Act serve important functions, but they can be adapted to encourage reductions in cement production CO_2 emissions.

The second action is to support research and investment into the use of carbon capture utilization and storage technologies for the cement industry. Cement production is unique from most other industrial processes in that it has emissions associated with energy generation and the production process. Thus, even if zero or low carbon fuels can be used, emissions will still be a fundamental part of the process. As a consequence, CCUS is necessary to meet deep decarbonization goals, and pilot programs in the cement industry are underway across the world.

Fortunately, there are several companies that are demonstrating how captured carbon may be used to produce binders and aggregates, thereby enabling circularity for these emissions. However, cost is a significant barrier to implementation of carbon capture technologies at cement plants, in terms of capital costs, and the adoption of carbon utilizing materials, in terms of higher product cost in the building material marketplace. Thus, there are significant opportunities for Congress to provide targeted CCUS research, development, and deployment funding that is specific to the cement sector and incentives for adoption of innovative technologies and materials.

The third action is to encourage measurement of the environmental footprint of concrete. The public sector uses approximately 45 percent of cement in the U.S. and thus can play a role in asking producers to report the CO_2 emissions associated with the concrete used in those projects. What gets measured matters. This will help to increase competition for the use of low-carbon cement and concrete, many of which are available today.

The final action is to encourage adoption of performance-based standards. Increasing the adoption of alternative binders will require overcoming the risk aversion of engineers specifying concrete. Engineers typically rely on prescriptive-based specification that detail the types and limits of materials that can be used in concrete mixtures.

In addition, there is a significant burden of proof to demonstrate that new low carbon materials will meet long-term structural and durability requirements. Supporting a shift to performance-based specifications for concrete would spur innovation in the design of low-carbon concrete mixtures. Sponsoring research on the long-term structural and durability performance of concretes using blended or alternative cements will help to mitigate perceived risks by engineers.

As you can see, there are steps Congress, industry, and academia can take together that would ensure the continued role of cement and concrete in sustainable development.

Ms. Chairwoman and members of the committee, we are ready to work with you to pursue the path toward the goal of a clean and sustainable economy together.

Thank you.

[The statement of Dr. Gregory follows:]

Testimony for the Congress of the United States House of Representatives Select Committee on the Climate Crisis hearing on "Solving the Climate Crisis: Reducing Industrial Emissions Through U.S. Innovation", September 26, 2019, Presented by Jeremy Gregory, PhD, Research Scientist, Department of Civil and Environmental Engineering, Executive Director, Concrete Sustainability Hub, Massachusetts Institute of Technology, On behalf of the Portland Cement Association

Good afternoon Chairwoman Castor, Ranking Member Graves, and esteemed Members of the House Select Committee on the Climate Crisis. I am pleased to be here on behalf of the Massachusetts Institute of Technology's (MIT) Concrete Sustainability Hub (CSHub) and the Portland Cement Association (PCA) to talk about concrete's role in a sustainable low-carbon economy and how Congress and the cement and concrete industries can work together to address emissions from the industrial manufacturing sector and advance our nation's climate reduction goals. I am Executive Director of the MIT Concrete Sustainability Hub, a dedicated interdisciplinary team of researchers from several departments across MIT working on concrete, buildings, and infrastructure science, engineering, and economics since 2009. The MIT CSHub brings together leaders from academia, industry, and government to develop breakthroughs using a holistic approach that will achieve durable and sustainable homes, buildings, and infrastructure in ever more demanding environments.

We conduct our research with the support of the Ready Mixed Concrete Research and Education Foundation and the Portland Cement Association (PCA). PCA is the premier advocacy, policy, research, education, and market intelligence organization serving America's cement manufacturers. PCA members represent 92 percent of the United States' cement production capacity and have distribution facilities in every state in the continental U.S. Cement and concrete product manufacturing, directly and indirectly, employs approximately 610,000 people in our country, and our collective industries contribute over $125 billion to our economy (see details in Figure 1). Portland cement is the fundamental ingredient in concrete. The Association promotes safety, sustainability, and innovation in all aspects of construction; fosters continuous improvement in cement manufacturing and distribution; and promotes economic growth and sound infrastructure investment. PCA also works hand in hand with our partner associations and companies advancing the interests and sustainability of concrete building materials and products through the North American Concrete Alliance (NACA).

	Unites States	
	Cement	Cement & Related
Employees	13,190	169,375
Payroll ($)	848,203,728	8,838,172,117
Contribution to State Taxes Revenues ($)	181,191,344	2,350,908,147
Economic Contribution ($)	19,293,119,956	124,358,344,936

Figure 1. Statistics on the US cement industry. Source: Portland Cement Association.

In my testimony today, I would like to leave the Committee with five fundamental points about the path to sustainability in the industrial manufacturing sector through the lens of the cement and concrete industries.

First, while cement and concrete are separate and distinct materials, with different manufacturing processes and emissions profiles, they are inherently linked as an end-use building material and should be measured in the context of that end-use sustainability profile. Cement and concrete building materials (CCBMs), like steel, wood, glass, and other building materials, should be considered in terms of their embodied carbon across their full life cycle—from materials sourcing and manufacturing, to productive use, reuse, recycling, or disposal. Anything less than a life cycle approach creates a shell game where carbon emissions just shift from one part of the economy to another, or one nation to another, without solving the global challenge of climate change.

Second, CCBMs are and will continue to be critical and irreplaceable building materials for our national economy, providing sustainable, resilient, safe, and energy-efficient building solutions for the development and maintenance of our nation's infrastructure and built environment. When considered across their full life cycle, CCBMs provide comparable if not superior performance in terms of embodied carbon, resilience, safety, and climate adaptability when compared against other building materials.

Third, CCBM manufacturers are committed to working with policymakers, environmental scientists and engineers, builders, and customers to improve their sustainability and carbon intensity while maintaining the performance characteristics and value that have made CCBMs so important to our economy. CCBM manufacturers already invested billions of dollars to upgrade manufacturing facilities and processes, increase the fuel and energy efficiency of the manufacturing process, and reduce carbon and other air, waste, and water emissions. Where allowed under federal and state regulations, many of our manufacturers have looked for opportunities to incorporate lower-carbon alternative fuels like used tires, biomass, and other non-hazardous secondary materials into the manufacturing process.

Fourth, the CCBM industry faces unique challenges in building upon these initial sustainability efforts. With respect to fuel-related emissions, most of the opportunities for energy efficiency improvements for cement plants have been leveraged, and those remaining are often prohibitively expensive with limited impact. Federal and state regulations discourage the use of many lower-carbon alternative fuel sources, treating non-hazardous secondary materials like non-recyclable paper, plastic, and fibers as dangerous wastes, and cement manufacturers as incinerators. Many cement facilities cannot even transition from coal to lower-carbon natural gas due to the lack of natural gas pipelines and delivery infrastructure.

But fuel emissions are only part of the emissions reduction challenge. Cement manufacturers face a heretofore unsolved basic chemical fact of life—the industrial process for manufacturing cement from limestone results in the chemical release of carbon dioxide. No level of investment in additional energy efficiency technology or alternative fuels will address these process emissions, which constitute the majority of the cement industry's emissions. Only innovation and new technologies for carbon capture, transport, use, and/or storage will address these emissions, and these technologies are still years, if not decades away from plant-scale deployment in the cement industry. Bringing these technologies to market will require billions of dollars of additional investment in research, development, pilot scale testing, and infrastructure.

Fifth, any national carbon reduction strategy will need to recognize the economic realities of today's global market economy. Cement is a fungible global commodity, and domestic cement manufacturers are price takers rather than price makers, with limited ability to pass additional costs on to customers who can easily switch to lower-cost, often higher carbon imported cement. Domestic cement manufacturers cannot compete in a global market against foreign importers and countries who are not doing their fair share to reduce emissions. If the U.S. is to maintain a healthy domestic cement industry and the jobs and contributions to the domestic economy it provides, policymakers will need to address the risk of trade leakage head on. Policymakers in the EU, Canada, and California have recognized the need to protect energy-intensive trade exposed industries from trade leakage, and Congress needs to provide for a level competitive playing field for cement, concrete, and other industrial manufacturers.

With these facts in mind, the concrete and cement industries will need help from Congress to do their part. Congress can start by reducing the barriers manufacturers face to taking early action:

- reform and streamline federal and state permitting regulations under the Clean Air Act's New Source Review program to update facilities with more energy efficient manufacturing equipment;
- reform federal air and waste laws to treat non-hazardous secondary materials like non-recyclable paper, plastic, and fibers as fuel sources, not just waste products destined for landfills;
- expedite the permitting process for energy infrastructure projects, including pipelines to transport natural gas and other lower-carbon fuels to cement plants; and
- perhaps most important, provide dedicated funding for research, development, and deployment of commercial scale carbon capture, transport, use, and storage technologies needed to manage industrial process emissions and other hard-to-abate emissions from industrial manufacturing.

The remainder of this document provides background on CCBMs and opportunities, barriers, and solutions for enabling low-carbon pathways in the sector.

1 Background on concrete and cement

1.1 Concrete is critical for sustainable development

Concrete plays a critical role in achieving societal goals for sustainable development. It is required for nearly all aspects of our built environment including buildings, pavements, bridges, dams, and other forms of infrastructure. Infrastructure is required to achieve all 17 of the United Nation's sustainable development goals.[1] As growth in urban and suburban areas of the US significantly outpaces growth in rural areas (13%, 16%, and 3%, respectively since 2000),[2] demand for buildings and infrastructure will increase to meet the needs of migration and immigration. Calls for increased housing to address affordable housing shortages and more resilient buildings and infrastructure to mitigate the impacts of natural disasters will also lead to increased construction using concrete. While this development is inevitable, it is possible to make it sustainable.

1.2 Concrete is the most used building material in the world

Concrete's critical role in our built environment is manifest in how much it is used. Figure 2 shows global production (per capita) of common building materials.[3] Production volumes for cement, the binding agent in concrete, are nearly three times as much as steel, and concrete production is approximately seven times as much as cement (as shown in the chart). This significant consumption means it is also important to address when setting industrial emission targets.

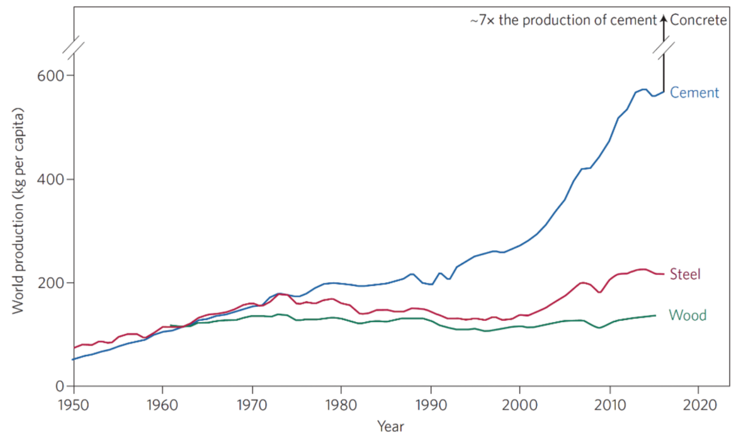


Figure 2. World production (per capita) of cement (the binder in concrete), steel, and wood [3]. Concrete production is about seven times higher than cement, so it is not shown on the chart.

1.3 Concrete is a mixture that usually includes cement as a binder

Concrete is made using five basic ingredients: coarse aggregates (gravel), fine aggregates (sand), binder (including cement), water, and admixtures (chemicals that can change concrete properties). These can be combined in infinite ways to meet performance requirements including strength, stiffness, density, constructability, and durability. When the binder is mixed with water it hardens to create a paste that keeps the aggregates in place.

There are numerous types of binders that can be used in concrete, as shown in Figure 3. Some are based on materials that can be mined and transformed into binders, whereas others are derived from waste materials. The most common binder used is portland cement (the name derives from the type of mineral first mined from the Isle of Portland in the UK when the process was developed in the 1800s). Portland cement is primarily made using limestone, which is abundantly available all over the world, can be produced within tight and reliable specifications, and has been used extensively for over 150 years, thereby making it the preferred binder for producing concrete. Alternative binders to portland cement are referred to as supplementary cementitious materials (SCMs). These include naturally occurring materials, such as natural pozzolans or calcined clays, and waste materials, such as fly ash from coal fired power plants, granulated slag from steel production, and more recently ground post-consumer glass. Availability and composition of SCMs can vary significantly, and they can have a different impact on the performance of concrete than portland cement.

Figure 3. Examples of binders that can be used to make concrete. Binders in the top row are created from materials mined in the earth, whereas those in the bottom row are derived from waste.

1.4 Cement production has energy and process-related emissions

The cement production process is shown in Figure 4 [4]. Limestone and other raw materials are mined and then go through a series of treatment steps before entering the kiln (step 6), which requires significant amounts of energy to maintain at 1,450 °C (these are referred to as energy or thermal emissions). The limestone is transformed into clinker in the kiln in a process called calcination that emits carbon dioxide (these are referred to as process emissions). The clinker may be blended with other cementitious binders and then ground to create the final cement product.

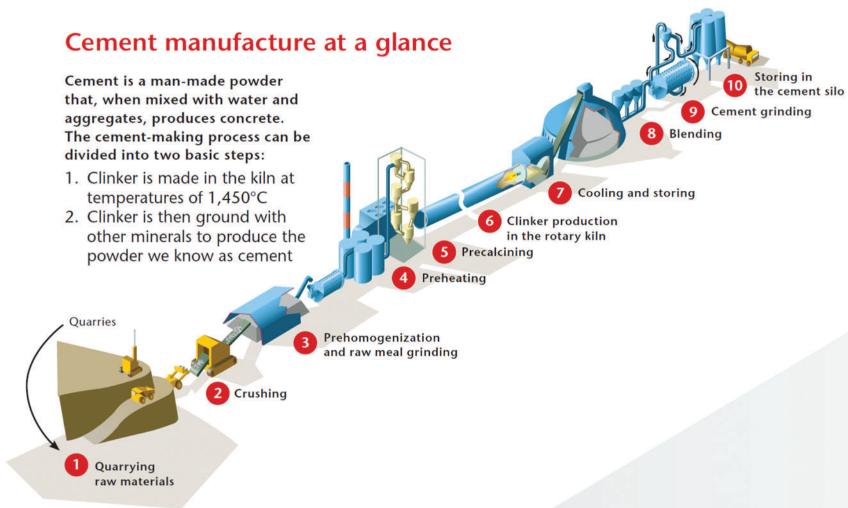


Figure 4. Cement production process [4].

Production of conventional portland cement in the US emits about 1 kg of carbon dioxide for every kg of cement produced [5]. As shown in Figure 5, approximately 50% of these emissions are from the calcination process, and 40% are from thermal or energy generation processes (maintaining the kiln at 1,450 °C).

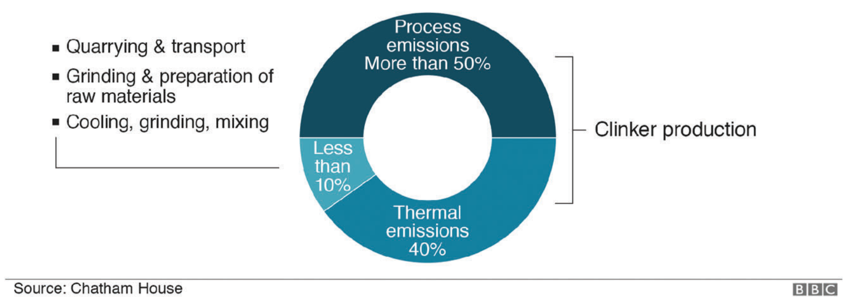


Figure 5. Sources of carbon dioxide emissions in conventional cement production [6].

1.5 Cement drives concrete's environmental impact

Figure 6 shows that by mass, concrete is primarily made up of aggregates. However, the greenhouse gas emissions (which are predominantly carbon dioxide) are from the cement. The aggregates have very low environmental footprint because they are simply mined from quarries without further transformation.

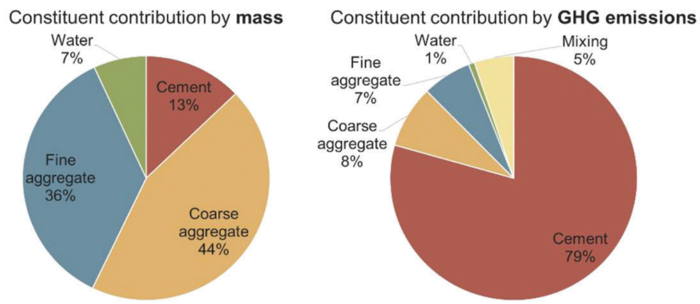


Figure 6. Concrete constituent contributions by mass and greenhouse gas (GHG) emissions for a conventional concrete (3000 psi) without SCMs. Source: CSHub calculations.

1.6 Concrete and cement are low-impact materials

On a per unit weight basis, concrete and cement have low embodied carbon dioxide and energy footprints (i.e., emissions and energy associated with production). Figure 7 compares these measures with those of other industrial materials [7]. Concrete's environmental footprint is so much lower than other materials because it is primarily made from aggregates, which, as noted above, have a low environmental footprint. While cement has significant process and energy emissions, they are smaller than those of other materials such as metals.

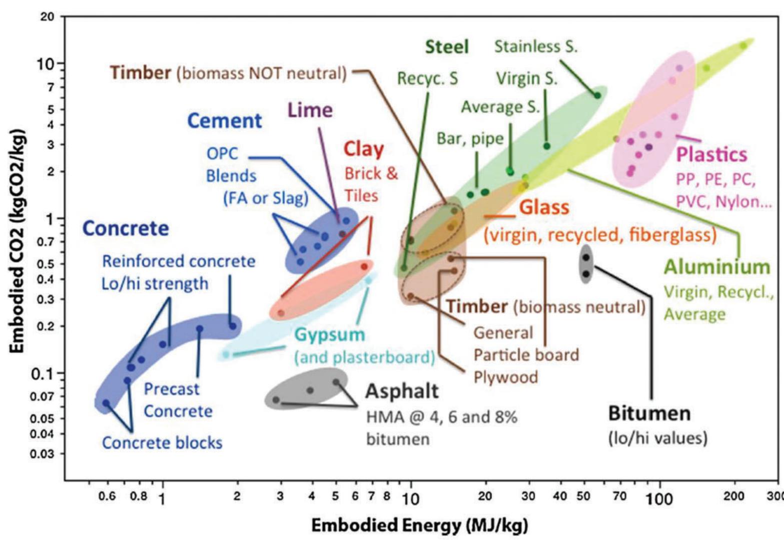


Figure 7. Embodied carbon dioxide emissions and energy from the production of various industrial materials [7]. Note that axes have a log scale.

1.7 Cement emissions constitute approximately 1% of US greenhouse gas emissions

Estimating greenhouse gas (GHG) emissions from cement production is difficult because it requires tracking both process and energy-derived emissions, and energy-derived emissions are rarely tracked for a specific industrial sector. For example, the most reputable quantitative estimate of global cement emissions as a fraction of all emissions has been done by the PBL Netherlands Environmental Agency [8]. They stated that process emissions contributed "to about 4% of the total global emissions in 2015" (pg. 64). To estimate total cement emissions, they state: "Fuel combustion emissions of CO_2 related to cement production are of approximately the same level, so, in total, cement production accounts for roughly 8% of global CO_2

emissions." (pg. 64–5) Their study details how they estimated cement emissions but does not describe how total GHG emissions are estimated. Thus, the 8% figure is an approximation.

Estimating US cement GHG emissions can be done using the US EPA's GHG inventory [9]. Process-derived emissions from cement production were 40.3 MMT CO_2 Eq. (million metric tons carbon dioxide equivalent) in 2017, out of 6,456.7 MMT CO_2 Eq., or approximately 0.6%. The inventory does not quantify energy-related emissions from cement production, so we are forced to use a similar approximation to the PBL study that energy and process-derived emissions are the same. This would make total cement industry emissions approximately 1.2% of total US GHG emissions in 2017.

1.8 The US produces a small fraction of the world's cement

China produces more than half of the world's cement, as shown in Figure 8 [6 8]. The US produced approximately 2% of global cement in 2015, compared to China's 58%, India's 7%, and the EU's 4% [8]. Thus, while it is important to strive to lower emissions from US cement production, it is also important to consider that the US has lower production than China, India, and the EU.

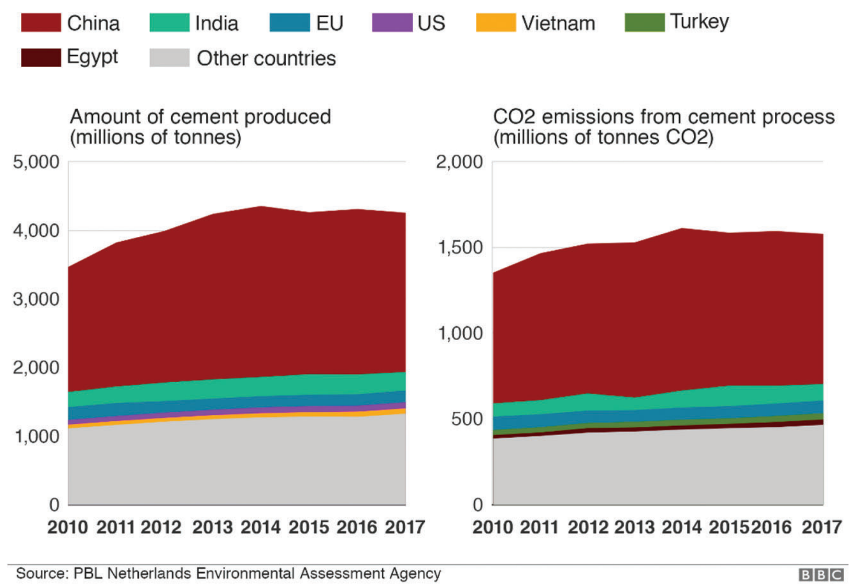


Figure 8. Global cement production volumes and process-related carbon dioxide emissions [6,8].

1.9 Different standards and practices for cement production worldwide present opportunities for leakage

It is basic economics that in a global market for a commodity product like cement, managing the costs of production is critical to ensuring the continued competitiveness of domestically-manufactured products. Facilities that can produce, ship, and deliver cement to customers at a competitive cost will flourish. Those that cannot maintain cost-competitiveness will fail.

These costs are determined in large part by the design and operating practices of the manufacturing facilities where cement is produced. While every cement manufacturing plant is different, the basic steps in the manufacturing process are the same. Costs of production are not, however, particularly with respect to compliance costs imposed by government entities. Government policies that impose additional costs on manufacturers have a direct impact on the global competitiveness of manufacturers and the risk of trade and carbon leakage.

This is particularly the case for the cement industry for several key reasons:

- The energy intensive nature of the manufacturing process, combined with the significant process emissions resulting from the conversion of limestone to cement makes the cement industry particularly vulnerable to policies that increase the cost to manage carbon emissions.

- U.S. cement manufacturers have limited ability to cost-effectively reduce GHG emissions and, therefore, to minimize compliance costs through investments in direct abatement.
- U.S. cement manufacturers have limited ability to pass through compliance costs to customers without a significant loss in market share.

Due to this unique combination of features, carbon pricing is likely to result in significant leakage in the U.S. cement industry unless countervailing measures are applied.

To illustrate this challenge, PCA estimates that given a carbon price of $40 per metric ton, the U.S. cement industry would experience an operating cost increase of more than $2.6 billion per year, representing roughly 50% of the U.S. cement industry's value added ($5.0 billion) and 30% of its total shipments ($8.7 billion) in 2016. Such increases could easily increase the cost of producing cement by more than $30 per ton, making domestic cement uncompetitive in many markets served by imports.

As Congress develops a comprehensive federal climate policy for U.S. manufacturers, this lesson in "economics 101" should be front and center as a consideration. Any comprehensive climate policy that imposes increased operating, compliance, or research and development costs on cement manufacture must include measures to address the risk of leakage from imported products.

2 Opportunities to lower carbon dioxide emissions of cement production

2.1 There are four primary levers for reducing cement production carbon dioxide emissions

The World Business Council on Sustainable Development (WBCSD) and the International Energy Agency's (IEA) Cement Sustainability Initiative (CSI) produced a technology roadmap for the cement sector in 2018 [10]. They identified four *carbon reduction levers*:

- Improving energy efficiency in the cement plant.
- Switching to alternative fuels that are less carbon intensive than conventional fuels, such as biomass and waste materials.
- Reducing the clinker to cement ratio by increasing the use of blended materials (including some of the aforementioned SCMs, among others) in the production of blended cements.
- Use emerging technologies to capture carbon and use, store, or sequester it, including in the production of new building materials.

The first three levers are already being used by the cement industry in the US and beyond.

2.2 The US cement industry has made significant efforts to improve energy efficiency and use of alternative fuels

U.S. cement manufacturers continue to invest billions of dollars in technologies to increase the energy efficiency of their plants and reduce carbon emissions associated with the cement manufacturing process. Duke University evaluated the improvement in the cement industry's energy performance over a 10-year period and found that: energy intensity improved 13 percent, the energy performance of the industry's least efficient plants changed most dramatically, total source energy savings were 60.5 trillion Btu annually, and environmental savings were 1.5 million metric tons of energy-related carbon emissions [11]. As a result, today's plants are far more fuel efficient than a generation ago, in many cases approaching the maximum levels of fuel efficiency technically feasible.

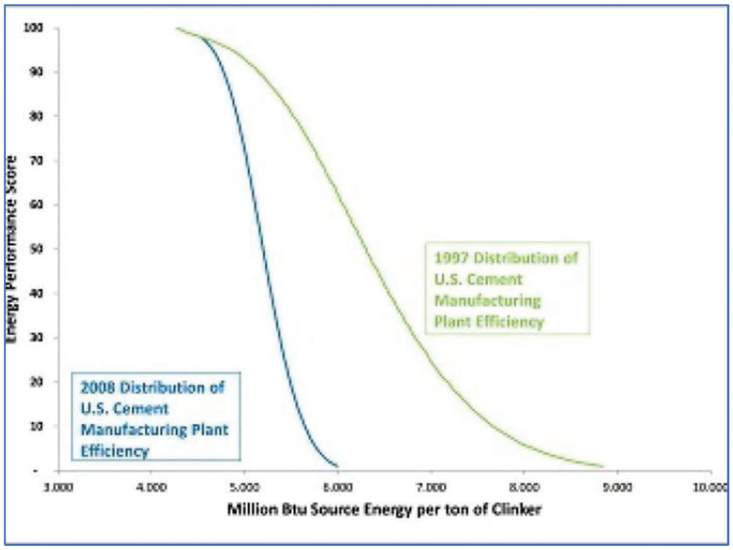


Figure 9. Comparison of 1997 (green) and 2008 (blue) distribution of US cement manufacturing plant efficiency as measured by the ENERGY STAR energy performance indicator [11].

Another key opportunity to reduce fuel emissions is to increase the use of lower carbon alternative fuels. Secondary materials like post-industrial, post-commercial, post-consumer paper, plastic, and other materials have tremendous energy value, providing a cost-effective and sustainable alternative to traditional fossil fuels. The cement industry has a long history of safe and efficient use of alternative fuels, ranging from used tires and biomass to a wide variety of secondary and waste materials. The high operating temperature and long residence times in the kiln make cement kilns extremely efficient at combusting any fuel source with high heating value while maintaining emissions at or below the levels from traditional fossil fuels. For the cement industry, secondary materials that would otherwise have little market value are valuable commodities, offering a cost-effective and environmentally sustainable alternative to traditional fossil fuels. While these efforts are important, there is much more to be done. Today, alternative fuels make up only about 15 percent of the fuel used by domestic cement manufacturers, compared to more than 36 percent in the European Union, including as high as 60 percent in Germany. Legal and regulatory barriers to alternative fuels use prevent the U.S. from having similar alternative fuels utilization rates to Europe.

The CCBM industry faces unique challenges in building upon these initial sustainability efforts. With respect to fuel-related emissions, most of the low-hanging fruit opportunities for energy efficiency improvements for cement plants have been leveraged, and those remaining are often prohibitively expensive with limited impact. Further improvements will also require cooperation by federal and state regulators that determine, through their regulations and permitting programs, whether and when facilities can adopt lower-carbon technologies, facility improvements, operations, and fuels.

2.3 Blended cements are available today

Portland limestone cement (PLC) is an example of a blended cement that is readily available from cement manufacturers. It is made by blending limestone with clinker (Step 8 of Figure 4). The limestone replaces clinker in the cement and therefore, has lower carbon dioxide emissions per unit weight of cement produced.

PLC has been used in Europe for over fifty years [12]. Current European standards allow for up to 35% replacement of cement with limestone, whereas in the US and Canada the limit is 15%. Studies have shown that PLC has nearly the same performance as ordinary portland cement (OPC) [12], but with a 10% reduction in carbon dioxide emissions from production (assuming 15% replacement) [13]. Costs of PLC are similar to OPC, as is its performance. Given, the lower environmental footprint, it would appear to be a strong candidate for increased use. However, PLC is approximately 1% of all cement produced in the US (all types of blended cements make up less than 3% of all cement produced in the US)[14]. This is primarily due to an unwillingness of concrete specifiers (such as engineers) to choose PLC over OPC, which has a longer history of use.

2.4 The technology roadmap for the global cement industry identifies emissions reductions required to meet global targets

CSI's 2018 technology roadmap[10] evaluated the required emissions reductions in the global cement industry required to meet a 2 °C climate scenario (2DS—maximum of 2 °C global temperature increase), as well as a beyond 2 °C scenario (B2DS—lower than 2 °C global temperature increase). They used a reference technology scenario (RTS) that assumed relatively flat direct carbon dioxide emissions until the year 2050 despite increases in cement production. This reference scenario assumes continued progress to reduce emissions associated with cement production at current rates.

As shown in Figure 10, the 2DS represents a 24% reduction in direct carbon dioxide emissions from the RTS by 2050. The B2DS represents an additional 45% reduction in direct carbon dioxide emissions over the 2DS.

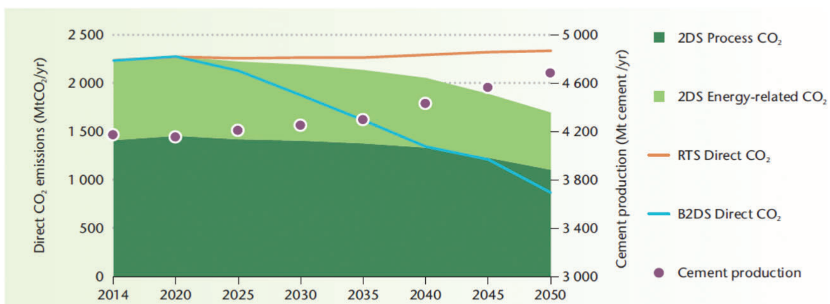
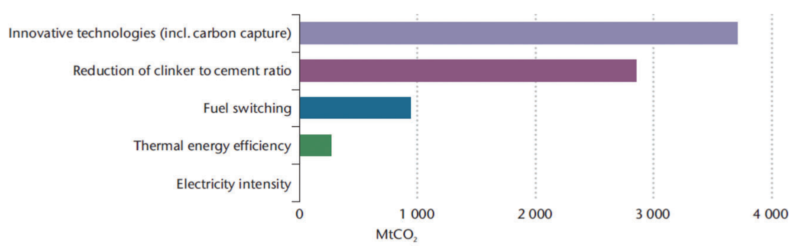


Figure 10. Global direct carbon dioxide emissions from cement production by scenario [10]. RTS = reference technology scenario. 2DS = 2 °C scenario. B2DS = beyond 2 °C scenario.

Lowering emissions requires a combination of the four levers mentioned in Section 2.1, as illustrated in Figure 11. Carbon capture technologies contribute 48% of cumulative emissions reductions, followed by use of blended cements (reduction of clinker to cement ratio) at 37%. There are fewer opportunities to improve thermal energy efficiency in cement plants or switch to alternative fuels.



Note: Cumulative CO_2 emissions reductions refer to the period from 2020 to 2050 and are based on the low-variability case of the scenarios.

Figure 11. Global cumulative carbon dioxide emissions reductions by applying the 2 °C scenario compared to the reference technology scenario [10].

The CSI roadmap includes estimates of global investments required to meet both the RTS and 2DS (Figure 12). $107 billion to $127 billion are estimated cumulative investments to meet the RTS globally by 2050 (24–28% increase over no action), and an additional $176 billion to $244 billion required to meet the 2DS (32–43% increase over RTS). No investment estimates are available for the US.

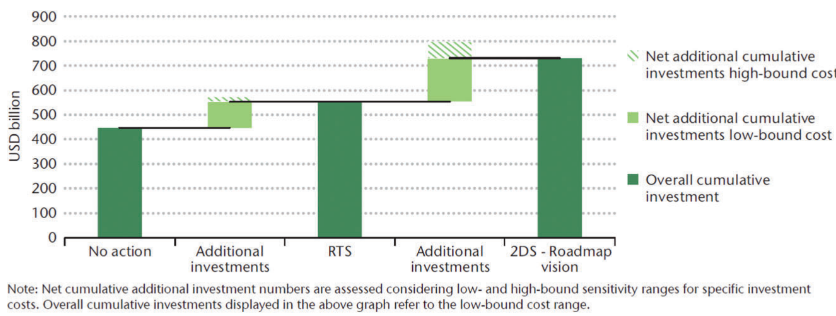


Figure 12. Global cumulative investments required to meet RTS and 2DS by 2050 [10].

3 Opportunities to lower carbon dioxide emissions of concrete

The majority of concrete's environmental footprint derives from the footprint of the materials in the concrete, rather than the production of the concrete, which primarily involves mixing (materials represented 95% of the GHG emissions in the case shown in Figure 6). Thus, use of low-carbon (i.e., low carbon dioxide footprint) constituent materials is the primary mechanism for lowering carbon dioxide emissions of concrete. There are three main categories of low-carbon constituent materials.

3.1 Blended cements

Blended cements, such as portland limestone cement, were described in Section 2.3 and are currently produced by cement manufacturers. They make use of many of the same SCMs used in concrete such as fly ash and blast furnace slags (described in Section 1.3). Production of blended cements varies significantly worldwide depending on demand, which is primarily influenced by historical practices for producing concrete, although availability of SCMs is a factor as well (e.g., China and India have significant availability of fly ash from coal fired power plants). There is currently limited demand for blended cements in the US—they make up less than 3% of all cement produced in the US. [14]

3.2 Supplementary cementitious materials

SCMs are used more extensively in the US in concrete than in cement. Conventional SCMs include fly ash and blast furnace slag, although other alternatives exist that are used more commonly in other parts of the world including silica fume, natural pozzolans, calcined clays, vegetable ash. More recently, binders made from ground post-consumer glass have become commercially available at small scales. Availability, chemical composition, performance, and cost often determine whether SCMs are used in concrete.

3.3 Cement, aggregate, and concrete made from captured carbon dioxide

The process of *mineralization* involves exposing minerals to carbon dioxide to create a carbonate mineral. It is a natural process that took place over millions of years to create the limestone used in the production of cement. More recently it has been proposed as a form of carbon capture and utilization (CCU) to create materials that can be used in concrete production. This includes the production of binders, aggregates, and concrete (i.e., carbon dioxide is used in the mixing process) using carbon captured from industrial sources, potentially including cement plants. Several companies have been created over the past decade in an attempt to commercialize mineralization for building products [15]. There is significant variation in the degree to which they make use of carbon dioxide. Most of the companies are in a start-up phase with demonstration plants or small production volumes, but several of them have products currently being used in construction projects. In some cases, the technologies can only be used to make concrete blocks in production facilities (as opposed to cast-in-place concrete on job sites) because of the requirements to control the mixing of carbon dioxide with minerals. As such, this limits their application to cases where concrete blocks can be used (such as buildings).

3.4 Considerations for the use of low-carbon constituent materials

It is important to note that substitution of these low-carbon constituent materials for conventional materials in a concrete mixture will not necessarily result in the same performance (strength, stiffness, constructability, durability) of the concrete mixture. Designing a concrete mixture to meet performance targets can be a complicated process that involves trade-offs of many factors that vary depending on the constituents being used. Furthermore, specifications for concrete often limit the use of blended cements or SCMs [16]. Thus, requirements for substitutions of conventional materials for low-carbon alternatives are not straightforward and may not be feasible for many situations.

4 Importance of a life cycle perspective in evaluating environmental impacts of buildings and infrastructure using concrete

The true environmental impact of concrete can only truly be evaluated using a life cycle perspective that encompasses its application in buildings and infrastructure. For example, a life cycle assessment of several building types conducted by our team at MIT has shown that embodied environmental impacts of buildings (associated with material production and building construction) are at most 10% of the total life cycle greenhouse gas emissions (Figure 13); energy use represents the vast majority of environmental impacts [17].

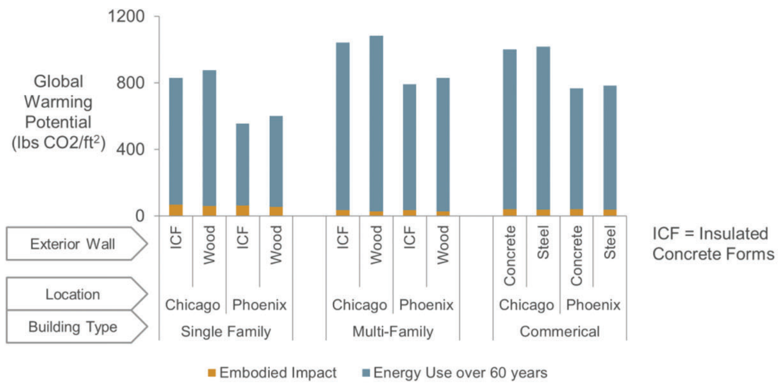


Figure 13. Life cycle global warming potential (greenhouse gas emissions) of three building types in two climates [17]. Embodied impacts include material production and building construction.

Similarly, the life cycle impacts of pavements are dominated by the use phase, which includes excess fuel consumption of vehicles due to roughness or deflection in the pavements (which leads to additional energy dissipation in the vehicle).[18] In the case of the urban interstate pavements in Figure 14, materials and construction make up only 26% of the life cycle GHG emissions.

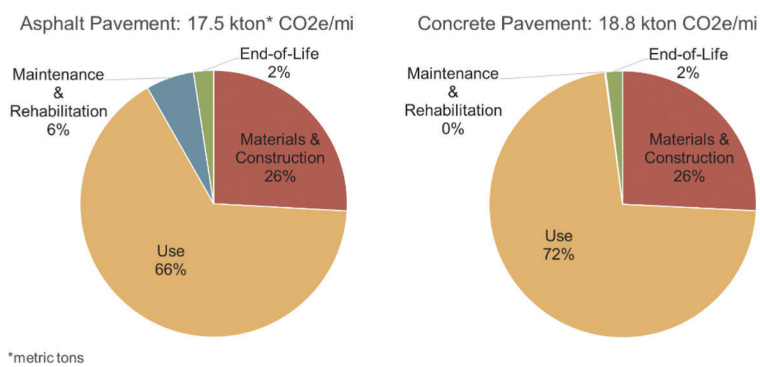


Figure 14. Life cycle greenhouse gas emissions for urban interstate pavements in Missouri.[18] The use phase includes excess fuel consumption from vehicles due to roughness or deflection in the pavements.

Finally, concrete naturally absorbs carbon dioxide over its lifetime as part of a chemical process called carbonation, which is the reverse of the calcination process that leads to process emissions in the production of cement. A study estimated that

4.5 gigatons of carbon dioxide has been sequestered in carbonating cement materials worldwide from 1930 to 2013, offsetting 43% of process CO_2 emissions (Figure 15)[19]. Hence, there is significant potential to use cement and concrete as a carbon sink in the future.

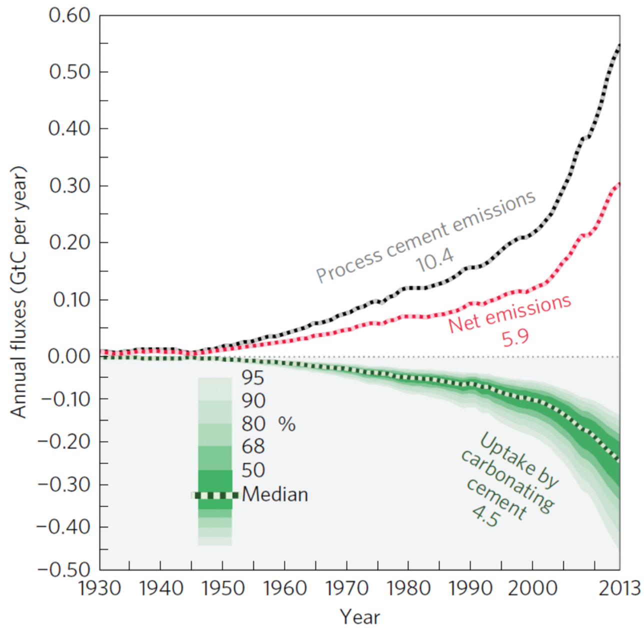


Figure 15. Process carbon dioxide emissions from production of cement (black line), uptake of carbon dioxide by carbonating cement (green line), and net of process emissions and carbon uptake (red line)[19].

Thus, while it is important to seek opportunities to lower embodied emissions in the built environment, it is also important to consider the impact that materials and design choices have on life cycle impacts, particularly if they can enable emissions reductions (e.g., through reduced building energy consumption or lower excess fuel consumption) and carbon uptake.

5 Barriers to adoption of low-carbon solutions

5.1 Regulations prohibit increased use of alternative fuels in cement plants

Federal policies often discourage rather than embrace the use of secondary materials as fuel in the industrial sector. The industry's use of alternative fuels falls under two environmental laws administered by the U.S. Environmental Protection Agency (EPA), the Clean Air Act (CAA), and the Resource Conservation and Recovery Act (RCRA). The CAA addresses ambient air quality and emissions from manufacturers, power plants, and motor vehicles. RCRA governs the management of solid waste and the generation, transport, and disposal of hazardous materials.

In recent years, narrow judicial and regulatory interpretations of RCRA, the CAA, and EPA regulations have discouraged the use of non-hazardous secondary materials and wastes as fuels, treating these materials as dangerous wastes, and facilities using them as incinerators. These policies are contrary to basic science and public policy, discouraging the productive conservation and recovery of resources and increasing the use of emissions-intensive fossil fuels.

EPA recognized this fact in 2011 and issued a regulation known as the Non-Hazardous Secondary Materials (NHSM) Rule, intended to allow for secondary materials to be used for energy recovery if they met specific legitimacy criteria. In theory, the rule provided a way to distinguish between true waste materials with little to no value as fuel and those material streams that, traditionally discarded as a waste, could now be put to far more productive use as alternative fuels. In practice, the rule has become yet another roadblock to sound energy and materials recovery policy.

Manufacturers face a costly and time-intensive process to prove, on a case-by-case basis, why commonly landfilled materials such as unrecycled plastics, paper, fabrics/fibers, and other secondary materials should qualify for treatment as fuels, despite their demonstrably lower greenhouse gas and other air emissions and comparable heat value. The result is predictable. While alternative fuels make up an average of 36 percent of the fuel used to manufacture cement in the European Union (60 percent in Germany), it constitutes only 15 percent of the domestic cement industry's fuel portfolio.

5.2 New Source Review and other permitting processes discourage energy efficiency and carbon capture improvements and critical infrastructure

One of the common-sense strategies for any industry to reduce GHG emissions is to maintain and improve the operational efficiency of its facilities over time. Unfortunately, the current Clean Air Act New Source Review program, as interpreted by the courts and some prior administrations, actually penalizes companies for increasing the efficiency of its facilities. This forces companies to reject upgrades and investments. To address these process emissions and further reduce industry GHG emissions, manufacturers will need to install carbon reduction and carbon capture, use, and storage (CCUS) technologies, other technological advances developed in the future, and implement process improvements. Under the NSR program, such investments would face the same permitting and regulatory barriers that new facilities would face, particularly where the addition of new emissions control technology for one pollutant has a negative impact on the emissions profile for another. Congress should revise the NSR process to encourage, rather than discourage, investments in energy efficiency and carbon capture, use and storage technologies.

Other energy improvements require investment in infrastructure, like pipelines and distribution networks. Cement kilns operate 24 hours per day and almost 365 days per year, and have historically used fossil fuels, such as coal and petroleum coke, due to the need for plentiful fuel supplies that can easily be stored and are in plentiful supply. In recent years, the cement industry has used more natural gas to reduce GHG and other air emissions. According to the PCA's Labor and Energy Survey, from 2011 to 2016 the industry increased natural gas use from 3.9% to 15.5% of its fuel use, displacing higher carbon fuels like coal and petroleum coke and, as a result, lowering GHG emissions. Natural gas use at cement plants could be further increased if pipelines and related infrastructure were in place to supply these plants. Unfortunately, the permitting process under NEPA, the Clean Water Act, and state standards is preventing many industries from taking advantage of natural gas by preventing or delaying the necessary supply infrastructure. Congress should reform the infrastructure permitting process for badly needed energy infrastructure.

5.3 There is limited room for additional energy efficiency improvements in cement plants

The heat energy required to heat raw materials to the temperatures needed to trigger calcination makes cement manufacturing an inherently energy-intensive process. As noted in Section 2.2, the cement industry has invested significantly to increase the energy efficiency of its kilns, grinding equipment, and other operations. Moving forward, the industry will face increasing challenges in squeezing additional efficiency improvements out of its operations.

Further increases in efficiency improvements in cement manufacturing are not on the horizon without a revolutionary advancement in a completely new technology. The industry's efficiency is already close to the theoretical maximum. Martin Schneider, a cement processing expert has noted, "Taking into account all process-integrated measures, thermal process efficiency [in cement manufacturing] reaches values above 80% of the theoretical maximum."[20] That level of thermal process efficiency is unparalleled.

Any marginal increases in efficiency that could be gained, including technologies such as waste heat recovery, require additional energy. The basic laws of thermodynamics dictate that it takes energy to save energy; there is no free lunch. That additional energy increases the carbon footprint of a cement plant, making each additional joule of energy efficiency that much more difficult to gain. This explains why the CSI technology roadmap shows thermal energy efficiency gains as having the smallest opportunity for carbon dioxide emissions reductions (Figure 11 in Section 2.4).

5.4 Increased cost of low-carbon cement and concrete products

Publicly available data on prices of low-carbon cement and concrete products relative to conventional products is not available. However, anecdotal evidence suggests that there are usually cost premiums for the low-carbon products. Although one would expect there to be increased demand for these products in a place like Europe where a carbon cap and trade system exists, that has so far not been the case. Furthermore, there is at least one case of an American start-up company that created a binder using a mineralization process but never achieved commercial success and had to pivot to other applications [15]. The highly cost-conscious nature of the construction industry will likely make this a key barrier for some time.

5.5 Risk aversion of engineers specifying concrete

Given the high stakes involved in structures that use concrete, it is understandable that civil engineers specifying concrete mixtures would be risk averse. Engineers typically rely on prescriptive-based specifications that detail the types and limits of materials that can be used in concrete mixtures. Following such specifications helps to mitigate risk for them and the concrete producers because they can point to the specifications in case there are unforeseen problems. They also prefer to rely on the use of constituent materials that have been used in the past because of their perceived familiarity with performance. The downside of this practice is that it often limits the use of low-carbon materials, either explicitly or implicitly [16]. As such, prescriptive specifications inhibit opportunities for innovative concrete mixtures that make use of low-carbon materials, included blended cements and SCMs that are available for use today. In addition, there is a significant burden of proof to demonstrate that new low-carbon materials will meet long-term structural and durability requirements.

6 Solutions to enable a low-carbon cement and concrete industry

6.1 Promote adoption of energy efficiency technologies for new and retrofit cement plants

As noted in Section 5.3, it is possible to make energy efficiency improvements in cement plants, but they will require more than a simple federal mandate. Industry will have to partner with government to identify promising new energy efficiency technologies and make the investments in research, development, and deployment to bring them to market.

6.2 Encourage and facilitate increased use of alternative fuels in cement plants

There is a step the Committee could take today to reduce greenhouse gas emissions: provide manufacturers with enhanced flexibility to expand their use of alternative fuels. Congress can and should address this issue as a simple and early first step by amending the definitions of "Recovered Materials" and "Recovered Resources" within RCRA to distinguish them from solid waste. A core mandate of the Resource Conservation and Recovery Act is to conserve and recover national resources. To do so, it must start by clearly recognizing that materials with energy value are truly "resources," not waste.

In the interim, the Committee should urge EPA to revise the NHSM Rule, implementing guidance, and interpretations to limit the processing requirements for "discarded" materials to those activities necessary to create useful fuel. EPA should not impose processing requirements that add costs to fuel use without materially improving the fuel value or the emissions associated with its use. Finally, Congress should urge EPA to act on PCA's pending petition to provide a categorical exemption for the use of nonrecycled paper, plastics, fiber, and fabrics as fuel, based on the extensive data already provided to EPA.

6.3 Encourage and facilitate use of blended cements

As noted in Section 2.3, several blended cements are produced in the US today, including portland limestone cement and other blended cements that make use of SCMs, but there is limited demand for them, most likely due to risk aversion of engineers specifying concrete. The adoption of performance-based specifications (described below in Section 6.5) would make it easier to use such cements. In addition, sponsoring research on the long-term structural and durability performance of concretes using blended cements will help to mitigate perceived risk by engineers.

6.4 Support development and deployment of emerging and innovative low-carbon technologies for cement production including carbon capture, storage, and utilization

With at least half of the cement industry's greenhouse gas emissions resulting from the chemical conversion of limestone and other ingredients into clinker, any long-term carbon reduction strategy for the cement manufacturing industry will require significant advances in carbon capture, use, distribution, and storage (CCUS) technologies.

But while many promising technologies are under development domestically and overseas, few have reached the commercial stage of development, and most of the research and all of the federal funding has focused on the energy sector (power, oil, gas), not industrial sector solutions. This is an important point because, if the US is going to develop a long-term strategy to reduce carbon emissions from the industrial sector, policymakers must realize there is no one-size-fits-all solution to capturing, transporting, and using or storing carbon emissions. Industrial sources face different and far more complex technical challenges and operating conditions in adopting carbon capture, use, and sequestration technologies.

In short, successful commercialization and deployment of any broadly-applied CCUS carbon mitigation strategy will require targeted funding and financial incentives to move the technology from the demonstration and pilot stage to commercial-scale use—particularly within the industrial sector.

Potential policy mechanisms that can help accelerate these technologies include:

- Provided targeted CCS research, development, and deployment funding for the cement sector.
- Use long-term and predictable tax policy to incentivize R&D and rapid investment in carbon capture, distribution, use, and storage technologies and infrastructure.
- Reward early investment and adoption in new technologies.

6.5 Support deployment of performance-based specifications for concrete to spur innovation in concrete mixtures

In contrast to prescriptive-based specifications, performance-based specifications define performance targets for concrete (strength, stiffness, constructability, durability) with minimal limitations on the constituent materials that may be used [21]. This enables significant opportunities to spur innovation in concrete mixtures by enabling use of low-carbon materials [22]. Although performance-based specifications have been proposed for over two decades, there has been limited adoption within the architecture, engineering, and construction community, most likely due to a preference for using materials and practices that have been used in the past. A shift in paradigm to performance-based specifications will require encouragement and incentives.

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Ms. CASTOR. Thank you very much.

Mr. Crabtree, you are recognized for 5 minutes.

STATEMENT OF BRAD CRABTREE

Mr. CRABTREE. Chair Castor, Ranking Member Graves, members of the select committee, thank you for inviting me to testify.

I also want to recognize my fellow North Dakotan, Congressman Armstrong. Good to see you.

I am vice president for carbon management at the Great Plains Institute, and I am here today in my capacity as director of the Carbon Capture Coalition.

The 70 industry, labor, and environmental members of the Carbon Capture Coalition are dedicated to a common goal: economy-wide deployment of carbon capture to reduce emissions, support domestic energy and industrial production, and protect and create high-wage jobs.

Economy-wide deployment of carbon capture is indispensable to reducing industrial emissions and to meeting midcentury climate goals.

In March, coalition members urged this committee to include carbon capture research, development, and commercial deployment as an essential component of a broader strategy to decarbonize power generation in key industrial sectors by midcentury. Their letter cited IEA and IPCC modelling to underscore that carbon capture is not optional but essential from a climate perspective.

Industrial sectors, it has been noted, are responsible for roughly one-third of U.S. global greenhouse gas emissions. Many sources of industrial carbon emissions are inherent to the chemistry of industrial processes themselves. They often have few, if any, alternative options beyond carbon capture to reduce those process emissions.

Industries such as refining, steel, cement, chemicals, and others are central to modern life. They provide high-wage jobs to millions of Americans, and they support the economic and social fabric of our Nation. Yet their low-margin, trade-exposed commodity businesses are vulnerable to increases in costs due to emissions reductions. Fortunately, Federal policy can reduce these costs while avoiding plant closures and the offshoring of jobs and livelihoods.

We also start from a strong foundation of American technology leadership. Successful large-scale carbon capture and storage began in 1972 in west Texas, and the U.S. now has 12 commercial-scale facilities capturing over 25 million tons of CO_2 every year from industrial sources. Roughly 5,000 miles of existing CO_2 pipelines in 11 States transport that CO_2 from where it is captured to where it can be stored.

We are also now seeing growing innovation and investment in technologies to produce fuels, chemicals, building products, and advanced materials from captured carbon. This will create new markets for industrial emissions of CO_2 and its precursor, carbon monoxide.

Important innovation is also occurring overseas. Earlier this month, a U.S. delegation, coordinated by the Great Plains Institute, traveled to the United Arab Emirates, where Emirates Steel has the first, the world's first and only large-scale carbon capture project in that sector.

We also visited Belgium, where ArcelorMittal is partnering with U.S. technology firm LanzaTech on a project that will produce just over 20 million gallons of ethanol from steel plant carbon monoxide emissions.

Federal policy has a crucial role to play in helping to sustain American leadership and innovation in building this new carbon economy. The coalition commends Congress for last year's passage of landmark bipartisan legislation to reform and expand the section 45Q tax credit for geologic storage and for the beneficial use of captured carbon. We need to build on this important first step.

Toward that end, the Carbon Capture Coalition recently released a Federal Policy Blueprint recommending Federal financial incentives and other policies to complement 45Q in achieving economy-wide deployment of carbon capture, transport, use, removal, and geologic storage.

The Blueprint reflects a consensus of the over 70 companies, unions, and NGOs that are participating in the coalition, something of a rarity in Washington right now.

Coalition participants recognize that a whole portfolio of policies has supported the successful development and commercial scale-up of wind, solar, and other low and zero carbon technologies. Economy-wide deployment of carbon capture will require a comparable policy portfolio.

My written testimony outlines many of the Blueprint's specific policy recommendations, and it is also submitted into the record.

In summary, the coalition's policy recommendations fall into four major categories: ensuring effective implementation of the 45Q tax credit by Treasury and other agencies to make sure that the tax credit provides the expected certainty and financial flexibility; providing additional Federal incentives to enhance and complement 45Q to help more carbon capture transport, use, removal, and storage projects to achieve financial feasibility; making the development and financing of CO_2 transport networks a key component of broader national infrastructure policy; and finally, expanding and retooling Federal funding for research, development, demonstration, and deployment to make sure that the next generation of innovative technologies that will lower costs and improve performance make it to the marketplace.

In conclusion, economy-wide deployment of carbon capture is not optional if we are to decarbonize industry and achieve climate goals while avoiding the offshoring of jobs. We must build on the nearly 50 years of successful experience in this country with large-scale industrial carbon capture and learn from successful policy precedents in other areas and go on to implement a comprehensive policy portfolio that helps put our Nation on a path toward midcentury decarbonization.

Thank you again for the opportunity to testify.

[The statement of Mr. Crabtree follows:]

Testimony of Mr. Brad Crabtree, Director, Carbon Capture Coalition, Before the House Select Committee on the Climate Crisis, September 26, 2019

Chairwoman Castor, Ranking Member Graves, and Members of the Select Committee, thank you for inviting me to testify. My name is Brad Crabtree, and I am Vice President for Carbon Management at the Great Plains Institute. I am here today in my capacity as Director of the Carbon Capture Coalition, a national partnership (https://carboncapturecoalition.org/about-us/) of over 70 energy, industrial and technology companies, labor unions, and environmental, clean energy and agricultural organizations.

My testimony will address:

- the essential role that carbon capture must play in managing industrial carbon emissions to meet midcentury climate goals;
- existing examples of U.S. and global technology innovation and leadership; and
- key elements of a U.S. federal policy framework needed to achieve deployment of carbon capture technologies in key carbon-intensive industrial sectors.

Carbon Capture is Essential to Managing Industrial Emissions to Meet Midcentury Climate Goals

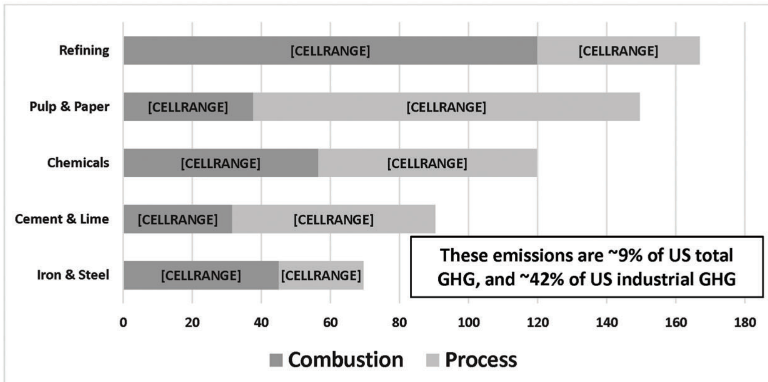
The Carbon Capture Coalition was established in 2011 to help realize the full potential of carbon capture as a national strategy for reducing carbon emissions, supporting domestic energy and industrial production, and protecting and creating high-wage jobs. The Coalition's members have forged an alliance of unprecedented diversity in the context of U.S. federal energy and climate policy, and they are dedicated to achieving a common goal: economywide deployment of carbon capture from industrial facilities, power plants, and ambient air.

Economywide deployment of carbon capture is indispensable to reducing industrial emissions. In March, the Coalition's industry, labor and NGO participants submitted a joint letter to this Committee and other committees of jurisdiction urging Congress "to include carbon capture research, development, and commercial deployment as an essential component of a broader strategy to decarbonize power generation and key industry sectors by midcentury."

In their letter, Coalition participants pointed to modeling by the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) that illustrates the critical role carbon capture must play in industrial decarbonization to meet climate goals. For example, in its modeling of scenarios for limiting warming to 2° Celsius, the IEA found that carbon capture must contribute 14 percent of cumulative emissions reductions by midcentury and 20 percent annually by 2050, with 45 percent of those reductions coming from industrial sources.

Capture from industrial facilities is not optional from a climate perspective. Industrial sources constitute roughly one third of global and domestic carbon emissions. While a range of measures can be taken to decarbonize energy inputs into industrial production (including carbon capture in power generation and reforming natural gas to produce hydrogen), many sources of carbon emissions are inherent to the chemistry of industrial processes themselves, which often have few, if any, alternative mitigation options available beyond carbon capture. Figure 1 highlights the significance of process emissions as a component of broader industrial emissions from refining, pulp and paper, chemicals, cement and lime, and iron and steel production.

Figure 1 - U.S. Greenhouse Emissions from Key Industrial Activities (million metric tons/year)



Source: Courtesy of the Clean Air Task Force. Data from US EPA https://www.epa.gov/ghgemissions for 2012 (cement & lime), 2013 (refineries & chemicals), and 2016 (iron & steel and pulp & paper). Distinction between "Combustion" and "Process" by CATF. Off-site electricity generation excluded.

The outputs of these and other industries are central to modern life, underpinning the livelihoods of millions of Americans and contribute to the economic and social stability of entire communities and regions across our nation. Industrial production and associated energy production and manufacturing support a high-skill, high-wage jobs base, yet these sectors' low-margin, trade-exposed commodity businesses leave them vulnerable to increases in costs incurred to reduce emissions. Deployment of carbon capture technologies, coupled with appropriate financial incentives and other policies to reduce costs and buy down risk, can enable the decarbonization and continued operation of existing industrial facilities, while avoiding their closure and the offshoring of jobs and livelihoods.

U.S. and global technology innovation and leadership

To underscore the challenge before us, over half of global industrial carbon emissions come from just three sectors—steel, cement and basic chemicals—and over half of those three industries' emissions are process emissions unrelated to energy inputs. Yet, there is only one large-scale commercial carbon capture facility operating in the world today in these three industries, and that is a steel plant in the United Arab Emirates.

Fortunately, carbon capture works, and we have a strong foundation of American technology leadership on which to build as we embark on strategies and policies to reduce industrial carbon emissions while sustaining our country's high-wage jobs base. Currently, there are 23 large-scale carbon capture and storage facilities operating in the world today, capturing nearly 40 million metric tons of CO_2 annually. Ten of those large-scale facilities are located in the U.S. In terms of industrial carbon capture, there are 12 operating commercial-scale facilities in the U.S. that capture CO_2 from a variety of industrial sources. They have a combined annual capture capacity of just over 25 million metric tons. The transport, use and geologic storage of that CO_2 is enabled by roughly 5,000 miles of existing CO_2 pipelines in 11 states.

Successful commercial and operational experience with large-scale industrial carbon capture with geologic storage dates back to 1972 in the U.S., when oil companies in West Texas first began capturing CO_2 from natural gas processing for use in enhanced oil recovery. Next, industrial carbon capture expanded to gasification for fertilizer and substitute natural gas production, followed by capture from fermentation at ethanol plants. Finally, large-scale commercial carbon capture from refinery hydrogen production came on line earlier in this decade.

These successful examples of commercial carbon capture represent higher purity industrial sources of CO_2 with lower costs of capture. These "low-hanging fruit" for industrial decarbonization include fermentation in ethanol production, gas processing, gasification and natural gas reformation for hydrogen production, all of which produce relatively pure streams of CO_2. Their costs of CO_2 capture and compression are now within range of the newly revamped federal Section 45Q tax credit. A key remaining deployment need for these sectors is federal support for financing additional infrastructure to transport the CO_2 from where it is captured to where it can be stored or put to beneficial use.

A second tier of industrial processes produce lower-purity streams of CO_2, and these include cement, catalytic cracking in refining, and steel production. These lower purity sources have seen little or no commercial-scale deployment of capture technology because of their higher capture costs. To varying degrees, they will need additional federal policy support for early commercial demonstration to complement the existing 45Q tax credit to reach financial feasibility.

In addition to effective demonstration of capture technologies, commercial markets and uses of captured industrial CO_2 in the U.S. have expanded over time as well. Until this decade, most CO_2 captured from industrial sources was utilized and geologically stored through enhanced oil recovery, with some CO_2 destined for food and beverage, dry ice and other high-value niche markets. In 2017, Archer Daniels Midland began large-scale storage of CO_2 from ethanol production in a saline geologic formation, a geologic storage pathway anticipated to grow significantly now that the 45Q tax credit provides $50 per metric ton for saline storage over $35 per ton for CO_2 stored through EOR. Looking ahead, rapidly growing interest and investment in the development and commercialization of different technology pathways to produce fuels, chemicals, building products, advanced materials and other beneficial products from captured carbon will create new markets for industrial emissions of carbon dioxide and its precursor carbon monoxide. To build upon the well-established pathway of CO_2 use and geologic storage through CO_2-enhanced oil recovery, it is critical that federal policy prioritize further development and commercial deployment of large-scale saline geologic storage and creation of new markets for captured carbon through stepped up R&D into beneficial uses of both CO_2 and CO.

American industry, labor and NGO leaders and federal and state officials are also learning from technology innovation overseas for application here at home. Earlier this month, a U.S. delegation coordinated by the Great Plains Institute traveled to the United Arab Emirates, where Emirates Steel began capturing 800,000 metric tons annually of CO_2 since 2016, and to Belgium, where ArcelorMittal is partnering with U.S. technology firm LanzaTech to construct a facility that will use microbes to transform waste carbon monoxide emissions captured from steel production into 17.5 million gallons of ethanol annually.

These successful examples of industrial carbon capture, coupled with emerging innovation in carbon utilization technologies and business models, are spurring the interest of U.S. companies, entrepreneurs and investors in a circular industrial economy in which waste carbon dioxide and carbon monoxide emissions become a source of economic value and part of the climate solution.

A robust federal policy framework is needed to sustain U.S. leadership and achieve economy wide deployment of carbon capture in key carbon-intensive industrial sectors

Federal policy has a critical role to play in helping to sustain American leadership and innovation in building this new carbon economy. Congress is to be commended for bipartisan passage last year of the FUTURE Act, a landmark reform and expansion of the Section 45Q tax credit for geologic storage and beneficial use of carbon captured from industrial facilities, power plants and ambient air.

To build on this cornerstone federal policy, the Carbon Capture Coalition released a Federal Policy Blueprint (https://carboncapturecoalition.org/wp-content/uploads/2019/05/BluePrint-Compressed.pdf) to Congress earlier this year, recommending federal financial incentives and other policies to complement the 45Q credit in driving private investment, and spurring innovation and cost reductions sufficient to achieve economywide deployment of carbon capture. The Coalition defines economywide deployment as advancing a critical mass of commercial-scale projects in key industrial sectors and power generation between now and 2030 to enable the scaling of the technology by midcentury to reach decarbonization goals. It's worth noting that the Blueprint reflects a consensus of the over 70 companies, unions and NGOs participating in the Coalition—a rarity on matters of federal energy, industrial and climate policy.

In crafting the Blueprint, Coalition participants recognized that an array of federal policies have supported the development and commercial scale-up of wind, solar and other low and zero-carbon technologies in the marketplace and that economywide deployment of carbon capture will require a comparable portfolio of policies. Toward that end, the Coalition recommends a package of federal policies that spans the full value chain of carbon capture, transport, use, removal and geologic storage.

The Carbon Capture Coalition's strategic vision for future policy action is to:

- Ensure effective implementation of 45Q by the U.S. Treasury to provide the investment certainty and business model flexibility intended by Congress;
- Provide additional federal incentives to complement, expand and build upon 45Q in financing carbon capture, utilization, removal and storage projects;
- Incorporate carbon capture, transport, utilization, removal and storage into broader national infrastructure policy; and
- Expand, retool and prioritize federal funding for research, development, demonstration and deployment (RDD&D) of the next generation of carbon capture, utilization, removal and geologic storage technologies and practices.

Economywide deployment of carbon capture will require federal legislative and administrative action in the following areas:

Investment Certainty

Effective implementation of the 45Q tax credit is crucial to providing the financial certainty and flexibility needed to leverage the private investment in projects sought by Congress. In particular, a longer time horizon for federal policy is needed to support early commercial-scale demonstrations of essential carbon capture technology in the most carbon-intensive industrial sectors, given long lead times needed to develop, permit, finance and construct such projects. The Coalition welcomes recent signals from the Treasury Department that the Internal Revenue Service (IRS) is now prioritizing completion of guidance to implement the 45Q tax credit, but significant concerns remain that hundreds of millions and perhaps billions of dollars in private capital remain on the sidelines as project developers and investors have waited 19 months for clarity from Treasury and the IRS.

Key Policy Priorities

- Lawmakers should extend the commence construction window for 45Q beyond the end of 2023 given Treasury delays on guidance and to send a signal of long-term policy continuity to project developers and investors.
- IRS should provide an additional equivalent pathway for demonstrating secure geologic storage through CO_2-EOR (in addition to the existing federal Subpart RR Greenhouse Gas Reporting Program) based on the International Organization for Standardization (ISO) Standard 27916 and supplemented with additional public transparency and accountability measures as recommended in the Coalition's June 28, 2019 comments (https://carboncapturecoalition.org/wp-content/uploads/2019/06/Final-CCC-submission-to-Treasury-6-28-19.pdf) to Treasury.
- Facilitate CO_2 transport infrastructure planning, siting and permitting through passage of the USE IT Act to help ensure the availability of infrastructure needed for development of carbon capture, use and geologic storage projects.

Technology Deployment & Cost Reductions

Just as federal investments in research, development, demonstration and deployment (RDD&D) have successfully helped scale up wind, solar and other low and zero-carbon energy technologies in the marketplace, expanding, retooling and prioritizing federal investments in transformational carbon capture, utilization, storage and removal technologies will be a critical component of driving down costs of carbon capture and utilization in key industrial sectors and making sure that the next generation of technologies with reduced costs and increased performance make their way to the marketplace. In this context, it is especially crucial that an expanded federal RDD&D program prioritize later-stage demonstrations of critical industrial capture and utilization technologies and not just early stage research and development.

The Carbon Capture Coalition welcomes and supports the many current bipartisan legislative efforts to update and expand federal authorities and funding for industrial carbon capture, utilization and storage as part of a broader innovation agenda. These bills enjoy widespread bipartisan and bicameral support and should be passed this Congress.

Key Policy Priorities

- Ensure robust federal appropriations for carbon capture, utilization, removal and storage RDD&D, ensuring inclusion of diverse industry sectors and processes, technology pathways and energy resources.
- Retool and expand federal RDD&D programs, including near-term passage of bipartisan legislation such as the USE IT Act, House Fossil Energy R&D Act, Senate EFFECT and LEADING Acts, and Clean Industrial Technology Act.

• Provide DOE cost share for Front-End Engineering and Design (FEED) studies to support the development of critical, commercial-scale industrial carbon capture and utilization and other technology demonstration projects.

Project Finance & Feasibility

An expanded portfolio of incentive policies to enhance and expand upon the 45Q tax credit will ultimately be necessary to foster early stage commercial demonstration and broader economywide deployment of industrial carbon capture and utilization technologies. These include: improvements to 45Q and other existing tax incentives that enhance monetization; technical corrections to 45Q that broaden eligibility and access; and complementary policies that contribute to overall financial feasibility by lowering the cost of debt and equity, reducing commodity risk and expanding markets.

An expanded incentive portfolio will be especially important to achieve widespread demonstration and deployment of carbon capture in three areas of crucial importance to industrial decarbonization: carbon-intensive industrial processes with higher costs of capture, such as the manufacture of steel and cement; electric generation needed to power and, where feasible, further electrify industrial processes; and natural gas reformation with carbon capture, which currently offers the lowest-cost pathway to provide zero-carbon hydrogen for process heat and other industrial applications.

Given the significant role that the federal government plays in the purchase of cement, steel and other key industrial commodities, federal procurement policy will play an especially important part in building markets for early commercial carbon capture and utilization projects in industry. In the case of low-margin industrial commodities, federal procurement policy can enable early innovators and investors to deploy technology to deliver a low or zero-carbon product to market, while only adding marginally to the total cost of federally-funded infrastructure, buildings and other projects.

Key Policy Priorities

Monetizing Financial Incentives

• Prevent the disallowance of 45Q under the BEAT Tax, similar to treatment of the Production Tax Credit for wind and Investment Tax Credit for solar.
• Enhance transferability of the 45Q tax credit consistent with the 45J tax credit for advanced nuclear.
• Provide a revenue-neutral refundability option for 45Q.
• Establish a 45Q bonding mechanism.

Technical Corrections to Expand Eligibility and Access

• Eliminate the 25,000-ton annual capture threshold in 45Q for carbon utilization projects.
• Fix the 48A tax credit to enable carbon capture retrofits of existing power plants (Carbon Capture Modernization Act).

Federal Policies to Complement 45Q

• Make carbon capture projects eligible for tax-exempt private activity bonds (Carbon Capture Improvement Act).
• Provide for eligibility of carbon capture projects for tax-advantaged master limited partnerships (Financing Our Energy Future Act).
• Reform the DOE Loan Program.

Creating Predictable Markets for Carbon Capture and Utilization

• Develop federal procurement policies for electricity, fuels and products produced from carbon capture, utilization, removal and geologic storage.
• Reduce commodity risk through federal contracts-for-differences (CfDs).
• Incentivize commercial production of low-carbon fuels from captured carbon.
• Ensure eligibility for carbon capture, if Congress enacts a federal electricity portfolio standard.
• Provide an enhanced investment tax credit for transformational carbon capture technologies.

Infrastructure Deployment

To achieve the full potential of carbon capture to reduce industrial emissions, while protecting and creating high-wage jobs, we must responsibly scale up infrastructure to create a nationwide network for transporting CO_2 captured from industrial facilities, power plants and ambient air to locations around the country where it can be put to beneficial use or safely and permanently stored in geologic formations. This buildout will include capacity expansions and extensions of existing pipeline networks, as well as the construction of long-distance, large-volume interstate trunk lines to serve states and regions that currently lack such infrastructure.

Key Policy Priorities

- Provide low and zero-interest federal loans to supplement private capital in financing pipeline projects.
- Provide federal grants to cover the incremental cost of supersizing pipelines to provide for extra capacity and realize economies of scale.
- Support flagship demonstration projects in key regions of the country, featuring large-volume, long-distance interstate trunk lines linking multiple industrial facilities and power plants that supply CO_2 to multiple utilization and geologic storage sites.
- Facilitate planning, siting and permitting of CO_2 transport infrastructure (USE IT Act).
- Provide eligibility for tax-exempt private activity bonds and master limited partnerships (Carbon Capture Improvement Act and Financing our Energy Future Act, respectively).

In summary, economywide deployment of carbon capture, use and geologic storage is not optional if we are to decarbonize industry and achieve midcentury climate goals. Carbon capture technology provides a viable pathway to enable the decarbonization and continued operation of existing and new industrial facilities, while avoiding plant closures and the offshoring of jobs and livelihoods. The U.S. is the world's leader in the capture, use and geologic storage of CO_2 from industry, with nearly 50 years of successful commercial and operational experience on which to build. We now have an opportunity to enact a broader portfolio of federal incentives and other policies for carbon capture, transport, use, removal and geologic storage. We must learn from our successful experience with wind, solar and other low and zero-carbon technologies and implement a broader policy framework for carbon capture in order to sustain U.S. leadership and help put our nation on a path toward midcentury decarbonization.

Thank you again for your opportunity to testify, and I look forward to your questions.

Ms. CASTOR. Thank you, Mr. Crabtree. And I have a copy of your May 2019 Federal Policy Blueprint from the Carbon Capture Coalition. So without objection, we will add that to the record.

[The information follows:]

Submission for the Record

Representative Kathy Castor

Select Committee on the Climate Crisis

September 26, 2019

ATTACHMENT: *Federal Policy Blueprint.* Carbon Capture Coalition, May 2019. This report is retained in the committee files and available at: https://carboncapturecoalition.org/wp-content/uploads/2019/05BluePrint-Compressed.pdf

Mr. CRABTREE. Thank you, Madam Chair.

Ms. Castor. Ms. Hight, you are recognized for 5 minutes.

STATEMENT OF CATE HIGHT

Ms. HIGHT. Thank you, Chair Castor, and thank you, Ranking Member Graves and members of the select committee, for inviting me to be here with you today.

It is truly an honor to be here with you during this very important week for climate, Climate Week, which really presents a special opportunity to bring attention to how we can decarbonize industry.

As the chair mentioned, I am a principal at Rocky Mountain Institute, where I lead our work on decarbonizing energy inputs to industry. RMI was founded in 1982 in Colorado, and we are an independent, nonpartisan charitable nonprofit dedicated to transforming global energy use to move the world toward a low carbon future that is clean, prosperous, and secure.

So I was invited here to provide RMI's perspective on decarbonizing industry and to speak specifically about how hydrogen can be used as part of the solution.

When we talk about industrial emissions, it is important to take into account the whole value chain, from start to finish. We need to consider how raw materials are sourced and processed, how products are manufactured, and finally, all of the transportation pathways—the ships, the trains, the planes, the trucks—that enable that package to arrive on your doorstep after you click the 2-day shipping button.

The environmental footprint of that package is unclear to customers who cannot see the emissions from each step in that value chain. But these activities contribute a huge share of greenhouse gas emissions, more than 40 percent worldwide, and these emissions are continuing to grow, putting our climate, our health, and our economy at risk.

Hydrogen can play a key role in reducing industrial emissions by displacing the fossil fuels that power much of this sector. The good news is that hydrogen is being produced in nearly every State, using a variety of different fuel sources.

Collectively, the U.S. makes about 10 million metric tons of hydrogen per year, which is about 15 percent of the global total. The challenge is that we need to produce a lot more of it, about 10 times as much, and we need more industrial sectors to use it. You, as legislators, can play a key role in making this happen.

About 95 percent of the hydrogen made in the U.S. today is manufactured through a process called steam methane reforming or SMR. Because this process uses natural gas as an input, it results in significant carbon dioxide emissions.

A commercially available alternative to SMR is electrolysis, which uses electricity to split water molecules into hydrogen and oxygen. In itself, this process produces no greenhouse gases, so its carbon intensity depends on the carbon intensity of the electricity used.

We will need both of these processes and others under development to manufacture the 600 million metric tons of hydrogen per year that we need no decarbonize industry. And to reach this level, production needs to steeply increase in the next decade and then continue to grow at a steady rate.

To date, ramping up hydrogen supply and uptake by industrial users has presented a sort of chicken or the egg problem. Industry doesn't use a lot of hydrogen fuel for power, because there is not enough of it for the market to be cost competitive, and hydrogen producers don't want to take on the financial risk of ramping up production if they don't have a sure market to allow them to recover costs. Targeted policy is key to resolving both sides of the problem so that we can meet our decarbonization goal.

On the supply side, the focus should be on leveraging our existing hydrogen production resources to build supply and bring down prices while also accelerating production based on low-carbon energy sources. This will require a mix of regulations and financial incentives, including renewable energy mandates, tax credits, loan guarantees, and feed-in tariffs.

On the demand side, clear regulations, direct investment, and loan guarantees for building additional transportation and distribution infrastructure can make hydrogen easier for industry to access. Financial incentives can be used to stimulate hydrogen use by large industrial facilities, and investment support programs can help reduce the costs associated with fuel switching at these facilities.

These are just some of the tools that Federal policymakers have to reduce investment risk in hydrogen production and grow the market to the scale we need to decarbonize industry. And the good news is that many of these tools have been applied with impressive results in similar markets.

For example, the solar investment tax credit has helped that industry to expand at an annual growth rate of 50 percent since 2006, which has brought the price of solar power down dramatically and facilitated deployment of thousands of megawatts of clean electricity onto our Nation's power grid.

Similar instruments have been used to expand wind energy, and the 45Q tax credit that Brad mentioned could do the same for CCS.

Today we have the same opportunity with hydrogen. If we are truly serious about decarbonizing industry, hydrogen will be a critical part of the solution.

Thank you for inviting me to testify today. I look forward to your questions.

[The statement of Ms. Hight follows:]

Testimony of Cate Hight, Principal, Rocky Mountain Institute, U.S. House of Representatives Select Committee on the Climate Crisis, Hearing entitled "Solving the Climate Crisis: Reducing Industrial Emissions Through US Innovation", September 26, 2019

Thank you, Chairwoman Castor, Ranking Member Graves, and distinguished members of the select committee, for inviting me to testify and for your leadership in focusing on climate change. My name is Cate Hight, and I am a principal at Rocky Mountain Institute (RMI). Founded in 1982, RMI is an independent, nonpartisan, charitable nonprofit dedicated to transforming global energy use to create a clean, prosperous, and secure low-carbon future. I am grateful for the opportunity to speak with you today about RMI's work to decarbonize industry, including the challenges present in this harder-to-abate sector, as well as the many opportunities we have to bring about transformative change.

I was invited here today to provide RMI's perspective on decarbonizing industry, as well as more specific information on how hydrogen may be used as a critical, low-carbon fuel in industrial processes. First, I'll share our wider perspective on this complex sector. At RMI, we think of industrial decarbonization in terms of the whole value chain, which means we consider the process from start to finish, thinking through how goods and services are designed, produced, sourced, and then ultimately delivered to consumers.

Consumer goods are formed through a set of industrial activities, starting with the sourcing of raw materials, either through recycling or virgin extraction. Those raw materials then undergo energy-intensive processes to refine and transform them. Next, the product is manufactured, generally in a large, energy-intensive factory, and finally, it is shipped to the end consumer, typically on a ship, plane, or truck that uses fossil fuels.

Although few of the activities in this chain are consumer facing, they play an important role in our everyday lives. They are essential to creating and delivering the things we use every day, from the cars and bicycles we use to get around, to the phones and laptops we use to connect to the world, and the cement, steel, and bricks we use to build houses. These products all require raw materials, along with energy, usually in the form of fossil fuels, to create and transport them. Not surprisingly, these activities also contribute a significant share of global greenhouse gas (GHG) emissions each year. If you include the emissions from the generation of electricity (Scope 2 emissions), the industry sectors represent more than 40% of the global GHG footprint today.[1] In addition to their contribution to climate change, these emissions create daily risks to our food and water, our health, our homes, and our economy. And industrial emissions are on the rise as economies around the world continue to grow, to a point where heavy industry alone will consume more than two times the remaining carbon budget for limiting global warming to 1.5 degrees Celsius.[2]

The main challenges in decarbonizing industry are not necessarily expensive solutions or the need to develop unknown technology. The main challenge is that we have to overcome three fundamental market forces that work against the energy transition: (1) maintaining the status quo to de-risk investments in long-life assets, (2) commoditizing the traded products to enable global competition and reduce the cost to consumers, and (3) siloing capital in asset classes, which isolates the processes that are in dire need of investments in low-carbon technology.

Overcoming these forces will take a combination of market, financial, and policy solutions. Today I will speak about how federal policy may be used to address each of these barriers by deploying more hydrogen into the industrial sector. When produced using renewable resources, hydrogen can play a critical role in decarbonizing this sector by replacing many of the fossil fuels the world relies on to power the economy. And we have the technology available today to produce large quantities of this clean energy source.

In fact, the US produces and uses hydrogen in its industrial economy today. Each year, we manufacture about 10 million metric tons of hydrogen, which is equal to about 15% of the global total. Most of this hydrogen is manufactured using natural gas and steam as inputs. Nearly three quarters of the hydrogen we produce is used in our domestic petroleum refining industry; the remainder is primarily used in fertilizer production.[3] There are hydrogen production facilities in almost every state in the US. However, scaling hydrogen production and use to the level we need to truly decarbonize industry will require intervention from policymakers, consumers, and the financial sector.

How much more hydrogen do we anticipate we will need to decarbonize industry? According to expert analyses by the International Energy Agency,[4] the Energy Transitions Commission,[5] and Shell,[6] this pathway requires the world to produce and use about 600 million metric tons of hydrogen per year by 2050. This is almost ten times the amount of hydrogen produced today. And to reach this level, production needs to steeply increase in the next decade and then continue to grow at a steady rate.

For hydrogen to play an essential role in decarbonizing industry, policymakers must focus on providing conditions that (1) stimulate rapid and wide-scale hydrogen production and its uptake as the primary fuel source for major industrial fuel consumers, including heavy manufacturers and heavy transport; and (2) enable a transition from fossil fuel-based hydrogen production to production that is based on renewable energy sources.

As mentioned earlier, right now most hydrogen is produced for use in the petrochemical sector, and most of it is produced using natural gas as a feedstock in a process called steam methane reforming (SMR). Unfortunately, SMR also produces a lot of carbon dioxide emissions. So, while there is capacity to ramp up production at these facilities, without carbon capture and storage (CCS), this production pathway cannot play a long-term role in industrial decarbonization using hydrogen.

SMR can, however, be part of the hydrogen story in the near term, in much the same way that our current fossil fuel-dominated power grid is part of the story for electric vehicles (EVs). EVs currently run on power provided by a mix of sources. The market for EVs is rapidly developing as more and more consumers demand them; simultaneously the electricity grid is becoming cleaner, and therefore EVs are running on greener power. In much the same way, SMR production can get more hydrogen to market and increase its uptake by driving down prices, while at the same time lower-emission hydrogen production methods displace SMR hydrogen production.

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[1] https://www.ipcc.ch/sr15.
[2] https://rmi.org/insight/the-next-industrial-revolution/.
[3] https://www.hydrogen.energy.gov/pdfs/16015_current_us_h2_production.pdf.
[4] https://www.iea.org/etp/publications/etp2012/facts/widerbenefitsof2ds/.
[5] https://www.energy-transitions.org/mission-possible.
[6] https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/shell-scenario-sky.html.

Currently, the commercially available alternative to SMR is hydrogen produced through electrolysis: grid-based electricity is used to split water molecules into hydrogen and oxygen. Just like EVs that run on grid-based power, this hydrogen is as "clean" as the electric power used to produce it. The more renewable electricity available to power hydrogen production, the more quickly the industrial sector can move into a decarbonized, hydrogen-based future.

To scale up hydrogen production as quickly and broadly as needed, federal policymakers can play a key role in stimulating the growth of the market by (1) reducing the risk associated with investment in large hydrogen production operations, and (2) helping kick-start regional hydrogen markets. Policy solutions could include the following:

- Policy or financial incentives/mandates for low-carbon hydrogen production, including natural gas-based production that includes CCS;
- Government procurement policies that require sourcing of hydrogen to power government operations;
- Policy or financial incentives/mandates to increase hydrogen uptake by industrial users, ensuring that SMR-based production includes CCS;
- A shift of federal subsidies away from oil exploration and development and toward investment in hydrogen infrastructure, which includes hydrogen production facilities and the transportation and distribution infrastructure needed to expand delivery routes to industrial users;
- Investment in infrastructure or investment loan guarantees for hydrogen transportation and distribution infrastructure to expand delivery routes to industrial users;
- Feed-in tariffs and tax credits to stimulate hydrogen production and deployment of more renewable electricity sources to the electricity grid;
- Investment support programs to reduce the costs associated with fuel-switching at industrial facilities;
- Safety regulations governing hydrogen production, transport, and use, similar to those for fossil fuel markets;
- Investment in research and development for new, sustainable hydrogen production pathways;
- Policy or financial disincentives for industrial facilities to use carbon-intensive resources such as coal or natural gas;
- Policy or financial disincentives for investment in carbon-intensive electricity generation; and
- Border adjustments for imported products in energy-intensive, trade-exposed industries that are manufactured using carbon-intensive pathways.

In summary, federal policymakers have a number of tools in the toolkit to reduce investment risk in hydrogen production and grow the market to the scale necessary to decarbonize industry. And the good news is that many of these tools have been applied to great effect in similar markets. For example, the solar investment tax credit has enabled that industry to expand at an annual growth rate of 50% since 2006, which has brought the price of solar power down dramatically and facilitated deployment of thousands of megawatts of clean electricity onto our nation's power grid. Today, we have the same opportunity with hydrogen. If we are truly serious about decarbonizing industry, hydrogen will be a critical part of the solution.

Ms. CASTOR. Outstanding. Thank you to all of you for your very helpful testimony.

At this time I would like to recognize Ms. Bonamici for 5 minutes for questioning.

Ms. BONAMICI. Thank you very much, Chair Castor. Thank you for the accommodation.

Thank you all for your very enlightening testimony.

According to the Intergovernmental Panel on Climate Change, limiting warming to 1.5 degrees Celsius above preindustrial levels would require unprecedented rates of transformation in many areas, including the energy and industrial sectors.

So we know that the industrial sector is notorious for being challenging to decarbonize. It is going to require both reducing the demand for energy, by improving efficiency of industrial production, and eliminating additional emissions from the industrial processes. So it is really a two-part step there.

In northwest Oregon, the district I am honored to represent, the industrial sector is turning to mass timber as an alternative to steel and concrete. Cross-laminated timber, when harvested using sustainable forest practices, can sequester and store massive amounts of carbon dioxide.

First Tech Federal Credit Union in Hillsboro, Oregon, recently built one of the largest CLT structures in the country. There are still questions about the lifecycle assessments of CLT, but the material raises the possibility of storing massive amounts of carbon in buildings for decades, perhaps in perpetuity.

Also in northwest Oregon, we have an affordable housing complex called The Orchards, 150 units of affordable housing built to passive house standards. It has seen about a 90 percent reduction in energy used for heating and about a 60 to 70 percent reduction overall in their energy costs.

And I wanted to ask you, Ms. Hight, it is my understanding that Rocky Mountain Institute Innovation Center is a net zero building, meaning that it produces as much energy as it uses in a year.

Are there sufficient incentives for new construction to use materials that are less emissions intensive in a circular economy model where materials that are extracted, produced, and used can be recovered or repurposed or reused more thoughtfully? And if not, how could Congress promote these efforts to reduce energy demand?

Ms. HIGHT. Thank you for the question.

In fact, I was at our Innovation Center in Basalt last week, and something that is so amazing about that building is, it is in Snowmass, Colorado, which is one of the harshest environments in the U.S., and it has no HVAC system and it has a very limited, small heating system. We actually have sort of a square on the ground for where the HVAC would have gone. So it is quite an extraordinary building, and I encourage all of you to visit it whenever you are in the area.

So there are a number of different opportunities for really stimulating the sort of construction that you are talking about in Oregon. Some of the things that my building colleagues have shared with me, since this is not my area of expertise, is really thinking about how we can set some clear Federal targets for building sector greenhouse gas emission reductions.

So this would be targets related not only to the greenhouse gas emissions that are emitted by the buildings themselves when they combust things but also the energy use at those buildings. Building codes and clear guidance for States to require all new construction to be all electric and zero carbon as well. Tax incentives to stimulate investment and efficiency upgrades for existing buildings.

So recognizing that not everything is going to be brand new, we need to retrofit some of the existing buildings as well.

Appliance standards, and, of course, investment in research and development so that we can really develop new technologies like the ones you cited in Oregon with the laminated timber.

Ms. BONAMICI. Right. Thank you so much.

And that leads me, research and development leads me to a question to Mr. Crabtree.

In your testimony, you discuss the value of strengthening investments in research and development, demonstration, and deployment of carbon capture utilization, storage, and removal, CCUS technologies. I have been on the Science, Space, and Technology Committee throughout my time in Congress, and we have spent a significant amount of time talking about the value of research and development, including in CCUS.

So can you discuss how we can get this technology closer to market deployment and avoid that sort of commercialization valley of death that can happen? How can we accelerate the widespread use of CCUS?

Mr. CRABTREE. Representative Bonamici, thank you for the question. It is a very good question. And your committee, the Science Committee, the House Fossil Energy R&D Act is actually something endorsed by the Coalition.

The essential, especially in the industrial sector, if you take the top three, globally, sectors responsible for carbon emissions, steel, cement, and basic chemicals, in that order, the steel plant in the United Arab Emirates is the only facility in the world operating at commercial scale right now. So it is really important that in addition to the 45Q tax credit, which is a deployment incentive, that we have both a larger program of RDD&D, but also that we prioritize some of these key sectors for which we do not yet have the commercial deployment.

And the legislation that just passed out of your committee takes us a big step in that direction, but that valley of death is the result of having a very good R&D program up to the point where a company or a project developer wants to put that technology into the marketplace at commercial scale and then Federal policy drops off the cliff, until that point where they somehow magically are able to develop the technology and then they can use a tax credit.

And so I think, especially in Federal RDD&D, we need to bring the demonstration back into it and increase resources for later stage demonstration of those technologies.

Ms. BONAMICI. Thank you so much.

I see my time has expired. I yield back.

Thank you, Chair Castor.

Ms. CASTOR. Thank you.

Ranking Member Graves, you are recognized for 5 minutes.

Mr. GRAVES. Thank you, Madam Chair.

Ms. Hight, I appreciate you bringing up the issue of sort of this whole chain and ensuring that we quantify emissions from start to finish. And oftentimes folks look at just one component.

If we carry out policies in the United States that are uncompetitive, and if manufacturing migrates to China as we have seen in many, many cases, in general, based on what we have seen, does that result in a greater emissions profile or a lower emissions profile as compared to manufacturing in the United States?

Ms. HIGHT. Well, I would argue that in particular with hydrogen, we have a huge opportunity to carve out a new competitive industry in the U.S.

Mr. GRAVES. And I got that in your testimony and certainly do appreciate it and think it needs to be part of our solution.

But right now, as we see the migration, the migration that has occurred, looking at kilowatt hour emissions in China compared to the United States, transportation emissions, and things along those lines, are we better off producing domestically or importing from China?

Ms. HIGHT. Well, given that we are not taking into account the carbon footprint of the goods that we are importing currently, I think that we are better off manufacturing in the U.S. using green production processes, including use of hydrogen and some of the technologies discussed today.

Mr. GRAVES. Thank you.

And I would actually say, if you look at statistics, you will note that not just with green practices, just by flatout comparing apples to apples, manufacturing in the United States, manufacturing in China, looking at their fuel sources, looking at our fuel sources, emissions profile to emissions profile, and of course transportation emissions to transportation emissions, you will find over and over again that we have lower emissions in the United States for the same widget as they do over there. And so I think it is an important point to make.

Mr. Crabtree, you talked a good bit about carbon capture storage, and certainly it is great seeing the United States playing a role in that technology.

Would you consider the United States to be a leader in carbon capture technology in terms of R&D, or are we somewhere behind others?

Mr. CRABTREE. I would consider the United States the world leader not only in R&D, but also deployment.

Mr. GRAVES. And what role do you believe that plays in our long-term objective of reducing emissions and hitting targets that have been established?

Mr. CRABTREE. Well, so I think the modeling that is perhaps clearest in suggesting the role that carbon capture needs to play in meeting midcentury decarbonization is the IEA, the International Energy Agency modeling which looked at the two-degree scenario and concluded that between now and 2050, a full—nearly 15 percent of all emissions reductions need to come from carbon capture, and by 2050 it needs to be up to 20 percent annually. Nearly half of that needs to come from industrial sources.

Mr. GRAVES. Great. Thank you very much.

Dr. Gregory, I was laughing whenever you were talking about concrete and cement. My father is an engineer. My entire life, if we misused the terms cement or concrete or interchanged, it was like nails on chalkboard to him. He couldn't—he was like, "No, no, stop!"

Dr. GREGORY. My kids don't make that mistake either, anymore, anymore.

Mr. GRAVES. Thank you for being here.

You made mention earlier about access to natural gas, and I might have screwed up a little bit exactly what you said. What role does access to natural gas for some of the concrete industry folks play in emissions strategies as we move forward, I guess now and as we move forward?

Dr. GREGORY. Sure. For cement plants, the temperatures they need to reach in order to make cement is 2,700 degrees Farenheit. And so right now they are using entirely fossil fuels. And so that is either coal or natural gas sources.

Certainly natural gas is the lower CO_2 option out of both of those. So having good access to natural gas is important for those plants.

Mr. GRAVES. Thank you.

And so whenever policies are carried out that are obstructing natural gas infrastructure, preventing pipelines from being built, what happens?

Dr. GREGORY. I think that will play a role in the development of new plants. For existing plants, the short answer is I think it loses an opportunity in order to lower CO_2 emissions with cement plants.

Mr. GRAVES. And if we stop producing these resources domestically, what happens?

Dr. GREGORY. The natural gas or the cement?

Mr. GRAVES. Cement. I am sorry.

Dr. GREGORY. Then we would have to get it from other countries.

Mr. GRAVES. And going back to my question to Ms. Hight, what is your understanding of emissions profile when it is produced in other countries and sent here versus produced domestically?

Dr. GREGORY. There is a whole range. But if you look at China, which makes more cement than the rest of the world combined—they make over 50 percent and the U.S. makes about 2 percent of the world's cement emissions—generally they have a higher carbon footprint associated with production of cement than the U.S. does.

Mr. GRAVES. So would you agree with the statement that from end to end, if we produce that cement domestically, that you are going to have a lower emissions profile than we would if we were to, again, end to end, have it manufactured in China and sent here?

Dr. GREGORY. That is correct.

Mr. GRAVES. Thank you.

Madam Chair, yield back.

Ms. CASTOR. Ms. Brownley, you are recognized for 5 minutes.

Ms. BROWNLEY. Thank you, Madam Chair.

Dr. Gregory, in your opening statement you talked about some solutions towards sustainable development, and you talked about measurement and reporting, you talked about performance-based standards.

Is there any example of that within the United States or outside of the United States where that is working well and proving productive?

Dr. GREGORY. I think a good first step has been in the LEED green building standards. There are points that projects can get for using products that have what is called an environmental product declaration, which is essentially a measurement of the footprint of that building product. And the whole idea behind that was to get firms to start measuring this and then use that as an incentive for that to be used in a project.

The challenge has been there is no decision that is actually made based on the reporting of that information. They are just trying to get those reports done.

And so concrete is actually—it seems very simple, you know, I mentioned it just has those few different ingredients, but you can combine them in almost infinite ways to get different performance.

So the next step of actually making decisions based on those EPDs has proved much more challenging. And so there has been legislation that is proposed in a couple of States, California and Washington. They haven't included concrete because of this need to shift to more performance-based specifications.

So there is a lot of discussion about how you actually implement that that we are involved in, and so there are some opportunities, but nothing that is really implemented yet to say let's make decisions based on performance-based specifications in government projects yet.

Ms. BROWNLEY. Thank you.

And, Mr. Crabtree, you also referenced successful policies from other places with regards to carbon storage and carbon capture. Can you point to any of those specifically?

Mr. CRABTREE. Representative Brownley, thank you for the question.

Actually I think overseas the examples of commercial demonstration are very compelling. The Section 45Q tax credit, as reformed by Congress last year, is widely considered the best incentive available today in the world for carbon capture. In New York this week, there were international leaders talking about 45Q, and they were talking about carbon capture.

That said, there are specific funds, for example, the ArcelorMittal steel plant that we visited in Belgium, they are accessing EU funds to support not only the demonstration of production of ethanol from waste emissions, which is an extraordinary thing, but also very specific decarbonization opportunities in their integrated steel mill process that aren't related to carbon capture.

And I think that gets back to your colleague's previous question about that valley of death. If there is a real gap, we need to improve our incentives, but we also need to provide more direct resources, I think this has been said by others, cost share and other support for the specific demonstration of core technologies that we are going to have to sector by sector to decarbonize.

Ms. BROWNLEY. And so if the United States decided that we were going to fully deploy a carbon capture infrastructure nationwide—so, I mean, what do you see are some of the barriers, particularly as it relates to permitting and other regulatory changes that would have to happen?

Mr. CRABTREE. Well, so if you are talking about the infrastructure to create a truly national system of CO_2 pipelines, we have a pretty successful history of building pipelines to date, over 5,000 miles in various systems, regional systems so far. I do believe that as we deploy in States with larger proportion of Federal lands, it is challenging to build linear infrastructure on Federal lands.

And the USE IT Act doesn't change any Federal statutes, but what it does do is it would bring together States, Federal agents, land agencies, States, Tribes, and key stakeholders, industry, environmental advocates, and others, to try to work proactively to think through the siting of pipeline infrastructure and try to accelerate the process of siting that.

I would say that the bigger challenge of building a national network to move CO_2 at the scale needed to address the climate challenge is we need a Federal role in financing extra pipeline capacity to build out that system in parts of the country that do not yet have it.

Ms. BROWNLEY. Thank you. Thank you for that.

And last question before my time is up.

Ms. Hight, is the cost of renewable hydrogen becoming more competitive? And I guess if you could cite is there anyplace where hydrogen is being used where it is cost competitive compared to other energy sources?

Ms. HIGHT. Yeah. Thank you for the question.

So hydrogen is still more costly than other fuels today, especially transportation fuels. But when you think about it, hydrogen is three times as energy intensive as gasoline. So it translates to roughly a price of about $5 a gallon for a kilogram of hydrogen. So it is still more expensive, but not prohibitively so.

And this sort of chicken or the egg problem I talked about before, about needing to sort of stimulate the market in order to bring that price down, is a key solution.

In terms of renewable hydrogen, there are places in the U.S. today, including the State of Texas, where I hail from, where there is renewable hydrogen that is able to produce from renewable wind power, which is at an affordable cost, and they are deploying that.

Ms. BROWNLEY. Very good.

Thank you, Madam Chair. I yield back.

Ms. CASTOR. Mr. Griffith, you are recognized for 5 minutes.

Mr. GRIFFITH. Thank you very much. I appreciate it.

Let me state up front, I am all for research and making sure that we are researching everything that we can. I do think we need to have some research parity so that we have our fossil fuels and our renewables both being researched at a high level.

Would you agree with that, Dr. Gregory?

Dr. GREGORY. Do you mean—what kind of research?

Mr. GRIFFITH. Dollars, dollars.

Dr. GREGORY. Research on what aspects of fossil fuels?

Mr. GRIFFITH. Oh, what we can do to make it cleaner, make better. And all kinds of research.

Dr. GREGORY. Sure. Yeah.

Mr. GRIFFITH. And the reason I bring that up is, is that we have got a number of things that I have been interested in over the years. I have a professor at Virginia Tech who has been working on trying to figure out how you extract rare earth minerals out of coal. As a result of that, they figured out how to do some other things.

They are not quite ready for primetime on the rare earth, but they have sold the technology to some Indian steel mills, because what they have done is they have been able to make it so that the carbon that they are mining in India, out of their coal, can be used for steel production at a better rate and they have lowered the carbon footprint or they are lowering the carbon footprint at these steel mills, and that makes a lot of sense to me.

We also have chemical looping which is, again, not quite ready for mass production. But the cost of—we were talking about carbon capture and sequestration—the cost there, about 60 percent of it is the capture. Chemical looping reduces that cost and you automatically just have the CO_2 that you are getting, as opposed to having to try and separate everything else.

And then we have a technology that is being developed also in conjunction with a company in my district and Virginia Tech where they have—and I will have to see if I—make sure I get the language right here—but they have exhaust gas enters—this would be MOVA Technolgies—exhaust gas enters the filter full of various chemicals, it passes through a series of chambers, each filtering out one pollutant. When it is finished, the gas is cleaner and the chambers each contain just one material, which then allows them to use those materials to be recycled into our industrial systems and again reducing the overall carbon footprint.

It takes money to get these kinds of researches from the drawing board or these technologies from the drawing board to the finished product. Wouldn't you agree, Dr. Gregory?

Dr. GREGORY. Absolutely.

Mr. GRIFFITH. And then last, but not least, Dr. Gregory, in your testimony you said that unfortunately the current Clean Air Act New Source Review program, as interpreted by the courts and some prior administrations, actually penalizes companies for increasing the efficiency of its facilities. And this time I am going to have to agree with you. And I have a bill to fix that.

Because what happened was, when they created the New Source Review in 1977, they picked up—or when they added that to the Clean Air Act—they picked up language from another section of the code, identical language.

Unfortunately, the EPA has interpreted those two sections differently. And what happens—and most people don't realize this—what happens is companies don't know what the term "modification" means because of its different interpretations.

And whether they are right or they are wrong—I have a furniture company—I am sure this applies to cement, too—but I have a furniture company in my district—and some of the members of the committee have heard this story before, but it is a real life example—where they have a conveyer belt that probably stretches about the length of this room that they no longer need. But the furniture goes all the way out to the end of the conveyer belt and comes back, because at one point in time they had a paint or lacquer process at the end of the conveyer belt.

They are afraid to change the conveyer belt and become more efficient because they are afraid it would trigger the entire facility having to be placed under New Source Review and be totally modified, where currently they don't have that problem. So they deal with the inefficiency.

Is that true in the cement industry, as well, and concrete?

Dr. GREGORY. It is a similar thing, where companies want to be able to invest in energy efficiency improvements but are concerned about what other things that that triggers.

Mr. GRIFFITH. Yeah. And, unfortunately, one of my colleagues in one of the hearings we had on the Energy and Commerce Committee said: I thought by now we would have gotten this problem resolved.

And I looked at him, and I thought: You know, what you don't realize is, if we could take one bite of the apple at a time, over the course of 10 or 15 or 20 years you probably would have a lot of this resolved.

But when you are a company and you are looking at having to swallow that apple whole, you decide you can't start because you don't have the resources or the ability to finish. Is that something you have run into as well?

Dr. GREGORY. It is the same situation, just like you said, where trying to make simple improvements in energy efficiency can often have unintended consequences. So, yeah.

Mr. GRIFFITH. So I think one of the things that we should do in this committee is try to look at things like that, because there are things we can do. We all want to make the air cleaner. There are things that we can do, that we can accomplish to do that where Democrats and Republicans can come together in a bipartisan way and make our environment better and keep our economy strong.

I appreciate it very much, and I yield back.

Ms. CASTOR. Mr. Casten, you are recognized for 5 minutes.

Mr. CASTEN. Thank you, Madam Chair.

You don't have to spend more than about 30 seconds understanding the CO_2 issues we are facing to know that we have got to get to zero CO_2 yesterday. The hard question is, how?

And I am delighted to have this panel, because if you are really honest about the "how" question, you have to sail into the fact that there are things like fertilizer, like cement, like steel, like silicon that we do not know how to make without using fossil fuels right now, and we need to focus on that. So thank you for being here.

And, oh, by the way. I don't know how to make a solar panel on a concrete pad without steel and silicon.

I was proud to introduce H.R. 4230, the Clean Industrial Technology Act, specifically to stand up an agency at the Department of Energy to do that research, to put about $650 million in the deployment, cosponsored with Representative McKinley and Chairwoman Johnson in the House.

I am pleased to report that the Senate, the version that is led by Senators Whitehouse and Capito, passed out at committee yesterday. So we are moving along. And anybody, please, cosponsors, we are pushing forward over here.

I want to start, though, with a question about barriers, because a lot of what we are talking about here is R&D. But a lot of times, Mr. Gardiner, I know you know this well, we don't do the right thing because there are regulatory barriers to existing technology.

So can you help me out a bit, Mr. Gardiner? You suggested the need for greater information about how combined heat and power and waste heat and power could be utilized. These are long questions, but I want to start simple and encourage you to follow up with more information, if we can.

When you design a combined heat and power plant you have an almost infinite degree of flexibility with the ratio of heat to power that you use in the system. It is easy to do a 25 megawatt power plant if I can have equivalent efficiencies over a huge range of waste heat to recover. The heat is used locally, the electricity may or may not be exported, and they are subject to wildly different prices.

Mr. Gardiner, would you agree that there are sometimes regulatory barriers that cause you to suboptimize that design?

Mr. GARDINER. I do. And even more broadly, in some cases, never to pursue the combined heat and power project in the first place. We have done a lot of research looking at what States do and what utilities do in the way of charging what are known as standby rates. So you know what these are, Congressman, but you have got to be basically, even with a combined heat and power plant on your facility, you still need to be connected to the grid. And the question is whether you should be charged a lot or a little for being connected to the grid. And we have discovered in the same States that——

Mr. CASTEN. I am sorry, I don't want to be rude, but I want to get like 3 or 4 questions. Totally agree. And please provide this to us.

Mr. GARDINER. Be happy to.

Mr. CASTEN. Because you know this, I know this, I don't think the committee knows it, and let's take more than 5 minutes to walk through it. But a list of those barriers, and if you have any estimate of what cost we impose economically and environmentally by that suboptimization nationally, because I think those are big numbers.

Mr. GARDINER. They are.

Mr. CASTEN. Second piece. You talked about combined heat and power versus waste heat to power. In the old days we called them bottoming and topping cycles. Terms change, it is the same idea.

When you build a waste heat to power project on the top of an industrial smoke stack or elsewhere, what is the marginal fuel use?

Mr. GARDINER. Zero, because you are basically taking waste heat from, let's say, a factory, that would otherwise just go off into the atmosphere, you are capturing it and you are turning it into productive power. So not only is there no additional fuel required, there are no additional emissions. So you are getting a lot of electricity.

In some cases—there is a project I am aware of at an ArcelorMittal in northwest Indiana——

Mr. CASTEN. And, I am sorry, this is going to be quick, I am going to be quick again. Is it safe to say that those projects are functionally equivalent to traditional renewable energy generation?

Mr. GARDINER. From their emission standpoint, yes.

Mr. CASTEN. Do they have access to the same incentives that traditional renewable generation has?

Mr. GARDINER. They do not. They don't even have—waste heat to power doesn't even have access to the investment tax credit, which is available to combined heat and power. Congress in some way did not insert those words actually in the Tax Code.

Mr. CASTEN. Please share that information with us as well.

I want to pivot in the little time I have left, Dr. Gregory, and this may be an opportunity for both of you, I may have teed up a sales opportunity for you.

We recently had a field hearing out at NREL in Golden. NREL has a huge facility. They have got wind turbines, they have got solar panels, they have got all this neat stuff, and they are integrating and showing how to integrate the grid.

Right at the edge of their property there is a little cement plant. You mentioned that runs about 2,700 degrees at the inlet, I think the waste heat is around 600 or so, roughly?

Dr. GREGORY. Sound about right, yeah.

Mr. CASTEN. Mr. Gardiner, can you make power with 600-degree heat?

Mr. GARDINER. Yes.

Mr. CASTEN. I encouraged my friends at NREL to consider reaching out to some people who might know how to do that, because I think that having 24/7 renewable energy would be a pretty nice thing to have there.

And I see I am now out of time. So thank you very much. And I yield back.

Ms. CASTOR. Thank you for making the most of your time, Mr. Casten.

Mr. Carter, you are recognized for 5 minutes.

Mr. CARTER. Well, thank you, Madam Chair.

And thank all of you for being here. This is certainly very important, industrial output and how it relates to our climate and to our environment.

I wanted to ask you, Dr. Gregory, I really appreciate your perspective on the lifecycle perspective and your explanation of that and how we should be looking at it throughout the whole process and the lifecycle carbon output. And I appreciate that, especially looking at it from that perspective.

You mentioned in your testimony that there are Federal and State laws that discourage the use of many of these lower carbon alternatives. And can you describe a couple of those for me?

Dr. GREGORY. I don't know that they explicitly discourage it, but they don't actually really provide much incentive to use them at all.

Mr. CARTER. Okay. Fair enough. Fair enough.

I am very interested in biomass. I am from Georgia, the number one forestry State in the Nation, and biomass is a big part. We have got quite a few plants in our district. And I wanted to ask you about that. An alternative like biomass, what about that?

Dr. GREGORY. That could play a critical role in being used as a form of alternative fuel in cement plants. So instead of using the coal or natural gas to heat up that kiln to 2,700 degrees, biomass or other kinds of waste materials could be a critical way to essentially be like a zero carbon source of fuel. So that is really important.

Mr. CARTER. Are there any plants that are doing that?

Dr. GREGORY. There are. In the U.S., the current challenge is that there are often limitations on the maximum amount of alternative fuels that can be used. So, for example, usually in the U.S. it is capped at about 15 percent, whereas in Europe and other parts of the world they are using 35 percent or more. And a lot of that has to do with these tensions between the use of those alternative fuels and the Clean Air Act or RCRA.

And so basically those are opportunities to modify both of those in order to encourage more use of alternative fuels because that can definitely be done in a way that preserves clean air while still lowering the carbon footprint of producing the cement through the use of alternative fuels.

Mr. CARTER. Okay.

Mr. Gardiner, in your opening comment you made, and I just caught the tail end of it, so forgive me if I am getting this wrong, but you said biomass used under the right circumstances. Can you elaborate on that?

Mr. GARDINER. Yeah. I think that there are a couple of issues that one has to think about. We have actually got a project underway to look at the carbon accounting associated with combusting biomass, because when you burn biomass there are greenhouse gases that go up into the atmosphere right away.

The upside is that they are going to be recaptured at some point back into other trees and things that are growing. That doesn't necessarily happen right away.

So that is an example of an issue that has to be thought through. I think there are plenty of sources of biomass where that is not an issue, but it is a complex issue that needs to be sorted through.

So we want to be sure that—we, in fact, have worked with Procter & Gamble, that did a project in Georgia recently on biomass that I think they feel very strongly about. I just was talking with them this morning about it. And I think they are opportunities for biomass to produce renewable heat, which is what they were looking for in the context of their production plant in Albany.

Mr. CARTER. Do you see it as part of the portfolio of the future of clean fuel?

Mr. GARDINER. Biomass?

Mr. CARTER. Yes.

Mr. GARDINER. Yes. It is already a gigantic portion of the portfolio for renewable heat. It is today the leading source of renewable heat in the world. I think it is 75 percent or something on that order.

So it is big. I think there are lots of questions about how big it can be, given the scale of what we have to do on climate change. How much biomass is really out there that is available? And how far can we go? I think those are important questions that need a lot more attention and focus.

Mr. CARTER. Dr. Gregory, any disagreement with that?

Dr. GREGORY. No. No.

Mr. CARTER. Let me move on, because I suspect I may get some at one point.

Mr. Crabtree.

Mr. CRABTREE. I just wanted to add, in addition to the opportunities with renewable heat and combined heat and power, if you are using a biomass feedstock to produce energy and you are capturing CO_2 on the back end, you have the potential to create an energy system with negative emissions, and that could be a very valuable way for decarbonizing industry if that energy is supplying an industrial process.

Mr. CARTER. Great.

Ms. Hight.

Ms. HIGHT. Sure. Biomass has a lot of hydrogen in it, so you break those hydrogen bonds, you make hydrogen energy.

Mr. CARTER. Great. Great. Good. I like this panel. We need to invite them back. Good.

Well, thank you very much. I appreciate your input. Biomass is extremely important. As I mentioned, Georgia is the number one forestry State in the Nation, we have sustainable forests where we are replanting as we cut these trees down. It is a byproduct, if you will, of the process by which we use. So I am just really high on it. So thank you very much. Really high in the sense that I am really——

Ms. CASTOR. Okay. I got that. That is a different biomass.

And it is appropriate now to go to Mr. Neguse from Colorado.

Mr. NEGUSE. Thank you, Madam Chair. I am sure that is coincidental, of course. Representative Carter enjoyed some time in Colorado recently for a field hearing that we had in Boulder. So you can pardon the faux pas there.

Thank you, Madam Chair, for holding this hearing.

And thank you for the witnesses. Just very informed, well-informed panel, and very thoughtful discourse and discussion today.

And of course, in Colorado, I represent the Second District, Boulder, northern Colorado, Fort Collins, and the central mountains. We have a number of businesses that are engaged in some really cutting-edge technology, some of which you all have described.

One in particular is a very local small business in Boulder called Cool Energy, which is a Boulder-based company that has developed a sterling engine that converts waste heat to electricity to create emission-free power.

So I just want to give a chance to you, Mr. Gardiner, just to kind of expound a little bit more on your exchange with my colleague from Illinois with respect to what else you think the Federal Government might be able to do to kind of incentivize and create an environment in which these kind of technologies can continue to advance and grow.

And I would say one example that you cited, the 45Q issue, we are working on a piece of legislation emulating some of what Senator Carper had proposed in the last Congress, a bipartisan bill on that front.

But just give you a chance to expound further.

Mr. GARDINER. Sure. Thank you very much.

I would say one of the biggest problems is that markets don't often reward these technologies for all the benefits they offer. If you reduce carbon emissions, nobody is paying you anything for that.

And so I think there is an important role for the government to step in and to help create the incentives that can't necessarily always replace all of that, but can make a step in the right direction.

So for combined heat and power, and I think we have seen this in other technologies that are zero or low carbon, the Tax Code has been an important thing. There is an existing investment tax credit on combined heat and power, and I think that is a helpful financial incentive that helps make up for the fact that combined heat and power and waste heat to power deliver very low emissions, but the market has no way of rewarding them for that.

So I definitely think the Tax Code, a very good place to look. And not only is there an existing credit, but I think there are proposals to do things like let the master limited partnership provisions apply to things like combined heat and power or waste to heat power, which could be an interesting new approach.

Mr. NEGUSE. Thoughts from other folks on the panel?

No.

So, Ms. Hight, just with respect to the work that you do—and, of course, we are thrilled to be able to have one of your installations actually in Boulder, Colorado, and so happy to be able to hear from you today.

As was mentioned, we were in Colorado earlier this year for a field hearing that our wonderful chair and fearless leader so graciously hosted in Colorado for us. And one of the places we went to was NREL, which is just some really incredible technologies that they are working on to reduce emissions, including hydrogen in the H2@Scale program, which I know, Ms. Hight, you will be familiar with.

So wondering if you can kind of, dovetailing with the exchange with Mr. Gardiner, if you could perhaps expound on what we could do at the Federal level to better incentivize the renewable energy development of renewable hydrogen?

Ms. HIGHT. Sure. Thank you for the question. And, yes, I think Colorado is very proud to have NREL just down the road from us in Golden, and it is a really amazing facility.

There are a number of things the Federal Government can do. I think it comes down to sort of the chicken or the egg, again, I am going to come back to that, right, sort of stimulating demand, stimulating supply of hydrogen.

We have the tools available today. We are producing hydrogen today, quite a lot of it in the Gulf Coast in Texas. We are producing them mostly from natural gas. We need to take advantage of that production, expand the amount of hydrogen we are producing, while also deploying additional renewables to produce more renewable hydrogen.

The more of this makes it to market, the price comes down. And then on the supply side, you work to stimulate uptake by the big industries who can use it as a replacement to their fossil fuels.

So I think we really need to look at both halves of the equation with a mix of incentives and mandates to get more renewable energy onto the grid in particular.

Mr. NEGUSE. Thank you.

With that, I yield back the balance of my time.

Ms. CASTOR. Thank you very much.

Mr. Armstrong, you are recognized for 5 minutes.

Mr. ARMSTRONG. Thank you, Madam Chair.

And I am just going to start with I wish more people watched these hearings, because this is kind of how Congress is supposed to work, I think. And we will have plenty of things to fight about as we go through, but in all honesty, I think that is really appreciated.

I will say to Ms. Hight that Mr. Crabtree and I might argue with you on the harshest climates in the U.S., which is going to be a nice segue into Project Tundra. And I know that is not necessarily why you are here, but I want to talk about North Dakota, because it is probably—it has the ability to be the first zero-emission coal plant in the United States.

And also for my friend from Virginia, he will be happy to know there is research going to it. DOE offered $9.8 million just recently to start this project.

So, Mr. Crabtree, you do—I would call you Brad and you can call me Kelly, but I am not sure we can really do that—you address carbon as essential in managing industrial emission and to meet climate goals. In North Dakota, Project Tundra is this initiative. Innovative technologies are being researched to retrofit existing plants, and I know you have a ton of background in coal as well, and capture over 92.

While these initiatives show that carbon capture utilization and storage is technically viable, how do we make these technologies economically and commercially viable?

Mr. CRABTREE. Well, so in the case of—obviously, this is a hearing on industrial emissions, but retrofitting coal-fired power plants for carbon capture is relevant because of the energy intensity of industrial processes and the need for 24/7 large amounts of energy all the time.

And we have the example of Petra Nova near Houston, which is—it was the second fully commercial carbon capture project on a coal-fired power plant in the world, is now the largest, and it was built on time and on budget.

With the project in North Dakota, in terms of making it financially viable, right now they are doing the feed study, that is where the DOE funding came in. What would really be helpful to that particular facility and several more in the country right now is there is about $2 billion sitting in the 48A tax credit program that Congress has already allocated.

And because of the criteria, the statute, initially it was for energy efficiency at power plants, and then Congress, I think wisely, added carbon capture later to the statute, but they didn't adjust the energy efficiency metric. And when you equip a power plant with carbon capture, obviously it takes power to run the carbon capture systems, and you can't then meet the energy efficiency requirement in the law.

The irony of this is that the emissions reductions that would come from retrofitting the power plant for carbon capture vastly exceed the emissions reductions from the energy efficiency requirement.

So I would argue it is important for North Dakota, but in a global context, if we could retrofit three or four coal-fired power plants with this $2 billion in available resources in the 48A tax credit, that would be of global significance in addressing climate change.

Mr. ARMSTRONG. Thank you.

So I am going to go back to that, too, because the first time I ever saw this was actually in Weyburn and up there and that was going to be used for enhanced oil recovery.

And I think—and you would be the expert on this—but there is a difference between capture and deployment, right? I mean, when Weyburn was originally designed, they were going to store the carbon, and then they were going to utilize the carbon for enhanced oil recovery. And unless it has changed a whole lot, that doesn't work really well, because you were talking about pipelines earlier and how we deal with that.

So, I mean, is the technology increasing on storing carbon versus then deploying it for other uses?

Mr. CRABTREE. So it is technically feasible to withdraw CO_2 from a reservoir once you have injected it. And, of course, if you doing geologic storage of CO_2 through the process of enhanced oil recovery, you are injecting the CO_2, you are liberating oil, producing that oil. Some of the CO_2 comes back up with the oil. The oil companies pay for that CO_2, so they strip it out and reinject it.

It is actually not easy to get CO_2 back out of the reservoir. The reality, I would suggest, though, is that the volumes of CO_2 available to us if we capture them are so large that they will exceed the potential for utilization. And so I don't think there will be a lot of interest or need in taking that CO_2 back out of a geologic storage situation.

Mr. ARMSTRONG. And then that will just move me into another thing because it will be litigated in North Dakota, and it doesn't necessarily relate to CO_2 other than it is going to be using the same space.

We also have a really cool project going at Red Trail Energy, which is an ethanol plant that is going to do carbon capture. So if we ever want to do a field hearing, I would recommend Red Trail because it is closer to my house, I could have you over for dinner, and Project Tundra really is kind of out there anyway.

But are we watching how different States, the Federal Government, is regulating pore space? Because that is going to be the next big conversation when we start having these—when we start continuing to move forward with this.

Mr. CRABTREE. Yes, I am not sure about Federal regulation, of course, because I think we are going to see a lot shake out about how States approach it and what works best, especially in saline storage. This actually—the Red Trail facility is very relevant to this hearing because it is CO_2 from fermentation ethanol, it is going to be stored in a geologic formation. And that really could achieve truly negative carbon emissions because the CO_2 captured through photosynthesis turned into ethanol is not readmitted to the atmosphere.

Mr. CRABTREE. Thank you.

Mr. ARMSTRONG. And I know I am over my time, but just one thing. I just think the real issue here is, regardless of what we are putting down there once we start litigating how that space—or once we start regulating and litigating who owns that space and how that space is allowed to be used, it is not going to matter whether it is CO_2 from methane, CO_2 for anything, because, I mean, we are going to have to watch that going forward.

So thank you.

Ms. CASTOR. I will recognize myself now for 5 minutes.

So the climate science dictates that we have to reduce carbon emissions in the industrial sector. And as we discussed today, this is not easy in industry because it is so energy intensive and it's trade exposed. And we are very sensitive to the fact that the cost of doing business is a real concern for competitiveness in the global market.

Mr. Gardiner, can we do this? What do you think?

Mr. GARDINER. Absolutely. I think there are lots of technologies that are available today. They sometimes have a hard time getting into the market because, as we were talking about before, sometimes there are barriers, or because there is not enough of a pull to bring them into the matter on the benefits that they offer on the carbon side and other benefits.

And, look, for an issue like renewable sources of heat, they are out there. We have heard about hydrogen, it is out there in small quantities. There definitely are projects that are being done today.

So I think all it takes is, depending on what technology we are talking about, it is either figuring out how to create the right incentives to get them into the marketplace, get rid of the things that are standing in the way. And research and development clearly is going to be a huge thing. We are going to need that in a very significant way on a very broad range of technologies.

The success we have seen in the electricity sector has largely come because we made the clean things cheap. So now they are the preferred things in the marketplace, and that is driving all the emission reductions that we are seeing in the power sector. And we just basically need to do the same thing in the industrial sector.

Ms. CASTOR. Right. So a lot of you have talked about how we reprioritize incentives, borrow from what we have learned, and how we have built incentives for renewable energy. Renewable energy deployment has also increased due to the demand side, policies like State renewable portfolio standards and clean energy standards.

You started to talk a little bit about this with Mr. Casten from Illinois. You drew the comparison with renewable thermal technologies in addition to financial support. Could you explain to the broader audience here renewable thermal technologies, first of all, and then what kind of demand side policies should be applied?

Mr. GARDINER. So there is a broad range of renewable thermal technologies, some more readily available than others. Renewable natural gas. So you are basically taking materials that come from wastewater treatment plants, landfills, and others, gases, and converting that into something you can insert in a pipeline, and it goes off to wherever you want to use it.

Solar thermal. Hydrogen produced from renewable sources is renewable thermal energy. You can electrify parts of industrial facilities. Research suggests there is pretty good opportunities there. And if your electric power is produced from renewables, then you have done renewable thermal technologies.

On the demand side, I think two thoughts. One is that we see a number of States, I think there are 14 now, that as a part of their standards that require utilities to produce more renewable electricity, they offer a credit for renewable thermal technologies. And it is a fairly diverse set of States, including places like North Carolina, Texas, and Nevada.

So that is an example of using demand—it is not quite a demand side policy, but it is an incentive that is helpful.

In transportation fuels, both the Federal Renewable Fuel Standard and California's Low-Carbon Fuel Standard are demand policies. They require a certain amount of either low carbon fuel or renewable fuel in the fuel mix. That is driving the development of renewable natural gas.

And so there are renewable natural gas projects happening all over the place. The challenge is that all of that renewable natural gas is really going into the transportation sector and not into the industrial sector. But that is a fixable kind of a problem.

Ms. CASTOR. Ms. Hight, you, prior to Rocky Mountain Institute, you did a lot on methane controls globally. There must be some red flags here when it comes to methane and the industrial sector and things like being more reliant on natural gas. What do you say?

Ms. HIGHT. So one of the things that we focus on at Rocky Mountain Institute is sort of solving this problem of kind of the transition from coal-fired generation to natural gas-fired generation that we are really facing in the country right now.

Natural gas does burn cleaner than coal and has less CO_2 emissions when you combust it. But the environmental footprint of natural gas is maybe not so good compared to coal when you take into account the methane leaks and the process emissions of methane that take place along the way.

So natural gas is going to continue to be part of our future. All the models demonstrate that natural gas is going to be one of the fossil fuels that are going to be around for a while. So we need to figure out how to address the leakiness of natural gas, using incentives and regulations that can bring those emissions down.

At the same time, we need to be using the abundant natural gas resources we have in the U.S., coupled with carbon capture and storage to produce real renewable resources like hydrogen, get more of that onto the market, help that market take off, so that we can bring more renewable hydrogen onto the grid to displace it.

Ms. CASTOR. Thank you very much.

Mrs. Miller, you are recognized for 5 minutes.

Mrs. MILLER. Thank you, Chairwoman Castor, and I really mean it. I am so thrilled that we have this panel in front of us today.

And thank you all for being here.

This issue today is so incredibly important. Innovation is key as we move forward in addressing climate change. Rather than completely shifting from key hydrocarbon baseload energy, such as coal and natural gas, we can use innovation and new technology to keep those same affordable forms of energy while working to reduce or even eliminate emissions across the board.

Further, by using these technologies in our industrial sector, we can produce more American goods and create jobs here in the United States.

I believe carbon capture is the critical component in our discussions on this committee. When the technology is fully realized, carbon capture will be able to allow us to continue to use the use of key baseload energy, keep energy costs low, and keep more jobs here in the United States.

Mr. Crabtree, what are the biggest obstacles, scientific or policy side, to fully developing carbon capture? The math and chemistry are there for this solution, so what is holding us back?

Mr. CRABTREE. Representative Miller, thank you for the question.

I would say that first and foremost with the current generation of technologies in the power sector, carbon capture technologies, the challenge is no longer one of technology but of policy and of business model. And so the 45Q tax credit is a huge step forward. It will provide $35 per ton of every CO_2 stored through enhanced oil solar recovery or $50 per ton of CO_2 stored in a saline geologic formation.

The challenge is that those credit values are below what is needed to retrofit a power plant in the power sector. Coal is more expensive. Natural gas even more expensive than coal in terms of carbon capture. So what we need to do is we need to complement the 45Q tax credit with additional incentives that will reduce the cost of capital of equity and debt.

For example, making a carbon capture project eligible for tax-exempt private activity bonds, master limited partnerships, things like that. Also, existing tax credits, enhancing them so that they can enable them more monetization. So expanding the pool of investors.

Right now with the 45Q tax credit, unlike with wind and solar, it is subject to the provisions of the BEAT tax, so there is a whole pool of investors that will not be able to supply capital to a carbon capture project.

There is also—we could provide the same level of tax credit transferability to 45Q that the nuclear 45J tax credit enjoys. And the wind industry, by the way, is seeking that for the production tax credit as well.

And then, finally, I don't want to repeat myself——

Mrs. MILLER. Do it quickly.

Mr. CRABTREE. The 48A tax credit has $2 billion in it and it is available right now, and the Carbon Capture Modernization Act would make that available and would put the United States even more on the map as a leader in innovation in the power sector.

Mrs. MILLER. Thank you.

While the U.S. has already greatly reduced emissions, how could carbon capture help reduce emissions from some of the world's biggest emitters, such as China and India?

Mr. CRABTREE. Well, so the average—the coal plant fleet in Asia is vastly greater than the one in the United States, and the average age of a power plant in Asia is 11 years. So if we are to meet midcentury climate goals, there is no alternative but to having a cost-effective, widely demonstrated option for retrofitting coal-fired power plants on Asia's power plant fleet. It is just an absolute must.

And so maybe our greatest leverage here in the United States is to demonstrate in our own marketplace how viable and effective it is to manage CO_2 emissions from power plants by doing projects and doing more of them. And it will be also very important to do that with natural gas, not just coal.

Mrs. MILLER. If we were to fully utilize carbon capture, could we go to a net zero carbon output while continuing to rely on our key baseline fuels?

Mr. CRABTREE. Yes. In fact, the global modeling that gets us to zero shows that we have to deploy carbon capture literally economy-wide on all power generation on all major industrial sources of CO_2.

And then not only that, we have to go negative and we have to start taking CO_2 out of the atmosphere with direct air capture technology, capturing CO_2 from energy production with biomass. It is an absolute essential component of getting to zero by midcentury.

Mrs. MILLER. Thank you.

Dr. Gregory, proposals like the Green New Deal push to move our entire Nation, including our industrial sector, to fully renewable schemes. How would that impact the creation of concrete and cement?

Dr. GREGORY. A fully renewable requirement on the production of cement is challenging without CCUS because it requires use of fossil fuels, at least right now, in order to do that. That is currently not possible using the current technologies that we have.

Mrs. MILLER. Thank you. I yield back.

Ms. CASTOR. Terrific.

Well, I want to thank you all very much for your compelling testimony, it is very helpful to the committee.

Without objection, all members will have 10 business days within which to submit additional written questions for the witnesses. Please respond as promptly as you can.

Without objection, I would also like to enter into the record a letter from Roxanne Brown, international vice president at large of the United Steelworkers, and a letter from Paul Noe, vice president of public policy at the American Forest and Paper Association.

[The information follows:]

Submission for the Record

Representative Kathy Castor

Select Committee on the Climate Crisis

September 26, 2019

SEPTEMBER 24, 2019.

Chairwoman CASTOR,
House Select Committee on the Climate Crisis,
Washington, DC.

Ranking Member GRAVES,
House Select Committee on the Climate Crisis,
Washington, DC.

DEAR CHAIRWOMAN CASTOR AND RANKING MEMBER GRAVES, On behalf of the United Steelworkers (USW), I would like to thank you and the members of the select committee for holding this week's hearing on the issue of industrial greenhouse gas emissions and the climate crisis. I write to you on behalf of the members of the United Steelworkers, North America's largest manufacturing union. Our members supply almost every sector of the economy, and produce a wide array of products, including paper, glass, ceramics, cement, chemicals, aluminum, rubber, and of course, steel. They produce these energy-intensive products in facilities that are as efficient as any in the world. In fact, over the past several decades the industrial sector and its workers have undertaken many initiatives to increase their energy efficiency. And while the industrial sector can, and must, further improve efficiency in order to decarbonize sufficiently to avert the worst potential consequences of the climate crisis, it is crucial that any policy undertaken to reduce emissions in this sector be developed in a manner cognizant of the unique factors that make this particularly challenging for industry. To that end, I thank you for allowing me to provide the perspective of our members and our union.

The United Steelworkers have, for decades, been a leader in the labor community on environmental issues, including climate change. We were the first industrial union to endorse a comprehensive climate change bill, and we have actively engaged for years on the development of environmental laws and regulations. We continue this work at both the state and federal level, working with partners such as the BlueGreen Alliance, which our union formed along with the Sierra Club in 2006, and which continues to provide a strong and credible voice articulating the shared commitment of the labor and environmental communities.

As Congress considers potential policies to address climate change, the way in which these policies affect the industrial sector is of paramount importance. With the industrial sector accounting for 22 percent of total U.S. greenhouse gas (GHG) emissions, it must be part of any comprehensive decarbonization effort both here and abroad. Still, this must be developed in a manner that recognizes the challenges this sector—with its large capital cost and embedded process emissions—faces. There is great potential for decarbonization in the industrial sector while still maintaining production and employment, but to achieve this requires significant upfront investment in proven industrial energy efficiency technologies; development and scaling of technologies such as carbon capture, utilization, and sequestration; and strong measures to ensure that additional costs placed on American industries by mandates or direct carbon pricing do not lead to emissions and job leakage.

INDUSTRIAL ENERGY EFFICIENCY

A key goal of the Steelworkers has long been advocating for the increased use of industrial energy efficiency technologies such as Combined Heat and Power (CHP) and Waste Heat to Power (WHP). CHP captures the heat produced in conventional power generation and WHP captures the heat produced in industrial processes. Both systems then use that heat in other industrial processes as useful energy. These, along with on-site renewable generation and other existing efficiency measures, are among the most efficient ways for industrial sources to reduce demand for external energy sources including electricity, which in turn can dramatically reduce energy consumption.

The Department of Energy found that increased deployment of efficiency technologies like CHP, WHP, and on-site renewable generation can reduce overall energy consumption in the industrial sector by 15%, from 47% to 32%, by 2025. That sort of reduction can make a real difference in total national energy consumption and, by extension, GHG emissions. These technologies are already reducing emissions and are in use in thousands of facilities across the U.S., many of which are in industries that Steelworker members work such as steel, oil, and pulp and paper. Further deployment can both further reduce emissions and bring down the cost of these systems through economies of scale.

In addition, policies to reduce industrial emissions need to be made in the understanding that unlike power generation, which could, in theory, be entirely decarbonized by replacing traditional fossil fuels with clean energy sources, industrial emissions cannot be entirely eradicated that way. Because industry produces process and other emissions that are unavoidable, policies to develop effective carbon sinks are necessary to achieve net-zero emissions. Carbon capture, utilization, and storage is therefore a critical component of any climate policy. We support policies—like the Utilizing Significant Emissions with Innovative Technologies (USE IT) Act—to make these technologies and necessary infrastructure more widely available to industry.

The challenge to further deployment of industrial energy efficiency technologies like these is largely one of available funding for investment. The benefits of these systems to industry are substantial, but they accrue over a long period of time through decreased energy costs, however the costs are also substantial and are almost entirely upfront. Manufacturers with limited access to capital often simply cannot put together the necessary funding in the short term to install these systems, even if the benefits outweigh the costs in the long term. Any policy that focuses on industrial emissions must include measures to lower the cost of investment for manufacturers to drive further deployment.

Many companies and sectors are experimenting with new technologies to reduce emissions from the industrial sector. These exciting opportunities are costly to research, develop, and deploy; therefore, not all companies are able to engage in these activities. We also urge Congress to robustly support and fund this type of research at the Department of Energy or other relevant agencies to ensure that new emissions reduction technologies are developed and commercially available to industrial sources as soon as possible.

EMISSIONS LEAKAGE

While industrial energy efficiency policies and carbon capture can provide options to industry to responsibly reduce emissions, many policy proposals to address GHG emissions involve some sort of carbon price. The Steelworkers have endorsed certain of these carbon price policies in the past, notably the 2009 Waxman-Markey bill. Our union does not oppose carbon pricing, so long as carbon price policies include necessary provisions to address the needs of our members. Foremost among these is a comprehensive policy to prevent emissions and job leakage.

The idea underpinning carbon pricing is that the assessment of a cost on emissions will provide an incentive to reduce them, either through the development of more efficient process or of new products which can be made with fewer emissions. This theory is sound, as long as those costs cannot simply be evaded by companies offshoring production to nations which do not apply a similar carbon price, or downstream producers and consumers avoiding the cost by purchasing imported goods from such nations.

In energy-intensive, trade-exposed industries like steel, glass, aluminum, chemicals, rubber, and pulp and paper, this threat is particularly acute because they are globally-traded commodity-based industries, in which even small differences in production costs can have a huge effect. A carbon price at almost any level that impacts American producers, but not imports will have a huge negative impact on domestic production and employment. In addition to those lost jobs and production, a carbon price that results in leakage will likely have the doubly undesirable effect of making the climate crisis worse, as production displaced to countries such as China, whose industries are less efficient, will result in more global GHG emissions.

The Steelworkers are pleased to see that a consensus has seemingly formed in the U.S. policy community that any serious carbon pricing policy must include a mechanism to prevent this leakage. The structure of the leakage prevention policy can vary somewhat based on the type of carbon pricing policy enacted, but the end result of any acceptable leakage prevention policy must be the enactment of a strong border adjustment mechanism.

The border adjustment, properly applied, will prevent leakage by ensuring that U.S. producers do not face a cost disadvantage relative to foreign producers. By applying a commensurate carbon cost on products consumed in the United States regardless of the country of origin, it would be compliant with international trade rules and would ensure that the commitment of the U.S. to combating climate change would not only drive increased efficiency in domestic production, but in foreign production as well.

As discussed earlier, the speed in which cost disadvantages in energy-intensive, trade-exposed industries can affect U.S. production in those industries cannot be overstated. As such, it is imperative that a border adjustment be fully in place and operational as soon as domestic industries face a carbon price. If the structure of the carbon price is a carbon tax, the border adjustment needs to be enacted at the same time that U.S. producers incur the tax. If the border adjustment cannot be stood up in time, the application of the tax on energy-intensive, trade-exposed industries must be delayed until the border adjustment can be applied.

The application timeline is somewhat different in the case of a cap-and-trade system, such as the one proposed in the 2009 Waxman-Markey bill. In that bill, which USW endorsed, the border adjustment was delayed for several years after the carbon price would have been applied to allow time for international negotiations. Critically, however, during the time between enactment of the carbon price and the application of the border adjustment, energy-intensive, trade-exposed industries were defended from leakage via the allocation of free allowances against the cap until such time as the border adjustment was ready. At that point, the allocations would phase out as the border adjustment phased in. Our Union's position is that the border adjustment should be applied as soon as possible, and if there are delays of any sort because of trading rules or other factors, the industrial sector must be held harmless via some method, whether that method is a delay in the application of the carbon cost on industrials or the provision of cost mitigation during the delay.

However, it is eventually structured to fit in a carbon price regime, the application of a strong border adjustment measure to prevent emission and job leakage is critical to the successful application of the carbon price.

CONCLUSION

Addressing the climate crisis is the defining challenge of our generation, and the United Steelworkers are ready to join in that effort. We have led the way within the labor community on these issues for decades and will continue to do so. However, for these efforts to be successful and lasting, they must be designed with an understanding of how they will impact America's industrial workers and move American industry into the future. The needs of energy-intensive, trade-exposed industries must be taken into account through the inclusion of policies that will drive innovation and efficiency in those industries, and policies including a border adjustment to prevent the loss of production and jobs due to carbon leakage.

On behalf of the United Steelworkers, I would like to thank the Select Committee for holding this hearing on this critical aspect of addressing the climate crisis. We look forward to continuing to work together to meet our shared goal of solving this crisis, while maintaining and creating jobs for Americans.

Sincerely,

ROXANNE D. BROWN,
International Vice President At Large.

Submission for the Record

Representative Kathy Castor

Select Committee on the Climate Crisis

September 26, 2019

SEPTEMBER 24, 2019.

Chairman KATHY CASTOR,
Ranking Member GARRET GRAVES,
House Select Committee on Climate Crisis,
Washington, DC.

DEAR CHAIRMAN CASTOR AND RANKING MEMBER GRAVES: Thank you for the opportunity to discuss key considerations for U.S. climate policy.

We appreciate the Committee's outreach to us and other stakeholders. Seeking input from stakeholders on such approaches will allow for more informed and productive discussion and deliberation.

The American Forest & Paper Association (AF&PA) serves to advance a sustainable U.S. pulp, paper, packaging, tissue and wood products manufacturing industry through fact-based public policy and marketplace advocacy. AF&PA member companies make products essential for everyday life from renewable and recyclable resources and are committed to continuous improvement through the industry's sustainability initiative—*Better Practices, Better Planet 2020.* The forest products industry accounts for approximately four percent of the total U.S. manufacturing GDP, manufactures nearly $300 billion in products annually and employs approximately 950,000 men and women. The industry meets a payroll of approximately $55 billion annually and is among the top 10 manufacturing sector employers in 45 states.

AF&PA's sustainability initiative—*Better Practices, Better Planet 2020*—comprises one of the most extensive quantifiable sets of sustainability goals for a U.S. manufacturing industry and is the latest example of our members' proactive commitment to the long-term success of our industry, our communities and our environment. We have long been responsible stewards of our planet's resources. We are proud to report that our members have already achieved the greenhouse gas reduction and workplace safety goals. Our member companies have also collectively made significant progress in each of the following goals: increasing paper recovery for recycling; improving energy efficiency; promoting sustainable forestry practices; and reducing water use.

AF&PA'S Voluntary Emissions Reductions

In 2011, as part of the association's voluntary Better Practices, Better Planet 2020 sustainability goals initiative, AF&PA set a goal to reduce member greenhouse gas (GHG) emissions—measured in carbon dioxide equivalents per ton of production—by 15 percent. After meeting that goal ahead of schedule, members set a 20 percent reduction goal and they now are close to achieving that goal as well, as emissions were 19.9 percent lower in 2016 than in 2005.

To put these and other emission reductions in context, it is helpful to consider the U.S. Nationally Determined Contribution (NDC that was part of the Paris Accord). Specifically, the U.S. NDC was to achieve a 17% GHG mass reduction between 2005 and 2020, and a 26–28% GHG mass reduction by 2025, with best efforts to achieve a 28% GHG mass reduction by 2025.

The US pulp and paper industry has already exceeded those targets, by reducing direct emissions by approximately 35 percent on a mass basis between 2005–2016.

Further, as stated above, AF&PA members have reduced their direct and indirect GHG emissions by 19.9 percent between 2005–2016 on an intensity basis.

In addition to our members' voluntary progress already discussed above, AF&PA currently is developing new sustainability goals to replace the existing Better Planet 2020 goals. Among others, we are working on a new GHG reduction goal.

Industry Innovation

The industry also is innovating for the future. The industry's Alliance for Pulp and Paper Technology Innovation—APPTI—works to transform the paper and forest products industry through innovation in its manufacturing and products. For instance, a project is underway to reduce the energy used in certain paper manufacturing processes by 23 trillion BTUs, which would lead to significant GHG reductions. This project is being carried out by a team led by the Georgia Institute of Technology and is funded by APPTI members and the Department of Energy's RAPID Institute.

APPTI identifies high priority, pre-competitive technology challenges for the pulp and paper industry and promotes scientific research and development projects to address them. Current projects under development, if implemented, could achieve significant energy and related GHG reductions for the industry

Climate Policy

AF&PA believes that any comprehensive climate legislation must balance environmental, social, and economic concerns to ensure that our nation's economy and forest products industry remain globally competitive.

In particular, any legislation should recognize the forest products industry's important and unique role in reducing greenhouse gases, including sustainable forest management practices, carbon sequestration, biomass energy use, electricity generation, and paper recovery for recycling. Sustainably managed forests and our products sequester and store approximately 14 percent of annual U.S. carbon dioxide emissions. Paper recycling reuses a renewable resource that sequesters carbon and helps reduce greenhouse gas emissions by avoiding landfill methane emissions and reducing the total energy required to manufacture some paper products. Any climate legislation should recognize early actions taken to reduce greenhouse gas emissions. The forest products industry's use of energy efficiency technology such as combined heat and power technology also needs to be given full consideration.

The carbon neutrality of biomass harvested from sustainably-managed forests has been recognized repeatedly by an abundance of studies, agencies, institutions, legislation and rules around the world and includes the guidance of the Intergovernmental Panel on Climate Change and the reporting protocols of the United Nations Framework Convention on Climate Change.

Prior to 2010, the U.S. clearly recognized forest-based biomass energy as carbon neutral. In EPA's Greenhouse Gas (GHG) Tailoring Rule, for the first time, no such designation was made, subjecting biomass energy used in stationary sources to Clean Air Act permit program requirements. In 2011, EPA issued a rule deferring regulation of biogenic carbon dioxide emissions while its Science Advisory Board (SAB) studied the issue and pledged to complete an accounting framework for biogenic emissions from stationary sources by July of 2014, but failed to finish the work.

Numerous EPA documents and policy memos have found positive benefits from forest biomass use, including EPA's original draft accounting framework (September 2011) and revised draft framework (November 2014). Both documents recognize the GHG reduction benefits of bioenergy from forest product mill residuals and byproducts, including black liquor. In April 2018, EPA issued a policy statement to treat biogenic carbon dioxide emissions from the combustion of forest biomass at stationary sources as carbon neutral. As the next step, EPA should implement regulations soon.

From a broader perspective, it is critical to recognize that U.S. manufactures must compete globally. To the extent that Congress adopts laws that increase the domestic cost of production for US based manufacturing, those higher costs of production will shift production jobs, and economic growth outside of the U.S.

In turn, since U.S. manufacturers are a more efficient user of fuel and natural resources than manufacturers in most other countries, when production shifts to outside the U.S., there will be a net increase in global GHG emissions.

In addition, global energy use trends and emissions projections indicate the US will continue to be comparatively advantaged as an efficient user of fuel and lower emissions intensity for the foreseeable future. This data suggests that policies adopted by Congress that increase competition remove barriers and lower costs to

US manufacturing, are the preferred policy prescription for achieving a net reduction in global GHG emissions.

Thank you for seeking our industry's input and we look forward to working with the Committee as this process moves forward.

Best Regards,

PAUL NOE,
Vice President, Public Policy American Forest & Paper Association.

Ms. CASTOR. I would like to remind everyone, we do have a request for information that is out. We are looking for the policy proposals to help build our National Climate Action Plan, the recommendations that will go to the Congress next spring. So I encourage you to check that out and share it widely. And thank you again for being here today.

The hearing is adjourned.

[Whereupon, at 3:36 p.m., the committee was adjourned.]

United States House of Representatives Select Committee on the Climate Crisis

Hearing on September 26, 2019, "Solving the Climate Crisis: Reducing Industrial Emissions Through U.S. Innovation"

Questions for the Record

David Gardiner, President, David Gardiner and Associates

NOVEMBER 22, 2019.

Hon. Kathy Castor,
Chair, Select Committee on the Climate Crisis,
Washington, DC.

DEAR CHAIR CASTOR, Thank you for inviting me to testify before the Select Committee on the Climate Crisis in September. I appreciated the opportunity to provide information to the Select Committee on combined heat and power (CHP) and waste heat to power (WHP). Thank you as well for your thoughtful follow-up questions and those of the Honorable Sean Casten. Please find attached my responses to your questions.

Sincerely,

DAVID GARDINER,
President, David Gardiner and Associates.

THE HONORABLE KATHY CASTOR

1. How can existing Federal procurement policies be updated to prioritize decarbonization in the industrial sector?

The federal government is the nation's largest energy consumer and, as a result, can and should be a leader in decarbonizing its own energy use, especially throughout the Department of Defense, the largest energy user within the federal government. The military has recognized the importance of combined heat and power (CHP) to ensure resilience of its installations. For example, Army Directive 2017–07 says "The Army will reduce risk to critical missions by being capable of providing necessary energy and water for a minimum of 14 days."[1] CHP can provide heat and electricity when the grid is down, so the Army is seeking to build microgrids and CHP projects. Among other CHP projects, the Army broke ground in November 2017 on a 2 MW CHP project at Picatinny Arsenal, a military research and manufacturing facility located in New Jersey. The CHP system will provide steam for heating and numerous ammunition manufacturing processes as well as 2 MW of electricity, which will be able to operate even when the grid is down.[2] Congress should do all it can to support these efforts and those at other government installations.

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[1] Secretary of the Army, "Army Directive 2017-07 (Installation Energy and Water Security Policy)," Feb. 23, 2017. https://www.asaie.army.mil/Public/ES/doc/Army_Directive_2017-07.pdf.

[2] J.E. "Jack" Surash, PE, Acting Deputy Assistant Secretary of the Army for Energy & Sustainability, "The U.S. Army's pivot to energy and water resilience," October 22, 2018. https://www.army.mil/article/212756/the_us_armys_pivot_to_energy_and_water_resilience.

In addition, Federal procurement policies could establish a goal to reduce emissions from its suppliers, as Walmart has done by adopting its Project Gigaton goal. Under such an approach, procurement policies could give preference in awarding contracts to product manufacturers who have decarbonized their industrial processes. In 2017, California adopted AB 262 under which suppliers' emissions performance will be taken into account when an agency is contracting to buy steel, flat glass, and mineral wool (insulation) for infrastructure projects.[3] Such an approach could be adopted at the federal level for a variety of products with significant carbon emissions. This would also encourage manufacturers to reduce their emissions further while ensuring a large federal market.

Many in manufacturing are already prepared for such a move as the private sector has given increased attention to reducing its emissions and increasing energy efficiency: a 2018 study of 160 of the largest manufacturing companies with U.S. facilities found that 79% of these companies had greenhouse gas (GHG) targets, while 43% had energy efficiency (EE) targets.[4] Signatories to the Renewable Thermal Energy Buyers' Statement have also demonstrated their interest in reducing their GHG emissions and are actively seeking ways to expand and accelerate the renewable thermal energy market.[5] Renewable thermal technologies will benefit from the same policies that have helped to advance other renewable energy sources such as wind and solar.

Utilization of CHP and waste heat to power (WHP) can help both the federal government and manufacturers to decarbonize. Conventional electric generation is very inefficient, with roughly two-thirds of fuel inputs lost as wasted heat from the process. Additional energy is lost during transmission from the central power plant to the end user. By generating both heat and electricity from a single fuel source at the point of use, CHP lowers emissions and increases overall fuel efficiency—allowing utilities and companies to effectively "get more with less." CHP can make effective use of more than 70% of fuel inputs. As a consequence, natural gas-fired CHP can produce electricity with about one-quarter of the GHG emissions of an existing coal power plant. WHP, which uses waste heat from industrial processes to generate electricity with no additional fuel and no incremental emissions, reduces emissions and offsets costs associated with purchased power.

As I noted in my written testimony, according to the Department of Energy, the chemicals, petroleum refining, food, paper, and primary metals industrial sectors have the greatest potential for CHP installation, creating a significant opportunity to cut industrial emissions while increasing competitiveness.[6]

Fueling CHP and WHP systems with renewable natural gas can help to further reduce emissions. CHP systems can run on renewable fuels, such as biomass—forest and crop residues, wood waste, or food-processing residue—or biogas—manure biogas, wastewater treatment biogas, or landfill gas. Renewable natural gas (RNG), or biomethane, is a pipeline- quality gas that is fully interchangeable with natural gas and compatible with U.S. pipeline infrastructure and can be used to fuel CHP systems. Over time, CHP systems can evolve and use different types of fuel. A system using natural gas today may run on RNG in the future.

2. Are there environmental, health, safety, or other risks and tradeoffs to pursuing industrial efficiency and renewable thermal? How can they be mitigated?

In addition to the land-use considerations addressed in question 7, pursuing additional CHP deployment at industrial sites could raise concerns about air quality as onsite emissions can increase, however this can be addressed through existing Clean Air Act regulations. WHP uses waste heat from industrial processes to generate electricity with no additional fuel and no incremental emissions.

The use of any type of combustible gas carries inherent risks, though the nation's natural gas delivery system has historically had excellent performance and natural gas utilities remain vigilant and committed to continually upgrading this crucial in-

[3] California. Legislature. Assembly. Public contracts: bid specifications: Buy Clean California Act. A.B, 262. 2017–2018. California State Assembly: October 16, 2017. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB262.

[4] Alliance for Industrial Efficiency, "Committed to Savings: Major U.S. Manufacturers Set Public Goals for Energy Efficiency," June 26, 2018. https://chpalliance.org/resources/alliance-report-finds-majority-u-s-manufacturers-make-commitments-save-energy-reduce-emissions/.

[5] Renewable Thermal Collaborative, "The Renewable Thermal Energy Buyers' Statement," https://www.renewablethermal.org/buyers-statement/.

[6] United States Department of Energy, "Combined Heat and Power (CHP) Technical Potential in the United States," March 2016. https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf.

frastructure based on enhanced risk-based integrity management programs.[7] There are additional challenges presented when injecting RNG into the natural gas pipeline network including variability in composition and supply of gas, the potential impact on end use applications, and odorization and leak detection. RNG quality standards can help to ensure that RNG will not harm the distribution company's infrastructure or customer end-use equipment and will also prevent harm to human health and safety.[8] Several utilities in the United States have already developed gas quality standards that specifically address RNG, demonstrating that such challenges should not be a barrier to RNG deployment.[9] Interconnection guidelines can also provide clarity when connecting RNG projects to gas pipeline systems and uniform standards can offer consistency for projects across jurisdictions. The Northeast Gas Association released an Interconnect Guide for RNG in New York earlier this year, and while the report is specific to one state, the framework it presents could be adopted by other states.[10] Though adding RNG to the gas distribution system requires careful planning, this need not be an impediment to additional deployment.

3. You mentioned in your testimony that CHP and WHP also have the benefits of being distributed energy resources and advancing the use of microgrids. Could you expand upon how these benefits help facilities obtain more reliable power and become more resilient?

Distributed energy resources allow energy to be created close to where it is consumed, reducing the use of electric transmission and distribution systems, reducing line loss of electricity and thereby saving money. Distributed energy resources can also provide increased reliability and resiliency, not only for facilities that host such resources, but also for a host facility's surrounding community. Facilities that are critical infrastructure—assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, economic security, or public health and safety[11]—are particularly well suited to utilize distributed energy resources as access to energy is a high priority for ensuring that critical facilities can continue to deliver services and assist in recovery.[12] In addition to the general benefits of distributed energy resources, CHP and WHP systems provide further benefits in that they typically run and are maintained continuously, providing a consistent source of heat and power unlike intermittent resources such as wind and solar, and have lower emissions than diesel or oil generators. These systems may also be connected to a microgrid, allowing several buildings or facilities to keep the lights on during a grid power outage.

Investments in microgrids have been encouraged by some policymakers at the state and federal level. When a traditional electric grid has an outage or needs to be repaired, all users of the grid are impacted. A microgrid is a local energy grid that can disconnect from the traditional grid and operate on its own during a traditional grid outage.[13] To function independently, a microgrid requires either battery storage or a form of distributed generation such as CHP or WHP. CHP systems provide 39% of the energy in existing microgrids.[14] Microgrids are used by universities, military installations, municipalities, and public institutions, helping to maintain their reliability of electric and thermal energy supply and to improve their resiliency against extreme weather and power outages.[15] In some locations, a number of critical facilities such as hospitals, fire and police stations, emergency shelters, and gas

[7] American Gas Association, "An Increase in Safety Leads to a Decrease in Emissions," 2019. https://www.aga.org/globalassets/2019-increase-in-safety-leads-to-a-decrease-in-emissions-v.3.pdf.
[8] M.J. Bradley & Associates, "Natural Gas Utility Business Models for Facilitating Renewable Natural Gas Development and Use," July 2019, p. 2. https://www.mjbradley.com/sites/default/files/RNGLDCOptions07152019.pdf.
[9] *Id.*
[10] Northeast Gas Association, "Interconnect Guide for Renewable Natural Gas (RNG) in New York State," August 2019. https://www.northeastgas.org/pdf/nga_gti_interconnect_0919.pdf.
[11] Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism (USA PATRIOT ACT) Act of 2001. Pub. L. 107–56 at Sec. 1016(e). 26 Oct. 2001. https://www.congress.gov/bill/107th-congress/house-bill/3162/text.
[12] United States Department of Energy Better Buildings, "Distributed Generation (DG) for Resilience Planning Guide," January 2019, p. 4. https://betterbuildingsinitiative.energy.gov/sites/default/files/attachments/DG%20for%20Resilience%20Planning%20Guide%20-%20report%20format.pdf.
[13] United States Department of Energy, "How Microgrids Work," Jun. 17, 2014. https://www.energy.gov/articles/how-microgrids-work.
[14] Greentech Media, "US Microgrid Growth Beats Estimates: 2020 Capacity Forecast Now Exceeds 3.7 Gigawatts," Jun. 1, 2016. https://www.greentechmedia.com/articles/read/u-s-microgrid-growth-beats-analyst-estimates-revised-2020-capacity-project#gs.fmnot7GL.
[15] *Id.*

stations can be connected and configured to operate in isolation from the larger utility grid, even during extended outages.[16]

Whether used to power a single building or as part of a microgrid, CHP systems have additional benefits over other types of backup power, such as onsite diesel generators. CHP systems generally run and are maintained continuously, avoiding the need to call a generator into operation that may not have been used recently. In addition, CHP systems frequently run on natural gas delivered directly via pipelines, avoiding the need for a fuel delivery as well as resulting increased emissions from diesel or oil.[17] Many critical infrastructure customers such as hospitals, universities, municipalities, and data centers have successfully deployed CHP and WHP systems, increasing their resiliency against natural disasters, emergencies, or other events that may impact the electric grid. Power outage protection can be designed into a CHP system that efficiently provides electric and thermal energy on a continuous basis.

CHP systems can improve the resiliency of critical infrastructure. If the electric grid is impaired, CHP systems can continue to operate, providing electric and thermal service without interruption. This can mitigate the impacts of an emergency by keeping critical facilities operational until power is restored. In addition to providing power and heat to a host facility to keep the facility operational, such host facility may also be able to provide services to their local community to aid in the recovery effort.

Case studies have demonstrated the benefits of CHP systems during severe weather events that result in electric grid service disruption. During and after Superstorm Sandy in the northeast United States, numerous facilities with CHP systems were able to remain operational. For example, South Oaks Hospital in New York was able to provide critical services for two weeks relying solely on its CHP system and admitted displaced patients, offered refrigeration of vital medicines to those who had lost power, and welcomed the local community to recharge phones and electronic devices at its facility.[18] In New Jersey, The College of New Jersey was able to disconnect from the electric grid for a week and the campus continued to operate despite the grid disruption. In addition, the College's equipment was used to assist the state's largest utility in reestablishing service after the grid outage: the utility was able to use the College's equipment to back-feed one of their power lines to bring it back in service.[19] Louisiana State University has also benefitted from a CHP system, the university never lost power during Hurricane Katrina, allowing the school to continue to operate and allow administrative offices of other institutions to relocate to the main campus.[20]

4. You mentioned that most of the policies for renewable heat occur within the European Union. Could you elaborate on some of these policies and how they could be applied in the United States?

Unlike the United States where policies have focused almost exclusively on renewable electricity and transport, the European Union Renewable Energy Directive (RED) takes a more comprehensive approach by requiring 20% of European Union final energy consumption to be met by renewables in 2020, with contributions from electricity, transport, *and* heating and cooling. Individual countries have also seen success in increasing renewable heat by setting ambitious targets, utilizing existing infrastructure to achieve economies of scale, and providing financial incentives.

District heating can facilitate the deployment of renewable heat because of economies of scale and siting of facilities, though government policies facilitating use of additional renewables are still necessary. Denmark, Finland, and Sweden are three countries with extensive district heating systems that also have ambitious long-term targets to switch to renewables. This combination of infrastructure and policy has made these countries leaders in the deployment of renewable heat: in 2015, the share of renewables in heat consumption was 39.6% in Denmark, 52.8% in Finland,

[16] United States Department of Energy, "CHP for Resiliency in Critical Infrastructure," May 2018, p. 3. https://betterbuildingsinitiative.energy.gov/sites/default/files/attachments/CHP_Resiliency.pdf.

[17] United States Environmental Protection Agency, "Valuing the Reliability of Combined Heat and Power," January 2007, p. 2. https://www.epa.gov/sites/production/files/2015-07/documents/valuing_the_reliability_of_combined_heat_and_power.pdf.

[18] ICF International, "Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities," March 2013, 13.

[19] *Id*. at 18.

[20] *Id*. at 24.

and 68.6% in Sweden, with biomass comprising the main source of renewable heat in each country.[21]

France and Germany also have ambitious targets for heat's role in their transitions to the greater use of renewable energy. France has distinct measures for different sectors: its commercial and industrial program includes subsidies for both project support and project execution and supported 3,600 projects from 2009–2015.[22] In the residential sector, tax credits of 30% of capital costs are the main incentive for renewable heat development along with a reduced value added tax (VAT) rate.[23] In Germany, the focus has been on buildings rather than industrial process heat: building code obligations for renewable heat in new construction and a subsidy program with extra incentives when linked to energy efficiency improvements have driven additional deployment of renewable heat.[24]

The United States does not have specific targets, nor a clear policy, for renewable heat at the federal level. However, some states have adopted renewable heating and cooling plans or have provided incentives, demonstrating that programs in the U.S. are possible. For example, Vermont established a goal to increase the share of renewable heat from 20% to 30% by 2025, New York offers a range of incentives for biomass heating systems, air and ground source heat pumps, and biodiesel blended with conventional heating oil, New Hampshire requires a specific portion of its renewable portfolio standard (RPS) come from heat,[25] and 14 other states offer a credit for renewable thermal energy as part of their state renewable electricity standards.[26] Other state-level incentives include sales tax exemptions and rebates.[27] While some states have taken the lead in increasing renewable thermal, not all states choose to participate, creating a patchwork of policies and a dearth of incentives to promote renewable heat in some areas. A further challenge is that many of the state programs are only focused on buildings and there is less support for accelerating the use of renewable thermal technologies in the manufacturing sector.

Setting ambitious targets for renewable heat deployment and providing financial support for projects has been successful in European countries and has begun at the state level in the U.S.. Additional support at the federal level could help to further increase the use of renewable heat in the country.

5. You mentioned that the high upfront capital costs of CHP and WHP systems make it difficult to compete for limited investment capital. How can the Federal government incentivize companies to make these investments? What types of financial instruments would be most effective?

A 2015 United States Department of Energy study found that some of the key economic and financial barriers to the accelerated adoption of CHP included internal competition for capital, the "split-incentive" between capital improvement and operation and management budgets, securing low-cost financing due to financial risks, and lack of financing instruments such as Master Limited Partnerships.[28] Regulatory barriers such as utility business models that result in rate designs that unfairly charge partial requirements customers and do not appropriately recognize the value of the services the CHP systems provide to the grid were also acknowledged by the Department.[29]

Installation of CHP systems typically requires a significant upfront investment which can eclipse long-term benefits. Insufficient capital and internal competition for capital prevent many facilities from installing CHP systems, even when such a system has an attractive financial return.[30] A company may also be hesitant to make investments outside of its core business and may require an even higher rate

[21] International Energy Agency, "Renewable heat policies: Delivering clean heat solutions for the energy transition," 2018, p. 21. https://www.iea.org/publications/insights/insightpublications/Renewable_Heat_Policies.pdf.
[22] *Id*. at 29.
[23] *Id*.
[24] *Id*. at 31.
[25] *Id*. at 40
[26] Clean Energy States Alliance, "Renewable Thermal in State Renewable Portfolio Standards," July 2018. https://www.cesa.org/assets/Uploads/Renewable-Thermal-in-State-RPS-April-2015.pdf.
[27] International Energy Agency, "Renewable heat policies: Delivering clean heat solutions for the energy transition," at 40.
[28] United States Department of Energy, "Barriers to Industrial Energy Efficiency," June 2015, p. 95. https://www.energy.gov/sites/prod/files/2015/06/f23/EXEC-2014-005846_5%20Study_0.pdf. *See also* United States Department of Energy, "Barriers to Industrial Energy Efficiency: Report to Congress," June 2015, p. 9–10. https://www.energy.gov/sites/prod/files/2015/06/f23/EXEC-2014-005846_6%20Report_signed_0.pdf.
[29] *Id*. at 103–104.
[30] *Id*. at 95.

of return compared to other, more familiar capital investments.[31] Internal accounting practices that separate plant operation and maintenance budgets from capital improvements, resulting in costs and savings accruing to different budgets, can also make it difficult to demonstrate the financial benefits of a system.[32] Facilities may also have a hard time finding favorable financing for a long-term investment in the facility upgrade.[33]

First signed into law in 2005 as part of the Energy Policy Act, the federal Investment Tax Credit (ITC) has played, and continues to play, a critical role in driving energy innovation and technological leadership in the United States. The federal ITC has helped to create thousands of jobs, lower electricity prices for families and businesses, reduce carbon emissions, and maintain the country's competitive edge in emerging energy technologies. Section 48 and Section 25D of the ITC provide tax credits that cover renewable energy technologies such as CHP, micro-turbines, solar energy, geothermal, fuel cells, and distributed wind energy. Increasing, or at the very least maintaining, this tax credit will continue to allow American businesses to realize energy and cost savings, support clean energy jobs, and reduce carbon and other GHG emissions.

While the ITC has helped to support the deployment of CHP systems, WHP systems have not been able to benefit from this policy. Despite the fact that WHP is a zero-emission energy resource, these systems currently do not currently qualify for the Section 48 ITC. There are key differences between CHP and WHP systems that prevent WHP from accessing the ITC as written: while CHP systems capture waste heat generated in the production of electricity for thermal uses, WHP systems capture waste heat and energy from thermal processes and operations and convert that energy into electricity. The exclusion of WHP systems from the federal ITC puts such projects at a competitive disadvantage. The proposed Waste Heat to Power Investment Tax Credit Act would rectify this problem by allowing an energy tax credit for investments in WHP property.[34]

Loan programs can also be an effective policy to support additional CHP deployment. For example, the LIFT America Act creates a loan program to support the deployment of distributed energy systems for states, institutions of higher education, and electric utilities as well as a technical assistance and grant program to disseminate information and provide technical assistance to nonprofit and for-profit entities for identifying, evaluating, planning, and designing distributed energy systems.[35] As discussed in question 3 above, distributed energy systems have significant reliability and resiliency benefits, especially for facilities that are critical infrastructure.

Federal grants could also help to increase CHP deployment in the United States and such legislation has previously been proposed. The Job Creation through Energy Efficient Manufacturing Act would require the Department of Energy to establish a Financing Energy Efficient Manufacturing Program that provides grants for energy efficiency improvement projects in the manufacturing sector.[36] Entities eligible for grants would include state energy offices, nonprofit organizations, electric cooperative groups, or certain entities with a public-private partnership.[37] The grant recipients would then distribute subgrants to nongovernmental, small or medium sized manufacturers located in the state in which the recipient is located to carry out projects that improve the energy efficiency of the manufacturers and develop technologies that reduce electricity or natural gas use by the manufacturers.[38] By improving the efficiency of industrial plants, policies such as this Act will reduce carbon and other GHG emissions, reduce energy costs for manufacturers making them more competitive, and create jobs.

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[31] *Id*. at 96.
[32] *Id*. at 97.
[33] *Id*.
[34] United States. Cong. Senate. Waste Heat to Power Investment Tax Credit Act. 116th Cong. 1st sess. S. 2283. Washington: 2019. https://www.congress.gov/bill/116th-congress/senate-bill/2283?r=2&s=1.
[35] United States. Cong. House of Representatives. Leading Infrastructure for Tomorrow's America Act. 116th Congress. 1st sess. H.R. 2741, Secs. 33303–33304. Washington: 2019. https://www.congress.gov/bill/116th-congress/house-bill/2741/text#toc-H364FAC1BA8D742599CF5C10984A7AF57.
[36] United States. Cong. Senate. Job Creation through Energy Efficient Manufacturing Act. 115th Cong. 1st sess. S. 1687. Washington: 2017. https://www.congress.gov/bill/115th-congress/senate-bill/1687. A similar bill was also introduced in 2018, *see* United States. Cong. House of Representatives. Job Creation through Energy Efficient Manufacturing Act. 115th Cong. 2d sess. H.R. 5042. Washington: 2018. https://www.congress.gov/bill/115th-congress/house-bill/5042/text.
[37] *Id*.
[38] *Id*.

Historically, tax policies have been able to stimulate investments in both conventional and clean energy projects. However, conventional energy technologies have access to low-cost capital through types of financing mechanisms that are not available to CHP projects. A Master Limited Partnership (MLP) is a business structure that provides tax advantages to the partners in the business, permitting investors to trade shares and thereby allowing energy projects that qualify as MLPs to have lower cost of capital.[39] Congress should adopt bipartisan legislation to allow clean energy projects to qualify as MLPs, as they do not qualify under current law.

To the extent any technology neutral tax credit regimes or economy-wide tax systems such as cap and trade are being considered, it is essential to ensure that the emissions for CHP systems are appropriately calculated. For example, with regard to technology neutral approaches on tax credits, the model in the Clean Energy for America Act calculates the emissions rate for CHP using both electrical and useful thermal energy.[40] If a carbon pricing regime is under consideration, allowance structures must appropriately account for the savings realized by CHP systems.

In addition to financial and tax barriers, regulatory barriers that impact project economics can also restrict capital outlays for CHP systems. Though CHP and WHP systems can operate independently from the electric grid, many facilities that install such systems still interconnect with the electric grid to provide backup power during scheduled or unscheduled outages. Public utilities implement standby rates to recover infrastructure costs related to providing this backup power service and ensure that CHP host sites have power available when it is needed. However, in many cases, these rates are burdensome, inflexible, unpredictable, or lack transparency.[41] By ensuring that standby rates better reflect the actual costs that a CHP or WHP system imposes on the electric grid, utilities can be compensated for costs while still encouraging investments in these systems.

Though standby rates are approved by state utility regulators, federal policies could help to make standby tariffs and rates simple, transparent, and consistent. For example, the HEAT Act directs the Department of Energy to establish model rules and procedures for interconnection and its associated costs and procedures for determining fees or rates for supplementary power, backup or standby power, maintenance power, and interruptible power supplied to facilities that operate CHP and WHP systems.[42] This legislation would establish a federal framework to help states develop solutions to meet growing energy demands efficiently and economically through the use of CHP and WHP, strengthening local economies and supporting national energy policy goals.

The ability of equitable standby tariffs to unlock the potential of CHP and WHP has been acknowledged by utility regulators at the national level. The National Association of Regulatory Utility Commissioners (NARUC) recently recognized the significance of standby rates to the viability of CHP and WHP projects as well as the potential of CHP and WHP to improve system reliability and resiliency. In a 2019 resolution, NARUC "encourages regulators to consider whether the cost of standby rates discourages further deployment of CHP and WHP, and could harm CHP and WHP facility competitiveness; and encourages Commissioners to assure that standby rates for partial requirements customers acknowledge that: (a) effectively coordinating CHP and WHP with grid system operations reduces demand and costs; and (b) CHP and WHP have the potential to improve system reliability and resiliency."[43]

6. During the hearing, you mentioned that you have a project looking at the carbon accounting associated with combusting biomass. Could you elaborate on the sources of emissions studied? Were emissions outside of combustion, such as tree removal and transport, taken into account? Could you share the findings of this project?

The Renewable Thermal Collaborative (RTC) serves as the leading coalition for organizations—businesses, cities and universities—that are committed to scaling up renewable heating and cooling at their facilities and dramatically cutting carbon

[39] *Id*. at 98.

[40] United States. Cong. Senate. Clean Energy for America Act. 116th Cong. 1st sess. S. 1288. Washington: 2019. https://www.congress.gov/bill/116th-congress/senate-bill/1288/text.

[41] Alliance for Industrial Efficiency, "Standby Rates: Barriers to CHP Deployment on a National Scale," May 2018. https://chpalliance.org/wp-content/uploads/2018/05/Standby-Rates-One-Pager_5.9.19.pdf.

[42] United States. Cong. Senate. Heat Efficiency through Applied Technology Act. 116th Cong. 1st sess. S. 2706. Washington: 2019. https://www.congress.gov/bill/116th-congress/senate-bill/2706.

[43] NARUC Board of Directors, "Resolution on Standby Rates for Partial Requirements Customers," February 13, 2019. https://pubs.naruc.org/pub/758747DC-F64E-BFD7-D411-817D44D3E571.

emissions. Our partner in the RTC, World Wildlife Fund, is leading a project to help large thermal energy buyers evaluate whether biomass, considered from a lifecycle perspective, emits greater or fewer carbon emissions than other fossil fuels. There is growing recognition that automatically assuming carbon neutrality for bioenergy is inadequate to account for climate impacts, particularly for forest biomass as a fuel where the time lag between emission and uptake from regrowth can take up to a century for slow-growing trees. Nor is there yet consensus on the best way to account for this biogenic carbon. However, the World Resources Institute intends to create new accounting guidelines for land sector emissions and removals within the Greenhouse Gas Protocol[44] over the next few years. The Greenhouse Gas Protocol is a voluntary standard for accounting that is widely used and accepted globally for emissions reporting. Until we have accepted accounting practices, it will be difficult to reach agreement on these challenging issues.

In the meantime, RTC's biomass project has been reviewing accounting options and developing a method (called GWPbio) for comparing biomass to other fuels to help large thermal energy buyers make sound investment decisions. Because the project is still underway, we do not have final results yet. However, the decision tool that is being developed adopts a lifecycle approach and considers emissions from many sources, from the traditional footprint including combustion, cutting, processing and transporting the wood product, to its biogenic impact, that considers the type of wood species, their regrowth rate (shorter is better for carbon), the amount of carbon and duration it is stored in a product (e.g., furniture vs fuel) and direct and indirect land use impacts of above and below ground carbon as well as soil carbon, among other attributes.

The decision tool is expected to be publicly available at the end of Q1 in 2020.

7. Could you expand upon what issues need to be considered when determining whether sources of biomass are appropriate for renewable thermal to reduce greenhouse gas emissions? Taking into account land-use considerations and the multiple uses of biomass, what is a reasonable scale for using biomass for renewable thermal?

Several key issues that need to be considered when determining whether sources of biomass are appropriate for renewable thermal to reduce greenhouse gases are outlined in the second paragraph of the answer to question 6. In addition to the GWPbio tool under development, the Greenhouse Gas Protocol for the land sector will be a definitive resource when completed.

In short, there is not yet a consensus on the reasonable scale for using biomass for renewable thermal energy or for other needs. The U.S. Department of Energy Oak Ridge National Laboratory completed the Updated Billion-Ton Report Study[45] in 2016 to estimate the amount of biomass available in the US. The study was a US-wide assessment of bioenergy feedstock availability. It considered issues of access, maintaining base case soil health and other factors, but did not explicitly apply sustainability criteria or standards in its analysis. The RTC has some work underway to develop criteria to filter against the results of the Updated Billion-ton Study results. However, a robust scientific study developed and carried out with stakeholder input and peer review is needed. For now, and until WRI completes the land sector Greenhouse Gas Protocol, a sound approach would use waste materials and materials that are harvested from sustainably managed forests, considering climate and forest health, including biodiversity. Forest Stewardship Council controlled wood supply would provide a sound sustainability filter.

In addition, we would note that some states have analyzed these issues extensively as part of their rulemakings to determine appropriate crediting of biomass thermal energy products in their Renewable or Alternative Portfolio Standards. Massachusetts' Alternative Portfolio Standard, for example, offers credits for biomass thermal projects under these guidelines. However, as outlined in a report from the Clean Energy States Alliance on these issues, states have taken different approaches to biomass in their standards. The RTC is only beginning to assess how the states have addressed these issues so does not endorse any particular approaches which the states may have taken.

David Gardiner and Associates is happy to share with the Committee any additional studies or reports we develop that address these issues.

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[44] http://ghgprotocol.org/.

[45] U.S. Department of Energy Oak Ridge National Laboratory. Updated Billion-Ton Study (2016). https://www.energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf.

THE HONORABLE SEAN CASTEN

1. In terms of designing a combined heat and power plant there can be a lot of flexibility in terms of how a system can be utilized to produce various ratios of heat to power. However, these two products can be subject to very different regulatory regimes that can in turn influence how a system is designed and its ultimate efficiency as you discussed in your testimony before the Committee. How can regulation at both the state and federal level create barriers that can incentivize CHP developers to sub optimize design of a plant with regard to overall efficiency?

Conventional electric generation is very inefficient, with roughly two-thirds of fuel inputs lost as wasted heat from the process. Additional energy is lost during transmission from the central power plant to the end user. By generating both heat and electricity from a single fuel source at the point of use, CHP lowers emissions and increases overall fuel efficiency. When electricity and thermal energy are provided separately, overall energy efficiency ranges from 45–55%, but, though efficiencies vary for individual CHP installations, a properly designed CHP system will typically operate with an overall efficiency of 65–85%.[46] Because they combust less fuel to provide the same energy services, CHP systems reduce all types of emissions, including greenhouse gases, criteria pollutants, and hazardous air pollutants. As a consequence, natural gas-fired CHP can produce electricity with about one-quarter of the GHG emissions of an existing coal power plant. WHP, which uses waste heat from industrial processes to generate electricity with no additional fuel and no incremental emissions, reduces emissions and offsets costs associated with purchased power.

Industrial and manufacturing facilities often have large thermal loads in comparison to their electric power needs. Installing a CHP system to meet such facility's entire thermal load would create the most energy and emissions savings: the optimal way to size a CHP system for a facility is by matching the thermal output of the system to the baseload thermal demand of the facility.[47] However, when a CHP system is deployed at such a facility, the CHP system is frequently not sized to meet the entire thermal load, but instead is capped at the electric demand of the facility because it is either impossible to sell the excess electric power or difficult to sell the excess electric power at a price that reflects its value. Regulations that prohibit the sale of excess power to the grid, prohibit wheeling[48] or the sale of excess power to another facility, or that do not appropriately value such power create this sub-optimization of CHP deployment. The inability to sell excess power, or to sell excess power at a competitive price, can be a deterrent to CHP projects sized to meet facility thermal loads.[49]

Policies that allow facilities that install CHP systems to sell excess electric power would help to encourage additional deployment of CHP and would result in increased energy efficiency by creating thermal and electric energy in one system. Policy options include power purchase agreements (PPAs) with a local electric utility which typically guarantee that a CHP system owner can sell power at a predetermined rate for a certain number of years. However, state utility regulation that does not provide fair treatment to all of the benefits and costs of CHP may curtail the attractiveness of these types of agreements.[50] Third-party PPAs are another policy option where a CHP system owner can sell excess electricity to neighboring facilities, however in many states CHP system owners are not able to deliver excess electricity to nearby plants that are under common ownership or sell excess power except to the electric utility that serves the CHP site, creating a potential barrier to CHP deployment.[51] In general, rules that prohibit or diminish the value of excess power sales leave large amounts of energy and emissions savings unrealized.

2. Given than waste heat to power represents a zero marginal fuel use source of energy with emission equivalent to those of renewable sources,

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[46] United States Department of Energy, "Combined Heat and Power (CHP) Technical Potential in the United States," March 2016, p. 3–4. https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf.

[47] *Id*. at 11.

[48] "Wheeling" in the electric market is the interstate sale of electricity or the transmission of power from one system to another. *See* U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, "United States Electricity Industry Primer," July 2015, p. 91. https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf.

[49] United States Department of Energy, "Barriers to Industrial Energy Efficiency," June 2015, p. 101. https://www.energy.gov/sites/prod/files/2015/06/f23/EXEC-2014-005846_5%20Study_0.pdf.

[50] *Id*.

[51] *Id*. at 102.

how should federal incentives treat these projects? Should they receive similar support to other zero-carbon sources of energy?

Waste heat to power (WHP) systems capture waste heat, a byproduct of industrial processes, and use it to generate electricity with no additional fuel and no incremental emissions. WHP is a clean form of energy that uses leftover heat from industrial, commercial and institutional operations to generate electricity for use onsite or for export to the electric grid. WHP systems capture waste heat from sources such as exhaust stacks, pipes, boilers and cement kilns, which would otherwise be lost to the atmosphere, and convert the waste heat into electricity. Because WHP generates electricity with no additional fuel or combustion, WHP is effectively a "zero emission" energy resource. Like wind and solar energy, waste heat is a resource we already have, but it just needs to be captured and used. However, the resource is underutilized in the U.S.: as of 2016, the U.S. Department of Energy determined existing WHP capacity to be 469 megawatts and the WHP technical potential to be 7,624 megawatts, meaning that the U.S. was utilizing around six percent of this resource.[52]

As of 2016, of the 40 states that had some form of portfolio standard, either an RPS, alternative portfolio standard (APS), or energy efficiency resource standard (EERS), 32 states included WHP systems.[53] While this recognition at the state level is important, it also demonstrates that WHP is not fully recognized for all of the benefits it delivers.

Despite being a zero-emissions technology, WHP does not currently qualify for the federal Investment Tax Credit. CHP and WHP have some key differences that prevent WHP from accessing the ITC as written. CHP systems capture waste heat generated in the production of electricity for thermal uses, whereas WHP systems capture waste heat and energy from processes and operations and convert that energy into electricity. WHP should receive support just as other zero-carbon sources of energy do.

Questions for the Record

Jeremy Gregory, Research Scientist and Executive Director, MIT Concrete Sustainability Hub

THE HONORABLE KATHY CASTOR

1. How can existing Federal procurement policies be updated to prioritize decarbonization in the industrial sector?

I recommend simply asking suppliers of construction materials for government projects to report on the environmental impacts and performance of their products across the full product lifecycle, along with steps being taken by the supplier to improve the product's environmental impact profile over time. If the projects involve buildings that are seeking LEED certification, this can be used to achieve points in the materials and resources portion of the rating system. Many suppliers do not think to lower the environmental impacts of their products because they do not measure the impacts and are not asked to report them. Changing these practices will likely cause them to lower their environmental impacts as a means of differentiating themselves in the marketplace.

2. Are there environmental, health, safety, or other risks and tradeoffs to pursuing solutions for low-carbon cement and concrete? How can they be mitigated?

In some cases, there are immediate opportunities to reduce the carbon footprint of cement and concrete—simply by switching to more of a performance-based system for materials selection. Portland limestone cement, for example, is a proven material that provides the same performance benefits of traditional cement formulations while reducing the emissions profile by approximately 10%. In other cases, it is too early to tell what the long-term impacts of alternative formulations will be over the lifecycle of specific projects. There will almost certainly be performance trade-offs with different solutions (e.g., changes in strength, durability, constructability, etc.) and these need to be considered by engineers and concrete producers when changing concrete mixtures. However, there are unlikely to be significant health and safety

[52] United States Department of Energy, "Combined Heat and Power (CHP) Technical Potential in the United States," March 2016, p. 18, 28–29. https://www.energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf.

[53] U.S. Environmental Protection Agency Combined Heat and Power Partnership, "Portfolio Standards and the Promotion of Combined Heat and Power," March 2016, p. 16–32. https://www.epa.gov/sites/production/files/2015-07/documents/portfolio_standards_and_the_promotion_of_combined_heat_and_power.pdf

issues directly resulting from the use of low-carbon cements and concrete because the industry knows the importance of developing solutions that do not affect workers or the users of structures containing concrete.

3. You mentioned that biomass could be used as an alternative fuel in cement plants. Could you expand upon what issues need to be considered when determining whether sources of biomass are appropriate for use in cement plants to reduce greenhouse gas emissions? Taking into account land-use considerations and the multiple uses of biomass, what is a reasonable scale for using biomass in cement plants?

Biomass and other nontraditional nonhazardous secondary materials provide excellent sopources of fuel for cement kilns due to the unique operating characteristics of cement kilns. Indeed, many facilities have also incorporated biomass sources into their fuel mix, from switchgrass and nut shells to used railroad ties.

With respect to technical considerations when selecting biomass or other alternative fuels for use in kilns, key considerations include the heat value of the fuel (paper, plastic, fibers and fabrics, for example, have very positive profiles) as well as the contaminant characteristics. Because of the extremely high temperatures and long-residence time for kiln fuels, these fuels offer favorable, and often better heat and emissions characteristics than traditional fossil fuels. The high heat and energy efficiency of modern cement plants allows for a high-level of conversion of fuel to energy.

From a resource use perspective, increased use of biomass and other alternative fuels is a net positive for both the environment, the economy, and society. Cement kilns can convert waste biomass streams into a valuable fuel commodity, without complicated chemical processing to create fuels. For some of our members that have chosen to grow switchgrass or other high-heat value biomass sources, the land used to cultivate the fuel provides a valuable ecological habitat and a natural buffer between the plant operations and the community.

With respect to potential scale of use, we see a considerable opportunity to increase the use of biomass and other alternative fuels within the cement industry. Today, for example, US cement kilns use derive roughly 15 percent of their kiln fuel from biomass and other alternative fuel sources (used tires, solid waste, etc.) while the average fuel mix in Europe ranges from 35 to 60 percent.

To get there, however, we are going to need to take a hard look at the federal and state permitting processes for alternative fuel use in specific kilns. Current EPA rules, and sometimes state regulations, can make it difficult to incorporate nontraditional fuels into the fuel mix. While EPA has provided limited exemptions for some biomass streams, regulatory burden and fear of inconsistent enforcement can create concerns.

Questions for the Record

Brad Crabtree, Vice President of Carbon Management, Great Plains Institute

THE HONORABLE KATHY CASTOR

1. In this committee, we've talked, often with frustration, about how China has cornered key parts of the clean energy market, such as batteries and solar panels. Has China cornered the market in carbon capture for industrial emissions, or is this an opportunity for the United States to take the lead and export critical technology to China and other countries?

According to the Global Carbon Capture and Storage Institute (GCCSI), China has commenced construction of one large-scale carbon capture and storage facility and another seven large-scale projects are in different stages of development. By contrast, the U.S. has 13 operating commercial-scale facilities that capture carbon dioxide (CO_2) from a variety of industrial and power generation sources and have a combined annual capture capacity of over 25 million metric tons. Thus, the U.S. remains the clear leader in the deployment of carbon capture, the commercial use of captured carbon and its safe and permanent geologic storage in oil and gas fields and saline formations, and we have the potential to expand that global leadership role. GCCSI recently updated its database of large-scale carbon capture and storage projects under development globally by adding ten new projects, eight of which are in the U.S.

The U.S. oil and gas industry has globally unmatched experience and expertise with large-scale CO_2 injection and storage that dates back to 1972. Multiple other U.S. industries collectively have decades of experience capturing and managing CO_2 at commercial scale. And American innovators, entrepreneurs and investors are on the cusp of a technological and economic transformation in the beneficial use of captured CO_2 and carbon monoxide (CO) to produce low and zero-carbon fuels, chemicals, advanced materials, and products.

However, if we are to maintain and strengthen America's global leadership position, Congress must build on last year's landmark bipartisan reform and expansion of the Section 45Q tax credit by enacting a broader portfolio of federal incentives and other policies for carbon capture, much as has successfully been done for other low and zero-carbon technologies, such as wind and solar. The 70-plus companies, unions and NGOs that participate in the Carbon Capture Coalition recently reached consensus on just such a policy portfolio for American leadership on carbon capture. The Coalition's *Federal Policy Blueprint* was submitted to the Committee for the record at the hearing.

2. Several labor unions are members of your coalition. Why is the topic of industrial efficiency and carbon capture so important to them?

Carbon capture technologies can enable the decarbonization of critical economic activities, while avoiding the closure of existing industrial and manufacturing facilities and power plants and helping to achieve the emissions reductions needed to meet midcentury climate goals. Key sectors of our economy suited to carbon capture deployment support a high-wage, highly-skilled jobs base vital to the livelihoods of working Americans and to the stability and well-being of entire communities and regions that depend on them. Therefore, economywide deployment of carbon capture represents a central and necessary objective of a broader federal climate strategy and policy framework for labor unions, and it is the reason why unions have participated actively in the Coalition since its founding in 2011.

3. What is the biggest challenge for industrial carbon capture and what policy would make the greatest impact?

While industrial carbon capture from high-purity industrial sources of CO_2 such as ethanol, natural gas processing and ammonia production have now become economically viable under the reformed federal 45Q tax credit, many industrial processes produce less pure streams of CO_2 and have higher costs of capture. These industries also tend to produce low-margin commodities that are vulnerable to global competition, and they are thus highly sensitive to any increases in costs of production associated with implementation of emissions reduction technologies such as carbon capture. Moreover, some of the most carbon-intensive industrial sectors, such as refining, chemicals, cement, and steel production, have deployed few and, in some cases, no examples of carbon capture and utilization technology at full commercial scale, which means that the first large-scale projects in these industries will be more costly and involve more commercial risk to project developers and their investors who are the early adopters.

Following last year's reform and expansion of the Section 45Q tax credit, there is no longer one single policy that would have the greatest impact, but rather we now need to take a page from the policy success of wind and solar by enacting a broader portfolio of federal policies to enhance and build on 45Q as noted in the response to question 1 above. The first component of this broader federal policy portfolio includes technical fixes and enhancements to 45Q and other existing incentives, as well as new incentives to reduce the cost of capital in financing carbon capture projects (see response to question 10 below for more detail). Second, now that we have the revamped 45Q credit as a cornerstone federal incentive for deployment, it is crucial that federal policymakers devote attention to ensuring that CO_2 transport infrastructure becomes an important element of broader federal infrastructure policy to ensure that we have robust infrastructure in place across the country to transport CO_2 from where it is captured to where it can be geologically stored and put to beneficial use (see response to question 9 for more detail.) Finally, Congress can help ensure that the next generation of carbon capture and utilization technologies with lower costs and improved performance make their way into the marketplace by continuing to advance bipartisan RDD&D legislation such as the USE IT Act, Clean Industrial Technology Act and the Fossil Energy R&D Act, which would provide dedicated federal funding for research, development and demonstration of capture and utilization technologies in key industrial sectors.

4. You mentioned that Federal procurement policies will play an important role for creating early markets for industrial carbon capture projects. Could you expand upon which types of industrial products would be best suited for government procurement? Which of these have potential for carbon utilization?

The Carbon Capture Coalition has identified as a priority the development of federal procurement policy for low, zero and even carbon-negative electricity, liquid fuels and products produced through carbon capture, utilization, removal and storage. While the Coalition has yet to develop specific policy recommendations, Coalition participants recognize the important role that federal procurement policy has played in providing demand-side support for other low and zero-carbon technologies, complementing the role of tax credits and other financial incentives on the supply side to help drive private investment in commercial technology deployment.

Carbon capture and utilization in industrial settings is multifaceted, so federal procurement policies not only need to support market development for different non-energy products, but also for electricity and a wide range of liquid fuels. For example, utilization of waste steel plant CO emissions to produce low carbon ethanol, jet fuels and chemicals is currently being commercialized in China and Europe and could readily be deployed in the U.S. with the right mix of policy support. Also, low and zero carbon-electricity and hydrogen are critical to decarbonization of industrial sectors, and government procurement policies can help stimulate deployment of carbon capture in power generation and in hydrogen production for industrial heat and other applications.

In addition, key industrial commodities such as steel and cement lend themselves to government procurement policies. Infrastructure and construction constitute a significant component of market demand for such commodities, and federal funding for projects plays a major role in these markets. Because the purchase of these commodities represents a small percentage of total project costs, the federal government can provide a meaningful premium in the marketplace for lower-carbon steel, cement and other commodities manufactured with carbon capture and/or incorporating carbon utilization, without significantly increasing the total federal contribution to such projects.

Finally, federal procurement policies can play an especially important role in establishing markets for products derived from the utilization of captured CO_2 and its precursor CO that have a smaller carbon footprint than their traditional counterparts. Considering both technological maturity and potential market size, building materials, fuels, chemicals and plastics produced from captured carbon are examples of promising areas where procurement policy could make a real difference in fostering deployment. Beyond reductions in carbon emissions, there are additional benefits to many of these technologies, including military readiness. Direct air capture-to-fuels applications, for example, could enable the military to produce fuels around the world through the capture of CO_2 from ambient air.

5. Are there environmental, health, safety, or other risks and tradeoffs to pursuing carbon capture utilization and storage? How can they be mitigated?

Carbon capture, pipeline transport and geologic storage of CO_2 have been undertaken at scale for nearly a half century in the U.S., and over a billion tons of CO_2 have been injected into geologic formations over that time period without significant environmental incidents. Industry currently purchases and manages on the order of 65–70 million metric tons of CO_2 annually for injection. Environmental, health and safety risks are known, minor, well-managed and regulated. The transport, use and geologic storage of that CO_2 is enabled by just over 5,000 miles of existing CO_2 pipelines in 11 states, the operation of which over decades has involved no fatalities or major environmental accidents. Few industries on this scale have a comparable safety and environmental record.

6. You mentioned the importance of the 45Q tax credit for carbon capture projects. Beyond 45Q, what policies does the Carbon Capture Coalition recommend for creating markets for industrial carbon capture?

This question is already addressed in responses to questions 1, 3, 4, 9 and 10, especially questions 4 and 10.

7. You mentioned in your testimony visiting two overseas demonstrations of CCUS at steel production facilities. Could you talk about what you learned from these visits that could be applied to facilities in the United States? Why do you think these innovative applications were demonstrated in other countries and not in the United States? What made these countries better environments for testing these technologies?

U.S. state and federal officials and representatives of industry, labor, NGO and philanthropy recently had the opportunity to visit the world's only large-scale carbon capture facility at a steel plant in the United Arab Emirates and a commercial-scale carbon utilization project under construction at a steel mill in Belgium and to consider how these technologies and business models could be applied here in the U.S. The direct reduction ironmaking process used by Emirates Steel in the UAE is widely deployed in the U.S. The specific HYL technology from Energiron produces a pure stream of CO_2 that can be readily configured for capture and compression, and it is currently installed at a steel plant in Louisiana, potentially creating a near-term opportunity in the U.S. In Belgium, the "Steelanol" project under development between the U.S. company LanzaTech and global steel producer ArcelorMittal to produce ethanol from steel mill CO emissions could also be pursued in the U.S. under the right policy circumstances.

In both the UAE and Belgium, the commitment of resources by Abu Dhabi (through the Abu Dhabi National Oil Company) and the European Union, respectively, and the economic opportunity to add value to existing energy and industrial production through carbon capture and utilization provided the impetus to these projects and made their development feasible. Here in the U.S., the existing 45Q tax credit, coupled with targeted federal resources and incentives for early commercial technology demonstration in key industrial sectors such as steel, cement, chemicals, etc., would enable similar steel and other large-scale industrial carbon capture projects to move forward. Specifically for carbon utilization-to-fuels pathways such as LanzaTech and ArcelorMittal's CO-to-ethanol process, incentive support for low-carbon fuels through the Renewable Fuels Standard or some comparable federal policy would be needed for deployment to proceed.

8. Are there ways that carbon capture can help industrial facilities with reliability and resilience?

Many types of industrial facilities are very energy-intensive and require cost-effective, reliable electricity and industrial heat on a 24/7 basis. Installing carbon capture on coal and natural gas power generation can decarbonize electricity inputs to industrial production without impacting supply or system reliability. Similarly, steam methane reforming of natural gas with carbon capture currently provides the lowest-cost source of zero-carbon hydrogen, thus enabling cost-effective, on-demand provision of near zero-carbon heat to industrial processes.

9. You mentioned that expanding infrastructure for the transport of carbon dioxide will be crucial for bringing down the costs of deployment of CCUS. Can you describe the existing carbon dioxide pipeline infrastructure in the United States and how and where it would need to be expanded to accommodate the volumes projected for deep decarbonization?

Currently, the U.S. has just over 5,000 miles of existing CO_2 pipelines in 11 states, and CO_2 has been safely transported and injected for injection and geologic storage at scale since 1972. The bulk of today's CO_2 transport infrastructure is concentrated in several pipeline networks, with the largest centered on the Permian Basin of Texas and New Mexico and other smaller networks on the Gulf Coast and in the Northern Plains, with the remainder consisting of single source-to-sink pipelines in several states.

For carbon capture to realize its full potential to contribute to midcentury emission reductions as borne out in modeling by the International Energy Agency (IEA) and Intergovernmental Panel on Climate Change (IPCC), a national system of CO_2 transport infrastructure will need to be developed on a scale comparable to systems now in use to transport oil and gas. This will entail scaling up existing regional CO_2 infrastructure hubs substantially, establishing new hubs in areas of concentrated industrial and energy-related emissions and geologic storage potential (e.g. Louisiana Gulf Coast and industrial Midwest), and developing new long-distance, large-volume CO_2 trunk lines and associated feeder lines to regions not currently served by infrastructure for carbon management, including the Upper Midwest, Midwest and coastal regions.

The Carbon Capture Coalition has urged Congress to make CO_2 transport infrastructure a core component of broader federal infrastructure policy, specifically recommending a federal role in leveraging private capital investment through:

- Low-interest federal loans to finance extra pipeline capacity and realize economies of scale;
- Support for large-volume, long-distance CO_2 trunk line demonstration projects to support development of key regional hubs; and
- Encouragement to state and local governments to designate anthropogenic CO_2 pipelines as "pollution control devices" to enable tax abatement.

The Investing in Energy Systems for the Transport of CO_2 Act of 2019 (INVEST CO_2 Act) recently introduced in the House incorporates the Coalition's recommendations for a federal role in helping to finance the buildout of national CO_2 transport infrastructure.

10. You mentioned that carbon capture projects are difficult to finance due to the high cost of debt and equity and the risk involved in the investment. Which government financing mechanisms would best lower these costs and risks?

As noted above, the Coalition recommends a portfolio of policies to expand the pool of eligible investors and projects, reduce investment risk, and make capital available to projects on more favorable terms. The following policies involve technical fixes and enhancements to the existing 45Q tax credit, improvements to other existing complementary incentives and new financial incentives.

First and foremost, Congress should extend now the authorization of 45Q beyond the current deadline for beginning construction at the end of 2023 in order to provide the kind of longer-term planning and investment horizon that has helped spur private investment, commercial deployment and cost reductions for other low and zero-carbon technologies. The newly-reformed 45Q credit provides a foundational incentive for early commercial carbon capture deployment, but significant delays by the IRS in providing guidance have reduced the time period available to plan, engineer, permit and finance large-scale, capital intensive carbon capture and utilization projects from six years to just four.

In addition, technical fixes and new policy options to enhance and complement 45Q would further incentivize private investment in the deployment of carbon capture technologies. The technical fixes identified below offer many potential near-term deployment benefits to the carbon capture industry:

- Eliminating the 25,000-ton minimum annual capture threshold in 45Q that inadvertently risks precluding most carbon utilization projects from eligibility;
- Preventing the disallowance of 45Q and the 48A tax credit under the Base Erosion and Anti-Abuse Tax—BEAT (a technical fix already afforded investors claiming the Production Tax Credit for wind energy and the Investment Tax Credit for solar energy), which otherwise risks reducing the pool of available investors in carbon capture projects; and
- Enabling developers of power plant carbon capture retrofit projects to access available 48A tax credits by incorporating needed technical fixes provided for in the Carbon Capture Modernization Act. (The legislation would address a conflict in current law that makes the tax credit unworkable for potentially eligible projects.)

The Coalition also recommends several new policy options to help the carbon capture industry achieve economywide deployment:

- Providing enhanced transferability for the 45Q credit in statute by including additional taxpayers who are involved in the carbon capture transaction to be allowable as transferees (modeled on the transfer provision in Section 45J(e) of the Advanced Nuclear Tax Credit);
- Establishing a revenue-neutral refundable option for 45Q to enable a greater diversity of companies and business models to benefit from the tax credit; and
- Creating an "American Energy Bond" option to allow project developers to make interest payments in the form of tax credits, if they invest bond proceeds in qualified energy infrastructure projects, including carbon capture and utilization.

Providing for the eligibility of carbon capture and utilization eligible for federal financial incentives that have proven effective in other industries can further reduce the cost of capital and complement and reinforce the deployment potential of the 45Q credit. The Carbon Capture Improvement Act would make carbon capture and utilization projects eligible for tax-exempt private activity bonds, and the Financing Our Energy Future Act would also allow carbon capture and utilization projects to become master limited partnerships, thus affording the tax advantages of a partnership coupled with the benefit of being able to raise equity in public markets.

Finally, ensuring the widespread availability of infrastructure to transport CO_2 from where it is captured to where it can be stored or put to beneficial use will reduce costs and increase investor confidence in proposed capture and utilization projects. As referenced in the response to question 9, the Investing in Energy Systems for the Transport of CO_2 Act of 2019 (INVEST CO_2 Act) would provide for a federal role in providing low-cost financing to support the deployment of CO_2 transport infrastructure and ensure that such infrastructure is built with sufficient capacity to stimulate private investment in ongoing development of capture and storage projects over time.

11. You mentioned that there is potential for using biomass as a feedstock for power generation and capturing the carbon dioxide on the back end to create negative emission energy for industry. Could you expand upon what issues need to be considered when determining whether sources of biomass are appropriate for power generation with carbon capture to reduce greenhouse gas emissions? Taking into account land-use considerations and the multiple uses of biomass, what is a reasonable scale for using biomass for power generation with carbon capture?

While IPCC modeling indicates that deploying atmospheric carbon removal strategies at significant scale—including bioenergy with carbon capture to achieve negative emissions—is necessary to meet midcentury climate goals, the Carbon Capture Coalition does not take a position regarding the appropriate future scale and scope of biomass utilization in bioenergy production with carbon capture relative to other negative emissions strategies, including direct air capture deployment. However, existing biofuels production and biomass power generation in U.S. provides ample opportunity to deploy carbon capture, use and geologic storage of biogenic CO_2 emissions to demonstrate the commercial potential for larger-scale negative emissions energy systems—without expanding beyond current levels of biomass feedstock use in energy production. If we are even to have the option of scaling up negative emissions energy systems in the post-2030 period, it is important that federal policymakers support commercial demonstration of bioenergy with carbon capture now at biofuels and biomass power facilities using existing feedstock supplies. In the meantime, federal policymakers and stakeholders can and should continue to work to forge agreement on policies that can help ensure long-term sustainable biomass utilization in the context of midcentury decarbonization.

Questions for the Record

Cate Hight, Principal, Rocky Mountain Institute

THE HONORABLE KATHY CASTOR

1. What is the biggest challenge to deploying renewable hydrogen for industrial processes? What single policy would be most effective at addressing this challenge?

Today's biggest challenge is that industry does not use a lot of "renewable" hydrogen because there is not enough of it on the market for it to be cost-competitive. The existing market is predominantly supplied by hydrogen produced through steam methane reformation (SMR), without consideration of the carbon footprint of this process. And hydrogen producers don't want to take on the financial risk of ramping up production if they don't have a sure market to allow them to recover costs. To increase hydrogen supply and bring down the cost, regulations and/or financial incentives could be used to stimulate low-carbon hydrogen production, including that produced using zero-carbon electricity and also though SMR with associated carbon capture and storage (CCS).

2. You mentioned government procurement of hydrogen as a potential policy solution. What considerations are important when designing procurement policy for hydrogen? How should the source of hydrogen play a role?

Government demand for hydrogen, articulated through procurement policies focused on procuring more hydrogen as well as products produced using hydrogen fuel (such as steel), can play a key role in stimulating hydrogen production. Such policies should focus on sourcing low-carbon hydrogen, including that produced though zero-carbon electricity and also though steam methane reformation (SMR) with associated CCS. In addition, The long-term goal should be for all hydrogen to be produced using renewable electricity; in the near term, however, the goal should be to build the supply of hydrogen to bring down the price. Additionally, the government should continue to invest in Department of Energy (DOE) programs, such as H2@Scale, to continue to drive development of hydrogen pathways.

3. Are there environmental, health, safety, or other risks and tradeoffs to pursuing the use of hydrogen? How can they be mitigated?

Hydrogen has been safely produced and used in the American industrial sector for more than half a century. As with every fuel, safe handling practices are required, but hydrogen is non-toxic and does not pose a threat to human or environmental health if released. In addition, when used to generate power and for several other industrial applications (e.g., steelmaking), hydrogen produces only water as a byproduct, and does not release air pollutants or particulate matter. The environmental impact of hydrogen production depends on the production pathway. Hydrogen can be produced through electrolysis using any power source, the cleanest being renewable power. Hydrogen can also be produced through reforming of fossil fuels including natural gas; this process releases carbon dioxide that must be captured. In addition, one would need to account for the environmental impact associated with the production, transmission and distribution of the natural gas to the hydrogen production facility.

4. You mentioned the similarities between hydrogen use and electric vehicles. Could you elaborate on how the Federal government can help the hydrogen market grow while simultaneously incentivizing lower-emission hydrogen production for this growing market?

The similarity between growing the hydrogen market and in the EV market relates to the fuel sources used to create both markets. Right now, EVs are simply powered by the mix of power offered on the grid; widespread availability of power at a reasonable price has enabled the EV market to take off, while simultaneously the grid is becoming greener and a larger share of that power is being provided by renewable sources.

The development of the hydrogen market should follow that same dynamic. Right now, over 90% of the hydrogen produced in the US in produced through SMR, but the goal is to produce more hydrogen using electrolysis powered by low-carbon electricity. The focus now needs to be on building hydrogen supply so the price can come down, the demand can increase, and additional investments can be made in renewable hydrogen production. This will require applying CO_2-capture at existing SMR facilities, and also regulations and financial incentives, including renewable energy mandates, tax credits, loan guarantees, and feed-in-tariffs. On the demand side, clear regulations, direct investment, and loan guarantees for building additional transportation and distribution infrastructure can make hydrogen easier for industry to access. Financial incentives can be used to stimulate hydrogen use by large industrial facilities, and investment support programs can help reduce the costs associated with fuel-switching at these facilities.

5. Are there ways that hydrogen can also help industrial facilities with reliability and resilience?

Hydrogen has the potential to be used as stationary power (for buildings), backup power, storage of energy harvested through wind and solar processes, and as battery-like portable power (most commonly used in forklifts today). Energy stored in hydrogen fuel cells allows for the seamless transition of energy within the power grid in the event of a power station failure or a black-out situation. In addition, Power-to-Gas (P2G) is the only technology capable of providing storage at terawatt-hour scale without location limitations. Renewable electricity is used to create hydrogen, which then is stored in a storage system like tanks, caverns, or the natural gas grid. Using the natural gas grid would allow for very large amounts of renewable hydrogen to be stored very economically, as very little new infrastructure needs to be build. Effectively, this hydrogen reservoir could be used as back-up capacity for when there are production disruptions or shortages in the power grid.

6. How do other countries view the use of hydrogen as a decarbonization strategy? What policies have they implemented and what can we learn from them?

Many countries are planning to use hydrogen as a mechanism to decarbonize. The scale of these applications and the role they play in the economy varies quite substantially. Australia for instance has a number of highly developed pathways focusing on the production and export of hydrogen in addition to use in heavy transport applications. Japan, Korea, China, and Germany have announced ambitious goals for deployment of hydrogen fuel cell electric vehicles; China plans to have 1 million fuel cell electric vehicles on its roads by 2030. Some nations are setting targets for the type of hydrogen used in industry: in 2018, France announced a target of 20-40% low-carbon hydrogen use in industrial applications. In addition, there is a large effort in Europe through the European Commission's Fuel Cell and Hydrogen joint undertaking. This effort is a public private partnership to develop multiple hydrogen pathways, including using existing natural gas pipeline networks to transport hydrogen.

7. You mentioned that government investment in hydrogen infrastructure for transportation and delivery will be needed to scale up hydrogen use in industry. Can you comment on how existing hydrogen infrastructure would need to be expanded? How would the footprints of hydrogen and carbon dioxide infrastructure overlap? Are there synergies we can take advantage of?

Current hydrogen production is largely concentrated in areas where oil and gas refineries are located, and integrated with other (petro)chemical facilities that use the hydrogen as feedstock. This infrastructure will need to be expanded into additional geographies as hydrogen production expands across the US. However, there is promise in using existing the nation's extensive natural gas pipelines to carry hydrogen instead. Current research supports blending of 20% hydrogen into natural gas streams without changes to pipeline infrastructure. This percentage could be higher if natural gas pipeline is retrofitted to carry the smaller hydrogen molecules.

Hydrogen and carbon dioxide infrastructure could overlap as transportation and pipeline infrastructure is developed. Storage and utilization approaches for CCS could in some instances co-locate with hydrogen production technologies such as SMR, but the development of large-scale carbon dioxide storage, in geologic formations for example, will require the transportation of CO_2 in the future. As such, planning for these infrastructure projects and indeed identification of storage capacity might offer potential for synergies in the development phases.

8. You mentioned that biomass could be used to make hydrogen energy. Could you expand upon what issues need to be considered when determining whether sources of biomass are appropriate for hydrogen feedstocks to reduce greenhouse gas emissions? Taking into account land-use considerations and the multiple uses of biomass, what is a reasonable scale for using biomass for hydrogen?

Biomass can be used to produce electricity that is then used to power via electrolysis; it can also be gasified to produce hydrogen, with appropriate controls to capture the resulting carbon monoxide and carbon dioxide byproducts produced. The production of hydrogen from biomass will likely be dependent on the relative cost of hydrogen production using this fuel source versus steam methane reforming. A more viable pathway for biomass in industrial applications may be to combust it directly and capture CO_2 emissions, rather than using the additional energy required to transform it into hydrogen before use.

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