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August 7, 2025

Professor Caroline Flammer
Professor Stefano Giglio
NBER PhD Student Workshop on Climate Finance
National Bureau of Economic Research (NBER)
1050 Massachusetts Ave.
Cambridge, MA 02138

Dear Professors Flammer and Giglio,

My name is María José Arteaga Garavito and I am writing to apply for participation in the NBER PhD Student Workshop on Climate Finance. I am a fifth-year Ph.D. candidate in Finance at Università Bocconi and expect to complete my degree in June 2026. My advisor, Professor Max (Mariano) Croce, has kindly agreed to serve as reference for this application.

The third chapter of my thesis, which I am submitting for consideration, studies how public financial intermediaries shape the flow of capital toward low-carbon investment and promote inclusive green growth. In this paper, *"The Rise of Green Banks: Implications for Inclusive Green Finance in the U.S."*, I construct the first project-level dataset on 15 U.S. Green Banks (2011–2024) and develop a Stackelberg model in which leverage caps and coordination frictions govern catalytic public lending. Empirically, I document that Green Banks crowd in private credit while steering funds toward disadvantaged communities, highlighting an overlooked channel through which climate policy can narrow financing gaps.

I am currently pursuing two complementary projects that extend my research agenda:

1. ***International Climate News*** (with Riccardo Colacito, Max Croce, and Biao Yang): We build a daily Climate Attention Index for 25 countries based on more than 23 million newspaper tweets and show that adverse climate-news shocks trigger currency appreciations and capital inflows into the most exposed countries to climate news shocks, while brown stocks underperform persistently. A two-country risk-sharing GE model rationalizes these patterns.
2. ***Climate Risk and Cross-Border Lending*** (with Deniz Igan, Jakub Demski, and Koji Takahashi): Using global syndicated-loan data and a monthly Climate Policy Risk index built from newspaper tweets, we find that a rise in climate policy risk in a borrower's country cuts foreign loan volumes, especially to brown firms, whereas a rise in riskiness in a lender's country

reallocates credit toward brown borrowers abroad, indicating that banks actively shift their international portfolios in response to perceived transition risk.

Together, these projects aim to clarify the channels through which climate related policies, financial intermediaries, and green technologies change capital costs and real economy outcomes. The workshop's focus on the interaction between climate change and capital markets aligns perfectly with my research goals. I would really value the opportunity to receive feedback from leading scholars and fellow students.

Thank you very much for considering my application. I look forward to the possibility of presenting my work and contributing to the workshop discussions.

Warm regards,



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Attached: CV; Research Project ("The Rise of Green Banks: Implications for Inclusive Green Finance in the U.S.")

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Education

Bocconi University 2020 —
Ph.D. in Finance
Committee: Max Croce (chair), Riccardo Colacito

Columbia Business School Spring 2024
Visiting Scholar

Centro de Investigación y Docencia Económicas (CIDE) 2016
M.Sc. and B.Sc. in Economics

Research Interests

Financial Intermediation, Banking and Financial Regulation, Climate Finance

Work Experience

Bank for International Settlements May - Sep 2023
Senior Associate Ph.D. Fellow, Monetary and Economic Department

Bank of Mexico 2016 - 2020
Financial Researcher, D.G. of Financial Stability

Publications

When Markets Get COVID: Contagion, Viruses and Information Diffusion (2024) (with M. Croce, P. Farroni and I. Wolfskeil), *Journal of Financial Economics*, Vol. 157: 103850.

Working Papers

The Rise of Green Banks in the U.S. (*Job Market Paper*)

International Climate News (with R. Colacito, M. Croce and B. Yang) (Data)

Climate Policy Risk and Cross-Border Lending (with D. Igan, and K. Takahashi)

Crypto Frictions for Fiat Currencies (with N. Borri, and M. Croce) (Slides)

Awards, Scholarships, and Grants

PhD Research Fellowship "Fondazione Romeo ed Enrica Invernizzi"	2025
BAFFI Centre Research Grant "New Frontiers of Green Lending"	2025
BAFFI Centre Research Grant (Project PRIN) financed by the European Union	2024
BIS PhD Research Fellowship, Bank for International Settlements	2023
VW Project Grant "Risk Sharing in the Euro Area", Junior Researcher	2021
Bocconi PhD Graduate Tuition Fellowship	2020 - 2024
Graduated with overall class rank 2nd, M.Sc. in Economics	2016
Excellence Scholarship for academic performance (CIDE)	2015 and 2016
CONACYT Scholarship (Government of Mexico) for fully funded Master's level studies	2014

Seminars and Conferences

NBER Summer Institute (July 2025, scheduled), EFA (August 2025, scheduled), Lindau Nobel Meeting (August 2025, scheduled), JRC European Commission Internal Seminar (February 2025), ECONDAT 2024 Fall Meeting (November 2024), Bocconi Finance Brown Bag Seminar (November 2024), MUR-PRIN SDA Bocconi Workshop (September 2024), SED Barcelona (June 2024), LUISS Finance Workshop (May 2024), BIS Internal Seminar Series (August 2023), EFA (August 2022), ICEA – RS Conference (March 2022), EEA (August 2021), RCEA (July 2021), SFS Cavalcade North America (May 2021), Banca d'Italia – FRB Conference (November 2020), Joint IMF – World Bank Virtual Seminar (2020)

Teaching Experience

Bocconi University, Italy

Instructor

Empirical Methods for Finance (Undergraduate)	Fall 2023

Teaching Assistant

Prof. Elena Carletti, International Banking (Undergraduate)	2021 - 2023
Prof. Nicola Gennaioli, Financial Markets and Institutions (Undergraduate)	2021 - 2023
Prof. Stefano Gatti and Prof. Massimo della Ragione, Investment Banking (Graduate)	2021
Prof. Mariano Massimiliano Croce, Empirical Methods for Finance (Undergraduate)	2021

Centro de Investigación y Docencia Económicas, Mexico

Teaching Assistant

Prof. Arturo Antón, Macroeconomics II (Graduate)	Spring 2016
Prof. Luciana Moscoso, Microeconomics II (Undergraduate)	Spring 2014 and Fall 2015
Prof. David Heres, Microeconomics I (Undergraduate)	Fall 2013

Other Professional Experience

Co-Founding Member of Women in Economics, Finance and Accounting (EFA) Bocconi
Referee work for Economic Letters and European Journal of Finance
Member of E-axes PhD Student Committee on Climate Finance 2024
Tutoring Volunteer, TALENTUM, Mexico, 2015

Additional Information

Citizenship: Mexican
Computer skills: Python, Matlab, R, Stata, MS Office, Gretl
Languages: English (Fluent), Spanish (Native), Italian (Intermediate)

The Rise of Green Banks: Implications for inclusive Green Finance in the U.S.

María José Arteaga Garavito*

Click here for the latest version

June, 2025

Abstract

I examine how U.S. Green Banks (i.e., public or mission-driven lenders that recycle capital for climate-related projects) shape the flow of green finance in the U.S. Using a newly hand-collected dataset of 39 state and local Green Banks from 2011-2024, I trace both funding sources and project-level deployment [ongoing]. A simple Stackelberg model, with a welfare maximising Green Bank that co-finances with profit-maximising lenders, highlights leverage caps and coordination frictions as key constraints.

Keywords: Green Banks, Climate Finance, Financial Inclusion, Public-Private Partnerships.

JEL Classification: G21, Q55

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1 Introduction

Green Banks are publicly-backed or quasi-public institutions designed to mobilize private investment for clean energy and climate related projects. Despite their name, Green Banks are not deposit-taking institutions and do not operate as traditional commercial banks. Instead, they function as specialized intermediaries that deploy public funds through loans, credit enhancements, co-investments, and guarantees to address market failures and financing gaps in green sectors. Their core mission is to leverage limited public resources to mobilize significantly larger flows of private capital, particularly in areas where risk perceptions, informational barriers, or project scale discourage traditional private financing. Over time, Green Banks have also taken on mandates to promote inclusive access to green finance, directing investments toward underserved or disadvantaged communities as part of broader environmental and social policy goals.

This paper examines the rapid institutional expansion of Green Banks in the United States and their role in shaping the flow and structure of green capital. The analysis is motivated by the landmark 2023 allocation of $20 billion by the U.S. Environmental Protection Agency (EPA) through the Greenhouse Gas Reduction Fund (GGRF), representing the largest federal investment to date in these institutions.[1] Despite their growing importance, there remains limited empirical evidence on how Green Banks deploy capital, interact with traditional lenders, and affect access to green finance across communities.[2]

A key contribution of this study is the construction of a novel hand-collected dataset documenting the project-level activity, financial instruments, and target sectors of U.S. Green Banks. This dataset enables the first systematic empirical analysis of where and how these institutions allocate capital, and to what extent their lending overlaps with, complements, or potentially substitutes for traditional credit provision.

The paper addresses three central questions: (1) How have Green Banks evolved institutionally across U.S. states? (2) How do they influence the allocation of climate finance across regions and

[1] On 11 March 2025 newly appointed EPA Administrator Lee Zeldin issued a press release terminating the $20 billion Greenhouse Gas Reduction Fund (GGRF) awards, alleging "fraud, waste and abuse" (EPA (2025); see also Politico (2025)). Several awardees immediately sued. On 15 April 2025 a preliminary injunction was granted blocking the termination (Post (2025)). The litigation is ongoing and the final outcome remains uncertain.

[2] While working on this draft, I became aware of contemporaneous and independent work by Rizzi et al., 2025, who study the impact of Green Bank loans on venture capital investment in climate-tech startups. Their focus is on startup-level investment dynamics and signaling mechanisms, whereas my paper centers on the institutional evolution and capital deployment strategies of Green Banks, especially in the context of inclusive access to green finance.

sectors? and (3) Do they play a meaningful role in expanding access to green finance for low- and moderate-income or otherwise underserved communities?

Section 2 provides institutional context on the development of Green Banks in the U.S. Section 3 introduces the novel dataset and describes key patterns in project-level activity. Section 5 outlines the empirical strategy and presents the main findings. Section 6 presents a simple model. Section 7 concludes with implications for policy and future research.

Related literature. This paper contributes to three strands of literature. First, it relates to the growing body of work on climate and green finance, particularly efforts to understand how institutional design can address investment frictions in the transition to a low-carbon economy (e.g., Flammer, 2021, Giglio et al., 2021, Krueger et al., 2020, Baker et al., 2022, Baldauf et al., 2020). Second, it builds on research examining the role of development banks and mission-driven financial institutions in financing public goods, innovation, and long-horizon investments (e.g., Lazzarini et al., 2015, Mertens et al., 2021, Griffith-Jones and Ocampo, 2018). Green Banks operate with similar aims but often at a subnational level and through more flexible institutional forms. Third, this work contributes to the literature on financial inclusion and equitable capital allocation, particularly in the context of climate policy (Kaul and Hernandez-Cortes, 2025, Wing et al., 2022, Crago, 2023, Sunter et al., 2019). By examining the geographic and demographic targeting of Green Bank investments, this paper offers new insights into how public financial institutions influence the distributional outcomes of green finance.

To the best of my knowledge, this is the first paper to build a comprehensive project-level dataset on U.S. Green Banks and link it to broader questions about financial system dynamics and access to capital in the green transition.

2 Institutional Background

Green Banks emerged in the United States in the aftermath of the 2008 financial crisis, with the Connecticut Green Bank established in 2011 as the nation's first. Since then, several states and localities have created similar institutions, often structured as nonprofit entities or quasi-public agencies, with mandates to mobilize private investment for clean energy, climate-change mitigation, and resilience projects. Green Banks in the United States vary significantly in their legal

and institutional structures. Some are formally established by state legislation or executive order, so-called "chartered" Green Banks (e.g., Connecticut Green Bank or NY Green Bank). These institutions typically operate as quasi-public entities, are governed by state-appointed boards, and are subject to statutory reporting requirements and public oversight. In contrast, a growing number of Green Bank institutions operate as independent nonprofit organizations without a formal charter. These "non-chartered" institutions, such as Michigan Saves or the Climate United Fund, often share the same core mission: mobilizing private capital for clean energy investment, but function outside of a state-created legal framework. They tend to rely on philanthropic support, federal grants, and partnerships with local lenders, and their transparency obligations are determined by funders rather than statute.

Legal charters. Four basic forms cover almost every case. (i) *Quasi-public corporations* created by their own state law, such as the Connecticut Green Bank and NY Green Bank. They can issue revenue bonds, offer credit guarantees, and recycle program income. (ii) *State finance authorities* that added a green-bank unit to an older infrastructure or development statute (for example, Rhode Island Infrastructure Bank or California IBank). (iii) *City development authorities* that run green-bank programs under local ordinance (for example, Invest Atlanta or Finance New Orleans); and (iv) *Independent 501(c)(3) nonprofits*, for example Michigan Saves and Inclusive Prosperity Capital, which rely on grants and partner lenders because they cannot tax or issue their own bonds.

Governance and oversight. A state-chartered Green Bank is treated like any other public authority: board seats for state officials, meetings that are open to the public, yearly budgets approved in a hearing, and audited financials. Non-profit Green Banks sit in yet another box. They file Form 990 with the IRS, follow state charity law, and must keep donor money in line with the stated mission, but they are not examined for credit risk the way a traditional bank is. Some nonprofits add voluntary safeguards (advisory boards, published loan policies, and third-party impact reviews) to reassure funders.

Funding. Commercial banks rely on customer deposits and can expand credit against those deposits. Green Banks cannot take deposits, so they assemble cash in three other ways. First, some receive a steady stream of public fees; for example, a small charge on every electricity bill in Connecticut and Rhode Island, or a fixed share of carbon-auction proceeds in New York and Massachusetts. Second, several issue tax-exempt bonds backed by a state or city pledge

(Hawai'i's Green Infrastructure Authority and Finance New Orleans). Third, many depend on programme money such as federal grants from the EPA's Greenhouse Gas Reduction Fund or low-cost "programme-related investments" from foundations.

Reporting. State-chartered and other quasi-public Green Banks must comply with their enabling statutes' disclosure rules, which typically require audited financial statements, annual budgets approved by their board, and regular performance reports that detail loan volumes, portfolio quality, and leverage ratios. For nonprofit Green Banks, the primary legally mandated disclosure is the IRS's Form 990, which includes financial statements and limited operational details. However, many institutions go beyond minimal requirements and voluntarily publish annual reports, project-level disclosures, and environmental impact metrics, often in response to public accountability pressures or funding stipulations.

The recent $20 billion allocation through the U.S. Environmental Protection Agency's Greenhouse Gas Reduction Fund (GGRF) introduces a new layer of federal reporting for grant recipients. These funds come with standardized reporting obligations concerning greenhouse-gas reductions, private-capital mobilization, project targeting, and service to disadvantaged communities. As a result, institutions receiving GGRF support are expected to adhere to a higher degree of financial and impact transparency going forward.

This fragmented regulatory landscape presents both a challenge and an opportunity for data collection. Because there is no centralized reporting framework, the dataset I construct in this paper is based on original hand collection from a range of primary sources, including institutional reports and public financial disclosures. This approach allows for detailed project-level analysis across a wide range of institutional models.

3 Data

Definition of Green Bank. To construct a consistent list of Green Banks, I apply a working definition grounded in both legal structure and operational function. Specifically, I define Green Banks as mission-driven financial institutions, typically quasi-public agencies or nonprofit entities, that deploy public or philanthropic capital through repayable financial instruments such as loans, credit enhancements, and co-investments to mobilize private investment in clean energy

and climate resilience. This definition excludes climate-focused institutions that engage solely in education, advocacy, or grantmaking, as these organizations do not function as financial intermediaries or revolve capital.

The primary sources for identifying candidate institutions are the Coalition for Green Capital, a national nonprofit that advocates for and incubates Green Bank models, and the Green Bank 50 coalition, an informal network of roughly 50 green lending institutions that formed in 2024 to share data and coordinate access to new federal programs such as the EPA's GGRF.

Institutions are classified as Green Banks if they meet at least three of the following criteria: (i) their core mission includes mobilizing climate-related private capital; (ii) they use market-based financial tools; (iii) they are structured to allow capital recycling; and (iv) they operate under a public mandate or nonprofit governance model. This filtering strategy ensures the dataset captures institutions that actively shape green capital flows through direct financial activity. Table 1 summarizes the list of Green Banks in my sample.

Data collection. A central contribution of this paper is the construction of a novel dataset on Green Bank activity in the United States. I assemble it manually from multiple primary sources: audited financial statements, Form 990 filings, EMMA-posted official statements, program dashboards, and publicly accessible project registries. For the roughly one-half of Green Banks that are public or quasi-public authorities, I filed state open-records (FOIA-equivalent) requests. Private nonprofit Green Banks are not subject to FOIA; I therefore relied on direct outreach. Most of the nonprofit institutions replied that they are still in a start-up phase and could only share high-level aggregates. Where detailed files were unavailable, I recorded balance sheet and program totals from their latest public disclosures.

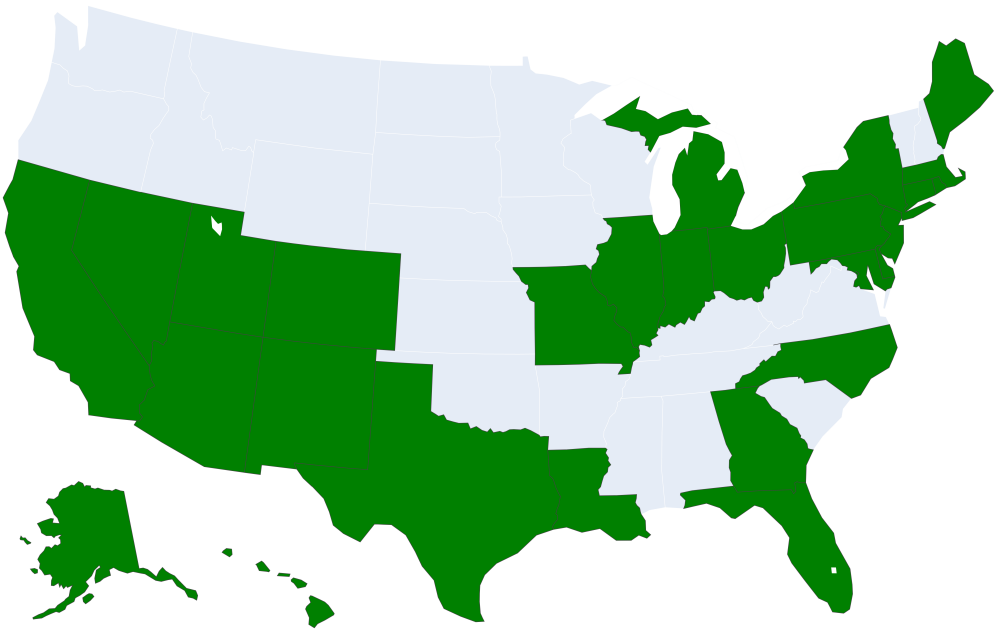


Figure 1: U.S. states that host at least one Green Bank, 2011–2024.

Notes: Shaded jurisdictions meet the Green Bank definition from Section 3 ("mission-driven lenders that recycle public or philanthropic capital through repayable instruments to crowd in private climate investment"). Highlighting is based on the list in Table 1 and reflects the institutional landscape as of July 2025. Both public/quasi-public agencies and nonprofit green banks are included; states hosting more than one qualifying institution (e.g., California, Massachusetts, Ohio) are not differentiated in the map shading. Puerto Rico, which also hosts a green bank, lies outside the map frame and is omitted.

Table 1: U.S. Green Banks: Legal Form and Year Founded

Name	State	Year	Type	Sub-type
Connecticut Green Bank	Connecticut	2011	Public Agency	—
NY Green Bank	New York	2013	Public Agency	—
Rhode Island Infrastructure Bank	Rhode Island	1989	Public Agency	—
California Infrastructure and Economic Development Bank (IBank)	California	1994	Public Agency	—
Hawaii Green Infrastructure Authority (HGIA)	Hawaii	2013	Public Agency	—
DC Green Bank	District of Columbia	2018	Public Agency	—
California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA)	California	1980	Public Agency	—
California Pollution Control Financing Authority (CPCFA)	California	1972	Public Agency	—
Atlanta Development Authority *d/b/a* Invest Atlanta	Georgia	1979	Public Agency	—
Illinois Finance Authority / Climate Bank	Illinois	2004	Public Agency	—
Finance New Orleans	Louisiana	1978	Public Agency	—
Efficiency Maine Trust	Maine	2010	Public Agency	—
Maryland Clean Energy Center	Maryland	2008	Public Agency	—
Massachusetts Clean Energy Center	Massachusetts	2008	Public Agency	—
Massachusetts Community Climate Bank	Massachusetts	2023	Public Agency	—
Environmental Improvement and Energy Resources Authority (EIERA)	Missouri	1972	Public Agency	—
New Jersey Economic Development Authority	New Jersey	1974	Public Agency	—
Ohio Air Quality Development Authority	Ohio	1970	Public Agency	—
Michigan Saves	Michigan	2009	Non-profit	Public Charity
Montgomery County Green Bank	Maryland	2016	Non-profit	Public Charity
Energize Delaware	Delaware	2010	Non-profit	Supporting Org.
Solar and Energy Loan Fund of Florida (SELF)	Florida	2010	Non-profit	Public Charity
Nevada Clean Energy Fund	Nevada	2017	Non-profit	Public Charity
Colorado Clean Energy Fund	Colorado	2018	Non-profit	Public Charity
Louisiana Clean Energy Fund	Louisiana	2023	Non-profit	Public Charity
Indiana Energy Independence Fund	Indiana	2023	Non-profit	Public Charity
Missouri Green Banc	Missouri	2022	Non-profit	Private Foundation
New Mexico Climate Investment Center	New Mexico	2023	Non-profit	Public Charity
New York City Energy Efficiency Corporation (NYCEEC)	New York	2010	Non-profit	Public Charity
North Carolina Clean Energy Fund	North Carolina	2020	Non-profit	Public Charity
Columbus Region Green Fund	Ohio	2021	Non-profit	Public Charity
GO Green Energy Fund (Growth Opps)	Ohio	2020	Non-profit	Public Charity
Philadelphia Green Capital Corp.	Pennsylvania	2021	Non-profit	Public Charity
Puerto Rico Green Energy Trust	Puerto Rico	2019	Non-profit	Public Charity
Clean Energy Fund of Texas	Texas	2021	Non-profit	Public Charity
SustainEnergyFinance	Utah	2023	Non-profit	Public Charity
Inclusive Prosperity Capital	National (CT)	2018	Non-profit	Public Charity
Spruce Root	Alaska	2012	Non-profit	Public Charity
Groundswell Capital	Arizona	2022	Non-profit	Supporting Org.

Notes: "Public Agency" covers both state agencies and quasi-public authorities created by statute or local ordinance. "Non-profit" entries follow IRS determinations; "Supporting Org." is a 509(a)(3) structure. Years are the enabling statute date or, for non-profits, the IRS incorporation year. Source: author compilation from statutes, Form 990 filings, and institutional websites.

Financial information. All balance-sheet and income figures come from publicly-available primary documents; no secondary databases are used. I rely on five source types that together cover every Green Bank in the sample:

(i) *State Comprehensive Annual Financial Reports (CAFRs)* and *component-unit audits*. Quasi-public and state-agency green banks appear in the enterprise-fund or component-unit sections of their state CAFR; the PDFs include a full Statement of Net Position, a Statement of Revenues and Expenses, and all debt footnotes.

(ii) *Standalone audited financial reports.* About one-third of the quasi-public banks (e.g. Connecticut Green Bank, DC Green Bank) publish their own GAAP-based audit separate from the CAFR. These reports provide detail on program loans, loan-loss reserves, and restricted net position that is not in the CAFR.

(iii) *IRS Form 990 filings*. Every non-profit bank files Form 990; the balance sheet (Part X) and revenue statement (Part VIII) supply cash, grants receivable, secured debt, and unrestricted net assets. XML versions are pulled from the ProPublica Non-profit Explorer webpage; PDFs are used when XML is missing.

(iv) *MSRB EMMA disclosures*. Whenever a Green Bank issues tax-exempt or "green" bonds, the Official Statement and continuing-disclosure filings on EMMA list coupon rates, amortisation schedules, and outstanding principal. These numbers are cross-checked against the liabilities shown in (i)–(iii).

(v) *Federal-grant and program reports*. For institutions that receive EPA Greenhouse Gas Reduction Fund (GGRF) or other public funds, I confirm draw-downs and unspent balances from the first-quarter 2024 financial reports, posted on USASpending.gov.

If a figure conflicts across documents, I follow a simple hierarchy: standalone audit $\rightarrow$ CAFR note $\rightarrow$ Form 990 $\rightarrow$ EMMA. Missing items (mostly for start-up non-profits that have not yet filed a 990) are requested directly from staff or, where necessary, via state FOIA. A log of every PDF and XML file, together with the code used to parse them, is archived in the Internet Appendix for reproducibility.

Project-level information. I collect project-level information for 11 Green Banks across 9 U.S. states between 2011 and 2024.[3] Each observation contains project characteristics such as funding amount, financial instrument (loan, guarantee, credit enhancement), co-financing details, target sector (e.g., residential solar, commercial efficiency), and geographic location (ZIP or census tract level where available). I use three primary sources:

(a) *Annual reports*: every Green Bank that publishes an Annual Impact Report, ACFR, or "Transaction Profile" series is scraped for deal-level tables.

(b) *Board packets and sunshine-law portals*: meeting minutes and project registers released under state open-records statutes (e.g., NY Open Meetings Law, Connecticut FOI) provide the most granular line-item data.

(c) *Direct requests and FOIA/FOIL queries*: for banks without public deal logs, redacted spreadsheets are obtained via negotiated data-sharing agreements or formal FOIA requests to the state energy office [ongoing].

4 Summary Statistics

Green Banks show significant variation in project size, leverage ratios, and regional targeting, highlighting the importance of institution-level heterogeneity.

[To be completed]

5 Empirical results

[To be completed]

[3]The sample covers the following institutions: Connecticut Green Bank; NY Green Bank; Rhode Island Infrastructure Bank; California Infrastructure and Economic Development Bank (IBank); California Pollution Control Financing Authority (CPCFA); Illinois Finance Authority (Climate Bank program); Maryland Clean Energy Center; Massachusetts Clean Energy Center; Massachusetts Community Climate Bank; Environmental Improvement and Energy Resources Authority (EIERA, Missouri); and New Jersey Economic Development Authority. **Ongoing FOIA and data-sharing requests cover the Hawaii Green Infrastructure Authority (HGIA), DC Green Bank, the California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA), the Atlanta Development Authority (Invest Atlanta), Finance New Orleans, Efficiency Maine Trust, and the Ohio Air Quality Development Authority.**

6 Model [preliminary and incomplete]

In this section I develop a simple baseline model of a nonprofit Green Bank that finances climate-related investment by leveraging private sector co-investment. The interaction between the Green Bank and private lenders is modeled as a Stackelberg game. The Green Bank acts as a leader, choosing the amount of public capital it will deploy and the share of the project it seeks to co-finance through private capital. Private banks respond by deciding whether to participate, depending on risk-adjusted returns.

Project financing and capital structure. Let L^{GB} denote the amount of capital that the Green Bank invests in a project. The Green Bank selects a co-financing share $\mu \in [0, 1)$, which determines the total size of the project:

$$L = \frac{L^{GB}}{1 - \mu} \tag{1}$$

The Green Bank finances its investment using tax-exempt debt D and internal funds E (e.g., grants, retained surpluses, or philanthropic contributions), subject to a regulatory leverage constraint:

$$L^{GB} = D + E, \tag{2}$$

$$D \leq \lambda L^{GB} \tag{3}$$

Borrowing costs are increasing in the Green Bank's leverage ratio, reflecting political, administrative, or reputational risks. Specifically, the cost of debt is modeled as:

$$r_D = r_0 + \phi \left(\frac{D}{D + E} \right)^2, \tag{4}$$

where r_0 is the base cost of capital and $\phi > 0$ is the convexity parameter of borrowing costs.

In addition, co-financing introduces coordination frictions that rise with the scale and complexity of private sector involvement (μ), and of the project size (L). These costs are given by:

$$F(\mu, L^{GB}) = \chi \mu^2 \frac{L^{GB}}{1 - \mu} \tag{5}$$

where $\chi > 0$ reflects the per-unit marginal cost of managing public-private project delivery.

The Green Bank maximizes a utility function that combines environmental and social impact with financial sustainability. The first component reflects total project size (mission), while the second captures net financial surplus after accounting for debt servicing and coordination costs (financial performance). The objective is:

$$\max_{L^{GB},\mu} \theta \log\left(\frac{L^{GB}}{1-\mu}\right) + (1-\theta)\log\left[\rho L^{GB} - r_D D - F(\mu, L)\right], \tag{6}$$

where $\theta \in (0,1)$ is the relative weight the Green Bank places on mission versus financial performance, $\rho > 0$ denotes the return on every dollar invested in green projects, and the remaining terms reflect costs associated with leverage and coordination.

After observing the Green Bank's proposal (L^{GB}, μ), a private bank (PB) decides whether to provide the complementary capital μL. It earns an expected return per dollar of investment equal to:

$$R^{PB} = \rho - \gamma(\mu, L), \tag{7}$$

where γ captures risk-adjusted coordination costs and is increasing in the scale of private participation. Coordination costs for the Private Bank are modelled as:

$$\gamma(\mu, L) = \psi \mu L \tag{8}$$

with $\psi > 0$ denoting the sensitivity of private bank costs to the scope of their involvement. The private bank invests only if the risk-adjusted return exceeds its required return r^{PB}:

$$\rho - \gamma(\mu, L) \geq r^{PB} \tag{9}$$

This yields a participation constraint:

$$\mu \cdot \frac{L^{GB}}{1-\mu} \leq \frac{\rho - r^{PB}}{\psi} \tag{10}$$

Definition 6.1 (Equilibrium)**.** The Stackelberg equilibrium is a pair (L^{GB*}, μ^*) such that the Green Bank maximizes its utility function (6), subject to the following constraints and (1):

$$
\begin{aligned}
& L^{GB} = D + E, \\
& D \leq \lambda L^{GB}, \\
& \mu \cdot \frac{L^{GB}}{1-\mu} \leq \frac{\rho - r^{PB}}{\psi} \quad \text{(Private bank participation constraint)}
\end{aligned}
$$

The Green Bank acts as a Stackelberg leader: it anticipates the private bank's response to any co-financing proposal (L^{GB}, μ) and chooses its strategy accordingly. The equilibrium characterizes the optimal allocation of public capital and co-investment share, ensuring participation by private banks while balancing the Green Bank's mission and financial objectives.

Proposition 6.1 (Stackelberg Equilibrium in Green Co-Financing)**.** Let the Green Bank choose its investment level L^{GB} and co-financing share $\mu \in [0, 1)$ to maximize it's utility function (6), subject to the financing constraint (2), the leverage constraint (3), and the private bank's participation constraint (10). Then, the unique Stackelberg equilibrium is characterized by:

$$
\mu^* = \frac{-\theta A + \sqrt{\theta^2 A^2 + 4(2\theta - 1)\chi A}}{2(2\theta - 1)\chi}, \qquad 0 < \mu^* < 1,
$$

and

$$
L^{GB*} = K \frac{1 - \mu^*}{\mu^*}, \qquad D^* = \lambda \, L^{GB*}, \qquad L^* = \frac{L^{GB*}}{1 - \mu^*}.
$$

where,

$$
\bar{r}_D = r_0 + \phi\lambda^2, \qquad A = \rho - \lambda \bar{r}_D, \qquad K = \frac{\rho - r^{PB}}{\psi} > 0.
$$

with $A > 0$, $\rho > r^{PB}$ and $\theta \neq \frac{1}{2}$.[4]

7 Conclusions

[To be completed]

[4] If $\theta = \frac{1}{2}$, the quadratic term in the first-order condition vanishes and the Green Bank chooses the maximal feasible crowd-in $\mu^* \to 1^-$ with $L^{GB*} = 0$.

Appendix

A (Public) Green Bank Programs

A.1 Connecticut Green Bank

The Connecticut Green Bank (CGB), established on July 2011, is a quasi-public successor to the former Clean Energy Finance and Investment Authority (CEFIA) and is recognised as the first state-level green bank in the United States (Connecticut General Assembly (2011)). Its statutory charter charges CGB with "promoting investment in clean energy" and, following a 2021 statutory expansion (Connecticut General Assembly (2021)), broader environmental-infrastructure sectors such as climate adaptation, land conservation and waste management, all while leveraging limited public resources to mobilise private capital.

The GGB delivers this leverage through a portfolio of targeted financing platforms:

- **Commercial Property Assessed Clean Energy (C-PACE)** offers up to 100% long-term financing for energy efficiency and clean energy upgrades on commercial and other non-residential properties, repaid via a voluntary benefit assessment collected with property taxes; the program operates as an open platform that channels both private capital and Green Bank warehouse funds. The first project closed April 2013 in Norwalk, marking one of the nation's earliest statewide C-PACE financings.

- **Smart-E Loans**, delivered through local lenders and supported by Green Bank credit enhancements, provide low-rate, flexible-term unsecured financing for a broad menu (90+ eligible measures) of residential energy efficiency, renewable, resilience, and healthy-home improvements, often structured to be cash-flow positive for homeowners.

- **Solar Marketplace Assistance Program (SolarMAP)**, introduced in 2020, to aggregate municipal and affordable-housing solar PPAs/leases, eliminating up-front capital for tax-exempt customers.

- The Multifamily suite, including low-interest **Navigator Pre-Development** loans and **LIME (Loans Improving Multifamily Energy)** term financing that can cover 100% of project costs and be repaid from energy savings, targets low- to moderate-income housing providers and

can be paired with Solar PPA or C-PACE solutions to bundle deeper retrofits with renewables.

- **Energy Storage Solutions** program offers nine-year statewide battery-incentive program launched January2022 and administered jointly with Eversource/UI; incentives can be paired with solar or efficiency measures.
- Finally, **Green Liberty Notes & Bonds** invite residents and investors to put their savings to work in the state's clean energy transition, broadening the capital base that underpins the Bank's programs.

A.2 NY Green Bank

The New York Green Bank (NYGB) was officially launched in December 2013 following approval by the New York State Public Service Commission (PSC) (New York State Public Service Commission (2013)). The PSC's order authorised a US$1billion capitalization sourced from uncommitted ratepayer funds held by New York State Energy Research and Development Authority (NYSERDA), a public-benefit corporation founded in 1975. The NYGB was structured not as a standalone entity but as a proprietary division within NYSERDA, with operational autonomy and a mandate to become financially self-sustaining.

The Bank's enabling order defined a dual mission: (i) to accelerate the deployment of clean energy and other sustainable infrastructure by mobilising greater private investment, and (ii) to build an enduring green financing institution capable of recycling capital over time. NYGB's market-oriented approach aims to close persistent financing gaps in distributed energy, energy efficiency, and other sustainable asset classes by tailoring credit structures and investment products to overcome underwriting frictions; particularly in markets where small transaction size, performance uncertainty, or lack of scale hinder participation by conventional lenders.

NYGB's activities were reaffirmed and extended under the Clean Energy Fund (CEF) Investment Plan, approved in 2016 and updated through multiple proceedings (New York State Energy Research and Development Authority (NYSERDA) (2025)). As of 2024, NYGB had committed over US$667 million across 52 transactions:

- **Construction Loans**: Nine transactions supported pre-commercial deployment, typically for

community-scale distributed energy or efficiency projects.

- **Construction-plus-Term Facilities**: Eleven transactions combined initial construction finance with takeout mechanisms, enabling longer-duration capital stacking.
- **Standalone Term Loans and Equity-like Investments**: Twenty-nine transactions provided fixed-term capital for mature-stage assets or platforms, including both senior and mezzanine positions.
- **Warehousing & Aggregation Facilities**: Three structures facilitated loan aggregation by private lenders or originators, with a view to eventual securitisation or sale into secondary markets.

Instruments are typically structured as **delayed-draw facilities**: capital is deployed only when agreed milestones or thresholds are satisfied. Where NYGB provides **credit enhancements**, such as subordinated debt or loan-loss reserves, these are contingent in nature and drawn only upon defined trigger events.

A.3 Rhode Island Infrastructure Bank

The Rhode Island Infrastructure Bank (RIIB) originated as the Rhode Island Clean Water Finance Agency in 1989, and in 2015, the Rhode Island General Assembly renamed it and expanded its mission (Rhode Island Legislature (2015)), broadening its mandate beyond water quality to encompass energy-efficiency, renewable-energy, brownfield remediation and other environmental infrastructure sectors, and reaffirming its status as a quasi-public corporation. RIIB thus operates as the state's hub for infrastructure finance, administering federally capitalised State Revolving Funds, issuing labelled green bonds and recycling loan repayments through multiple specialised revolving pools to advance both climate-mitigation and climate-resilience objectives.

The SRFs provide subsidised, long-tenor finance for wastewater, storm-water and related projects, while bond proceeds and state appropriations feed several specialised revolving pools. Some examples include the Efficient Buildings Fund, which underwrites municipal energy-efficiency and renewable-energy retrofits, and the Clean Energy Fund, a flexible source for carbon-reduction investments across public and private sectors. Credit-enhanced securitisation is complemented by

direct federal transfers, such as Infrastructure Investment and Jobs Act allocations that enabled zero-interest lead-service-line replacement loans to Providence Water.

Programmatically, RIIB operates a diversified portfolio designed to address both climate mitigation and adaptation:

- **Commercial Property Assessed Clean Energy (C-PACE)** offers 100% long-term finance for energy and renewable upgrades in commercial and industrial buildings, repaid via property assessments.
- The **Brownfields Revolving Loan Fund** supports remediation of contaminated sites, while the **Stormwater Project Accelerator** supplies upfront capital for green storm-water infrastructure that will later be reimbursed by grants.
- The **Municipal Resilience Program**, which provides planning support and competitive grants for locally prioritised resilience projects.
- Complementary retail-scale offerings (**Community Septic System loans**, **Sewer Tie-In loans**, and the **Drinking Water SRF**) extend concessional finance to homeowners and small systems.

A.4 California Infrastructure and Economic Development Bank (IBank)

The California Infrastructure and Economic Development Bank (IBank) was established in 1994 under the Bergeson-Peace Infrastructure and Economic Development Bank Act (California Legislature (2020)) as a state-owned financing authority within the Governor's Office of Business and Economic Development. Its statutory purpose is to promote economic development, strengthen environmental quality, and support public infrastructure by providing access to low-cost financing for eligible entities, including municipalities, non-profits, and private borrowers.

IBank manages several green financing programs through both direct lending and credit support:

- Its flagship offering, the **Infrastructure State Revolving Fund (ISRF)**, provides low-interest loans to local governments, schools, special districts, and non-profits for a wide range of in-

frastructure projects, including renewable energy systems, energy efficiency upgrades, water conservation, and climate resilience initiatives.

- Through the **Climate Catalyst Fund**, launched in 2021, IBank delivers flexible financing and credit enhancements for public and private sector projects that reduce greenhouse gas emissions, build climate resilience, and support the state's transition objectives. The Fund targets sectors such as sustainable agriculture, wildfire mitigation, zero-emission transportation, and building electrification, and prioritises catalytic investments that crowd in private capital.

- IBank also administers the **California Lending for Energy and Environmental Needs (CLEEN) Center**, which facilitates green infrastructure deployment by issuing tax-exempt and taxable bonds and direct loans to public agencies for eligible clean energy, energy efficiency, and water infrastructure projects. CLEEN can support both distributed and utility-scale investments, often layering federal, state, and private funding sources.

- In addition to direct lending, IBank offers **bond financing** through its 501(c)(3) Revenue Bond Program and its Public Agency Revenue Bond Program, enabling large-scale green and sustainable infrastructure projects to access capital markets.

A.5 Hawaii Green Infrastructure Authority (HGIA)

The Hawaii Green Infrastructure Authority (HGIA) was constituted in November 2014 (State of Hawaii Legislature) to implement the Green Energy Market Securitization (GEMS) financing program, utilizing proceeds from a $150million bond issuance to catalyze clean energy investment statewide, particularly among underserved ratepayers. It is administratively attached to the Department of Business, Economic Development and Tourism (DBEDT).

HGIA's mission is to "make clean energy investment accessible and affordable to Hawaii's underserved ratepayers; stimulate private investments; and leverage innovative financing tools," oriented toward the state's goal of 100% renewable energy supply by 2045.

HGIA green financing programs include:

- **GEMS On-Bill**, launched in April 2019, is a meter-linked repayment program that offers up

to 25-year, fixed rate financing with onbill payments rather than credit screens, dramatically expanding access for renters and low-income households.

- **HI-C-PACER**, initiated 2024 is statewide C-PACE scheme that supports 100% long-term financing for commercial, multifamily, and nonprofit resilience, energy, water, and cesspool conversion projects, repaid via property assessments.
- **HI-CAP Programs** (CollateralSupport, CDFI loan participation, etc.), funded under SSBCI, launched in2022 to enhance access for small businesses and nonprofits.
- **Solar Hui Investment Fund**, is expected to enable multifamily and condominium owners to invest in shared solar and storage via energy services agreements. It is expected roll-out in late 2025.
- **Solar for All & Clean Water Adaptation**. HGIA was awarded $62.45million under the EPA Solar for All initiative in April2024. In parallel, it received technical support to explore equitable clean water finance as part of a broader infrastructure mission.

A.6 DC Green Bank

The DC Green Bank (officially the District of Columbia Green Finance Authority) was created on July 2018 (Council of the District of Columbia (2018)), and began operations in April 2020 as an independent instrumentality of the DC government. The institution's mandate is to mobilize private capital through a full suite of financial tools (loans, loan guarantees, credit enhancements, bonds, and other mechanism) for a broad spectrum of "sustainable projects and programs" including clean energy, clean transportation, stormwater, energy and water efficiency, water infrastructure, and green infrastructure.

DC Green Bank green lending programs include:

- **PACE (Property Assessed Clean Energy)** program offers up to 100% long-term financing for energy, water, resilience, EV charging, and stormwater measures, repaid via property tax assessments. Open guidelines support both hard and soft costs (e.g. audits, modeling) for commercial, multifamily, institutional, nonprofit, industrial, and other qualifying buildings.

- **Pre-Development Loans** are small-dollar, early-stage loans to cover feasibility, engineering, and technical advisory costs prior to construction financing, targeted toward community-serving projects and underserved borrowers.
- **Commercial Loan for Energy Efficiency & Renewables (CLEER)**, launched in2020 as DCGB's first structured loan product.
- **Small Business Loan Fund** is forthcoming program offering up to US$150k loans at 3% for clean energy, efficiency, or stormwater resilience improvements, developed in partnership with City First Enterprises.
- **Open Solicitation "Community Impact Initiative"** is a rolling RFP inviting private-sector partners (capital providers, developers, CDFIs) to propose collaborations across any eligible sustainable sectors—infrastructure, clean energy, green tech, stormwater
- **Capital Provider Network & Guarantees** DCGB maintains a roster of registered capital providers for PACE and other financings; acts as a conduit between owners, lenders, and technical validators.
- **Credit Enhancements & Structured Finance Tools** offers subordinated debt, loan-loss reserves, and warehouse facilities to de-risk and amplify private investment.
- **Bonding Authority & Fund Capitalization** Authorized to issue revenue bonds under the Home Rule Act; maintains the Green Finance Authority Fund, which consolidates public deposits, repayments, and any earned interest or gifts.

A.7 California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA)

A.8 California Pollution Control Financing Authority (CPCFA)

The California Pollution Control Financing Authority (CPCFA) was established in 1972 and operates within the State Treasurer's Office. While it began as an environmental conduit-bond issuer, successive statutory amendments (most recently its inclusion in the multi-agency California Green Bank (with CAEATFA and IBank)) have layered a suite of credit-enhancement and grant

programmes onto its legacy tax-exempt bonding powers. CPCFA's dual mandate is therefore to (i) provide low-cost, tax-exempt capital for private projects that deliver public environmental benefits, and (ii) expand credit access for small businesses undertaking clean transport, energy efficiency and brownfield remediation investments. In every case it acts strictly as a conduit: it neither underwrites nor guarantees the debt but issues on behalf of eligible private entities, drawing bond volume cap from the California Debt Limit Allocation Committee (CDLAC).

CPCFA now deploys three inter-locking platforms:

- **Tax-Exempt Private-Activity Bond (TEPAB) Programme** where CPCFA issues federally tax-exempt "exempt-facility" bonds for solid-waste disposal, water furnishing, wastewater treatment, recycling, and the newly authorised category of carbon-dioxide capture facilities.
- **California Capital Access Program (CalCAP)** is a family of loan-loss-reserve and collateral-support schemes that reimburse a share of losses to participating financial institutions (PFIs).
  - **CalCAP for Small Business** (1994–) focuses on general working-capital and equipment loans, now supported with SSBCI funds.
  - **CalCAP Collateral Support** (2013–) which pledges cash collateral to unlock larger credits.
  - **CalCAP Zero-Emission Heavy-Duty** (2024 pilot) offers loan-loss reserves for fleets purchasing zero-emission trucks and charging infrastructure.
  - Sunset programmes: **CalCAP/CARB Heavy-Duty Vehicle** (2009–2023) and **EV Charging Station Finance** (2015–2022).
  - Special-purpose subsets (still authorised, modest volume): **Seismic Safety** and **ADA Accessibility** finance.
- **Brownfield Revitalisation – CALReUSE** offers revolving site-assessment loans and remediation grants, funded through recycled repayments and cap-and-trade proceeds.

Together with CAEATFA's equipment leasing and IBank's direct lending and catalyst fund, CPCFA completes the "green-bank tripod" that channels both private and federal dollars (IIJA, SSBCI, cap-and-trade) into California's climate transition.

A.9 Atlanta Development Authority d/b/a Invest Atlanta

A.10 Illinois Finance Authority (IllinoisClimateBank)

The Illinois Finance Authority (IFA), created in 2004 through the consolidation of seven legacy financing bodies, is a self-supporting, quasi-public conduit issuer that mobilises private capital for economic development and public-purpose infrastructure across the state. In 2021, the IFA was formally redesignated as the Illinois Climate Bank (ICB), widening its remit to "accelerate the investment of private capital into clean-energy projects … in a manner reflective of the State's geographic, racial, ethnic, gender, and income-level diversity." (Illinois Environmental Protection Agency (2021)).

The IFA leverages three complementary toolkits: (1) capital-markets issuance (tax-exempt/green bonds and conduit private-activity bonds); (2) credit-enhancement facilities capitalised with federal StateSmallBusinessCreditInitiative funds; and (3) statutory authority to make direct, low-rate loans to governmental units under the Climate Bank Loan Financing Act.

IFA's green financing programs include:

- **StateSmallBusinessCreditInitiative (SSBCI)—Participation Loan Programme (PLP).** The flagship clean-energy small-business product provides subordinated, fixed-rate IFA participations alongside senior bank debt:
  - *Standard PLP*: up to **25 %** of total project cost (max$2m) at a **2%** fixed coupon for up to seven years.
  - *SEDI/VSB PLP*: deeper support—up to **50 %** of project cost—at a concessionary **1%** fixed rate when the borrower is *socially and economically disadvantaged* (SEDI)–owned or a *very small business* (10 FTE).
- **Capital Access Programme (CAP)** and **Other Credit Support Programmes (OCSP Loan & Equity).** Authorised under Illinois' SSBCI allocation but no originations yet.
- **Commercial Property Assessed Clean Energy (C-PACE) Programme.** IFA sponsors a statewide "open-market" C-PACE platform that lets counties adopt a turnkey ordinance and tap IFA's conduit-bonding capacity. Eligible owners can finance up to 100% of energy-efficiency, re-

newable, EV-charging and resilience upgrades over 20–30years, repaid via a non-accelerating special assessment.

- **State Revolving Fund (SRF) Green Bonds.** In partnership with IllinoisEPA, IFA issues AAA-rated *Clean Water Initiative* green bonds (e.g., $544m Series2025) to replenish the Water Pollution Control and Drinking Water loan pools that serve municipalities statewide.
- **Climate Bank Loan Financing Act Facilities.** Since 2023, any local governmental unit can borrow directly from IFA for qualifying clean-energy infrastructure—often at below-market, tax-exempt rates—bypassing traditional bond issuance.

A.11 Finance New Orleans

A.12 Efficiency Maine Trust

A.13 Maryland Clean Energy Center

A.14 Massachusetts Clean Energy Center

A.15 Massachusetts Community Climate Bank

A.16 Environmental Improvement and Energy Resources Authority (EIERA)

A.17 New Jersey Economic Development Authority

A.18 Ohio Air Quality Development Authority

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