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Key Considerations for US Climate Policy: Clean Energy Standards & Carbon Pricing

Prepared for the US House of Representative Select Committee on the Climate Crisis

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Select Committee on the Climate Crisis
US House of Representatives
ClimateCrisisRFI@mail.house.gov

Dear Members of the House Select Committee on the Climate Crisis:

On behalf of Resources for the Future (RFF), I am pleased to share the attached information related to your recent request for input on key considerations for US climate policy.

RFF is an independent, nonprofit research institution in Washington, DC. Its mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. RFF is committed to being the most widely trusted source of research insights and policy solutions leading to a healthy environment and a thriving economy.

While RFF researchers are encouraged to offer their expertise to inform policy decisions, the views expressed here are those of the individual authors and may differ from those of other RFF experts, its officers, or its directors. RFF does not take positions on specific legislative proposals.

This information represents the contributions of nearly a dozen researchers, although, as noted above, it should not be considered a consensus view.

We appreciate the breadth of thinking that informed the request for information. In the attached response, we chose to focus on a core set of policy areas where RFF has considerable expertise and recent bodies of research. Additionally, RFF has a number of ongoing research projects that will, upon completion, address a number of the questions posed in the RFI that are outside the scope of this response. We recognize the value of the full suite of questions and would welcome the chance to share future research and lend our expertise to inform a more expansive set.

Finally, we would welcome the opportunity to speak in more detail with the Committee members and staff about any of the ideas, issues, or publications included in this input. If you have any questions or would like additional information, please contact Kristin Hayes at hayes@rff.org.

Sincerely,

Richard Newell
President and CEO

RESOURCES for the FUTURE

US House of Representatives Select Committee on the Climate Crisis Request for Information

Response from Resources for the Future

Question 1b) Electric power. The Select Committee would like policy ideas across the electricity sector but requests specific comment on two areas:

If you recommend a Clean Energy Standard, how should it be designed?

Economists view the imposition of a carbon price, applied throughout the economy, as the most cost-efficient policy tool to drive emissions reductions. When pricing carbon directly is not possible, a tradeable clean energy standard (CES) could be a suitable alternative. This approach makes use of economic incentives and can be designed to be clean technology neutral. A well-designed CES can approach the economic efficiency of emissions reductions achieved under a carbon pricing approach. This **issue brief** describes how a CES would work, and this **issue brief** provides projected effects of the federal *Clean Energy Standard Act of 2019*, introduced by Sen. Tina Smith and Rep. Ben Ray Luján.

There are a number of important policy features to consider when designing CES legislation that can greatly impact the effectiveness and cost of the policy.

Define "Clean" Based on Carbon Emissions Intensity

- To maximize cost-efficiency of emissions reductions, a CES policy should provide electricity generators with an economic incentive to reduce their emissions that is uniform for each ton of their emissions. A design approach that provides this set of continuous incentives is to award full or partial clean energy credits based upon a comparison of the emissions intensity (i.e. emissions per MWh of electricity generated) of each generator against a benchmark emissions intensity. Employing such an emissions-based crediting system creates relative incentives to reduce emissions across a fleet of emitting generators, enabling lower cost emissions reductions. All sources that have emission rates lower than a specified benchmark will earn partial-to-full credits in accordance with the crediting formulation; the lower the emission rate, the greater the incentive for generation.

- Awarding clean energy credits based solely on the emissions of CO_2 from combustion at the power plant will not account for the full emissions from a given unit of electricity generated. To the extent possible, accounting for the full lifecycle emissions for electricity will allow for the greatest cost-efficiency and provide the set of relative incentives for clean generation that most accurately reflect their total emissions. For example, methane leakage upstream of natural gas power plants can be a significant contributor of greenhouse gases, as can methane emitted in the production of coal. Encompassing such upstream emissions in a CES policy, converting methane emissions to CO_2-equivalent emissions using an estimated damage ratio similar to the 100-year global warming potential as necessary, would improve the policy's overall cost-efficiency in reducing total emissions related to the power sector. Similarly, the crediting of electricity from biomass should be based on its emissions on a lifecycle basis. For all sources, estimated emissions from construction and decommissioning could be included.

A Broader Policy Scope Enables Lower-Cost Emissions Reductions

- A more inclusive set of technologies eligible to earn credits allows for greater flexibility and more options for emission reductions. Including all sources of generation—existing and new, domestic and foreign, from zero- to high-emitting—will lower the cost of achieving a given reduction in emissions under the policy. Similarly, **this RFF Working Paper** demonstrates (among other points) how exemption of small utilities can reduce efficiency of the policy and create regional disparities.
- The level of the benchmark emissions intensity is one key parameter in determining scope and inclusion of generators across an emissions-rate spectrum. A higher benchmark enables a more expansive set of generators to earn partial credits, thereby creating stronger relative incentives within the generator fleet, and resulting in a more cost effective and efficient policy.
- A related and important consideration in setting the benchmark is that all sources with emission rates equal to or above the benchmark will receive no partial credits and therefore are undifferentiated by the policy—a higher emitting source above the benchmark will be treated as equivalent to a lower emitting source above the benchmark. One design approach that would address the absence of relative incentives for generators above the benchmark and improve efficiency would be to impose a symmetric feebate-like structure. Under this structure, generators with an emissions intensity below the benchmark would be eligible to receive clean energy credits and generators with emissions above the benchmark would be required to surrender credits in proportion to their relative carbon intensity above the benchmark.

- Though RFF and others' analysis has shown that a more technology-inclusive clean energy standard offers the potential for greater cost-efficiency overall, if a broad CES incentivizes investment in new emitting resources (such as natural gas capacity without carbon capture), some have expressed the concern that it may result in stranded assets in the future (when the stringency of the policy is greater).

An Illustrative Analysis Comparing Two CESs with Differing Benchmarks

A forthcoming RFF simulation analysis explores in greater detail the tradeoffs in setting the benchmark intensity by comparing two federal CES policies that differ with respect to crediting of natural gas-fueled generation. One CES sets the benchmark at 0.4 metric tons per megawatt-hour (MWh)—the approximate emissions rate of an efficient natural gas generator—while the other sets the benchmark at 0.82 metric tons per MWh—the approximate emissions rate of an uncontrolled, ultra-supercritical coal-fired power plant. The former effectively excludes any gas that does not have carbon capture and storage from earning credits, while in the latter, much of the natural gas fleet is eligible to earn partial credits. The stringencies of both policies are calibrated such that they reduce equivalent power-sector GHG emissions (relative to business-as-usual). Relative to the lower benchmark CES, for the model simulation year 2035 the higher benchmark CES:

- Reduces coal generation more and natural gas generation less by providing a stronger relative incentive for natural gas over coal.
- Reduces methane emissions less (greater natural gas usage leads to greater upstream methane emissions) and CO_2 emissions more.
- Reduces emissions at a lower cost to end users.
- Reduces wholesale prices more by requiring a higher clean energy credit price and thereby providing a larger subsidy to generation. (Note that decreases in profits by clean energy generators from the reduced wholesale prices are projected to be more than offset for eligible clean energy generators through revenues from CES credit sales.)
- Achieves greater health co-benefits by reducing more emissions from SO_2 and NO_X (largely driven by reduction from coal-fired generation).
- Achieves greater estimated net benefits to society (largely driven by health and climate benefits).

In summary, this case study indicates that setting the benchmark at the level of an efficient, uncontrolled coal generator—thereby allowing lower emitting natural gas-fueled generation without carbon capture to earn partial credit—can reduce the cost of the policy and increase its air quality benefits over a policy that does not credit uncontrolled natural gas, while achieving the same reduction in greenhouse gas emissions.

Additional Considerations

- Applying emissions policies of similar stringencies to the CES in other sectors of the economy can prevent "leakage" of emissions from the electricity sector.
- A price ceiling (alternative compliance payment) can reduce uncertainty about what future prices will be, so companies are willing to invest. A price ceiling can limit the extent of emissions reductions if the credit price reaches the ceiling level.
- Crediting existing resources may change the distributional effects of the policy, as existing resources that will dispatch regardless of the policy (e.g., wind, solar, and hydroelectric facilities) may earn windfall profits.
- Applying starting CES percentage targets at a sub-national level (e.g. utility or state) based current levels of "cleanliness" (as defined by the policy) can level the playing field. However, if significant existing clean energy resources later retire (e.g. a nuclear facility), then that particular region will need to compensate with new investments, potentially resulting in higher costs.

Question 4a) What role should carbon pricing play in any national climate action plan to meet or exceed net zero by mid-century, while also minimizing impacts to low- and moderate-income families, creating family-sustaining jobs, and advancing environmental justice? Where possible, please provide analytical support to show that the recommended policies achieve these goals.

Economists often favor policy solutions that introduce a direct price on carbon emissions that escalates over time. A price on carbon changes the relative cost of fuels by making fuels that have greater emissions more expensive.

A carbon price is viewed favorably by economists for the following reasons:

- It percolates through the entire economy, providing an incentive for all decision makers in the economy to look for ways to reduce emissions, for example, by improving the boiler in a factory or buying a more efficient air conditioner at home.
- It provides firms with the flexibility to make decisions that make sense based on their own information.
- Existing product markets can seamlessly incorporate changes in relative prices of goods and services.

For a further, high-level overview of carbon pricing, please see RFF's **Carbon Pricing 101 explainer**.

RFF has also developed an interactive, exploratory **carbon pricing calculator** based upon output from RFF's economy-wide modeling, that allows users to compare the environmental and economic impacts of both current legislative proposals that place a price on carbon and a custom user-specified carbon tax path. Users can see the impacts of each policy on annual emissions, annual revenues, cumulative emissions, consumer prices, gross domestic product, and the distribution of impacts across income groups. The tool includes the projected impacts of the following policies:

- The American Opportunity Carbon Fee Act (Whitehouse-Schatz, 2019 version)
- The Climate Action Rebate Act (Coons-Feinstein)
- The Energy Innovation and Carbon Dividend Act (Deutch et al.)
- The Healthy Climate and Family Security Act (Van Hollen-Beyer)
- The MARKET CHOICE Act (Curbelo)
- The Stemming Warming and Augmenting Pay Act (Rooney)
- The Raise Wages, Cut Carbon Act (Lipinski).

Carbon taxes and cap-and-trade programs primarily differ by the type of certainty they provide. Carbon taxes provide price certainty, as entities subject to the tax know how much they'll have to pay per ton emitted—but simply setting a tax rate doesn't guarantee any particular level of emissions reductions. Cap-and-trade programs, on the other hand, set a cap on emissions and therefore provide quantity certainty—but price fluctuations under the trading market structure can provide a less solid basis for business planning decisions. Hybrid systems, however, can be used to reduce price or emissions uncertainty. Under cap-and-trade programs, price floors, ceilings, and steps have been **proposed** and **utilized** to prevent prices from being "too low" or "too high." Carbon taxes can also be **designed** to automatically adjust if actual emissions miss some predetermined emissions path.

Carbon Taxes

A carbon tax is perhaps the most straightforward way to introduce a price on carbon, and setting the price path is an important component of carbon tax policy design. There is significant economic evidence that a carbon price will affect short-run behavior and long-run investments, and will reduce emissions.

RFF has developed extensive modeling and other analytic tools for evaluating the effects of a carbon tax. These tools allow for the assessment of the effects of carbon tax policies across a number of key metrics, including annual emissions, annual revenues, cumulative emissions, consumer prices, economic growth, and the distribution of economic impacts. RFF researchers have used these tools directly to inform policymakers in carbon tax policy design and provide publicly accessible research that:

- Analyzes a number of policy proposals including the **2015**, **2017**, and **2019** versions of the American Opportunity Carbon Fee Act (Whitehouse-Schatz); the **MARKET CHOICE Act** (Curbelo); and the Climate Leadership Council **Carbon Dividends Plan**.
- Assesses the level of tax required to meet the **US obligation under the Paris Agreement**.
- Evaluates the **distributional effects** of various approaches to carbon taxes and recycling the generated revenues.
- Assesses the **effects of a carbon tax on employment**.

An additional consideration in the implementation of a carbon tax is the level of uncertainty in emissions reductions resulting from a given price path of a carbon tax. RFF researchers have recently described in detail how a **carbon tax might adjust automatically** to achieve an emissions target.

Cap and Trade

An alternate way to introduce a carbon price is through cap and trade, such as was implemented in the successful acid rain sulfur dioxide program. A carbon price is embodied in a trading program as the price of a tradable emissions allowance. Under cap and trade, the emissions goal is identified by the cap, but, in the absence of other policy constraints, the carbon price is set by the market as it adjusts to meet the annual limit on emissions.

To date, cap and trade has been the dominant approach to putting a price on carbon in the United States and abroad. For example, in the United States, eleven states have enacted a carbon cap for all or some portion of their economies. This has allowed for considerable experience and evolution of the policy mechanism. Lessons learned from these experiences as well as further considerations for policy design are highlighted in the following resources:

- This ***Resources* magazine article** and **this article** from the *Review of Environmental Economics and Policy* provide historical context for cap-and-trade programs, including specific policy design and implementation lessons and some political considerations that affect cap-and-trade policy design. It also provides guidance to assist with implementation of future policies and notes on the implications for climate change policy.
- One of the longest running carbon cap-and-trade programs in the United States is the Regional Greenhouse Gas Initiative (RGGI). This ***Resources* article**, written on the occasion of RGGI's 10th anniversary, describes some of the more innovative features, including auctioning of allowances and the use of cost containment mechanisms.
- Cap and trade programs have moved away from free allocation of emissions allowances because of concern that windfall profits could result when firms receive allowances for free that have substantial economic value in the market. However, in some cases the introduction of an auction for allowances is politically or economically difficult to achieve. RFF's work described a consignment auction approach that was used in the sulfur dioxide trading program and elsewhere, in which allowances are conditionally allocated, but they must be sold in auction with revenue coming back to the original recipients. This design adds considerable transparency and stronger incentives for efficient outcomes. The approach suggested was adopted by Virginia, and an **RFF article** described how this could work.
- Recently, in response to cost considerations, cap and trade programs have begun to adjust the size of their emissions caps. For example, RFF researchers worked with RGGI states to develop an **"emissions containment reserve"** (ECR) that would provide several important

benefits to help improve the functioning of the market for emissions allowances. The ECR has **now been adopted**.

- Markets are increasingly watching government policy to inform their investment plans. This fact alters the relative strengths of alternative policy approaches, like cap and trade versus carbon taxes. Cap and trade policies have a feature that carbon taxes don't, which under certain conditions can encourage more cost-effective emissions reductions. Under a cap, the market price of permits reflects traders' expectations about future policy changes, such as tightening the cap as was done recently in Europe. Market participants then closely watch for potential changes in the cap when determining their emission reductions, whereas under a carbon tax, this determination is simply driven by the statutory tax rate. Current and former RFF researchers have explored these concepts in this **article**.

Use of revenues generated under carbon pricing proposals

Carbon pricing proposals are also often touted for the revenue they generate that can be used for other purposes. Though they impose their price on carbon in distinct ways, a carbon tax and cap and trade both convey a value on emissions that is evident in tax revenue or cap and trade allowance value. Past modeling along with analysis of recent US federal proposals has shown that such value can total more than **$1 trillion over a decade**. How such value is allocated provides a substantial opportunity in policy design and largely determines distributional outcomes.

At a high level, there are three main types of proposals:

- Imposing a tax swap (for example, using carbon revenue to reduce other corporate or payroll taxes)
- Rebating dividends back to households
- Spending on programs to accelerate emissions reductions or adapt to a changing climate ("green investment" strategies)

RFF and other organizations have conducted **research** on the trade-offs related to various tax swaps, as well as with lump-sum rebates back to households across various income quintiles. In comparison, at the current time there is not the same depth of research on the efficiency and effectiveness of proposed green investment strategies. Given that, in a number of policy proposals, such investment strategies are put forward as critical elements for achieving target emissions reductions, understanding more about their utility moving forward will be vital for informing the design of such policies.

Question 4b) How could sector-specific policies, outlined in questions 1-3, complement a carbon pricing program?

In practice, carbon pricing policies such as cap and trade, domestically and abroad, almost always coexist with other policies to encourage clean energy investment. RFF research has explored policy interactions between such policy tools.

- Allowing for emissions caps to **adjust automatically** in response to changes in market prices can preserve the integrity of other policies that lead to emissions reductions.
- This **analysis of the NY carbon pricing policy** illustrates how one jurisdiction's decision to impose a higher price on carbon emissions within the electricity sector interacts with price responsive emissions supply, in the form of the RGGI Emissions containment reserve, to yield CO2 emissions reductions within NY State and beyond.
- Results from **this article** as well as **this one** suggest that the optimal set of policies for reducing emissions is a combination of policies that includes emission pricing and funding of research and development.
- Tax incentives have commonly been used alongside other policies to reduce emissions to promote particular technology solutions. Care must be taken in the design of such incentives to ensure that they are delivering the intended or expected level of reductions. **This study** provides a case study of the "refined coal" tax credit, now being claimed at $1B annually, which was intended to reduce conventional air pollutants, but instead is failing to achieve its goals and actually hindering reductions in carbon emissions by increasing coal use by power plants.

Question 5b) How can Congress incentivize more public-private partnerships and encourage more private investment in clean energy innovation?

Tax incentives can be an effective tool for stimulating innovation in the low-carbon space as well as for increasing market penetration of innovative technologies. The investment tax credit (ITC) and production tax credit (PTC) programs for renewable electricity provide good examples of the effect such incentives can have to increase deployment of solar, wind, and other eligible technologies and in turn to bring down costs through expanding markets. It is worth specifically highlighting the use of tax credit incentives in stimulating carbon capture, utilization, and storage (CCUS) and the use of hydrogen, the former through the 45Q program and the latter though the proposed ITC for hydrogen (and other approaches) for energy storage.

In the former case, the original **45Q legislation** was not successful in incentivizing significant deployment of non-enhanced oil recovery CCUS projects. This lack of success can be attributed to a relatively low value for the tax credit as well as other limitations on qualifying for the credit. To address these issues, the recent revisions to 45Q offer a higher tax credit and fewer restrictions on qualifying for the credit. IRS guidance for implementing the new version of the program are being drafted, however, and depending on its ultimate content, this guidance could either negate the rule or alternately could make it even more effective. Several RFF researchers submitted **comments** to the IRS in response to their request for information, and, given the importance of such guidance, the Select Committee should be reviewing these rules carefully to ensure that they will allow 45Q to have the stimulative effect on CCUS that Congress intended.

In the latter case, Senator Martin Heinrich and Representative Mike Doyle have introduced bills that would expand the 30% ITC to include energy storage technologies, with hydrogen among the eligible "technologies." The level of subsidy is likely to be effective at driving deployment of hydrogen and other storage technologies, although RFF researchers have noted one significant shortcoming: the bills do not target decarbonized hydrogen for the subsidy. Even hydrogen sourced by electrolysis can produce significant carbon emissions if the electricity used in the process is not generated with low-carbon sources; therefore, it may be more effective to include only low-carbon hydrogen in the subsidy. Further, "blue" carbon hydrogen (produced using the standard steam reforming process, but with CCUS) appears to be ineligible for the tax credit (although it may be eligible under 45Q). Attachment A details the issues. Ongoing research at RFF is examining the design and benefits of a 45Q-type law providing subsidies for decarbonized hydrogen, irrespective of how the hydrogen is used.

Two major criticisms of the tax credits are that they are often short-term in nature and periodically expire, and that they provide uneven incentives that are targeted at specific technologies. Both of these attributes hamper long-term investments in renewables as well as investments in new technologies for which the existing tax credits may not apply.

There are opportunities to improve upon the existing ad-hoc nature of the credits by rationalizing such tax incentives to become technology-neutral and long-lasting, providing greater certainty for investment in current and developing technologies. One potential approach would be to provide production and/or investment tax credits that are based upon the emissions-intensity of the energy delivered to the market. Such incentives would allow technologies to compete on the basis of emissions, could be set for a relatively long time-horizon to allow for stability in the investment climate for existing technologies, and would also provide clear rules for the road for incorporating new technologies. One proposal to implement this type of approach has been put forward by Senator Wyden and cosponsors in the Clean Energy for America Act.

Attachment A: Investment Tax Credits for Hydrogen Storage

Jay Bartlett and Alan Krupnick, Resources for the Future

Hydrogen in the Energy Storage Tax Incentive and Deployment Act of 2019

The Energy Storage Tax Incentive and Deployment Act of 2019, introduced by Representative Mike Doyle as H.R. 2096 and by Senator Martin Heinrich as S. 1142, would expand the 30% investment tax credit to include energy storage technologies—"equipment which receives, stores, and delivers energy." With hydrogen among the technologies specified, the Act has the potential to: (i) motivate the utilization of hydrogen to store and deliver power and (ii) reduce CO_2 emissions from hydrogen production. To inform discussion of the legislation, we have prepared this explainer on hydrogen's role in energy storage, production methods and costs, and infrastructure.

Hydrogen Overview

Hydrogen (H_2) is of interest both due to its wide range of applications and the fact that it generates no CO_2 upon combustion (although depending on how it is produced, large quantities of CO_2 can be emitted at that stage). Currently, hydrogen is produced on a massive scale for the industrial sector, with global use of approximately 70 million metric tons per year (equivalent to the energy content of 50% of annual US gasoline consumption). The primary uses of hydrogen are in the production of ammonia and in the processing of petroleum fuels. While this tax credit is limited to energy storage, hydrogen has the potential for extensive use as a decarbonized fuel—in transportation, industrial heating, commercial and residential space heating, and combined heat and power. Industrial heat is a particularly attractive end use; hydrogen is one of the few options that provides the necessary temperatures and has the possibility of low emissions.

Benefits of Hydrogen for Energy Storage

With a growing amount of wind and solar power (from almost nothing in 2000 to 8% today and up to 31% by 2030 if the tax credits are extended[1]), energy storage becomes increasingly important to limit the costs of managing intermittent generation and to avoid wasting energy that cannot be used at a particular time (known as curtailment).

A challenge with wind and solar is that their output varies—not only throughout the day—but also over weeks and months. While lithium-ion batteries are well-matched to frequently storing and discharging energy for several hours, their value decreases with longer durations that occur less regularly. Storing energy in a battery requires expensive capacity; utilizing that capacity less frequently makes it harder to cover the fixed costs. In contrast, hydrogen—once produced—can be stored relatively cheaply and then used over any time scale. To generate electricity, hydrogen can be utilized in either a combustion turbine or fuel cell. Compared with the other options for long-term energy storage, such as pumped hydropower and compressed air, hydrogen has the advantages of fewer locational constraints and some ability to use existing natural gas infrastructure (explained below).

Potential to Decarbonize H_2 Production

While the combustion of hydrogen does not generate CO_2, the current production processes are very CO_2-intensive. Global hydrogen production accounted for 830 Mt CO_2 in 2017, an amount equal to 2.2% of global fossil CO_2 emissions and more than the emissions from Germany.[2] Over 95% of present hydrogen generation is from steam reforming of methane (SMR, known as “grey hydrogen”) or gasification of coal (known as “brown hydrogen”). A promising pathway to decarbonized hydrogen is SMR combined with carbon capture and sequestration (CCS), termed “blue hydrogen.”

Less than 5% of hydrogen is generated from the electrolysis of water, and the current production costs are 3 to 6 times higher than those for SMR.[3] By providing an investment tax credit for hydrogen produced using electricity, the Act would promote a method with greatly reduced CO_2 emissions. The amount of CO_2 emissions depends on its source of power. If the electricity to power this process comes from renewables or nuclear power, the hydrogen would be decarbonized—"green hydrogen.” Only a tiny percentage of electrolyzed hydrogen is produced this way, but there is rising interest in green hydrogen production. The project pipeline for the next five years is 12 times larger than all of the green hydrogen capacity installed since 2000.[2]

With increasing wind and solar on the grid, there will be hours when electricity has a price of zero. This has led to the false hope that electrolysis could be powered by free (and green) electricity. Although early electrolysis capacity could receive some hours of zero-priced power, as more electrolysis capacity (and other demand) is added, the amount of “free” electricity would diminish. Furthermore, if electrolysis only operates during certain hours, production costs will increase due to low utilization.

With respect to decarbonized hydrogen, the tax credit plan being considered has two deficiencies. First, the tax credit would be available to electrolysis projects regardless of the source of power to be used. As such, the hydrogen produced would not necessarily be green. Second, the tax credit, as written, could potentially be used by SMR projects with reactors using electric, rather than gas-fired, heating (SMR requires steam at around 900 °C). Although electrified SMR would have lower emissions than combustion-based SMR, without CCS the hydrogen produced would have higher emissions than its alternative—directly using natural gas for power generation.

Blue hydrogen appears not to be eligible for these credits, but such projects would be eligible for the tax credits for CCS under section 45Q. We note that 45Q has a deadline for starting construction by the end of 2023, and policy should support decarbonized hydrogen irrespective of the production method.

Hydrogen Infrastructure

While safety is a common concern with hydrogen, in some respects, it is safer than natural gas. Hydrogen disperses more quickly and is non-toxic. On the other hand, hydrogen ignites more easily than natural gas and requires leak and flame detection.

Hydrogen can make use of existing natural gas infrastructure, such as pipelines and combustion turbines, if it is blended with natural gas. However, hydrogen is less dense than natural gas, requiring greater volume and/or compression, and it can make steel brittle. Therefore, as the percentage of hydrogen in the blend increases, equipment modifications and then specialized infrastructure become necessary. For storage, hydrogen can be held under pressure in salt caverns and depleted oil and gas fields. Storage does impose costs and has some geographical constraints, but there are a large number of suitable geological features in various parts of the United States.

Finally, we note that the water usage for electrolysis—even on the scale of natural gas consumption—would be minimal relative to the amount of water currently used to cool US thermal power plants.

Hydrogen for Industrial Use

We will publish later a more detailed report on how a broader tax credit for decarbonized hydrogen could be efficiently designed to reduce heating and feedstock emissions in the industrial sector.

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[1] Larson, J., et al. (2019). "Can Tax Credits Tackle Climate?" Rhodium Group, Energy & Climate Research.

[2] Wood Mackenzie Power & Renewables. (2019). "Green Hydrogen Production: Landscape, Projects and Costs."

[3] Friedman, S. J., Fan, Z., and Tang, K. (2019) "Low-Carbon Heat Solutions for Heavy Industry: Sources, Options, and Costs Today." Columbia University, Center on Global Energy Policy.