Solar Thermal Technology Assessment

Prepared by the Renewable Thermal Collaborative

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Thank You.

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Executive Summary

Industrial, commercial, and institutional energy users working to decarbonize their thermal energy footprints – thermal energy is used for industrial processes and to heat and cool buildings – face a significant set of technology, economic, and market challenges. Low-carbon renewable thermal technologies are typically more expensive than incumbent fossil natural gas-based solutions, and energy users may not be sufficiently familiar with renewable thermal solutions to understand the decarbonization potential they offer.

This project considers solar thermal: its technical potential to meet industrial and commercial needs, and the market, technical, and policy barriers that influence solar thermal’s pace of deployment.

The project considers insights from solar thermal developers across a range of different technologies and the perspectives of global energy users with deep renewable energy experience and ambitious decarbonization targets.

There are significant barriers to be addressed, primarily around providing large energy users efficient mechanisms to assess and understand solar thermal’s potential applicability to their specific facilities and requirements. There are also policy-related opportunities to increase support for accelerated solar thermal deployments.
Introduction

Thermal energy is a key component of energy use in the United States and around the world, particularly in the industrial sector. Energy used for process heat and space heating accounts for 75 percent of global final industrial energy demand. In the U.S., fossil fuel combustion to produce heat and steam creates about 52 percent of U.S. industrial direct greenhouse gas (GHG) emissions.¹

At present, renewable energy meets only 13 percent of global industrial heat demand.² Solar thermal technologies produce less than 1 percent of global industrial heat, despite having a much greater technical potential.³

Decarbonizing thermal energy – especially in the industrial sector – is critical to avoiding the most severe impacts of global climate change, and will require significant acceleration of renewable thermal technology deployment.

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

Large energy users working to decarbonize their thermal energy use will typically need to consider implementing multiple renewable thermal technologies in order to meet emissions reduction goals, process performance requirements, resource availability, economic parameters, and more.

The Renewable Thermal Collaborative (RTC) is developing a series Technology Action Plans (TAPs) to accelerate the deployment of specific renewable thermal technologies and solutions. The RTC has completed a TAP on Industrial Electrification and is developing a TAP on renewable natural gas. This Solar Thermal Technology

Assessment (TA) is designed to provide the substantive basis for RTC members to consider developing a full solar thermal TAP.

The Assessment addresses four primary questions:

1. What is the potential of both non-concentrating and concentrating solar technology to deliver cost-effective, sustainable, low-carbon thermal energy in the short-term (by 2030) and the long-term (2050)?
2. What are the major technical, market, economic, institutional, and policy barriers impeding accelerated development and industrial deployment of solar thermal technologies?
3. What priority solutions would ensure that solar thermal technologies are sustainable, cost-competitive (especially relative to natural gas), and scalable?
4. What actions could large industrial, corporate, and institutional buyers implement, perhaps in collaboration with others, to help accelerate and scale solar thermal technologies?

The RTC addressed Questions Two, Three, and Four by convening a dedicated Working Group comprised of solar thermal developers and industrial end users. The developers, including several current RTC Sponsors, represent a wide range of different solar thermal technologies that can, in aggregate, provide heat across the full range of industrial temperature requirements. The developers include both U.S.- and European-based companies. The industrial users, all current RTC Members, represent a complex, global operational footprint with low-, medium-, and high-temperature heat requirements.

The RTC supplemented the group discussions with direct interviews with additional technology providers, industrial energy users, and additional solar thermal market experts.
Introduction to Solar Thermal Technologies

Solar thermal includes two main types of technologies: non-concentrating and concentrating solar thermal. Non-concentrating solar thermal technologies include, but are not limited to, flat plate, evacuated tube, Integral Collector Storage (ICS), and thermosiphon collectors. Non-concentrating solar thermal technologies can produce temperatures up to 100°C.

Figure 1: Solar thermal temperature production by technology type and end use. (Sources: IEA, 2014; European Renewable Heating and Cooling-Platform. Photos courtesy of Industrial Solar; Roth Werke; Solitem; Solvis; SRB Energy; Wagner & Co.)

Concentrating solar power (CSP) technologies typically utilize optical elements – such as parabolic troughs, compact linear Fresnel reflectors, power towers, and dish engines among others⁶ – to concentrate the sun’s energy. CSP can produce heat up to nearly 1000°C.⁷

Some solar thermal technologies include integrated photovoltaics: These products provide both heat and electricity output.

**Technical Potential: Non-Concentrating Solar Thermal**

The Solar Heating and Cooling Program at the International Energy Agency (SHC-IEA) estimates non-concentrated solar thermal collectors have the technical potential to supply 30-40 percent of global low-medium temperature process heat demand. SCH-IEA calculates this to equate to 14,000 petajoules (PJ) total potential worldwide in 2030.⁸

The International Renewable Energy Agency (IRENA) projects that by 2050, solar thermal energy will account for 6.3 percent of industrial energy use; approximately 8,000 PJ, or just over half of SCH-IEA’s 2030 technical potential projection.⁹ This estimate combines an assessment of solar thermal energy’s technical potential and a projection of market development factors over the next three decades.

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Technical Potential: Concentrating Solar Power

The U.S. Department of Energy’s Solar Energy Technologies Office has set a goal to reduce CSP costs from $0.98/kWh in 2018 to $0.05/kWh by 2030. Assuming this cost reduction is realized in a linear fashion, the National Renewable Energy Laboratory (NREL) expects few additional CSP installations to come online in the U.S. before 2030. NREL predicts that by 2050, CSP will account for 135 GWh in the U.S. This is equivalent to about 1 percent of final energy consumption in the U.S. industrial sector.

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Assessing Barriers, Solutions, and Actions

The Solar Thermal Working Group identified, discussed, and weighted: barriers that are impacting the industrial, commercial, and institutional solar thermal market; solutions that could address some or all of those barriers; and actions that large energy buyers could take to help overcome those barriers.

Each group member weighted each barrier, solution, and action on a one-to-three scale; three being the most impactful and one the least. The RTC averaged the weightings, and the resulting rankings are included below. The weighting results suggest starting points for additional investigation and potential development of a solar thermal Technology Action Plan.

The Working Group placed each barrier, solution, and action into the three broad categories that help frame the RTC’s overall activities: Market, Technology, and Policy. Issues within these categories can interact and influence each other; policies for well-funded research and development (R&D) can improve technology, for example.

Barriers

The Working Group identified 12 different barriers across the three categories. Some barriers reflect the specific experience and perspective of a stakeholder, not all Working Group members agreed that each barrier listed constitutes a barrier for their specific objectives. Some barriers are more distinctly buyer- or developer-centered.
Table 1: Barriers to accelerated solar thermal adoption; see below for expanded descriptions

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Category</th>
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<tr>
<td>Solar thermal system complexity</td>
<td>Technology</td>
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<tr>
<td>Installation space is constrained</td>
<td>Technology</td>
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<tr>
<td>Solar thermal is not a bankable technology</td>
<td>Technology</td>
</tr>
<tr>
<td>Low natural gas prices</td>
<td>Market</td>
</tr>
<tr>
<td>No easy guide to solar thermal technologies</td>
<td>Market</td>
</tr>
<tr>
<td>Solar thermal perceived as “pre-mainstream”</td>
<td>Market</td>
</tr>
<tr>
<td>Lack of attribute crediting or tracking</td>
<td>Market</td>
</tr>
<tr>
<td>Need for performance predictability</td>
<td>Market</td>
</tr>
<tr>
<td>Difficulty finding correct scale</td>
<td>Market</td>
</tr>
<tr>
<td>No net-metering option</td>
<td>Policy</td>
</tr>
<tr>
<td>Lack of financial incentives</td>
<td>Policy</td>
</tr>
<tr>
<td>Lack of a solar thermal compliance market</td>
<td>Policy</td>
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</tbody>
</table>

Note: Barriers are listed by category, not weighting.

Barrier Descriptions

**Solar thermal system complexity:**
- Buyers are concerned that solar thermal systems require customization for each specific installation or facility. Customization adds complexity, time, and cost for buyers, and limits solar thermal energy’s perceived value as a scalable solution across large energy portfolios.

**Space constraints:**
- Buyers don’t know whether their facilities offer adequate and structurally-suitable installation space to make solar thermal a compelling solution.
- Solar-suitable buyer sites may also be candidates for solar photovoltaic installations; solar thermal systems may be competing with solar PV for a given site.

**Low natural gas prices:**
- Particularly in the U.S., the low-cost of incumbent natural gas is a challenge to scaling almost all renewable thermal technologies.

**Solar thermal is not a bankable technology:**
- “Bankability” describes a technology’s ability to deliver predictable, reliable, and verifiable performance while managing risk sufficient to attract investors.
- Bankability was crucial to accelerating solar PV and wind deployments in the U.S. by expanding renewable electricity’s access to capital.
- There have been technical challenges to making solar thermal a bankable technology. For example,
high-quality, investment-grade heat output metering would need to be included in deployments to verify that systems are performing to specification. Investment-grade heat meters have posed availability and cost challenges.

- Large C&I energy buyers typically rely on third-party financing to deploy renewable energy and GHG-reduction solutions rather than using their own capital to finance these projects. Buyers will likely require similar third-party solutions to support scaled deployments of solar thermal systems.

**No easy guide to solar thermal technologies:**
- Buyers report difficulty finding an easy-to-use resource that helps them match available solar thermal technologies to process requirements by temperature range and heat output.

**Solar perceived as “pre-mainstream”:**
- Many energy users perceive solar thermal technologies as developing; insufficiently mature or “mainstream” to be trusted.

**Lack of crediting or tracking:**
- Renewable energy certificates (RECs) for solar thermal – both the instruments and the markets for the instruments – aren’t as developed as those for renewable electricity.
- RECs – or equivalent thermal instruments – help energy users track and account for their renewable energy production and utilization. Buyers wanting to make greenhouse gas (GHG) emissions reduction claims based on renewable thermal energy use may need thermal RECs to do so.
- In electricity markets, RECs can be transacted separately from their underlying electrons. This enables a much larger market: buyers can purchase RECs from projects to which they are not physically connected. A REC can be sold into a compliance market (typically at the state level) or a voluntary market.
- GHG accounting and claims guidance do not yet fully integrate solar thermal energy or other renewable thermal technologies, impeding large energy users from including renewable thermal solutions in their GHG accounting and claims.

**Need for predictability:**
- Buyers expressed concern that solar thermal technologies cannot provide the consistent minimum load that their production sites require.
- Many buyer concerns in this category were geographically or time-of-day based.
- Buyers are concerned their facilities are in unsuitable geographic locations for solar thermal deployment.

**No net-metering option:**
- In some solar PV markets, buyers can utilize net-metering to sell excess solar electricity production back to the grid.
- This provides a financial value stream that can improve a project’s economic viability.
- Net-metering for solar thermal does not exist since excess heat cannot be recirculated in the same way as electricity. Net-metering is not an option due to technology and policy limitations.
Difficulty finding correct scale:
• Industrial energy users have large energy loads across global geographies. These buyers find it difficult to identify solar thermal solutions that can meet their needs at scale – a combination of the total amount of heat required and the specific amounts of heat at different temperatures.

Lack of financial incentives:
• Relatively few financial incentives exist for renewable thermal technologies, including solar thermal, compared to renewable electricity.
• Policies could include tax credits, research and development efforts, subsidies, and more. Incentives like the Production Tax Credit and Investment Tax Credit have been very helpful for the U.S. wind and solar markets, respectively.

Lack of compliance market:
• Renewable portfolio standards (RPSs) for electricity require that a specific percentage of electricity sold in the covered market come from renewable sources.
• RPSs have been critical to the growth of renewable electricity in the U.S. as they have provided market certainty and, in some cases, financial incentives to drive deployments.
• Some RPSs have included thermal options, but these are the exception rather than the rule.
• Expanded thermal RPS requirements or frameworks could be very helpful to accelerating renewable thermal deployments, including for solar thermal systems.

Each Working Group member weighted each barrier: three points for the most significant barriers, two points for the less significant, one point for the least significant. Averaged weightings are displayed in Figure 3.

Market barriers are both the most numerous and the most heavily weighted.

Low fossil gas prices are a fundamental challenge for thermal decarbonization efforts: All renewable thermal technologies are competing against an inexpensive incumbent solution. Commodity fossil energy prices are a difficult barrier for large energy buyers to address directly.

The other heavily weighted Market barriers are primarily information barriers. Buyers reported that they had insufficient technical understanding of solar thermal technologies to understand how solar thermal solutions could be effectively deployed across their facilities. Buyers identified specific knowledge gaps including different solar thermal technologies’ capabilities, complexities, and space requirements; solar thermal’s ability to produce industrial-scale heat output, and solar thermal’s suitable geographic range. Information barriers may be directly addressed and resolved through collaboration and dialogue between thermal energy buyer, solar thermal technology providers, and other stakeholders, including renewable energy procurement advisors and consultants.

Buyers and developers also described policy limitations as significant barriers. These discussions noted the importance of federal and state policy support for renewable electricity: tax incentives like the Production Tax Credit (PTC) and Investment Tax Credit (ITC) at the federal level, and Renewable Portfolio Standards (RPS) at the state level. Similar thermal-focused policy mechanisms could help narrow the cost gap between fossil gas and renewable thermal solutions and provide additional market certainty to support commercial transactions.

Figure 3: Barriers weighted by importance
Solutions

The Working Group identified 11 potential solutions to address the barriers described above.

Table 2: Solutions for overcoming identified barriers to solar thermal technology deployment; see below for expanded descriptions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Category</th>
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<tbody>
<tr>
<td>Increase financial incentives</td>
<td>Policy</td>
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<tr>
<td>Increase regulatory or compliance market support</td>
<td>Policy</td>
</tr>
<tr>
<td>Create a carbon price or fuel tax</td>
<td>Policy</td>
</tr>
<tr>
<td>Increase tracking and crediting mechanisms</td>
<td>Market</td>
</tr>
<tr>
<td>Create a thermal power purchase agreement template</td>
<td>Market</td>
</tr>
<tr>
<td>Combine solar thermal with heat recovery systems</td>
<td>Market</td>
</tr>
<tr>
<td>Increase investor trust to expand financing options</td>
<td>Market</td>
</tr>
<tr>
<td>Create a decision matrix for energy users</td>
<td>Market</td>
</tr>
<tr>
<td>Create educational resources for buyers</td>
<td>Market</td>
</tr>
<tr>
<td>Develop a landscape study tool to assess viability across geographies</td>
<td>Market</td>
</tr>
<tr>
<td>Deploy marketing campaigns to increase trust in solar thermal</td>
<td>Market</td>
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</tbody>
</table>

Note: These solutions are listed by category, not priority

Increase financial incentives:
- Implement or expand policy measures such as tax credits and subsidies for renewable thermal and solar thermal technologies.
- Tax credits and subsidies helped launch the renewable electricity market, replicating this political assistance would likely have a similar effect in the solar thermal market.

Increase regulatory or compliance markets:
- Include thermal requirements in existing Renewable Portfolio Standards, or create new, similar frameworks focused on renewable thermal energy.

Create a carbon price or fuel tax:
- Place a price on carbon emissions or implement a fuel tax for carbon emitting fuels to increase the economic competitiveness of low- or zero-carbon fuel options, including solar thermal systems.

Increase tracking and crediting mechanisms:
- Expand tracking and crediting mechanisms such as thermal RECs.
- The Midwest Renewable Energy Tracking System (M-RETS), an RTC Sponsor, includes renewable thermal attributes in its system.
- The Center for Resource Solutions has been developing a Green-e certification standard for Renewable Natural Gas (RNG). Green-e could include additional renewable thermal technologies in future developments.
Create a thermal power purchase agreement template:
- Power purchase agreements (PPAs) have been highly-useful in the renewable electricity markets. PPAs help renewable energy buyers and sellers manage risk, and managing risk effectively leads to more project development.
- Standard, non-proprietary PPAs were a helpful educational tool in the renewable electricity market, especially in the early stages of the market.
- A standardized heat purchase agreement could be similarly helpful accelerating renewable thermal deployments.

Combine solar thermal with heat recovery systems:
- Deploying solar thermal technologies with heat recovery systems can increase total net thermal efficiency and value, improving overall project economics.

Increase investor trust to expand financing options:
- Solar thermal will need to attract third-party capital and financing tools to achieve deployment scale that aligns with its technical potential.
- Increased third-party capital and financing tools will allow companies to pursue more solar thermal deployment opportunities quicker than relying on internal capital budgets.

Create a decision matrix for energy users:
- Buyers need a streamlined resource or tool to match solar thermal technology capabilities and purchase options based on their heat and load needs.

Create educational resources for buyers:
- Buyers need a resource or tool to navigate the solar thermal technology questions, needs assessment, and deployment options and processes to help develop a solar thermal deployment strategy.

Develop a landscape tool to assess viability across geographies:
- Buyers need a tool to easily to determine economic and technical viabilities for solar thermal technologies across their facilities portfolios by location.

Deploy marketing campaigns to increase trust in solar thermal:
- A marketing campaign aimed at commercial and industrial energy users could reduce information gaps and barriers.

Each Working Group member weighted each solution: three points for the most potentially impactful solution, two points for the less impactful, one point for the least impactful. Averaged weightings are displayed in Figure 4.
The three Policy solutions all ranked highly in terms of estimated impact. In the renewable electricity markets, financial incentives, and regulatory or compliance markets have proven to be very effective at accelerating renewables markets.

Several proposed solutions center around buyers' stated needs for more effective solar thermal information and tools.

That the Working Group didn’t suggest any Technology solutions underscores one of the themes from the Barriers discussions: Solar thermal technologies will likely continue to improve, but they are commercially viable now. The fundamental challenge of accelerating solar thermal deployments is not one of moving pre-commercial technology to market-readiness, but one of expanding the market’s ability to understand the technology, its value, and how to deploy it.

**Corporate and Institutional Buyer Actions**

The RTC was created in part to help large energy users better understand the actions that they can take across markets, technologies, and policy to accelerate deployment of renewable thermal solutions. The Working Group proposed several actions large buyers could consider to specifically accelerate solar thermal deployment.
Support renewable thermal policy:
- Companies can actively promote and advocate for state and federal policy that supports solar thermal technologies.
- Policies could include tax credits, research and development efforts, renewable thermal portfolio standards, and more.

Increase internal value for sustainability:
- Companies can place explicit organizational and financial value on sustainability performance and GHG emissions reductions; example strategies could include internal carbon pricing and green revolving funds.
- Quantifying this value can help close the economic gap between solar thermal energy and incumbent fossil gas solutions.

Be “renewable ready” in new construction:
- Companies can include provisions for solar thermal technologies in new facility/building construction – space for plumbing runs, roof or wall penetrations, etc. – reducing cost for subsequent deployments.

Commit to solar thermal pilot projects:
- Large energy buyers can make proactive commitments to deploy solar thermal technologies, sending an important market signal.

Pursue collaborative off-take projects:
- Multiple buyers can work together to deploy solar thermal technologies.
- Companies can share learnings and increase process efficiency.

Convene a collaboration forum:
- A Working Group buyer suggested a pre-projects collaboration to address fundamental technology information gaps and identify other buyers interested in collaborative off-take projects.

Table 3: Potential actions large energy buyers can take to accelerate solar thermal adoption; see below for expanded descriptions

<table>
<thead>
<tr>
<th>Action</th>
<th>Category</th>
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<tbody>
<tr>
<td>Support renewable thermal policy</td>
<td>Policy</td>
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<tr>
<td>Increase internal value for sustainability</td>
<td>Market</td>
</tr>
<tr>
<td>Be “renewable ready” in new construction</td>
<td>Market</td>
</tr>
<tr>
<td>Commit to solar thermal pilot projects</td>
<td>Market</td>
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<tr>
<td>Pursue collaborative off-take projects</td>
<td>Market</td>
</tr>
<tr>
<td>Convene a collaboration forum</td>
<td>Market</td>
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Note: These actions are listed by category, not priority
Participants were asked to weight the list of six possible actions on a three-point scale: three being highest impact, two for medium impact, and one for lowest impact. The averages are presented in Figure 5 below.

Corporate climate and clean energy public goals and commitments continue to increase: Witness the growth of initiatives like Science-Based Targets, We Mean Business, and the RTC’s own membership. These commitments clearly reflect companies’ internal value for sustainability. Every energy buyer interviewed for this Assessment confirmed that their company already had an internal value of sustainability, and indicated that it was a primary driver for pursuing renewable thermal technologies. Helping additional companies set new climate and clean energy targets may help expand interest in solar thermal solutions, but stakeholders will still need to address the information gaps and barriers buyers described in the Barriers section above.

Both the Solar Thermal Working Group and the broader RTC membership have identified renewable thermal-supportive policy as a key priority. On March 2, 2021, the RTC published Low-Carbon Renewable Thermal Technology Solutions: Policies to Support Development and Deployment, a review of 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. RTC Members are beginning to engage with policymakers, particularly at the U.S. federal level, on these issues.

“Solar-ready” construction standards have been developed for solar photovoltaics in some markets and have proven to reduce deployment costs later. Similar practices and specifications could be developed for solar thermal technologies. This action ranked relatively low in terms of potential impact because it doesn’t affect existing buildings and facilities, and existing facilities are replaced by new ones very slowly. Strategies that include existing facilities and buildings are likely to be more impactful.

Nearly every buyer interviewed indicated that they would be interested in considering pilot projects, but they’re constrained by the technology and process information gaps described in Barriers above.

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Buyers were generally receptive to collaborative actions but noted that buyer-centered collaborations may not be as effective on their own as strategies to address the technology and process information barriers they are identifying. Buyers also identified several potential complications and complexities with collaborative off-take projects, i.e., a solar thermal installation that serves multiple buyers. These included the need for geographic proximity between off-takers, a sizeable enough project to serve multiple off-takers, and the increased complexity of having to align multiple buyers in the decision-making and execution processes.
Conclusions, Recommendations, and Next Steps

In considering the four questions listed in the Introduction, this Technology Assessment has:

- Confirmed that solar thermal technologies and systems can meet a significant percentage of industrial heat requirements, making solar thermal an important decarbonization solution;
- Identified an important set of Market, Policy, and Technology barriers, pathways to address some of those barriers, related actions large energy users could consider pursuing;
- Suggested opportunities for expanded collaboration between market stakeholders – solar thermal technology providers, large energy buyers, and others – that may be useful in addressing some of the most fundamental barriers that large energy users reported.

Large energy users clearly stated that before they can do anything else on solar thermal energy, they need a pathway to quickly and easily understand their specific solar thermal opportunities. This is one of the leading findings of this Assessment: buyers need a way to assess their solar thermal opportunities efficiently in order to consider solar thermal as a strategic resource across their complex and often multinational portfolios.

The RTC will continue our work on solar thermal and engage the key stakeholders that can drive markets, technologies, and policies. These stakeholders include:

- Large energy users: This is the RTC’s core audience. To accelerate solar thermal energy deployments, we need to address buyers’ barriers and provide solutions that buyers can use.
- Technology providers: Solar thermal technologies continue to evolve, improve, and provide expanded capabilities for end-users. Technology providers have deep expertise in this range of solutions, and the RTC will help make this expertise accessible.
- Renewable energy advisors: Advisors provide specialized expertise in renewable energy markets, technology and developer diligence, strategy design, commercial execution support, and monitoring and verification services. Leading advisors are expanding their capabilities to include renewable thermal strategies, including solar thermal.
- Energy project financiers: Third-party finance has also been essential to scaling renewable electricity. Third-party financing options continue to expand across energy efficiency, renewable electricity, and...
other energy services. Many large energy users will continue to utilize external capital to address energy-related projects and transformations. Financiers will have perspectives on how to align financing solutions with solar thermal opportunities.

There is work we can do to accelerate solar thermal deployments. The technologies are robust and continuing to develop, and large energy users are interested in solar thermal solutions. We can make significant progress on decarbonizing industrial, commercial, and institutional thermal energy use by expanding and continuing this collaboration.
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.