Low-Carbon Renewable Thermal Technology Solutions:

Policies to Support Development and Deployment

Prepared by the Renewable Thermal Collaborative

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RENEWABLE THERMAL COLLABORATIVE

Thank You.

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Executive Summary

Thermal energy, energy used for industrial processes and to heat and cool buildings, is a significant contributor to global energy demand and to greenhouse gas (GHG) emissions. While policy solutions have been implemented for decades to expand the development of and access to renewable electricity, **low-carbon renewable thermal technologies in particular, and low-carbon technologies for industry in general, have not benefitted from such widespread policy support.**

In order to be effective, **any framework to reduce GHG emissions must address thermal energy.** Thermal energy is a key component of energy use in the United States and around the world, particularly in the industrial sector. Worldwide, industrial heat makes up two-thirds of industrial energy demand and almost one-fifth of total energy consumption.[1] However, renewable energy meets only ten percent of this demand.[2]

Thus far, **policy has been an underutilized tool to advance low-carbon renewable thermal technology solutions,** especially when compared to the robust use of policy to expand the development and deployment of renewable electricity. Barriers to low-carbon renewable thermal development and implementation include disaggregated supply, distributed demand, a wide range of specific temperature needs for industrial users, and market barriers. Policy can help to lower these barriers.

This report reviews the leading policies that support the deployment of low-carbon renewable thermal technologies in Europe and at the state and federal levels in the U.S. as well as U.S. federal policies that are proposed, but have not yet been adopted.

See pages 5 and 6 for key insights and recommendations from this report.

Key Insights and Recommendations

Key insights from low-carbon renewable thermal energy policy development thus far include:

- Fragmented policies that only apply in certain locations, to certain technologies, or to certain customer classes can lead to uneven support for the deployment of renewable thermal technologies.
- Performance targets, benchmarks, and standards can increase low-carbon renewable thermal energy use in a range of industrial sectors.
- An economy-wide carbon price could incentivize more low-carbon renewable thermal solutions.
- Financial incentives can play a significant role in scaling low-carbon renewable thermal technology deployment.
- Research, development, demonstration, and deployment (RDD&D) and partnerships with the private sector are pivotal to accelerating low-carbon renewable thermal technology development.
- Additional data about low-carbon renewable thermal applications and the effectiveness of low-carbon renewable thermal policies is needed.
- Increased deployment of renewable thermal technologies and the resulting decarbonization of industry can contribute to an equitable and just energy transition.

Key recommendations for actions that policymakers could take to accelerate the development and deployment of low-carbon renewable thermal technologies include:

- RDD&D
  - Federal RDD&D could **support a wide range of low-carbon renewable thermal technologies,** including those that can provide thermal energy at a variety of temperatures. Expanded RDD&D can support solutions that could be implemented both in the near-term and long-term.
  - The federal government could more fully explore **public-private partnerships** that can enhance technology transfer and leverage private capital to accelerate commercially available low-carbon renewable thermal technologies.
- Technical Assistance
  - The federal government could give the industrial sector improved **access to federal laboratories** to better collaborate on demonstration and pilot projects that are critical to deploying low-carbon renewable thermal solutions at scale.
  - Policymakers could establish **clear sustainability criteria** for bioenergy that ensure that it delivers genuine climate benefits.

- Financial Incentives
    - Policymakers could offer financial incentives to a **diverse and balanced portfolio** of low-carbon renewable thermal technologies. Financial incentives could include tax incentives, grants, low-cost loans, and loan guarantees.
- Market-based Mechanisms
    - Policymakers could adopt market-based mechanisms such as a **thermal renewable portfolio standard** (thermal RPS) and a **thermal renewable energy credit** (thermal REC) market; an escalating, economy-wide **price on carbon emissions**; or a **tradeable industrial performance standard.**
- Federal Procurement
    - **Emissions reduction objectives for relevant procurement processes** could be incorporated at federal agencies.
    - Policymakers could set **clean performance targets for materials** in construction and manufacturing and support verification programs.
- Supporting Impacted Communities
    - Policies for decarbonization could be designed to **take into account the most affected people and communities.**

01

Introduction

Energy used for heating and cooling is a significant contributor to global energy demand and to greenhouse gas (GHG) emissions. While policy solutions have been implemented for decades to expand the development of and access to renewable electricity, low-carbon renewable thermal technologies have not benefitted from such widespread policy support. This chapter provides a brief introduction to the importance of reducing emissions from thermal energy use, the challenges facing increased development and deployment of low-carbon renewable thermal technologies, and how policy can help to ameliorate some of these challenges.

Chapter 2 of this report describes leading policies that support the deployment of low-carbon renewable thermal technologies in Europe and in the United States, while Chapter 3 covers U.S. federal policies that are proposed, but have not yet been adopted. Finally, Chapter 4 concludes with insights from lessons learned from the European and U.S. state and federal experiences thus far, and recommendations that could support low-carbon renewable technology solutions through policy development.

What is low-carbon renewable thermal?

This report considers policies that impact low-carbon renewable thermal technologies. Low-carbon renewable thermal technologies use sustainable renewable or waste-derived sources to provide energy.

Low-carbon renewable thermal technologies include biomass, biogas (including landfill gas), renewable natural gas (or biomethane), geothermal, beneficial electrification, green hydrogen, and solar thermal.

For more information about these technologies, see:

Biomass, geothermal, biogas, renewable natural gas, beneficial electrification, and solar thermal: https://www.renewablethermal.org/a-landscape-review-of-the-global-renewable-heating-and-cooling-market/

Hydrogen: https://www.renewablethermal.org/hydrogen-an-introduction-for-commercial-and-industrial-end-users/

a. The Importance of Reducing Thermal Energy Emissions

In order to be effective, any policy to reduce GHG emissions must address thermal energy. Thermal energy is a key component of energy use in the U.S. and around the world, particularly in the industrial sector. Worldwide, industrial heat makes up two-thirds of industrial energy demand and almost one-fifth of total energy consumption.[3] However, only ten percent of this demand is met using renewable energy.[4]

What is thermal energy?

Thermal energy is the result of converting a primary energy source into kinetic energy, or heat. Unlike electricity, where mechanical energy is transformed into an electric current that is distributed to end users through a transmission system, thermal energy cannot travel over long distances, so it is produced on-site or near its use and distributed locally. Primary energy sources include traditional fossil fuels such as natural gas, oil, and coal as well as low-carbon renewable thermal sources.

Thermal energy delivers industrial process and non-process heating and cooling, in addition to building space heating and cooling. Once produced, thermal energy is disbursed through conduction, convection, radiation, or a combination of these applications to generate material changes in the production of basic materials (such as steel, chemicals, aluminum, and cement) and consumer goods.

"Low-carbon renewable thermal energy" describes energy used for process, water, and space heating and cooling applications and that is derived from a sustainable renewable or waste-derived source, as described in the box on page 7.

Globally, more than 50 percent of final energy demand is for heating, and about half of this is industrial heating demand.[5] In the U.S., fossil fuel combustion to produce hot gases and steam used for process heating, process reactions, and process evaporation, concentration, and drying creates about 52 percent of the country's industrial direct GHG emissions.[6] The predominance of fossil fuels in the production of thermal energy presents a significant opportunity for the industrial sector to reduce carbon and other GHG emissions.

Because of its use in industrial processes, thermal energy is especially important to the manufacturing sector. In 2018, direct industrial GHG emissions accounted for 22 percent of total U.S. GHG emissions, making it the third largest contributor to U.S. GHG emissions, after the transportation (28 percent) and electricity (27 percent) sectors.[7]

The decarbonization of thermal energy across sectors is essential in order for businesses, governments, and institutions to meet their long-term carbon reduction goals. Numerous companies have set ambitious public climate goals for themselves, and need support to access technologies that will help them to achieve those goals.

b. The Challenges of Reducing Thermal Energy Emissions

Thus far, policy has been an underutilized tool to advance low-carbon renewable thermal technology solutions, especially when compared to the robust use of policy to expand the development and deployment of renewable electricity. Additional barriers to reducing emissions from thermal energy use include challenges with supply of low-carbon renewable thermal energy and market structures.

As noted in the box on page 8, a significant difference between electricity and thermal energy is that while primary energy sources that are used to produce thermal energy may be easily transportable, thermal energy itself cannot travel over long distances, so it is produced on-site or near where it will be used and distributed locally. This presents a challenge to utilizing low-carbon renewable thermal energy, as the supply of low-carbon renewable thermal energy sources and technologies is often limited by geography, especially for biomass, solar, or geothermal resources. The disaggregated supply of low-carbon renewable thermal resources makes it more difficult for those interested in utilizing these resources to develop a systematic and comprehensive strategy to evaluate low-carbon renewable thermal opportunities.

> Disaggregated supply and distributed demand adds complexity to decision making and makes it difficult to match available low-carbon renewable thermal resources with the appropriate industrial facility.

Layered on top of this is the wide range of specific temperature needs in industrial processes. Different technology types are able to deliver different heating needs. Figure 1, below, summarizes several low-carbon renewable industrial process heat technologies and their applications. Matching the available supply of low-carbon renewable thermal resources with a particular industrial process's requriments adds complexity to decision making, and this distributed demand makes it more difficult for low-carbon renewable thermal suppliers to match their resources with the appropriate end user.

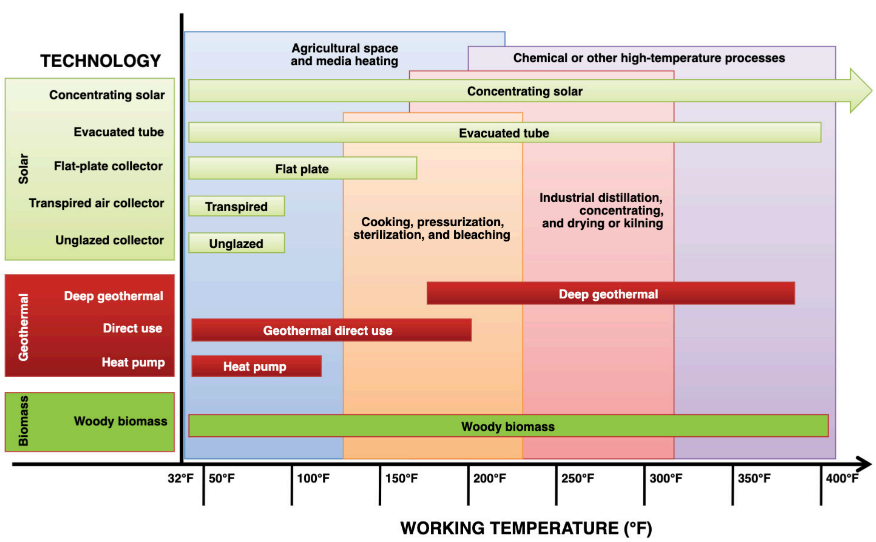


Figure 1: Renewable Industrial Process Heat Technologies and Applications (United States Environmental Protection Agency, 2021)

Market barriers also pose a challenge to increasing low-carbon renewable thermal energy use. Low natural gas prices and difficulty tracking or gaining ownership of environmental attributes from low-carbon renewable thermal projects dampen market signals that may otherwise show the increasing demand for low-carbon renewable thermal energy.

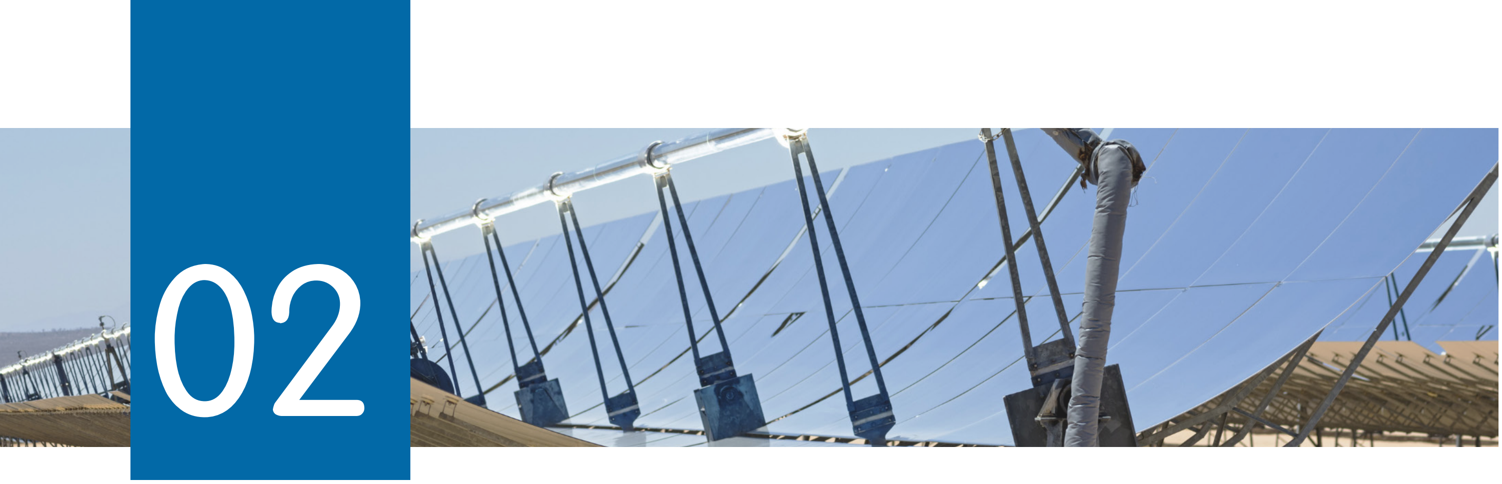
c. The Importance of Policy

Though a range of low-carbon renewable thermal technologies exists, low-carbon renewable thermal energy use is growing at a much slower pace than renewable electricity and has received much less attention from policymakers than the renewable electricity sector. In 2007, global direct renewable heat consumption was higher than renewable electricity consumption, but by 2015, renewable electricity had overtaken renewable heat, and is expected to continue deployment at a more rapid rate.[8]

Low-carbon renewable thermal technologies could benefit from a suite of policies similar to those that led to renewable electricity technology innovation and improvement in renewable electricity markets.

Renewable electricity has been a major focus of energy policy in many countries and has benefitted from extensive financial and other policy support programs.[9] While more than 120 countries have introduced policies designed to promote renewable electricity, only about 40 have specific policies for renewable heat, mostly within the European Union.[10]

Steady technology innovation and improvement in renewable electricity markets have made wind and solar cost-effective and the preferred choice in many markets. This innovation and improvement was made possible by a range of policies including research and development, financial incentives, portfolio standards, and other deployment policies. Low-carbon renewable thermal technologies can benefit from a similar suite of policies to drive the development of innovative new technologies and ensure deployment of market-ready technologies.



The Current Policy Landscape

a. Introduction to the Current Policy Landscape

While policy has been underutilized to support the decarbonization of thermal energy use, there are policies in some locations that are designed to support the deployment of low-carbon renewable thermal technologies. This chapter identifies the leading policies already enacted that support the deployment of low-carbon renewable thermal technologies in Europe, in U.S. states, and at the U.S. federal level. These policies fall into seven main categories: research, development, demonstration, and deployment, (RDD&D); financial incentives; performance standards or targets; rewarding environmental benefits; technical assistance; procurement; and multifaceted policy frameworks. It should be noted that not all policies are included here, and our understanding of policy development would continue to benefit from additional research and analysis. The sections in this chapter include lessons learned from policy development and implementation in each of the geographic areas covered. Chapter 3 examines proposed U.S. federal policies that could support the deployment of low-carbon renewable thermal technologies.

b. Europe

i. Introduction to Low-carbon Renewable Thermal in Europe

According to the European Commission, heating and cooling in industry and for buildings account for half of the EU's energy consumption.[11]

In industry, 70.6 percent of energy consumption (193.6 Mtoe) is for industrial process and space heating, 26.7 percent (73.3 Mtoe) for lighting and electrical processes such as machine motors, and 2.7 percent (7.2 Mtoe) for cooling.

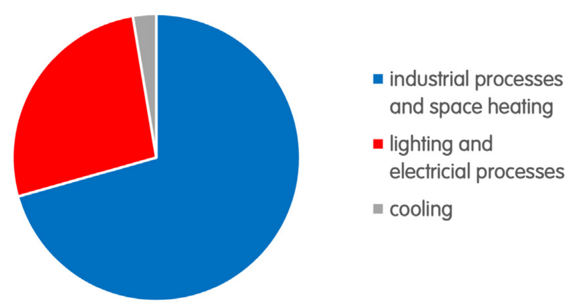


Figure 2: Industrial Energy Consumption in Europe

2019 data from Eurostat shows that heating and cooling for both households and the industrial sector are still dominated by fossil fuels (75 percent), while renewable energy generates only 22 percent. For example, according to a mapping analysis contracted by the European Commission, coal is still the dominant energy carrier for the steel industry in the EU. In glass melting furnaces, natural gas is the dominant fuel due to process control and purity. Other industries are able to use some renewable energy for heating. In the cement industry, co-firing of waste (renewable and fossil) as well as biomass in the clinker kilns is common practice and the fuel selection depends on energy prices. In combined heat and power (CHP) systems as well as steam boilers, biomass is used in Sweden and Finland, but to a relatively low extent compared to fossil fuels.[12]

While electricity is readily interchangeable regardless of how it is generated, allowing renewable sources to be substituted for traditional fossil fuel sources, the type of fuel used in industrial processes is highly dependent on the industrial application and facility location, adding complexity to adoption of low-carbon renewable thermal solutions. Low-carbon renewable thermal solutions are crucial if the EU is to accelerate the energy transition and meet its carbon neutrality commitment by 2050.

In February 2016, the European Commission proposed an EU Heating and Cooling Strategy focusing on exploring the issues and challenges in this sector and potential policy solutions. In line with the Strategy's proposed solutions, the European Commission initiated a series of roundtables from 2018 to 2019 for industry representatives to discuss barriers to increased adoption of energy efficiency and renewable energy. Based on the input from these roundtables and the analysis of barriers, drivers, and best practice policies, the European Commission proposed and published recommendations for EU-level policy interventions in the study *Shaping a sustainable industry: Guidance for best practices and policy recommendations*.[13] The study concludes that policymakers need to consider "a holistic approach, integrating all pillars of the decarbonization strategies of companies, when designing policies and that there is a need for a nuanced set of policy instruments to address various barriers."[14] The EU has been successful with this approach in some cases, but faces challenges in others.

The following subsection takes a closer look at the leading policies in the EU that incentivize the development of low-carbon renewable thermal solutions and the successes and lessons learned from the development and implementation of these policies.

ii. Current Policies

1. A Comprehensive EU-level Renewable Energy Target. The EU Renewable Energy Directive (RED) takes a comprehensive approach to renewable energy utilization by requiring 32 percent of the European Union's final energy consumption to be met by renewable energy by 2030, with requirements for electricity, transport, and heating and cooling.[15]

In 2009, the EU RED established a high-level policy framework for scaling renewable energy, with an EU-wide target of at least 20 percent of total energy needs in electricity, transport, and heating and cooling to be met by renewable energy by 2020. The Renewable Energy Directive 2018 (RED II) updated the overall renewable energy targets to at least 32 percent by 2030, with specific targets for Member States to increase renewable heating and cooling by 1.3 percent each year up to 2030.[16] RED II also increased the target for the share of renewable fuels in transport from 10 percent in 2020 to 14 percent by 2030 and strengthened criteria for ensuring bioenergy sustainability.

RED II also laid out the new policy framework that: 1) provides long-term certainty for investors and speeds up procedures to receive permits for projects; 2) puts the consumer at the center of the energy transition with a clear right to produce their own renewable energy; 3) increases competition and market integration of renewable electricity; 4) accelerates the uptake of renewables in the heating and cooling and transport sectors; and 5) strengthens the sustainability of bioenergy and promotes innovative technologies.[17]

RED II is the first EU-wide renewable energy target for heating and cooling. Setting a long-term renewable target for the heating and cooling application allows Member States to develop long-term sectoral strategies and increases investor and market confidence in low-carbon renewable thermal solutions.

In 2018, the share of renewable energy in the EU reached 18 percent. Among the 28 EU Member States, 12 Member States have already reached a share equal to or above their national 2020 binding targets. The RED progress report in 2017 also revealed additional benefits, including:[18]

- Energy security: using more renewables resulted in a €16 billion saving in fossil fuel imports in 2015, and this is projected to rise to €58 billion in 2030.
- Market integration: cheaper technologies and new proposals under the Commission's "Clean energy for all Europeans" package will further enable renewables to participate in markets on an equal footing with other energy sources.[19]
- Energy efficiency: renewable power could help reduce primary energy consumption and improve buildings' energy performance.
- Decarbonization: in 2015, renewables contributed to reducing GHG emissions by the equivalent of Italy's total emissions.
- Innovation: the EU has 30 percent of global patents in renewable energy and is committed to prioritizing research and innovation to further drive the energy transition.[20]

However, according to IEA, results in heating and cooling are below expectations.[21] While setting a long-term renewable target for heating and cooling is a meaningful first step towards a holistic incentive framework, the policy design and implementation on the Member State level is crucial to accelerate renewable energy consumption in heating and cooling.

> While setting long-term targets is a meaningful first step, policy design and implementation is crucial to accelerate renewable energy consumption in heating and cooling.

2. Carbon Pricing - The EU ETS. Set up in 2005, the EU emissions trading system (EU ETS) is a cornerstone of the EU's policy to combat climate change and is the EU's key tool for cost-effectively reducing GHG emissions. It covers around 40 percent of the EU's GHG emissions, and limits emissions from more than 11,000 heavy energy-using installations (power stations and industrial plants) and airlines operating among these countries.

The EU ETS has proved to be an effective tool in cost-effectively driving emissions reductions. Emissions from installations covered by the ETS declined by about 35 percent between 2005 and 2019.[22]

Since 2000, European industry cut its energy intensity twice as fast as the U.S. The improvement rate is steeper in energy-intensive sectors. For example, the chemical sector in the EU halved its energy intensity over the last 20 years. By putting a price on carbon dioxide emissions, the EU ETS provides an incentive to use low-carbon fuels and to invest in energy efficiency.[23]

The introduction of the Market Stability Reserve in 2019 led to a higher and more robust carbon price, which helped to ensure a year on year total emissions reduction of 9 percent in 2019, with a reduction of 14.9 percent in electricity and heat production and a 1.9 percent reduction in industry.[24]

Additionally, EU ETS will generate revenues for an Innovation Fund from the auctioning of 450 million allowances from 2020 to 2030. The Innovation Fund will support large- and small-scale projects focusing on innovative low-carbon technologies and processes in energy-intensive industries, including substitution of carbon-intensive products, innovative renewable energy generation, and energy storage.

3. Finanical Incentives and Sustainability Criteria for Bioenergy. The 2008 RED identified bioenergy as a renewable source. The competitive cost of bioenergy compared to other renewable energy sources in heating applications and the development of biomass furnace technology in the EU have made bioenergy an attractive alternative to fossil fuels. Due in part to the aforementioned factors, financial incentives for low-carbon renewable thermal solutions in the EU have been disproportionately focused on biomass and other bioenergy.

Subsidies are the main support for bioheat, whereas feed-in-tariffs and feed-in-premiums support bioelectricity. Sixty percent of EU Member States provided financial subsidies for biomass from 2005 to 2015; 36 percent of those were related to biomass for heating and cooling.[25] Please refer to Appendix I for a summary of financial incentives for bioenergy in EU Member States.

Financial incentives for low-carbon renewable thermal solutions in the EU have been disproportionately focused on biomass and other bioenergy.

Additionally, nine EU countries (Czech Republic, Denmark, Ireland, Greece, France, Latvia, Lithuania, Netherlands, and Sweden) apply tax mechanisms (such as tax relief or tax reduction) to support the use of biomass for heating purposes.[26] Sweden also provides tax reductions for biomethane as a fuel, investment programs, specific aid for farm-based biogas from manure, tax exemptions from vehicle taxes, and carbon and energy tax exemptions for biomethane application.[27]

Bulgaria applies a loan scheme to support small cogeneration plants. At least 50 percent of a project's benefits must come from energy savings. The investment payback period is up to seven years and ranges between €15,000 and €1,500,000. Germany applies loans to support solid biomass installation exclusively for thermal usage. France also applies loans to support wood-fueled heating plants and subsidies for the biomass plants with a heat production of over 1 kilotonne of oil equivalent (ktoe) per year.[28]

According to Natural Resource Defense Council, in 2017, 15 EU Member States spent more than €6.5 billion to directly subsidize bioenergy.[29] More than half of these subsidies were paid out in just two countries: Germany and the United Kingdom.[30] The substantial financial support for bioenergy rapidly accelerated the growth of bioenergy use in EU Member States. As of 2016, bioenergy contributed 116 million tonnes of oil equivalent (59 percent of all renewables and 10 percent of all energy sources) to the gross final energy consumption in the EU, 75 percent of which were used for heating purposes.[31]

However, the rapid growth of bioenergy brought widespread criticism and concern over whether bioenergy is truly "carbon-neutral," as well as broader forest, land use, and biodiversity concerns. Not all bioenergy can deliver climate benefits. For instance, bioenergy from purpose-grown crops, tree trunks, and coarse forest harvest residues such as stumps are unlikely to be "lower carbon" than conventional fossil fuels and in many cases will be counterproductive in climate terms.[32] A new study in 2021 by the Joint Research Centre (JRC) shows that the aforementioned biomass sources and the conversion of natural forests into bioenergy plantations are detrimental to local biodiversity.[33]

To address these concerns over the climate impact of bioenergy consumption, RED II put forward new sustainability criteria for bioenergy that requires certain levels of GHG savings against their fossil fuel comparators.[34] However, these sustainability criteria in RED II may require closer examination and stricter rules may be needed to ensure that bioenergy used in the EU delivers genuine climate benefits over fossil alternatives. The EU should have GHG criteria based on a full lifecycle assessment including all pertinent factors and based on a climate-relevant timeline. Additionally, Forest Stewardship Council (FSC) certification, Roundtable on Sustainable Biomaterials (RSB) certification, or FSC controlled wood standards need to be applied to any biomass sourcing to ensure a win-win forest management pathway for climate and biodiversity.

4. RDD&D. The European Commission established two leading RDD&D programs for low-carbon renewable thermal technologies: Horizon 2020 and the ETS Innovation Fund.

Horizon 2020. Horizon 2020 was the biggest EU Research and Innovation program ever with nearly €80 billion of funding available over 7 years (2014 to 2020). In the last three years of Horizon 2020, €2 billion was earmarked to support decarbonizing Europe's building stock, strengthening the EU's leadership in renewable energy, developing integrated and affordable energy storage solutions, and deploying electric vehicles. Horizon Europe will follow with €100 billion for 2021-2027.[35]

Horizon 2020 supported the development of biomass initiatives such as the Bio-Based Industries Public-Private Partnership, which, with a budget of €3.7 billion, aimed at increasing investment in the development of a sustainable bio-based industry sector in Europe.[36] Furthermore, Technology Platforms supported by Horizon 2020 such as the EU Biofuels Platform or the Renewable Heat and Cooling Platform played an essential role in the definition of the future of the biomass sector and the development of new initiatives.[37]

Additionally, Horizon 2020 funded a series of projects for the industrial application of solar heating, including:

- SOLPART: High-Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates.[38]
- SDHp2m: Advanced policies and market support measures for mobilizing solar district heating investments in European target regions and countries.[39]
- INSHIP: Integrating National Research Agendas on Solar Heat for Industrial Processes.[40]

As of 2017, over 40 percent of Horizon 2020 projects led to a new business model, over 40 percent led to a new service, over 35 percent led to a new process, and over 25 percent led to a new product.

ETS Innovation Fund. The Innovation Fund supported by revenues from EU ETS is one of the world's largest funding programs for the demonstration of innovative low-carbon technologies. It improves the risk-sharing for projects by giving more funding flexibly through a simpler selection process and is also open to projects from energy-intensive industries. For the period 2020 to 2030, revenues from EU ETS earned from the auctioning of 450 million allowances will be sent to the Innovation Fund. This will amount to about €10 billion, depending on the carbon price. In parallel to the Innovation Fund, the EU ETS makes a stronger economic case for these low-carbon technologies to be deployed.

The Innovation Fund focuses on highly innovative technologies and flagship projects within Europe that can result in significant emissions reductions. It aims to finance a varied project pipeline to achieve an optimal balance of a wide range of innovative technologies in all eligible sectors and Member States, Norway, and Iceland. The fund supports cross-cutting projects on innovative low-carbon solutions that lead to emissions reductions in multiple sectors, for example, through circular economy projects.[41]

5. Recognition of Environmental Benefits and Certification. Among low-carbon renewable thermal solutions, the European market currently offers certification for biofuel and renewable natural gas (RNG), with low-carbon and low-carbon renewable hydrogen certification under development.

Biofuel Voluntary Schemes. The biofuel voluntary schemes help to ensure that biofuels are sustainably produced by verifying that they comply with the EU sustainability criteria. As such, the schemes ensure that: 1) production of biofuel feedstock does not take place on land with high biodiversity; 2) land with a high amount of carbon is not converted for biofuel feedstock production; and 3) biofuel production leads to sufficient GHG emissions savings. Several schemes also take into account additional sustainability aspects such as soil, water, and air protection, as well as social criteria. For the certification process, an external auditor verifies the whole production chain from the farmer growing the feedstock to the biofuel producer or trader. While the schemes are run privately, the European Commission can recognize them as valid.[42]

Guarantees of Origin (GOs) for Renewable Natural Gas (RNG). The EU RED required that guarantees of origin (GOs) were issued to provide information on the source of electricity generation to the final electricity customers. The RED II extends the purpose of GOs for consumer disclosure for gas including hydrogen. According to Article 19 of RED II, only certificates issued under the supervision of governments or government-designated bodies can be called GOs. European legislation encourages the Member States to facilitate the Europe-wide cross-border exchange of renewable gas GOs. To track the movement of renewable gases in a secure, trustworthy, and transparent manner, the market requires a European system for cross-border transfer and exchange of renewable gas GOs.

Hydrogen. The Europe Hydrogen Strategy, released in August 2020, proposed to introduce a comprehensive terminology and European-wide criteria for the certification of low-carbon and low-carbon renewable hydrogen (by June 2021).

The RED II contains provisions for the establishment of GO schemes that will include hydrogen. Article 25.2 of this proposal requires that the GHG emissions savings from the use of renewable liquid and gaseous transport fuels of non-biological origin excluding recycled carbon fuels shall be at least 70 percent as of January 1, 2021.

The CertifHy Project is currently developing the first EU-wide tracing and tracking scheme for low-carbon and green hydrogen for a GO scheme envisioned by the RED II as well as Supply Certificates to demonstrate the 14 percent target of renewables in transport.[43]

6. Just Transition Mechanism (Part of the European Green Deal). The Just Transition Mechanism (JTM) is a key tool to ensure that the transition towards a climate-neutral economy happens in a fair way in Europe, leaving no one behind.[44] It provides targeted support to help mobilize at least €150 billion over the period from 2021 to 2027 in the most affected regions, to alleviate the socio-economic impact of the transition.

iii. Lessons Learned

The EU experience shows that long-term federal- and state-level low-carbon renewable thermal targets provide investors, corporate energy buyers, and other market stakeholders with the long-term certainty that is critical for making investment decisions. The progress so far from EU Member States indicates that while high-level, long-term low-carbon renewable thermal targets and strategies create positive policy and market signals, concrete and effectively implemented policy incentives remain crucial to scaling low-carbon renewable thermal solutions.

European industry cut its energy intensity twice as fast as the U.S. since 2000. Putting a price on carbon emissions provided broad-based incentives for the industrial sector to increase energy efficiency and explore options for innovative carbon solutions.

The rapid growth of bioenergy in the EU demonstrates that the suite of substantial financial incentives – including subsidies, tax incentives, and loans – can serve as effective policy tools to scale low-carbon renewable thermal solutions. However, policy design for bioenergy should take into account the climate impact of the entire life cycle of bioenergy consumption to ensure delivery of climate benefits over fossil alternatives.

Country-specific financial incentives are fragmented and usually target specific bioenergy technologies or even specific sectors in a piecemeal manner. To fully unlock the decarbonization potential of the industrial sector, these financial incentives could be carried out in a more systemic and holistic manner aligned with broader EU-level climate and energy strategies.

More importantly, the disproportionate focus on bioenergy created unintended climate impacts. Applying financial incentives to a more diverse and balanced portfolio of low-carbon renewable thermal solutions not only ensures companies and investors can accelerate their actions in the short-term transitional solutions (such as opportunities for bioenergy), but also meaningfully unlocks investment for longer-term transformational low-carbon renewable thermal solutions.

Dedicated RDD&D funding support for renewable energy and innovative decarbonization solutions through Horizon 2020 and the ETS Innovation Fund are proving effective in accelerating the research, development, and commercialization of low-carbon renewable thermal solutions.

The Just Transition Mechanism is a meaningful first step in providing dedicated financial support for policy design for industrial decarbonization that takes into account the most affected people and communities.

Finally, in the process of developing this report, it is apparent that there is limited empirical evidence on the effectiveness of low-carbon renewable thermal policies implemented in the EU. Additional data would support further analysis.

c. U.S. States

i. Introduction to Low-carbon Renewable Thermal in U.S. States

While the U.S. lacks a federal low-carbon renewable thermal policy, some states have taken the lead in increasing low-carbon renewable thermal energy utilization by adopting their own state policies. States that adopt low-carbon renewable thermal policies use numerous policy tools, including RDD&D, financial incentives, performance standards or targets, acknowledging environmental impacts, procurement programs, and comprehensive planning.

> Some U.S. states have taken the lead by adopting policies that support low-carbon renewable thermal energy technologies.

However, not all states have chosen to participate, creating a patchwork of policies despite the interstate nature of both thermal fuel production and distribution, as well as emissions. In addition, many of the existing state programs are only focused on buildings and there is less support for accelerating the use of low-carbon renewable thermal technologies in the manufacturing sector. Moreover, numerous state policies are targeted at specific types of low-carbon renewable thermal resources, which may hinder low-carbon renewable thermal adoption in subsectors whose thermal requirements cannot be met by those specific resources.

ii. Current Policies

This subsection describes a variety of state-level low-carbon renewable thermal policies in states throughout the country. This subsection is not a comprehensive list of all state low-carbon renewable thermal policies, but includes examples of the types of policies that are found at the state level.

1. RDD&D. While much of the RDD&D support that is available for low-carbon renewable thermal technologies is provided at the federal level, states have engaged with other entities in their locales to conduct research that could support the acceleration of low-carbon renewable thermal technology adoption.

In Maine, the Efficiency Maine Trust conducted research about the barriers to beneficial electrification in the transportation and heating sectors in the state.[45] The resulting report was intended to serve as a primer for the state's legislators, and presented a range of potential solutions to the identified barriers for legislators to consider in future policymaking. While this type of research is focused on policy, rather than technical solutions, it can help to foster understanding of the challenges that the state will face as it moves forward with low-carbon renewable thermal solutions, while laying the groundwork for policy developments that could support technical RDD&D.

Natural gas utilities can also be involved in RDD&D through pilot programs designed to support RNG resources and facilitate integration of RNG into the natural gas supply chain, and public utility commissions can investigate flexible funding mechanisms for such programs. In 2018, the North Carolina Utilities Commission approved a three-year pilot program for a natural gas utility to gain experience receiving RNG.[46] State support of pilot programs can move forward the demonstration and deployment phases of RDD&D, providing real-world examples, case studies, and data to support future low-carbon renewable thermal projects.

2. Financial Incentives. State-level incentives for low-carbon renewable thermal technologies include direct financial incentives, sales tax exemptions and rebates, incentive payments for interconnection costs, and pilot programs. As can be seen in the examples below, these incentives are frequently aimed at specific technologies and specific customer classes. While this level of specificity may be a result of the fuels or technologies available in a particular state or based on a state's largest sources of emissions, excluding technologies or sectors may create an uneven playing field for promising solutions, or leave certain customer classes without access to the low-carbon renewable thermal solutions they need.

Many state-level financial incentives for low-carbon renewable thermal solutions are aimed at specific technologies or customer classes.

In 2007, California launched a program aimed to install new distributed solar and transform the market for solar energy by reducing the cost of solar generating equipment.[47] The portion of this program overseen by the California Public Utilities Commission, known as the California Solar Initiative (CSI) program, had a goal to install 1,940 MW of customer-sited solar capacity.[48] One component of the CSI Program is the CSI Thermal Program, which provides incentives to eligible solar thermal technologies. As of 2017, the CSI Thermal Program was authorized to operate into 2020, and reserved 10 percent of its budget for industrial applications, for an industrial budget of just over ten million dollars.[49] However, it appears that only one industrial project applied to the program out of more than ten thousand total applications from all customer classes.[50]

California also incentivizes using biomethane through a financial incentive program that creates incentive payments that can be used toward the interconnection costs of transporting biogas to processing centers primarily from dairy cluster projects (defined as three or more dairies in close proximity).[51] Continued support for the incentive program led to its extension for five years until 2026.[52]

As of October 2020, eight states offer statewide rebates or tax incentives to purchase and install pellet or wood stoves or boilers.[53] Requirements vary from state to state, and include removal of old stoves, displacement of other types of fuel, conversion of primary heating systems, and appliance efficiency standards.[54]

New York state offers a clean heating fuel credit, but only for space heating or hot water production for residential purposes within the state.[55]

Tax exemptions have also been used to support low-carbon renewable thermal technologies, such as Washington state's sales and use tax exemptions for RNG equipment that can be used to purchase anaerobic digesters which facilitate the expansion of RNG.[56] In 2019, Oregon created specific incentives for the cost recovery of RNG investments in pipelines, connections, and other infrastructure equipment.[57]

Some states incorporate low-carbon renewable thermal into their RPS, but approaches vary widely.

Recent electrification policies in Maine have focused on the transportation and building sectors, including a pilot program for electrifying transportation and a heat pump rebate program for homes and businesses.[58]

3. Performance Standards or Targets. While state renewable portfolio standard (RPS) programs historically focused on electricity generation, some states have incorporated low-carbon renewable thermal power for heat generation into their RPS. Thirteen states and Washington, D.C. include low-carbon renewable thermal in their RPS: some states classify low-carbon renewable thermal technologies separately from electricity-generating renewable technologies, while in other states, low-carbon renewable thermal technologies are included with electricity-generating renewable technologies.[59] There are also variances among states for technology-specific carve outs and the classification of technologies, as can be seen in Figure 3, below.

Figure 3: Low-Carbon Renewable Thermal RPS Policies by State*

State	Eligible Technologies	Value within RPS	REC Definition
AZ	Biomass, biogas, solar, geothermal,	Distributed energy resource, 30% requirement	BTU Conversion
DC	Solar	Tier I technology, same as solar electric	BTU Conversion
IN	"Clean energy" thermal resources	Alongside renewable electricity	BTU Conversion
MD	Residential solar water, geothermal, biomass (except wood)	Tier I, solar water eligible for solar carve out	BTU Conversion
MA	Solar, biomass, biogas, geothermal	Alternative Energy Standard (5% by 2022)	BTU Conversion
NV	Solar, geothermal	Renewable resource	BTU Conversion
NH	Solar, geothermal, biomass	Required 2% thermal by 2023	BTU Conversion
NC	Solar, waste heat from biomass	Solar thermal is in solar specific target	BTU Conversion
OR	Biomass electric with thermal byproduct	TRECs	BTU Conversion
PA	Solar hot water and case-by-case	Tier II	kWh Displacement
TX	Solar hot water, geothermal heat pumps, landfill gas	Solar and geothermal are generation offset	kWh Displacement
UT	Solar, geothermal	'renewable resources,' separate from electric	kWh Displacement
VT	All	Tier III	kWh Displacement
WI	All	Non-electric resources (electric displacement)	kWh Displacement

*For more information, see the 2018 Clean Energy States Alliance Report "Renewable Thermal in State Renewable Portfolio Standards" (https://www.cesa.org/assets/Uploads/Renewable-Thermal-in-State-RPS-April-2015.pdf).

Several factors cause these variations. There is no universal means of quantifying thermal energy because it cannot be uniformly measured due to variations in technologies. For the purposes of a state RPS, the thermal energy must be calculated as kilowatt hours (kWh) displaced, or converted from British thermal units (BTUs) produced into a kWh equivalent. In addition, once this unit of measurement is determined, states have different approaches in how they value a unit of thermal energy. While some states hold the value as an electric equivalent, others attribute the value to separate carve outs, or award "partial credit" by assigning a lower tier in the RPS compared to renewable electricity resources.

4. Recognition of Environmental Benefits and Certification. States in the U.S. recognize the environmental benefits of emissions reductions in different ways, including through cap-and-trade programs and the issuing of certificates to track environmental attributes.

Cap-and-trade. A cap-and-trade program is one way to acknowledge the environmental impacts of emissions. Some cap-and-trade programs only apply to certain sectors. These include the Regional Greenhouse Gas Initiative (RGGI) and the Transportation Climate Initiative (TCI) in the northeast U.S., which apply to electricity generation and transportation, respectively.[60] While such sector-specific programs can help to reduce emissions, they do not drive economy-wide emissions reductions. While some industrial facilities and other large emitters may strive to achieve emissions reductions without cap-and-trade requirements, these facilities are not able to realize the benefits of participating in such a program. In addition, excluding large sources of GHG and other emissions from a cap-and-trade program leaves potential emissions reductions "on the table" that could otherwise be reduced by inclusion and participation.

California's program is an example of how cap-and-trade can be inclusive and incentivize additional economic sectors to reduce their emissions. The state has an economy-wide program that includes large industrial plants as well as natural gas and petroleum distributors.[61] Such comprehensive programs can incentivize emissions reductions in the industrial sector and drive adoption of low-carbon renewable thermal technologies. Solutions will be required for industrial facilities with varying thermal energy needs as these facilities are required to reduce their emissions, creating demand for additional low-carbon renewable thermal technology solutions.

Certificates for RNG. Tracking environmental attributes will be important to states adopting renewable thermal policies to ensure compliance, as well as market integrity and transparency.[62] The Public Utilities Commission (PUC) of Oregon adopted rules to allow the state's utilities to procure RNG for delivery to their customers and established accounting, tracking, and recordkeeping requirements and processes for RNG and its environmental attributes.[63] The PUC of Oregon created renewable thermal certifications to track the chain of custody of the environmental attributes that are issued, monitored, accounted for, and transferred by or through a third-party, the Midwest Renewable Energy Tracking System (M-RETS).[64]

In general, third-party standards and tools can help to establish consistent protocols and data sharing. In addition to the M-RETS tracking platform that may be used by states, the Center for Resource Solutions is in the process of developing environmental criteria and verification standards for RNG sold to residential and commercial customers.[65]

> States can use their purchasing power to support low-carbon products.

5. State Procurement. States can use their purchasing power to support low-carbon products, including those made using low-carbon renewable thermal energy. State procurement policies can require state agencies or entities to consider the carbon footprint of the materials or products they buy. For example, the Buy Clean California Act requires state's agencies to consider the carbon footprint of materials used in infrastructure projects when purchasing steel, flat glass, and mineral wool (a broad category of insulation for buildings).[66] The state's Department of General Services is required to establish the maximum acceptable Global Warming Potential for these materials.[67]

6. Comprehensive Planning. In 2017, the New York State Energy Research and Development Authority (NYSERDA) published a Renewable Heating and Cooling Policy Framework, an integrated, long-term policy framework to encourage the adoption of renewable clean heating and cooling technologies. However, this Framework excluded process heating, so the analysis presented only assessed the residential and commercial sectors, not the industrial sector.[68]

iii. Lessons Learned

State-level support for low-carbon renewable thermal technologies is fragmented in several ways: the availability of support, the types of low-carbon renewable thermal solutions that are supported, and the customer classes that are able to benefit from the supports all vary from state to state. Despite this variation, some key lessons learned, as described below, could be applied at the federal level.

Pilot projects can help to push low-carbon renewable thermal technologies past the research and development phases into the demonstration and deployment phases of RDD&D. While research and analysis of emerging technologies and new applications of existing technologies will continue to be important, creating real world examples where these technologies are utilized is important to show their efficacy.

Financial incentives appear to be a popular tool, as can be seen by the variety of programs available across states as well as two examples of programs in California that were extended. There are a variety of options for financial incentives that can be used to support technologies that are in different phases of their development timeline.

RPSs worked well for the electricity sector, as demonstrated by increased adoption of RPSs by states and increased percentages of renewable requirements. However, significant differences between electric and thermal energy make it difficult to include thermal energy in an electric RPS, as demonstrated by the range of approaches taken by the states that do include thermal energy in their electric RPS.

State policies generally target specific technologies, which may hinder low-carbon renewable thermal adoption in subsectors whose thermal requirements cannot be met by those specific resources.

Many state policies focus on decarbonization of transportation and buildings or offer support to residential and commercial customers. There is less support for low-carbon renewable thermal solutions for the industrial sector.

d. U.S. Federal

i. Introduction to Low-carbon Renewable Thermal at the U.S. Federal Level

In the U.S., about 63 percent of industrial emissions come from burning fossil fuels to produce heat or steam.[69] In order to realize a fully decarbonized economy, the U.S. will have to accelerate the adoption of low-carbon renewable technologies to reduce heat energy-related emissions from the industrial sector, and policies will be needed to catalyze the necessary private investments. Many of the policies examined here can be applicable to a broader range of low- and zero-carbon technologies for the industrial sector, reviewed further in a separate report.

ii. Current Policies

A slate of current federal policies supports the development and deployment of low-carbon renewable solutions, although the mechanisms and eligibility vary. Policy mechanisms generally fall into the following categories: RDD&D, technical assistance, financial incentives, performance standards, and procurement. A review of the current policy landscape can be helpful in identifying effective tools as well as gaps where additional policies are needed.

U.S. programs work to advance low-carbon renewable thermal energy solutions.

1. Research, Development, Demonstration, and Deployment (RDD&D). In the U.S., innovation plays a dominant role in shaping not just our economy, but also the global technology landscape. Federal programs have supported key advances in strategic sectors, including defense, information technology, and energy.[70] Historically, the private sector underinvested in energy relative to its potential societal benefit. Privately funded research often creates societal benefits that firms are not able to monetize, creating what is known as a "spillover effect." This effect leads to underinvestment and is magnified in the climate arena, where firms are neither required nor easily able to pass along to consumers the costs of reducing their emissions or avoiding climate impacts. However, the potential economic benefits can also be difficult to realize without sufficient access to capital and financing to develop and commercialize nascent and often risky energy technologies.

A number of programs at the U.S. Department of Energy (DOE) work to advance low-carbon renewable thermal energy solutions. The Advanced Manufacturing Office (AMO), currently housed in the Energy Efficiency and Renewable Energy (EERE) Office at DOE, leads a number of programs engaging in important research on thermal efficiency and combined heat and power (CHP) technologies. AMO administers a number of important research and development consortia, including the critical materials and energy-water desalination energy innovation hubs as well as the Manufacturing USA program, which manages 16 manufacturing innovation institutes. Energy innovation hubs and manufacturing innovation institutes each have a singular technology focus, but utilize a public-private model that facilitates collaboration while advancing new technologies, increasing workforce training, and supporting sustainable business models.[71]

Other programs at DOE focus on a range of technologies with applications in the low-carbon renewable thermal space. For example, the Advanced Research Projects Agency-Energy (ARPA-E) – fast becoming a model for translational and applied research at DOE due to its integration of active management and technoeconomic analysis – has also launched a number of programs focused on thermal energy.

2. Technical Assistance. The AMO also administers federal technical assistance programs, which provide an array of analytical, financial, and technical support to deploy industrial decarbonization solutions. A number of other offices at DOE provide technical assistance programs in addition to their research capacities. This includes the hydrogen and fuel cell technologies office, which is focused on advancing hydrogen for a variety of applications, including heat generation and chemical and industrial processes. Currently, hydrogen production is extremely costly and not yet at parity with fossil fuel prices. Technical assistance programs have proven critical to companies seeking to deploy low-carbon renewable thermal technologies.

Companies seeking to deploy low-carbon renewable thermal technologies can access DOE technical assistance programs.

These programs can also provide instrumental support for expanding markets for low-carbon renewable thermal technologies. The Combined Heat and Power (CHP) Technical Assistance Partnerships provide tools and support for companies looking to implement CHP, waste heat to power, and district energy technologies. The program works with end users (including industrial and commercial heat users) to advance solutions, engages with stakeholders to reduce barriers to deployment, and provides technical service support to sites to assess CHP feasibility. While some first-generation CHP units historically rely on fossil fuels, there are CHP units capable of using lower-carbon fuels, including RNG, biogas, or hydrogen. Although fuels such as hydrogen are not readily used in CHP systems at present, more widespread use is possible as technologies emerge to produce, store, and transport hydrogen. Research is underway to examine how existing pipeline infrastructure can accommodate hydrogen gas distribution.

The Energy Act of 2020 authorized the creation of an industrial emissions reduction technology development program.[72] The program would focus on reducing emissions from production processes for steel, aluminum, iron, cement, and chemical production as well as for high temperature heat generation. Additionally, the program would encourage smart and sustainable manufacturing, using alternative materials and developing net-zero emission fuels, and increasing energy efficiency. The Energy Act also authorized a Federal Advisory Committee to work with DOE on developing programmatic goals for the industrial emissions reduction program.

Deployment incentives such as grants, loan guarantees, and tax credits can accelerate commercial-ready technologies and reduce industrial emissions.

3. Financial Incentives. A broad suite of existing financial incentives has also proven critical for accelerating low-carbon renewable thermal adoption. These include, but are not limited to, grants, loan guarantees, and tax credits. These deployment incentives can accelerate commercial-ready technologies and reduce industrial emissions. Currently, there is an Investment Tax Credit (ITC) for CHP, but it is set to expire in 2022. The ITC is currently also applicable to solar thermal and geothermal heat pumps, while the Production Tax Credit (PTC) applies to solar and ocean thermal technologies. There are also tax credits available for capturing and converting waste heat for power, which would otherwise be released as a byproduct of industrial operations. This technology can generate power on-site and eliminates the need for transmission and its associated losses, just as CHP does. In December 2020, Congress passed an omnibus spending bill allowing waste heat to power to qualify for a 30 percent Investment Tax Credit (ITC) for the first time.[73]

DOE's Loan Program Office (LPO) provides project finance to accelerate the deployment of new, high-impact energy- and transportation-related technologies. Its loan programs have provided access to debt capital, flexible financing, and technical expertise, and were the catalyst for the utility scale solar photovoltaic market in the U.S.[74] In recent years, the only loan guarantee that LPO issued was for the Vogtle advanced nuclear project. Although projects including CHP and industrial waste recovery are eligible, there are currently no active LPO projects in these categories. The Energy Act of 2020 expanded LPO eligibility to include hydrogen production and high temperature heat generation.[75]

Companies considering renewable biomass or RNG have the potential to further reduce emissions, even achieving negative emissions, if the carbon dioxide post combustion is captured. Currently, the 45Q tax credit provides incentives for capturing carbon and storing captured carbon in geologic formations as well as utilizing carbon as a feedstock for other products. However, the tax credit only applies to projects that begin construction before 2026.

EPA also administers the ENERGY STAR program specifically for manufacturing plants in the U.S. and Canada. Plants must meet a minimum, industry-specific ENERGY STAR Energy Performance Indicator score to earn the certification. EPA benchmarks industrial plants in the U.S., measures a facility's energy performance, and compares it to other plants with similar characteristics nationwide. Eligible plants include those manufacturing cement, glass, and steel, among others.[76] Although currently a voluntary program, benchmarking can identify gaps, find opportunities for cost and energy savings, and help companies set energy efficiency and emissions reduction goals.

4. Federal Procurement. There are currently no federal procurement programs in place for purchasing industrial products such as steel, iron, and glass from energy-intensive, trade-exposed sectors. However, there are example procurement programs from other sectors, including the Department of Agriculture's BioPreferred program, which mandates federal agencies to follow certain purchasing requirements for biobased products.[77] The General Services Administration has also used federal contracts in transportation, printing services, and professional services to encourage emissions reporting and using lower emitting vendors. The federal government spent nearly $600 billion on the procurement of goods and services in 2019 alone, making procurement a vastly underutilized opportunity to drive demand for low-carbon products.[78] Accurately determining the GHGs embodied in a given product could enable far greater emphasis in procurement processes to incentivize low-carbon product development.

Finally, a market-based, economy-wide price on carbon would play a significant role in deploying low-carbon renewable thermal technologies. While a price has not yet been implemented at the federal level, any carbon price or national clean energy standard could include provisions aimed at safeguarding competitiveness and minimizing carbon leakage risks. Properly designed, a carbon price can help domestic energy-intensive, trade-exposed industries reduce emissions on a level playing field with global competitors who are not using low-carbon renewable thermal technologies, while boosting demand for low-emission goods.

iii. Lessons Learned

While policy helped spur a level of low-carbon renewable thermal technology deployment at various scales, it is thus far insufficient to deliver at scale the set of low-carbon renewable thermal solutions needed to drastically reduce emissions. In particular, high temperature users within industry need low-carbon renewable thermal technologies to be commercially viable and at cost parity with fossil fuels.

Federal innovation programs recently began to better integrate the private sector, but much more could be done to refine and scale such collaborations. Further, while some research and development focuses on low-carbon renewable thermal applications, far greater resources could be dedicated to a difficult and important decarbonization challenge.

A regional approach supported by the federal government can be successful for technical assistance programs such as the CHP Technical Assistance Partnership. A regional model provides flexibility as policy priorities sometimes differ among states, and can also facilitate knowledge sharing. Additional resources would go a long way toward enabling these offices to reach a larger number of stakeholders.

Financial incentives are impactful in the renewable energy sector. The PTC and ITC spurred investment on the order of hundreds of billions in the solar photovoltaic and wind industries. This led to drastic cost declines and rapid scaling of renewable electricity technologies. Similar incentives could catalyze the low-carbon renewable thermal sector, with broad enough eligibility and sufficient expiration horizons, including those for CHP and waste heat to power.

Performance standards are an effective tool to regulate emission sources while delivering guaranteed emissions reductions. In electricity markets, RPSs helped broaden adoption of renewable sources of energy by mandating a minimum percentage of electricity generated from renewable sources. Performance standards can vary in their flexibility and sometimes include the generation and trading of credits, creating a market-based approach.

While no current federal procurement program that prioritizes lower-emitting products and services exist, experiences with state programs suggest such a program could prove valuable.[79] Voluntary performance standards such as EPA's ENERGY STAR program for industrial plants are an important catalyst for companies to improve energy efficiency, saving money and increasing overall plant performance.[80]

Currently, industry, investors, and consumers do not accurately internalize the true cost of GHG emissions. Incorporating the impacts of GHG emissions could correct this market failure. In the U.S., there is currently no market carbon price although programs exist at the state level, as described in section c of this chapter.

03

Proposed U.S. Federal Policies

a. Introduction to Proposed U.S. Federal Policies

Additional policies would be needed to accelerate the deployment of low-carbon renewable thermal technologies in the coming decades, given the number of gaps in the existing policy landscape. Several policymakers have proposed legislative actions that could address this gap in the 116th Congress (2019 to 2020). A number of examples described in the following section are instructive.

Policymakers have proposed legislative actions that could address gaps in the existing low-carbon renewable thermal policy landscape.

b. Proposed Policies

i. Research, Development, Demonstration, and Deployment (RDD&D)

- The House Select Committee on the Climate Crisis' Action Plan calls for Congress to fund DOE to establish grants for research and demonstration of innovative clean heat technologies.[81]
- The Grid Modernization Research and Development Act of 2020 (H.R.5428) proposes a new DOE research, development, and demonstration program on cost-effective hybrid energy systems. These hybrid energy systems would include thermal energy generation and storage for applications in the manufacturing and buildings sectors.[82]

ii. Technical Assistance

- The Leading Infrastructure for Tomorrow's America Act (H.R.2741) proposes a DOE technical assistance and grant program to identify opportunities to use distributed energy systems. Distributed energy systems include energy sources that produce, store, or distribute thermal energy from renewable or waste thermal energy sources.[83]

iii. Financial Incentives

- The Growing Renewable Energy and Efficiency Now Act of 2020 proposes to extend the ITC for CHP through 2025, after which is would phase down over two years.[84]
- The Hydrogen Utilization and Sustainability Act (S.4970) proposes amending the PTC to include qualified hydrogen projects with non-positive carbon intensity to the list of eligible technologies.[85]
- The Leading Infrastructure for Tomorrow's America Act (H.R.2741) proposes a loan program to increase the deployment of distributed energy systems, including CHP and thermal energy from renewable and waste energy sources. It also proposes financial assistance for partnerships using CHP technologies.[86]

iv. Performance Standards

- The Tradeable Performance Standard Act (H.R.8582) aims to create carbon intensity standards for the electric and industrial thermal energy sectors and an emission allowances trading program to achieve emissions reductions. This program would include a variety of technologies and benefit facilities using qualified low-carbon energy sources over those using fossil fuels for thermal energy.[87]

v. Federal Procurement

- The House Select Committee on the Climate Crisis calls for federal procurement programs for iron, steel, cement, concrete, and chemicals – developing a "Buy Clean" policy. The government is a major purchaser of these commodities and procuring low-emission options would create a significant market and increase the deployment of these alternatives.[88]
- The Buy Clean Transparency Act of 2019 proposes each federal agency assess the GHG impact of products procured by the agency. Agencies would require contractors to disclose the climate product declaration of eligible materials expected to be manufactured, constructed, or renovated for a publicly funded project. [89]
- The House Energy and Commerce Committee also introduced a discussion draft for future legislation, entitled the CLEAN Future Act. This draft also includes a "Buy Clean" policy that that implements performance targets for construction materials and products used in federally funded projects.

vi. Carbon Pricing

- America's Clean Future Fund (S.4484) would delay the start of a carbon fee until an economic indicator is met (but no later than 2023). The carbon fee on fossil fuels would start at $25 per metric ton of emission, escalating $10 annually, and could rise if emission targets are not met. Carbon dioxide and methane emissions from energy and large industrial facilities would be covered two years after the price goes into effect. Program revenue would primarily go towards a rebate, and could also be used to fund agriculture- and land-based sequestration, a climate bank, and transition assistance for impacted communities.

04

Recommendations

This chapter first provides a summary of the lessons learned from the policy development to date in Europe, U.S. states, and at the U.S. federal level. Section b of this chapter includes U.S. federal policy recommendations that could support the accelerated development of low-carbon renewable thermal technologies.

a. Key Insights

Fragmented policies that only apply in certain locations, to certain technologies, or to certain customer classes can lead to uneven support.

The examples in Europe and in U.S. states demonstrate how fragmented low-carbon renewable thermal policies can lead to uneven support, and potentially slow technology development. In the EU, country-specific financial incentives are fragmented and usually target specific bioenergy technologies or even specific sectors. Similarly, in U.S. states, not all states have low-carbon renewable thermal policies and those that do vary in the types of low-carbon renewable thermal solutions that are supported and the customer classes that are able to benefit from supports. The EU experience shows how disproportionate focus on one type of solution can create unintended climate impacts, while U.S. state policies that target specific technologies may hinder low-carbon renewable thermal technology adoption for subsectors whose thermal requirements cannot be met by those specific supported resources.

However, examples at the U.S. federal level show how regional models that are coordinated by the federal government, such as the CHP Technical Assistance Partnerships, can be successful by providing flexibility and facilitating knowledge sharing across regions.

Performance targets, benchmarks, and standards can increase low-carbon renewable thermal energy use in a range of industrial sectors.

The EU experience shows that long-term federal- and state-level low-carbon renewable thermal targets provide investors, corporate energy buyers, and other market stakeholders with the long-term certainty that is critical for making investment decisions. The progress so far from EU Member States indicates that while high-level, long-term low-carbon renewable thermal targets and strategies create positive policy and market signals, concrete and effectively implemented policy incentives remain crucial to scaling low-carbon renewable thermal solutions.

In electricity markets, RPSs have helped broaden adoption of renewable sources of energy by mandating a minimum percentage of electricity generated from renewable sources. At the U.S. state level, RPSs worked well for the electricity sector, as demonstrated by increased adoption of RPSs by states and increased percentages of renewable requirements over time.

While no current federal procurement program that prioritizes lower-emitting products and services exists, experiences with state programs suggest such a program could prove valuable. For example, the voluntary performance standards in EPA's ENERGY STAR Industrial Plants program are an important catalyst for companies to improve energy efficiency, saving money and increasing overall plant performance.

A carbon price could incentivize more low-carbon renewable thermal solutions.

Since 2000, European industry cut its energy intensity twice as fast as U.S. industry. The EU put a price on carbon emissions, providing broad-based incentives for the industrial sector to increase energy efficiency and explore options for innovative carbon solutions. In the U.S., industry, investors, and consumers do not accurately internalize the true cost of carbon pollution. Incorporating the impacts of climate pollution could correct this market failure.

Financial incentives can play a significant role in scaling low-carbon renewable thermal technology deployment.

In the EU, the rapid growth of bioenergy demonstrates that the suite of substantial financial incentives, including subsidies, tax incentives, and loans, can serve as effective policy tools to scale low-carbon renewable thermal solutions. The numerous examples of financial incentives in U.S. states, as well as the extension of some incentives in California, demonstrate their popularity. At the federal level, the PTC and ITC spurred investment on the order of hundreds of billions of dollars in the solar photovoltaic and wind industries, leading to drastic cost declines and rapid scaling of renewable electricity technologies. Similar incentives could catalyze the low-carbon renewable thermal sector, especially with broad eligibility and sufficient expiration horizons.

RDD&D and partnerships with the private sector are pivotal to accelerating low-carbon renewable thermal technology development.

Two initiatives in the EU, Horizon 2020 and the ETS Innovation Fund, demonstrate that RDD&D funding support can be effective in accelerating the research, development, and commercialization of low-carbon renewable thermal solutions. In U.S. states, pilot projects can help to push low-carbon renewable thermal technologies past the research and development stages into the demonstration and deployment phases, creating case studies and data for further analysis. Federal innovation programs recently began to better integrate the private sector, though they will need to continue to refine and scale these collaborations.

Additional data about low-carbon renewable thermal applications and the effectiveness of low-carbon renewable thermal policies is needed.

While some research and development has focused on low-carbon renewable thermal applications, far greater resources could be dedicated to a difficult and important decarbonization challenge. Further research and development, as well as demonstration and deployment, would provide additional empirical evidence on the effectiveness of low-carbon renewable thermal policies.

Increased deployment of renewable thermal technologies and the resulting decarbonization of industry can contribute to an equitable and just energy transition.

In the EU, the Just Transition Mechanism is meaningful first step to provide dedicated financial support for policy design for industrial decarbonization that takes into account the most affected people and communities.

b. Recommendations

In general, policymakers should support policy mechanisms that provide broad support to a varied portfolio of low-carbon renewable thermal technologies throughout their development trajectory. A wide range of policy mechanisms will help to ensure the development of technologies that can address an extensive array of thermal energy needs, including those that will serve the disparate needs of individual facilities within the industrial sector.

These recommendations are aimed at federal policy, and are organized into six main categories: RDD&D, technical assistance, financial incentives, market-based mechanisms, federal procurement, and supporting impacted communities.

i. Research, Development, Demonstration, and Deployment (RDD&D)

In general, federal RDD&D could support a wide range of low-carbon renewable thermal technologies, including those that can provide thermal energy at a variety of temperatures. Support for RDD&D could be for both near-term and long-term low-carbon renewable thermal solutions.

The federal government could more fully explore public-private partnerships that can enhance technology transfer and leverage private capital to accelerate commercially available low-carbon renewable thermal technologies, including low-carbon fuels such as hydrogen, RNG, and biofuels. The federal government could provide flexibility in cost-sharing models with the aim of helping technology developers commercialize critical technologies. The government could continue to support progress in smart and sustainable manufacturing, particularly for energy-intensive, trade-exposed industries including steel, iron, aluminum, cement, glass, pulp, and paper.

- Policymakers could elevate and significantly increase funding for AMO within DOE to better enable it to coordinate related RDD&D efforts across the department. AMO's research focus could expand to include more low-carbon renewable thermal and innovative industrial processes with much smaller

GHG footprints. The office could also prioritize demonstration projects for viable low-carbon renewable thermal technologies such as hydrogen. Increases in funding could also focus on growing low-carbon renewable thermal research at ARPA-E, as well as multi-stakeholder and multi-disciplinary programs such as energy innovation hubs, Manufacturing USA, and Energy Frontier Research Centers.

- Policymakers could establish an energy innovation hub dedicated to low-carbon renewable industrial heat.
- Implementing agencies could ensure data collection and develop methodologies for coherent monitoring and ex-post analysis of policy measures.

ii. Technical Assistance

Policymakers can help increase technical assistance to various stakeholders in the industrial sector by exploring low-carbon renewable thermal opportunities. In particular, the industrial sector could be offered improved access to federal laboratories to better collaborate on demonstration and pilot projects that are critical to deploying thermal solutions at scale. Such projects could include electrification and hydrogen – all potentially viable technologies for high temperature heat users. To bolster other avenues for technical assistance:

- Policymakers could fund and direct DOE to establish the Industrial Technology Innovation Advisory Committee authorized in the Energy Act of 2020. This Committee could coordinate DOE's technical assistance programs, including the Hydrogen and Fuel Cell Technologies Office and CHP Technical Assistance Partnership Programs as it develops missions and goals for technologies aimed at industrial emissions reduction.
- Policymakers could allocate additional funding to the CHP Technical Assistance Partnership Program. The CHP Technical Assistance Partnerships could include low-carbon renewable thermal solutions, such as examining how low-carbon renewable fuels such as hydrogen could be used in CHP units. Increases in funding would also support regional program offices to increase end user engagement and technical assistance on low-carbon renewable thermal solutions.
- DOE could replicate the highly successful Gateway for Accelerated Innovation in Nuclear (GAIN) program for low-carbon renewable thermal technologies. A GAIN analogue would provide the industrial community with a single point of access for technical, regulatory, and financial resources necessary to catalyze innovative low-carbon renewable thermal solutions toward commercialization.

Technical assistance is also needed in establishing clear sustainability criteria for bioenergy that ensure that it delivers genuine climate benefits over fossil alternatives.

- The government could design policies that incorporate clear and strict sustainability criteria for bioenergy that take into account the climate impact of the entire life cycle of bioenergy consumption to ensure delivery of genuine climate benefits over fossil alternatives. Forest Stewardship Council (FSC) certification, Roundtable on Sustainable Biomaterials (RSB) certification, or FSC controlled wood standards could be applied to any biomass sourcing to make sure that the lands from which the biomass is derived are managed well. Bioenergy could be treated as a transition solution as policy incentives support a broader set of more sustainable low-carbon renewable thermal solutions including concentrated solar, beneficial electrification, and green hydrogen.

iii. Financial Incentives

Policymakers can play an important role in advancing low-carbon renewable technologies by leveraging public resources to drive stronger private investments. To provide critical financial incentives:

- Policymakers could extend, expand, and establish longer-term tax and other incentives for a range of low-carbon renewable thermal technologies (biomass, biogas (including landfill gas), RNG (or biomethane), geothermal, beneficial electrification, green hydrogen, and solar thermal). Financial incentives could be applied to a diverse and balanced portfolio of low-carbon renewable thermal solutions. Financial incentives can be tailored to individual technologies based on where a technology is in its development timeline.
- Policymakers could establish a National Climate Bank, whose objectives could include providing grants and low-cost loans for low-carbon renewable thermal technologies in the residential, commercial, and industrial sectors. While the bank could fund a variety of different projects, low-carbon renewable thermal projects could include infrastructure for hydrogen and multi-user industrial parks that aggregate and centralize demand for low-carbon renewable thermal resources.
- DOE's LPO could expand eligibility for its loan guarantee programs to include RNG and beneficial electrification, as well as the infrastructure needed to facilitate these solutions. LPO could also work to reduce administrative costs and barriers to program participation.

In addition to supporting low-carbon renewable thermal technologies, financial incentives can also be designed in a technology-inclusive manner to support a wider array of decarbonization technologies.

iv. Market-based Mechanisms

As described in Chapter 2, market-based mechanisms have been implemented to broaden adoption of low-carbon renewable thermal and renewable electricity solutions. Three market-based mechanisms are described below: a thermal renewable portfolio standard (thermal RPS) and thermal renewable energy credit (thermal REC) market, carbon pricing, and industry performance standards.

Market-based mechanisms can be designed to support low-carbon renewable thermal technologies, but can also be designed in a technology-inclusive manner to support a wider array of decarbonization technologies. Program specifications will determine which resources are eligible to participate.

1. Thermal Renewable Portfolio Standard (Thermal RPS) and Thermal Renewable Energy Credits (Thermal RECs). In electricity markets, state RPSs helped broaden adoption of renewable sources of energy by mandating a minimum percentage of electricity generated from renewable sources. A similar system for thermal energy could help to support the adoption of low-carbon renewable thermal energy technologies, though some significant differences between electricity and thermal energy sources and markets will require close examination of a thermal RPS structure. While some states include thermal energy in their electricity RPSs, policymakers could consider creating a separate thermal RPS, coordinating applicability with those states that already include thermal energy in their RPS.

Thermal RECs would support such a market-based mechanism and help to develop credible standards and certification of environmental attributes for low-carbon renewable thermal sources: the standardization and certification of low-carbon renewable thermal solutions is more complex compared to renewable electricity and varies for each type of technology.

- Policymakers could create a thermal RPS, taking into consideration state-level policies that already include low-carbon renewable thermal energy.
- Policymakers could establish a certification process for low-carbon renewable thermal technologies that would create thermal RECs.

2. Carbon Pricing. A central element to deploying low-carbon renewable thermal solutions could be a market-based policy that creates an escalating, economy-wide price on carbon emissions. This price could be accompanied by a suite of other policies, such as those described in this section. Carbon-pricing strategies can generate significant revenue, which can support other climate mitigation efforts, address impacts on low-income households and affected workers and communities, and remedy other fiscal concerns. To establish a federal price on carbon:

- Policymakers could begin consultations on designing an economy-wide pricing program, which could include provisions aimed at ensuring environmental integrity; safeguarding global competitiveness of domestic, emissions-intensive, and trade-exposed companies; minimizing leakage; providing for equivalent state programs; and addressing environmental justice concerns. Such pricing policies could also allow for appropriate use of offsets for carbon removal.

3. Industry Performance Standards. In the absence of an economy-wide carbon price, a tradeable performance standard can drive decarbonization across the industrial sector. Design principles for an effective performance standard can include environmental integrity, predictability and transparency, competitiveness, cost containment, alignment with state policies, and inclusion of complementary federal measures.

- EPA could undertake a process to benchmark major industrial subcategories, laying the foundation for developing intensity-based GHG objectives for these subcategories. This benchmarking analysis could be used to determine how a mandatory, tradeable performance standard could be applied to domestic and imported products, as well as provide a foundation for domestically produced products to compete in global markets with a market-based mechanism in place.

v. Federal Procurement

The federal government is the largest purchaser of goods and services, presenting an opportunity to leverage its purchasing power to drive the U.S. economy's decarbonization. Alongside reducing the government's carbon footprint, purchasing lower-GHG emitting and environmentally sustainable products can save taxpayer money by lowering the government's energy costs while also helping to scale important low-carbon products. In order to leverage the federal government's buying power:

- The White House could direct agencies to incorporate emissions reduction objectives into relevant procurement processes. Agencies could set targets for reducing their scope 3 emissions and could prioritize purchase of lower-GHG emitting, environmentally sustainable products and services, including products produced with lower embodied GHG emissions (such as low-carbon cement and steel).

- EPA, in conjunction with other agencies such as NIST and DOE, could establish a Buy Clean Program to reduce the embodied carbon of construction materials and products used in projects supported by federal funds. EPA could maintain a list of eligible materials for a Buy Clean Program where products with lower embodied GHG emissions would receive preferential treatment.
- EPA could set clean performance targets wherever feasible for materials in construction, manufacturing, and other relevant industries and create a technical assistance program to help companies and small businesses develop and verify environmental product declarations for eligible materials.
- EPA could prioritize the development of digital measurement, reporting, and verification (MRV) technologies to track supply chain emissions from cradle to disposal and incorporate standardized lifecycle emissions accounting, data transparency, and third-party verification. This would allow agencies, companies, and consumers to factor embodied carbon into purchasing decisions, including under a Buy Clean Program.

vi. Supporting Impacted Communities

Various communities in the U.S. have historically been and continue to be disproportionately affected by environmental consequences of energy use as well as climate change impacts that are already being felt. In addition, the clean energy transition will have economic effects on individual workers and entire communities. Policy design for industrial decarbonization can take into account the most affected people and communities.

- Beyond targeted financial and technical support for impacted groups, policymakers could also consider environmental and social justice issues among the workforce and frontline communities, especially in the context of heavy industries, to ensure fair treatment and meaningful involvement of all people in the design and implementation of policy incentives for low-carbon renewable thermal solutions.
- Policymakers could establish and fund a multi-agency program, building on the Obama Administration's POWER+ Plan, to leverage and target federal economic, workforce development, health, and community resources to assist fossil fuel-dependent communities in the energy transition, starting with coal and industrial communities.

Appendix

Appendix I: Summary of financial incentives for bioenergy in EU Member States[a]

Country	Support scheme	Sub-technology	Support level	Unit
DK	FIP	Biogas	1,34	€/GJ
LT	FIT	Landfill gas	34	€/MWhth
LT	FIT	Anaerobic digestion	72	€/MWhth
NL	FIP	Fermentation in CHP	125	€/MWhth
FI	Price mechanism	CHP	50	€/MWhth
FI	Price mechanism	CHP plants working on wood fuel	20	€/MWhth
DE	Subsidy	Pellets installations	80	€/kW
NL	FIP	Other biomass	55	€/MWhth
NL	FIP	CHP	67	€/MWhth
NL	FIP	Boiler liquid biomass ≥0,5 MWth	70	€/MWhth
NL	FIP	Boiler liquid or solid biomass ≥0,5 MWth en < 5 MWth	55	€/MWhth
NL	FIP	Boiler on liquid or solid biomass ≥5 MWth	43	€/MWhth
NL	FIP	Boiler on wood pellets ≥5 MWth	62	€/MWhth
NL	FIP	Biomass ≤100 MWe	53	€/MWhth
NL	FIP	Extended lifetime ≤50 MWe	61	€/MWhth
UK	DRHI	Biomass boilers and biomass stoves	72,6	€/MWhth
UK	NDRHI	Small commercial biomass <200 kWth -first year	32,8	€/MWhth
UK	NDRHI	Small commercial biomass <200 kWth –afterwards	23	€/MWhth
UK	NDRHI	Medium commercial biomass >200 kWth < 1 MWth - first year	32,8	€/MWhth
UK	NDRHI	Medium commercial biomass >200 kWth < 1 MWth – afterwards	23	€/MWhth
UK	NDRHI	Large commercial biomass (1 MWth and above) - first year	23	€/MWhth
UK	NDRHI	Large commercial biomass (1 MWth and above)	32,8	€/MWhth
UK	NDRHI	Solid biomass CHP systems	47,6	€/MWhth

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84. Growing Renewable Energy and Efficiency Now Act of 2020, H.R. 7330, 116th Congress, Section 102 (2020).

85. The Hydrogen Utilization and Sustainability Act, S. 4970, 116th Congress, Section 2 (2020).

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87. Tradeable Performance Standard Act, H.R. 8582, 116th Congress, Section 721 (2020).

88. House Select Committee on the Climate Crisis, Solving the Climate Crisis, Majority Staff Report – House Select Committee on the Climate Crisis, June 2020, https://climatecrisis.house.gov/sites/climatecrisis.house.gov/files/Climate%20Crisis%20Action%20Plan.pdf.

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The Renewable Thermal Collaborative (RTC) serves as the leading coalition for organizations that are committed to scaling up renewable heating and cooling at their facilities and dramatically cutting carbon emissions. RTC members recognize the growing demand and necessity for renewable heating and cooling and the urgent need to meet this demand in a manner that delivers sustainable, cost-competitive options at scale.

The Renewable Thermal Collaborative was founded in 2017 and is facilitated by the Center for Climate and Energy Solutions, David Gardiner and Associates, and World Wildlife Fund.

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