

DEEP DIVE

CLEAN AIR TASK FORCE



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This report was updated in November 2024. Unless otherwise cited, information in this deep dive comes from direct correspondence with Clean Air Task Force.

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Questions and comments are welcome at givinggreen@idinsight.org.

Cover image: Peter Leahy



Summary

[Clean Air Task Force \(CATF\)](#) is one of the top climate nonprofits selected by Giving Green in 2024. We previously recommended CATF in [2023](#), [2022](#), [2021](#), and [2020](#). CATF has a history of successfully advocating for a wide array of climate provisions in the US and is expanding its influence internationally. In particular, CATF has begun to scale its work on technology innovation to include global implementation and commercialization, focusing on technologies that are either nascent or lack broad support from civil society. By raising awareness and advocating for favorable policies in these areas, we think CATF can speed up decarbonization in sectors that might otherwise struggle to secure funding.

When we reassessed CATF in 2024, we closely analyzed three program areas aligned with our sectors of focus—superhot rock energy, zero-carbon fuels, and transportation decarbonization—and were impressed by the teams' technical analysis, stakeholder engagement, and policy advocacy. While we have not assessed the other program areas in detail, we have a strong view of CATF's work overall; our recommendation is for unrestricted funding of the organization at large.

CATF would use additional funds to support the multi-year strategies of its existing programs and continued international expansion.

- **What is CATF?** CATF is a nonprofit that advocates for a suite of technologies and policies to decarbonize the economy across sectors. CATF's work can be generalized into three categories: modeling and systems analysis, technology innovation, and policy advocacy. While it has predominantly focused on the US in the past, it has expanded its work to the EU, the Middle East, and Africa.
- **How could CATF address climate change?** Many technologies that CATF prioritizes are either nascent or not broadly supported by civil society despite being recognized as critical to decarbonization. By elevating these issue areas to public attention and advocating for favorable policies, CATF can help accelerate decarbonization in areas that may otherwise struggle to secure funding.
- **What are some of CATF's historical accomplishments?** CATF helped secure key climate provisions in the bipartisan US. Energy Act of 2020, and provided technical assistance and input on important authorization and funding measures in the Infrastructure Investment and Jobs Act (IIJA). It also successfully advocated for Inflation Reduction Act (IRA) provisions relating to cutting methane pollution, advancing neglected low-emissions technologies, and making tax incentives and grants stackable. CATF was instrumental in catalyzing the Global Methane Pledge, introduced by US President Joe Biden and EU President Ursula von der Leyen in September 2021, and signed by more than 100 countries at COP26. Under this pledge, countries collectively agree to reduce methane emissions by 30% by 2030.
- **What's new at CATF in 2024?** CATF has been deeply engaged in advancing key policy priorities in the US and EU that align with our philanthropic strategies, including a federal clean fuel standard and R&D funding for advanced geothermal technologies. Moving forward, CATF is continuing its



expansive policymaker engagement and education on these crucial policy levers. CATF is conducting first-of-a-kind modeling of the full U.S. transportation sector to assess the impact on fuel demand and emissions under a range of potential policy developments. In terms of its work on geothermal, CATF continues to provide thought leadership on superhot rock geothermal and has broadened its policy work to include supporting demonstrations of existing next-generation geothermal technologies. CATF's efforts underpin its goals to enable positive policy progress on key technologies in priority geographies.

- **Is there room for more funding?** We think that CATF could effectively absorb more money to expand geographically and sustain multi-year program strategies.
- **Are there major co-benefits or potential risks?** We think the major co-benefits and adverse effects of CATF's work are more directly linked to the technologies for which CATF advocates. For example, co-benefits for geothermal include a geothermal power plants' smaller land footprint compared to other generating technologies, improved air quality compared to continued fossil fuel usage, and job opportunities for former fossil fuel workers. Adverse effects include risks of contaminated groundwater and induced seismicity. Co-benefits for ZCFs include lower air pollution, and adverse effects include toxicity and other safety concerns. For more information, see our deep dives on [Geothermal Energy](#) and [Decarbonizing Aviation and Maritime Shipping](#).
- **Key uncertainties and open questions:** Key uncertainties include the consequences of rapid growth, support of incentives for power sector carbon capture utilization and storage (CCUS) and enhanced oil recovery (EOR) for storage of captured emissions or atmospheric removals, support for a broad low-carbon hydrogen portfolio, hedging our bets on next-generation geothermal technologies in different stages of development, and the general feasibility of decarbonizing aviation.
- **Bottom line / next steps:** We classify CATF as one of our top recommendations for nonprofits addressing climate change. We think there is strong evidence to support its work in technological innovation and its increasingly international influence. Also, we think its strategy of focusing on emerging technologies and neglected sectors can help accelerate interventions and activities that would otherwise struggle to secure funding. In particular, we find its work in superhot rock energy, zero-carbon fuels, and transport decarbonization to be highly effective and complementary to the work of our other recommendations in geothermal energy and decarbonization of aviation and maritime shipping: [Project InnerSpace](#) and [Opportunity Green](#), respectively.

What is CATF?

Clean Air Task Force (CATF) is a nonprofit that advances technologies and policies for economy-wide decarbonization. Its work can be generalized into three categories: modeling and systems analysis, technology innovation, and policy advocacy.¹ Since its founding in 1996, it has built close relationships with policymakers and brought in staff with extensive legal, technical, and policy experience.²

¹ "As problem solvers and creative environmentalists, we achieve change in three main ways..." [CATF \(n.d.\)](#)

² Founding date: "When CATF was launched in 1996, our strategy was simple: enact federal policy to force older coal plants to meet the same emission rates as new plants." [CATF \(n.d.\)](#) Staff: For more information on CATF's staff, please see its "[Meet Our Experts](#)" page.



Our impression is that CATF's strategy promotes the innovation of targeted climate technologies that are either emerging or not broadly supported by civil society. For example, CATF has program areas in nuclear, geothermal, and hard-to-electrify transport, which we consider relatively neglected by philanthropy. CATF's work focuses on nascent technologies, such as advanced nuclear, superhot rock (SHR) geothermal energy, and zero-carbon fuels, within each of these sectors. See the figure below for a full list of CATF's program areas.



Figure 1. CATF program areas (courtesy of CATF)

While its policy work has historically been focused on the US, CATF has been increasing its international engagement. For example, it was instrumental in catalyzing the Global Methane Pledge, which was introduced by US President Joe Biden and EU President Ursula von der Leyen in September 2021 and signed by over 100 countries at COP26.³ Under this pledge, countries collectively agreed to reduce methane emissions by 30% by 2030.

CATF has also begun to scale its work on technology innovation to include global implementation and commercialization. For example, it is interested in expanding energy access in Sub-Saharan Africa and connecting people to low-emission energy sources like SHR. In the Middle East and North Africa, CATF has

³ "President Biden and President Von der Leyen announced at the September 17 Major Economies Forum (MEF) meeting that the United States and the European Union are inviting countries to support the Global Methane Pledge to be launched at COP 26 in November 2021 in Glasgow... Participants joining the Pledge agree to take voluntary actions to contribute to a collective effort to reduce global methane emissions at least 30 percent from 2020 levels by 2030, which could eliminate over 0.2°C warming by 2050... With over 100 countries on board, representing nearly 50% of global anthropogenic methane emissions and over two thirds of global GDP, we are well on our way to achieving the Pledge goal and preventing more than 8 gigatons of carbon dioxide equivalent emissions from reaching the atmosphere annually by 2030." ["About the Global Methane Pledge" \(n.d.\)](#)



focused on catalyzing and accelerating networks for low-carbon hydrogen, including that produced from natural gas and supported with carbon capture and storage (CCS) and upstream methane controls.

Giving Green recommended CATF in [2022](#), [2021](#), and [2020](#), concentrating our assessment on its US federal policy work. Following the passage of the bipartisan Infrastructure Investment and Jobs Act (IIJA) and Inflation Reduction Act (IRA), we shifted our focus from general US domestic policy to concentrating on sector-specific philanthropic strategies with a global focus. To match this shift, we evaluated the work of CATF that overlapped with some of our prioritized strategies for [2023](#) and 2024. Specifically, we analyzed CATF's work on [SHR](#), [zero-carbon fuels](#), and [transportation decarbonization](#). The next section presents a more detailed, program-specific analysis of these three areas.

Program snapshots

For the three program areas mentioned above, we give an overview of each program, describe its main strategies, illustrate our interpretation of its theory of change, and evaluate the assumptions behind the theory of change. For each assumption, we rank whether we have **low**, **medium**, or **high** certainty about the assumption.⁴ Our assessment is based on both primary and secondary evidence, as well as our general impression of the plausibility of the assumption. Importantly, a number of the stages of the theory of change may not be amenable to easy measurement or quantification, are not supported by a robust evidence base, or are expected to occur in the future but have not occurred as of yet.

Superhot rock energy

Strategies

CATF focuses on superhot rock energy (SHR), a proposed energy source that could potentially supply cost-competitive and on-demand renewable energy for heating and electricity generation.⁵ SHR is considered further from technological readiness compared to other enhanced geothermal systems and has been described as a moonshot technology.⁶ (For more information on geothermal energy, please see our [geothermal energy deep dive report](#).) CATF's SHR team's strategies include conducting technical analyses, building momentum for SHR globally through stakeholder engagement, and advocating for supportive policies in the US.

⁴ We describe our certainty as low/medium/high to increase readability and avoid false precision. Since these terms can be interpreted differently, we use rough heuristics to define them as percentage likelihoods the assumption is, on average, correct. Low = 0-60%, medium = 70-80%, high = 80-100%.

⁵ "Superhot rock energy is poised for a breakthrough as a high-energy-density, zero-carbon, always available energy source that could be commercialized worldwide in the 2030s. Analyses for Clean Air Task Force (CATF) by Lucid Catalyst and Hotrock Energy Research Organization (HERO) suggest that, with more ambitious geothermal energy funding and public-private partnerships to spur innovation, it could be cost-competitive with most zero-carbon technologies—transforming global energy systems by providing clean, firm, cost-competitive renewable energy while requiring significantly less land than other sources." [CATF \(2022\)](#)

⁶ The Superhot Moonshot: [PIVOT from Hydrocarbons to Heat \(2022\)](#)



Technical analysis

The SHR team analyzes and communicates research and technological gaps in SHR development. An example of its work is its 2023 [Bridging the Gaps](#) series, five flagship reports analyzing key barriers and pathways forward for SHR development. It has also developed a [Superhot Rock Project Map](#), an interactive map that indicates how deep projects will need to dig to reach 450°C, the temperature needed for SHR, and the locations of existing and planned SHR projects and wells.⁷ This tool is intended to drive awareness of SHR.

Stakeholder engagement

CATF creates networks for sharing resources and knowledge to speed up innovation and reduce risks related to SHR projects. To do so, CATF acts as a catalyst and coordinator between technology companies, industry partners, government officials, and potential investors.⁸ It has identified opportunities for research and demonstration globally, including efforts in Africa, Asia, the Americas, Europe, and Oceania.⁹ CATF introduced SHR at global fora, such as COP27, to drive public awareness and convince delegates that SHR is worth supporting. Furthermore, in 2024, CATF organized the first technology-specific SHR summit, which convened experts to help build a roadmap for international technology development.¹⁰ Our understanding is that this summit supports CATF's engagement of the US Department of Energy and the Advanced Research Projects Agency–Energy (ARPA-E), which have released a Request for Information for novel approaches to using SHR for electricity production and other uses.¹¹

Policy advocacy

In the US, CATF's SHR team has urged Congress to include SHR pilot demonstrations in budget appropriations. We think its advocacy has been successful given that the bipartisan Infrastructure Investment and Jobs Act (IIJA) of 2021 included \$74 million to support pilot demonstration projects of

⁷ "In order to drive awareness of superhot rock energy's unparalleled potential, CATF created a Superhot Rock Project Map which highlights superhot rock projects in various states of maturity. The map shows the estimated depth to reach 450°C across the world, as well as existing and planned superhot rock projects and wells." [CATF \(n.d.\)](#)

⁸ "Act as a catalyst and coordinator, bringing together technology companies, industry partners (including multinational energy companies), government officials, and potential investors to create a network that galvanizes the SHR ecosystem and facilitates a roadmap for SHR research and development and demonstration (RD&D) projects". [CATF \(n.d.\)](#)

⁹ "CATF has identified opportunities for SHR research and demonstration across the world. These include recent EU-funded efforts in Iceland, Italy, Mexico, and New Zealand; venture capital investments such as GA Drilling, an energy drilling start-up in Slovakia; geothermal energy resources in Ethiopia and Kenya; the world's first SHR demonstrations, run by U.S.-based startups AltaRock Energy, Eavor, Geothermic Solutions, and GeoX Energy; critical technology development by U.S. national laboratories and companies like Houston's Quaise; key RD&D taking place in Japan to develop low-risk SHR resources; and work in China (where we currently advise a private company that has since built an SHR laboratory) and India (where we are in dialogue with an Indian NGO)." [CATF \(n.d.\)](#)

¹⁰ "COP: 'We are here to raise awareness – this energy source is nearly unrecognised in the decarbonisation debate, despite the fact that it is truly unparalleled,' she added. 'It is taking the niche industry of geothermal to the next level by amping it up with additional temperature and additional pressure.' Rogers is hoping to convince delegates to make a bet on deep geothermal energy as a key technology for the future." [Keating \(2022\)](#). Superhot Rock Energy Summit: "Sessions include author presentations of CATF-commissioned reports, panels from leading experts in the field, and strategy sessions with other leading experts to build a roadmap for international technology development in this space." [CATF \(2024\)](#)

¹¹ "The U.S. Department of Energy (US DOE) and the Advanced Research Projects Agency–Energy (ARPA-E) have published a Request for Information (RFI) to evaluate novel approaches to superhot enhanced geothermal power for generating electricity and other uses." [Cariaga \(2024\)](#)



enhanced geothermal systems, including SHR.¹² According to CATF, \$20 million of those funds are allocated for SHR pilot demonstrations. From our conversations with policymakers, we learned that CATF was instrumental in shaping the US geothermal roadmap that includes SHR. CATF also works on the regulatory side, identifying and documenting best practices related to seismicity and groundwater protection.¹³ We think its work on identifying regulatory best practices could act as a blueprint for geothermal projects outside the US.

In 2024, CATF's ongoing policy work includes engaging with policymakers on H.R.6482, a bill to boost geothermal production on federal lands, and a related Senate bill. Our understanding is that H.R.6482 will likely include provisions for field testing of some ultra-temperature technologies helpful for SHR development. CATF is also working in collaboration with other leading NGOs to support clean firm power by leveraging the Inflation Reduction Act's energy transition "adders," which incentivize specific elements of an equitable clean energy transition.

Although CATF remains keenly focused on SHR, CATF broadened its policy scope in 2024 to also support existing geothermal technologies with a focus on next-generation technologies. It aims to enable demonstrations at temperatures available today and create a strong foundation for future geothermal advancements, including SHR. For example, it was a driving force behind H.R.8665, which would fund R&D for SHR and enable data sharing and coordination to benefit all next-generation geothermal energy.¹⁴ We think CATF's broadened scope can help derisk next-generation geothermal technologies and drive down costs, potentially leading to wider deployment and reduced emissions.

¹² Bipartisan Infrastructure Law: "On February 8, 2023, the U.S. Department of Energy (DOE) announced up to \$74 million to support enhanced geothermal systems (EGS) pilot demonstration projects called for in President Biden's landmark Bipartisan Infrastructure Law. The legislation authorizes DOE to support up to seven competitively selected pilot projects that collectively demonstrate EGS in different geologic settings, using a variety of development techniques and well orientations." [Geothermal Technologies Office \(2024\)](#). Inclusion of SHR: SHR was listed as one of the topic areas in DOE's funding opportunity announcement. Ibid.

¹³ "Identify and document best practices relating to seismicity and groundwater protection to facilitate establishment of smart, supportive, and protective regulatory oversight." [CATF \(n.d.\)](#)

¹⁴ For more information on H.R. 8665, please see <https://www.congress.gov/bill/118th-congress/house-bill/8665>. Evidence of CATF's engagement: "Ms. Terra Rogers, Program Director, Superhot Rock Energy, Clean Air Task Force, Boston, Massachusetts [H.R. 7053 & H.R. 8665], [Minority Witness]" [House Committee on Natural Resources \(2024\)](#).



Theory of change

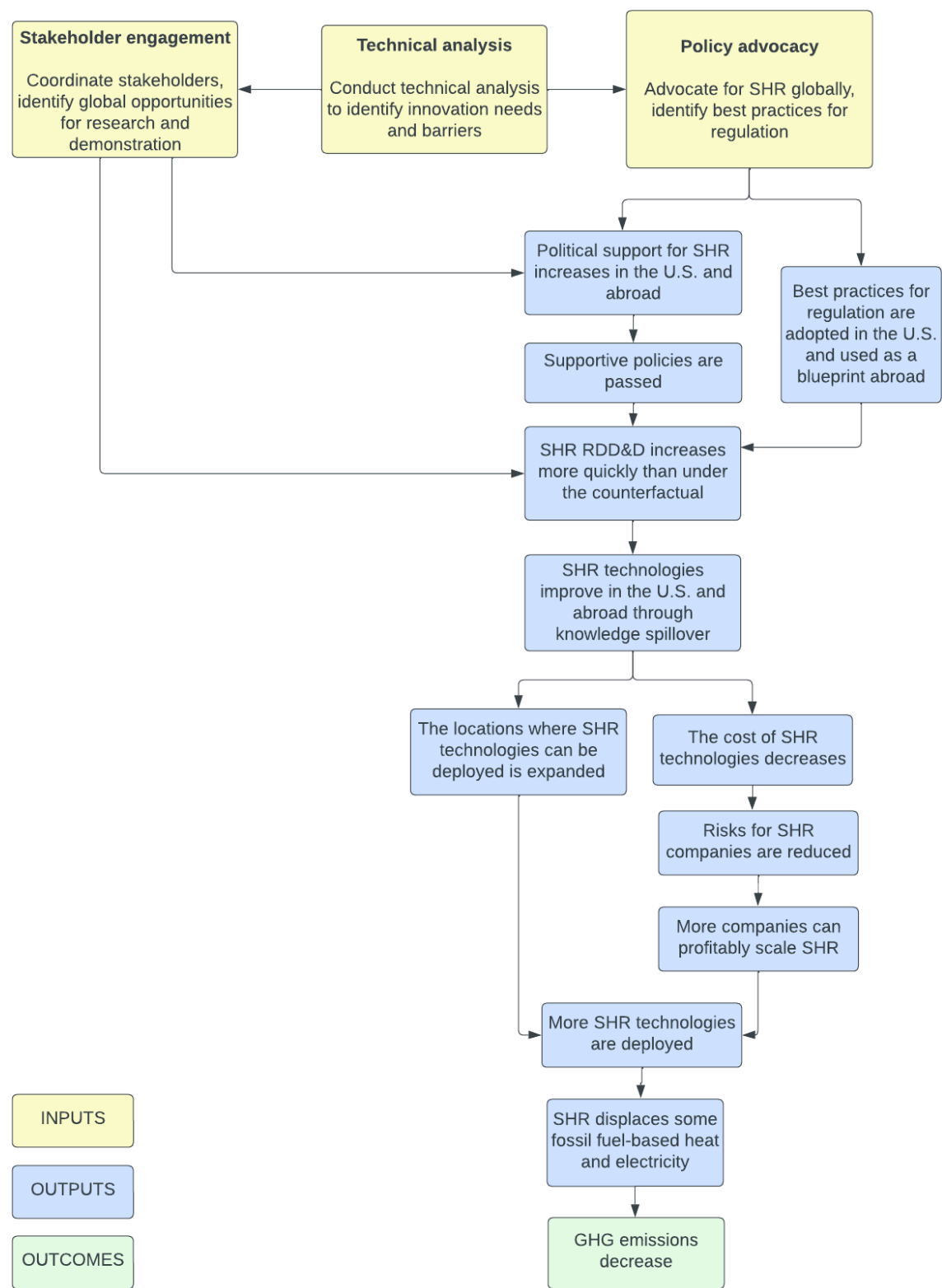


Figure 2: Theory of change diagram for CATF's SHR program



Examining key assumptions

To better understand and evaluate how CATF's SHR program can lead to decreasing greenhouse gas (GHG) emissions, we developed a theory of change (**Figure 2**). We note two key assumptions in our theory of change for CATF's SHR program:

1. *CATF's work increases the likelihood that supportive policies for SHR are passed and speeds up RDD&D relative to the counterfactual (**high certainty**)*

We have high certainty that CATF's efforts increase the chances of passing supportive policies for SHR and accelerating SHR research, development, demonstration, and deployment (RDD&D). We believe that without CATF, there would be a lack of advocacy for SHR policies. This impression is based on the fact that, among the limited number of nonprofits supporting geothermal energy, CATF has been the most outspoken advocate for SHR.¹⁵ Given that SHR is a specialized technology, we also believe that the few companies working on it lack a significant platform for advocacy. Geothermal experts and funders have told us that CATF has played a crucial role in raising awareness of SHR in the public eye. Furthermore, we have learned from others that CATF's technical reports have been valuable in roadmapping a potential future for SHR in the US.¹⁶

2. *Supporting SHR RDD&D will increase the likelihood of its commercial viability (**medium certainty**)*

We think it's likely that supporting SHR RDD&D will improve the technologies needed to access SHR and increase the likelihood that it becomes commercially viable. However, we are not certain that SHR will ever be viable because, compared to other next-generation geothermal technologies, SHR is not as far along in its development timeline. Other next-generation technologies may be able to outcompete SHR in terms of cost, but there is always considerable uncertainty in predicting what learning curve a new technology will follow. We discuss the trade-offs between SHR and other next-generation options in our section on [key uncertainties and open questions](#).

Zero-carbon fuels

CATF's zero-carbon fuels (ZCF) program aims to advance low-carbon hydrogen to reduce emissions across sectors where limited or no other energy-efficient or cost-effective alternatives for decarbonization exist, including maritime shipping, long-haul trucking, ironmaking, industrial heating, aviation, and energy storage.¹⁷ The team's primary focus is reducing emissions from existing hydrogen production and deployment in end-use sectors, including steel, ammonia for fertilizers, methanol, and oil refining. The team's secondary focus is promoting low-carbon hydrogen for scaled next-generation applications, such as producing synthetic jet fuel for aviation and ammonia for shipping. Its efforts have

¹⁵ Our understanding is that Project InnerSpace is more focused on deploying next-generation geothermal technologies that are further along in RDD&D and less focused on SHR. Other geothermal organizations represent the interests of both conventional geothermal technologies and next-generation technologies and are less focused on SHR compared to CATF.

¹⁶ While it restricts our transparency with readers, we frequently engage in confidential conversations where we promise to protect the identity of our sources. As a result, we cannot disclose the names of these specific sources.

¹⁷ Unless otherwise cited, information in this section comes from direct correspondence with CATF as well as the following resources: [CATF ZCF Overview \(February 2023\)](#), [CATF ZCF \(July 2023\)](#)



mainly focused on the US, EU, and Middle East, but it plans to continue expanding globally to meet demand and production opportunities for ZCF.

Strategies

Technical analysis

CATF supports the scaling of zero-carbon fuels globally by undertaking technical analysis which produces reports and tools to grow public awareness, influence policy and regulation design, promote innovation, and shape the market. In parallel, this work serves to enhance and support the work of other CATF programs, including [Transportation Decarbonization](#). Reports and tools produced by the ZCF team include:

- Public, peer-reviewed, techno-economic models of low-carbon hydrogen production and [long-distance transport](#) to elevate factors that could reduce present-day challenges such as cost, storage, and transportation.
- The [Hydrogen Production Calculator](#), which is intended to help quantify the resources needed to produce a selected amount of hydrogen (by type) or ammonia.
- A [model for the full lifecycle emissions of hydrogen production](#) based on jurisdiction and production pathway, published in October 2023. Not only will this help to inform the structure of standards and incentives, but it can also be used to address air quality and climate impacts such as supply chain methane emissions and hydrogen leakage. The team also published [a cost model for hydrogen and ammonia production](#) to help stakeholders estimate costs and understand the parameters influencing costs.
- An [assessment of the role of low-carbon hydrogen in the power sector](#), which concluded that while technically feasible, using hydrogen as a fuel for decarbonizing power generation is unlikely to be economical at a large scale compared to other options.

Stakeholder engagement

The team aims to elevate awareness of the role of ZCFs in hard-to-electrify sectors through [public events](#), communications materials, policy briefings, and alignment and [convenings of key stakeholders](#). It also facilitates global dialogue between emerging ZCF producers and buyers to align potential supply and demand, strengthen the market ecosystem, and pave the way for offtake agreements. The team maintains a network of partners in industry, civil society, and academia. It uses these partnerships to find the needed innovation initiatives for ZCF production and adoption and to promote practical ways to expand ZCF technology in global markets.

Policy advocacy

The ZCF team identifies policy and regulation as key levers supporting innovation, infrastructure, and market shaping. It encourages policies that support ZCF production in hard-to-decarbonize sectors, align emissions accounting and certification for international hydrogen trade, and fund demonstration projects to help launch technologies, infrastructure, and partnerships. Examples include its engagement on [US](#)



[hydrogen hubs](#)—regional networks of low-carbon hydrogen producers, consumers, and enabling infrastructure—and [Fit for 55](#)—a policy package aiming to reduce the EU’s emissions by 55% by 2030.

Theory of change

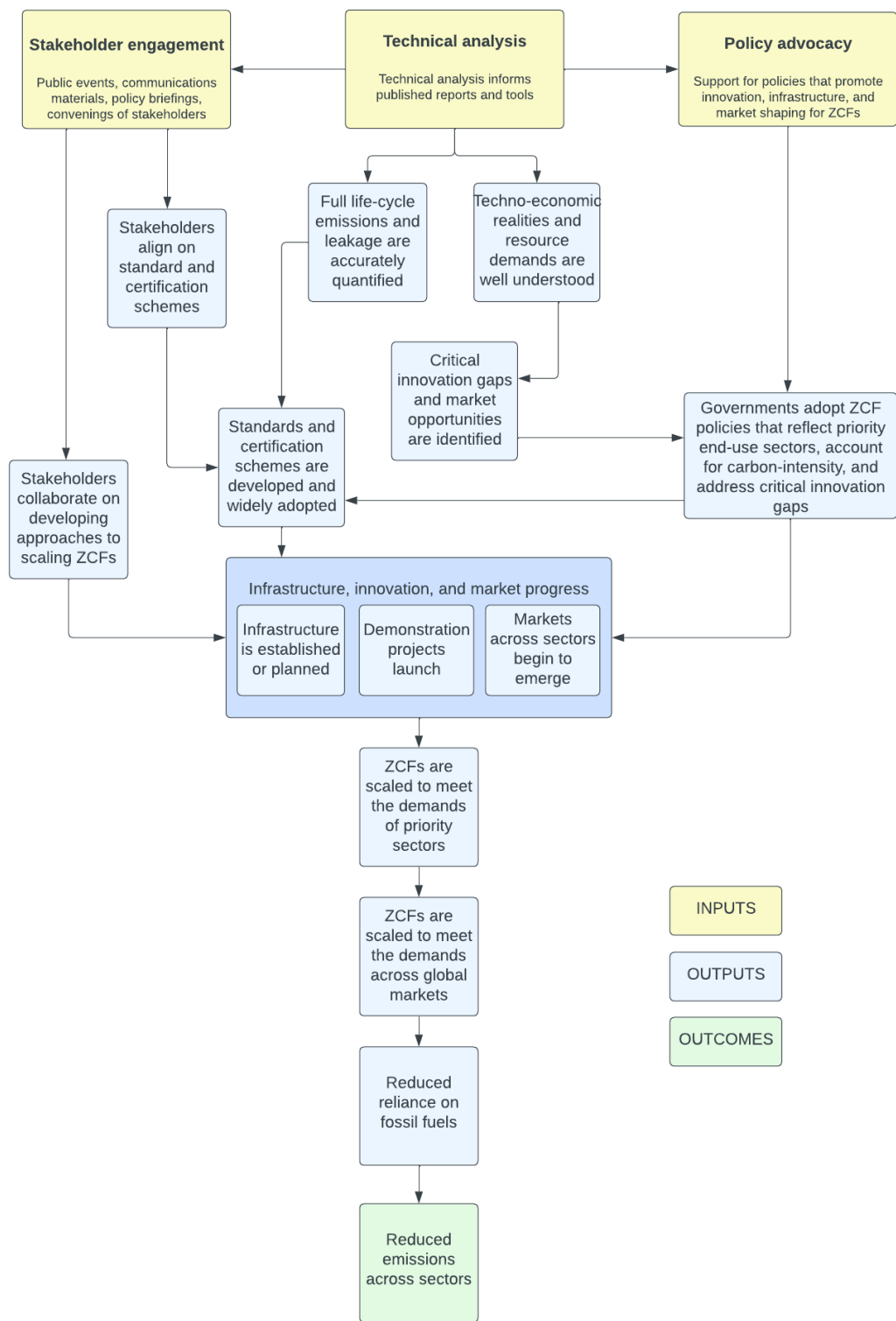


Figure 3: Theory of change diagram for CATF’s ZCF program



Examining key assumptions

To better understand and evaluate how CATF's ZCF program can lead to decreasing GHG emissions, we developed a theory of change (**Figure 3**). Below, we discuss and evaluate three key assumptions related to our theory of change for the ZCF program.

1. *CATF's ZCF analysis informs standards setting, certification schemes, policy advocacy efforts, and stakeholder engagement (high certainty)*

We believe CATF's strong suit is its in-depth technical analysis, which we confirmed by evaluating its publications and talking to external experts. In the context of ZCFs, we find that CATF's tools and reports address critical technical gaps in the sectors for which (i) research is still ongoing, (ii) information is hard to access for groups like communities, civil society, or policymakers; or (iii) resources are needed for creating or implementing specific standards and policies. One example is its work to model hydrogen production's resource demands, including energy and water feedstocks. We think this could help avoid future uncertainties around incentive structures such as those that arose for the 45V tax credit.¹⁸

2. *CATF's efforts to build public awareness and convene stakeholders facilitate alignment for standards-setting and certification schemes, broaden support and investment for innovation and infrastructure, and encourage market growth (medium certainty)*

Because of CATF's established reputation, international presence, and strong cross-sectoral network, we have high confidence in its role as a convener of diverse stakeholders.¹⁹ Given the broad applicability of ZCFs, we think it is likely that CATF's team can leverage well-established partnerships forged through past work in other program areas. However, given its advocacy for a broad low-carbon hydrogen portfolio, as well as the organization's historical support of incentives for power sector carbon capture utilization and storage (CCUS) and enhanced oil recovery (EOR) for storage of emissions or atmospheric removals, we have less certainty about its effectiveness at facilitating alignment across stakeholders who perceive these technologies as levers to prolong fossil fuel use. We address some of these concerns in more detail in our section on [key uncertainties and open questions](#).

3. *CATF's policy advocacy efforts increase the likelihood of widespread adoption of robust ZCF policies (high certainty)*

Similar to our assessment of its convening power, we have high certainty in CATF's ability to influence policy, given its track record of success in the US and its growing international presence. For example, CATF helped secure key climate provisions in the bipartisan Energy Act of 2020 and provided technical assistance and input on important authorization and funding measures in the IIJA. It also successfully advocated for the IRA and its provisions for cutting methane pollution, advancing neglected

¹⁸"The worries, shared by the Clean Air Task Force, the Environmental Defense Fund and the Union of Concerned Scientists, are grounded in a study from a team of scientists at Princeton University. It concludes the looser accounting guidelines influential industry players are seeking would enable them to make the energy-intensive fuel without adding enough new clean power to local electricity grids to produce it." [Halper \(2023\)](#)

¹⁹"At COP27, panelists explored how the Middle East and North African regions can seize the opportunity before them and transform themselves from suppliers of unabated fossil fuels into a climate-forward, global suppliers of abundant clean energy." [CATF \(2022\)](#)



low-emissions technologies, and making tax incentives and grants stackable.²⁰ In addition, it continues to be engaged throughout the implementation phase of these policies. For example, after the [October 2023 announcement](#) regarding the allocation of \$7 billion to seven regional hydrogen hubs, CATF released guidance on [priority end-use sectors](#) and the role of [community engagement](#). We believe the US policies it contributed to and its advocacy strategies can be used as blueprints for different contexts and geographies as it expands its ZCF work.

4. *Policies and stakeholder coordination enable low-carbon hydrogen to scale to meet the needs across sectors (medium certainty)*

Given cross-sector demand and the uptick in supply-side hydrogen policy initiatives, we have medium certainty that low-carbon hydrogen can scale to meet needs as a direct energy source or as a feedstock for other alternative fuels.²¹ For more information, see our [deep dive report on decarbonizing aviation and maritime shipping](#).

Transportation decarbonization

CATF's Transportation Decarbonization program aims to reduce emissions from the transportation sector to zero by mid-century.²² Its Transportation Decarbonization team concentrates on hard-to-electrify transportation modes like aviation, maritime shipping, long-haul trucking, and road transport in emerging economies with inadequate electric grids for vehicle electrification. In parallel with its efforts promoting zero-emission vehicles, the Transportation Decarbonization team supports work to develop and scale low- and zero-carbon fuels and the requisite infrastructure.

Thus far, the Transportation Decarbonization team has focused on the US and EU because it claims these geographies (i) hold the most feasible political opportunities and investments to launch ZCF markets and (ii) are centers of influence for relevant international bodies such as the [International Maritime Organization \(IMO\)](#) and [International Civil Aviation Organization \(ICAO\)](#). In 2022, the team began expanding its work to emerging economies (India and Kenya) and it plans for further growth.

Strategies

Technical and market analysis

The team conducts technical and market analyses to identify innovation needs and market barriers for each transport pathway. For example, the team assessed alternative fuel options for maritime shipping and identified hydrogen and ammonia as the most viable, and it developed a tool for assessing and

²⁰Energy Act of 2020: [CATF \(2020\)](#); IIJA: [CATF \(n.d.\)](#) IRA: [CATF \(2022\)](#)

²¹ Hydrogen policy: for instance, see [IEA's hydrogen policy database](#).

²² Unless otherwise cited, information in this section comes from direct correspondence with CATF as well as the following resources: [CATF Transportation Decarbonization Overview \(February 2023\)](#), [CATF Transportation Decarbonization Program \(November 2023\)](#)



managing the cost of transitioning to alternate marine fuels.^{23,24} It has also released a [report on the benefits and limitations of emerging fuels in aviation](#) and an [assessment of emerging aviation decarbonization technologies](#). We think this analysis is foundational to informing the team's focus areas and policy recommendations and to supporting these positions publicly.²⁵

Stakeholder engagement

The transportation team engages companies—e.g. vehicle manufacturers, fleet owners and operators, and fuel suppliers—with technology experts to validate and align around its analysis and findings, including major innovation and market gaps. It also fosters cross-sector collaboration to support the demonstration and adoption of new technologies, such as low/zero-emission vehicles, and promote ZCF market growth.

Policy advocacy

The team advocates for policies that support innovation through levers such as incentives, mandates, and performance standards. Our understanding is that this work happens in coordination with other CATF teams, including ZCF and Middle East and North Africa (MENA).

In the US, the team advocates for state and federal emissions standards, clean fuel standards, and effective sustainable aviation fuel (SAF) tax credit structure. It also supports ZCF fueling infrastructure in US ports proximal to hydrogen hubs and pushes the US government to support a strong framework for achieving IMO's net-zero emission targets. CATF is leading the development of a federal carbon-intensity-based fuel standard that would decarbonize all transportation fuels, including electricity, by midcentury.

In the EU, the team advocates for zero-emission truck mandates and infrastructure. It tracks and supports ZCF marine vessel development and green shipping corridors and promotes stronger FuelEU Maritime implementation.²⁶ It also advocates for regulations to guardrail biofuels and policies to scale non-biofuel SAF alternatives.

The team coordinates power sector and transportation decarbonization in emerging economies, with a current focus on India and Sub-Saharan Africa. It works to prompt ZCF fueling infrastructure in ports and shipping corridors, for example, between Singapore and Shanghai and between the US and the UK. It also works to ensure that the federal hydrogen hubs program leverages opportunities for shipping and trucking decarbonization and establishing clean transport corridors between hubs.

²³ "Clean Air Task Force has conducted extensive analysis to determine pathways to eliminate emissions from the global marine shipping sector, and has found that switching the sector from high-emitting fuels to zero-carbon fuels like hydrogen and ammonia has the greatest likelihood of success." [CATF \(2021\)](#)

²⁴ [CATF \(2024\)](#).

²⁵ Examples: [Greenwald \(2021\)](#), [Lewis \(2021\)](#)

²⁶ "Green maritime shipping corridors are an avenue for coordinating across stakeholder groups in specific high-potential geographies to align incentives, test-drive new technologies, target investments, and build public-private partnerships." [Our Shared Seas \(2023\)](#)



Theory of change

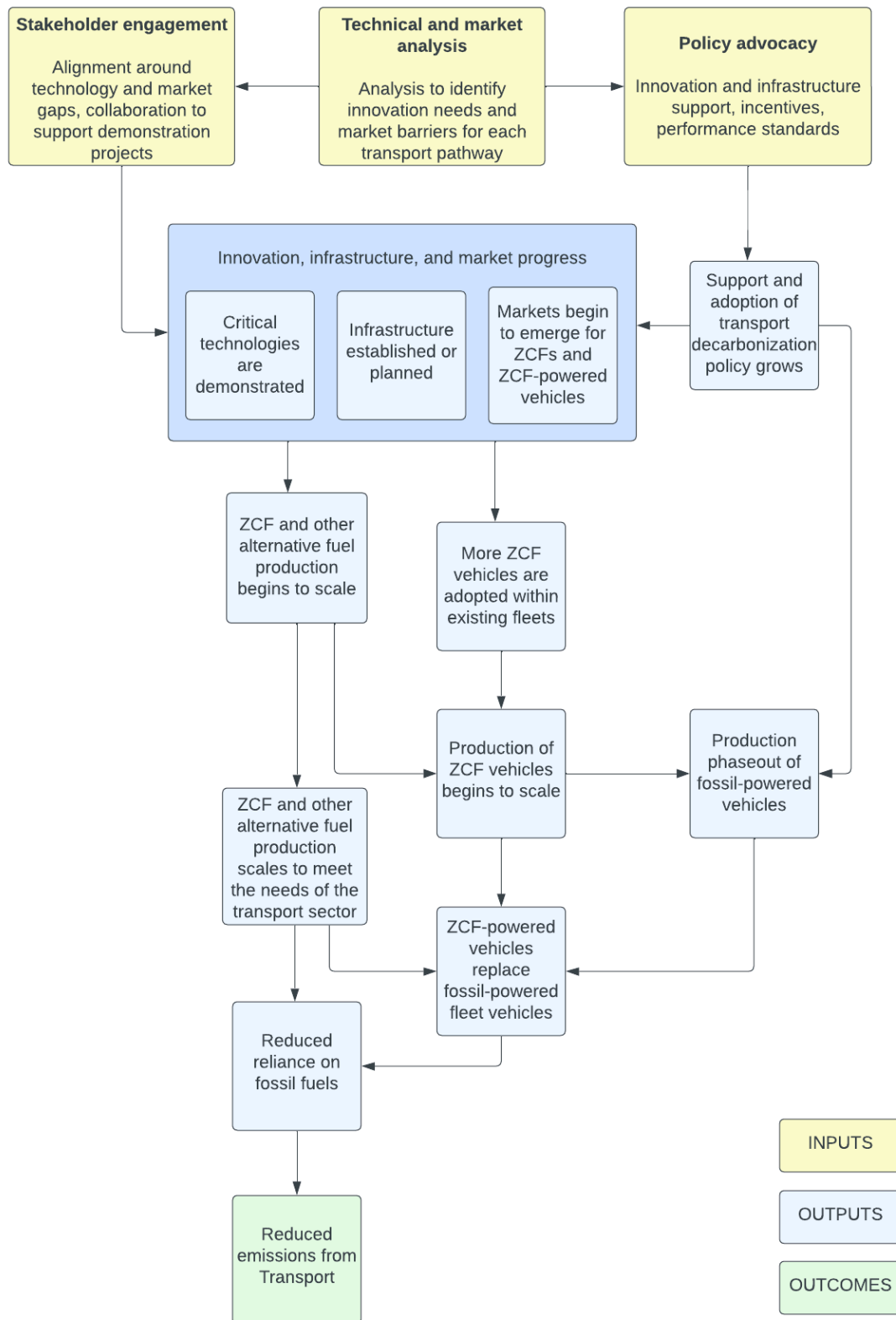


Figure 4: Theory of change diagram for CATF's Transportation Decarbonization Program



Examining key assumptions behind the theory of change

To better understand and evaluate how CATF's Transportation Decarbonization program can lead to decreasing GHG emissions, we developed a theory of change (**Figure 4**). Below, we discuss and evaluate key assumptions related to the theory of change for the Transportation Decarbonization Program.

1. *CATF's technical analysis supports stakeholder engagement and policy advocacy and influences innovation, infrastructure, and market progress (**high certainty**)*

Technical and market analysis has led the team to focus on hard-to-electrify transport sectors and identify key technological and market gaps. For example, the modes of transport on which the team focuses, such as aviation and maritime shipping, have been neglected with respect to general road transport. Within aviation and maritime shipping, the team has identified ZCFs as a critical yet nascent technology for decarbonization.

We think conducting deep technical analysis enables the team to channel its stakeholder engagement and policy advocacy toward the greatest marginal impact, targeting the organization's efforts to address neglected yet critical innovation needs. For example, CATF's analysis of the limited overall potential of biofuels led to the development of a policy to transition biofuel use from the road sector, which can largely electrify, to the aviation sector, which cannot.

2. *CATF's policy advocacy leads to increased adoption of policies supporting transportation decarbonization (**high certainty**)*

As described in the strategy description, the team has targeted policy approaches for each geography in which it works, including the US, EU, India, and Sub-Saharan Africa. We think that this global scope, paired with local considerations, demonstrates experience and familiarity with policy advocacy in different contexts and the ability to leverage the comparative advantages of certain political contexts or geographies. This, combined with CATF's track record of success with US policy, gives us high certainty that its advocacy work will increase the support and adoption of policies for decarbonizing transport globally.

3. *Policies for ZCFs and other fuels enable alternative fuels for shipping and aviation to become cost-competitive and scale to meet the needs of the sectors (**medium certainty**)*

The cost trajectories of alternative fuels are highly correlated to the cost of low-carbon hydrogen. Given cross-sector demand and the uptick in supply-side hydrogen policy initiatives, we have medium certainty that low-carbon hydrogen can become cost-competitive in the near term and be scaled to meet these needs as a fuel or feedstock for low-carbon shipping and aviation fuels. On the other hand, the production cost of synthetic jet fuels, or e-sustainable aviation fuels (e-SAFs), will depend on the cost of sourcing low-carbon hydrogen and climate-neutral CO₂. The most climate-beneficial sources of CO₂ may either be through carbon removal technologies like direct air capture, which are currently quite expensive, or through sustainable biomass, for which feedstocks are limited. E-SAFs are among the most costly fuels, given the price of feedstocks and the complex chemical reactions involved in the production process. We think that broad and ambitious incentives will be required for e-SAFs to become



cost-competitive with conventional jet-fuel or biomass-based sustainable aviation fuels, and we have less certainty in their ability to scale to meet the sector's needs. We address the feasibility of decarbonizing aviation as a [key uncertainty](#).

Is there room for more funding?

CATF's target 2025 expense budget is currently angled at \$41 million USD. Over the past year, CATF has shifted from a strategy of rapid growth to a focus on building a sustainable revenue base and stabilizing its revenue to \$45-50 million per year over the next five years. We think that this goal is important given its recent revenue challenges and that many of its programs are built upon multi-year strategies that require sustained, multi-year funding. It is our understanding that CATF would use additional funding for:

- **Maintaining and growing existing programs:** CATF programs have developed multi-year strategies requiring sustained or increased funding. For example,
 - The Superhot Rock Energy program needs \$12.5 million over three years to implement its strategies. This includes expanding its policy capacity to seize opportunities in Europe and the US, conducting technical and market analysis for SHR, and continuing its advocacy efforts.
 - The ZCF team seeks to raise an additional \$6 million over three years to execute its strategies, including capacity building, further technical and market analysis, education of stakeholders, and support of first-movers projects and infrastructure development.
 - The Transportation Decarbonization team needs \$6.5 million over three years to execute its strategies, including commissioning or conducting technical and legal analysis, partner engagement, and policy advocacy.
- **Expanding geographically:** CATF plans to expand its geographic scope and policy focus to meet the global decarbonization challenge. We think it is well-positioned to capitalize on the current political climate, influence policy debate within the US and EU, and promote pragmatic climate pathways in Africa and the Middle East.

CATF said it has used past funds from Giving Green donors to support and grow existing programs and launch new initiatives. For example, CATF has cited Giving Green's fundraising as critical to supporting its international expansion to Europe, Africa, and the Middle East.

Based on the above, we think CATF could effectively absorb more money across its programs, especially for work in new geographies. However, we also think there have been consequences for CATF's rapid growth over the past few years, which we mention in our section on [key uncertainties and open questions](#).



Are there major co-benefits or potential risks?

We think the major co-benefits and potential risks of CATF's work are related to the technologies for which CATF advocates. For example, co-benefits for geothermal include geothermal power plants' smaller land footprint compared to other energy-generating technologies, improved air quality compared to continued fossil fuel usage, and job opportunities for former fossil fuel workers. Potential risks include contaminated groundwater and induced seismicity. Co-benefits for ZCFs include lower air pollution, and potential risks include toxicity and other safety concerns.

For more information, see our deep dives on [Geothermal Energy](#) and [Decarbonizing Aviation and Maritime Shipping](#).

Key uncertainties and open questions

- **Consequences of CATF's rapid growth:** CATF more than doubled its budget in recent years, going from a total revenue of almost \$20 million in 2020 to \$46.4 million in 2023.²⁷ We think that this rapid growth caused both internal growing pains and fundraising challenges, as the organization's expansion was predicated on the expectation of continued budget growth year-over-year. We think the departure of several key technical staff raises concerns for us about its capacity to complete important projects. In the coming year, we will reassess how CATF fills these capacity gaps and readjusts its organizational and growth strategy.
- **Advocacy for incentives for power sector CCUS and captured CO₂ storage via EOR:** CATF's advocacy for enhancements to the US [Section 45Q](#) tax credit included continued eligibility for power sector applications of carbon capture utilization and storage (CCUS). There is concern that the tax incentives may extend the life of US coal and natural gas-fired power plants. One analysis suggests that 45Q could increase the operating years of an otherwise end-of-life coal plant into the 2040s, resulting in at least 6 million metric tons of additional CO₂e emissions.²⁸ CATF claims that it foresees little deployment of CCS in the US power sector but that the plants that use it will help bring down its cost through learning by doing, resulting in accelerated uptake in emerging economies. While Giving Green thinks CCS could be a valuable technology in contexts such as heavy industry or power plants in emerging economies, we share concerns about incentivizing its use for US fossil fuel power plants. In addition, CATF has continued to advocate for the inclusion of enhanced oil recovery (EOR) for storage of captured emissions or atmospheric removals in subsidies such as 45Q. CATF argues that EOR is climate-beneficial, that it serves as the primary niche market for scaling capture technologies, and that it can help transition to large-scale saline storage.²⁹ Others question the need to subsidize it, especially given concerns over environmental

²⁷ 2020 budget: "Total Revenue \$19,594,322" [CATF \(2020\)](#)

²⁸ "My analysis suggests that [adding CCS could be worth \\$5-6 billion](#) for this power plant, while increasing emissions by 6 to 8 million tonnes of CO₂-equivalent relative to closing the plant at its end of life." [Grubert \(2023\)](#)

²⁹ "Leveraging the demand for CO₂ from the Enhanced Oil Recovery (EOR) industry is a critical step to building out a robust ecosystem for large-scale CO₂ storage in saline sites." [CATF \(2019\)](#)



justice, the potential to prolong oil extraction, and the involvement of the fossil fuel industry in the trajectory of emerging climate technologies like direct air capture (DAC).³⁰

- **Support for a broad low-carbon hydrogen portfolio:** CATF supports low-carbon hydrogen, including hydrogen produced from steam methane reforming (SMR) paired with methane emissions control and CCUS. Given that this process uses natural gas, we are concerned about continued dependence on fossil fuels, the fossil fuel industry's role in blue hydrogen production, and the climate impacts of blue hydrogen due to methane leaks.³¹ We are also unsure whether investing in general low-carbon hydrogen and the requisite infrastructure could lock in fossil-fuel-derived hydrogen and decelerate the transition to hydrogen produced via clean energy and electrolyzers, a production process we think is more sustainable in the long term.
- **Questioning methanol as a key fuel for shipping vessels:** CATF has elevated hydrogen and ammonia as scalable fuels for decarbonizing the shipping sector and de-emphasized the role of methanol. However, our impression is that the technology to retrofit engines to run on methanol is relatively advanced and that private sector orders for methanol-powered vessels are outpacing those for ammonia-powered vessels.³² Our understanding is that CATF finds ammonia to be more likely to scale and favorable as it does not involve CO₂ as either a feedstock or byproduct of combustion. To reduce the climate impacts of methanol, the CO₂ used as a feedstock must be captured directly from the atmosphere through expensive and emerging technologies like DAC or derived from sustainable biomass, for which feedstocks are limited. If methanol continues to dominate ammonia as an alternative shipping fuel, we are uncertain how effective CATF's advocacy will be. However, we also acknowledge that general carbon-intensity performance standards, such as those for which CATF advocates, may help shift the market to lower-carbon fuels, including low-carbon methanol.
- **Betting on a specific next-generation geothermal technology:** We are uncertain about the expected value of different next-generation geothermal technologies. Giving Green is supporting CATF and [Project InnerSpace](#), which take different approaches to advancing geothermal energy. Our understanding is that Project InnerSpace focuses on new technologies that are further along in development than SHR, which is CATF's primary focus. We think SHR's development trajectory is less clear, but it could offer cheaper and abundant carbon-free energy if it becomes commercially viable. Due to this uncertainty, we think it is important for us to be technology-agnostic and diversify the next-generation geothermal technologies we support. We also recognize that in 2024, CATF expanded its policy scope to support existing geothermal technologies with the aim of paving a path forward for SHR. We think this more diversified approach is in line with our approach to supporting geothermal technologies.

³⁰ "But the core of the climate case against EOR is simple: Climate change is an emergency. We need to bury lots of carbon, but it is crazy to let the oil and gas industry set the pace and the terms." [Vox \(2019\)](#)

³¹ "Far from being low carbon, greenhouse gas emissions from the production of blue hydrogen are quite high, particularly due to the release of fugitive methane." [Haworth et al \(2021\)](#)

³² "By a small margin, methanol proved the most popular alternative fuel choice in 2023 with 138 ships ordered...The year also saw the first orders for vessels due to run on ammonia (11) come through, whereas with just five orders, hydrogen was a less popular choice compared to the previous year (18)." [DNV \(2024\)](#)



- **Feasibility of decarbonizing aviation:** Aviation is one of the most difficult sectors to decarbonize as there is no clear, viable technological pathway. Given the high cost of producing e-SAFs, we think that a possible scenario is that the aviation sector cannot fully decarbonize and could, for some time, rely on carbon removal to compensate for these unabated emissions.³³
- **CATF's cost-effectiveness:** We chose not to quantify CATF's cost-effectiveness given the high uncertainty across key parameters and the shortcomings of these models to address the complexity of the space. Instead, our general research into what is needed to promote emerging geothermal technologies and to decarbonize aviation and maritime shipping forms the basis of our evaluation, and we think that our analysis of the technical, policy, investment, and philanthropy landscapes enables us to identify organizational strategies that are highly effective. By not modeling CATF's organizational cost-effectiveness, we may lose the ability to compare its cost-effectiveness with that of other giving opportunities. However, it's important to note that our cost-effectiveness analyses are generally regarded as rough plausibility checks.

Bottom line / next steps

We classify CATF as one of our Top Nonprofits addressing climate change. We think there is strong evidence to support its work in technological innovation and its increasingly international influence. Also, we think its strategy of focusing on emerging technologies and neglected sectors can help accelerate interventions and activities that would otherwise struggle to secure funding. In particular, we find its work in SHR, zero-carbon fuels, and transportation decarbonization to be highly effective and complementary to the work of our other recommendations in these sectors, [Project InnerSpace](#) and [Opportunity Green](#), respectively.

We plan to continue assessing our key uncertainties and believe that we will be able to substantially improve our understanding of the severity and importance of some or all of these uncertainties in the near future.

³³ "This is difficult in practice, and CDR could start well before 2050 to accommodate a more feasible trajectory of emissions reduction. It is followed by an increasing removal effort due to the rising RF induced by the fleet." [Sacchi et al \(2023\)](#)

