Summary for CIFE Seed Proposals for Academic Year 2020-21

Proposal number:	**2020-06**
Proposal title:	**Assessing Climate Risk in Energy Infrastructure Investments**
Principal investigator(s) and department(s):	Ram Rajagopal, Civil and Environmental Engineering
Research staff:	Ram Rajagopal (PI), Ashby Monk, Soh Young In, Yasat Berk Manav
Total funds requested:	**$ 100,000**
Project URL for continuation proposals	**N/A**
Broad Category Addressed in this Research	**climate & natural environment / energy & resource use / resilience / fosters business & economy / experience improved for all stakeholders**
Project focus area addressed by proposal	**Team Collaboration / Project Collaboration / Feedback in Construction / other – Vision for Future of Energy Infrastructure / Sustainable Finance and Investment**
Stakeholders' benefitted by the research	Research is *primarily* expected to benefit each of the following stakeholder groups: **Owners & Operators, Designers, Builders, Other: Consultants, Investors, Insurers**
Expected time horizon to impact the industry	**2 to 5 years**
Type of research	**Exploration**
Industry Involvement	**N/A**
Abstract (up to 150 words)	**Observed Problem:** • The impacts of climate change are no longer a distant phenomenon. • However, owners, operators and investors are mispricing climate risks associated with energy infrastructure investments. That is, the value of "stranded assets" might

	not be fully reflected in the value of company holdings and investment portfolios. • The rising climate risks cannot be managed by rising insurance risks: instead, these risks must be addressed via a fundamental change of climate risk assessment. **Primary Research Objective and Solution:** This project aims to assess the financial resilience of energy infrastructure projects to climate change on an asset-by-asset basis. **Anticipated Value to CIFE Members and Industry:** We will demonstrate how to integrate climate data and scenarios into an asset valuation model, which is useful from an investment perspective for builders, owners and operators of infrastructure. **Proposed Research Approach and Methodology:** Using cash flow modeling and stress test methodologies, we will estimate an energy asset's probability of default due to climate risks (physical and transition) and the size and time of the losses by the given default. **Anticipated Research and Theoretical Contributions:** Differently from previous climate risk assessments, which are mostly on a macroeconomic level, we highlight asset-level granularity in pricing climate risks of energy infrastructure investments.

Engineering or Business Problem

The impacts of climate change are no longer a distant phenomenon. 2019 was again a costly year for natural disasters in the US, Europe, and Asia at $150bn, following a record-breaking year of losses in 2018. Recent extreme weather events have driven up uninsured losses; only about one-third of the economic losses of the natural disasters were insured in 2019.[1]

In the meantime, the global effort to mitigate the impact of climate change has accelerated the energy transition. The Paris Agreement's climate mitigation target requires a massive scale-up of investments in renewable energy technologies and a phase-out of investments in fossil-fuel based plants. Corporations are under increasing pressure of stringent environmental legislation, regulation, and taxation (e.g., carbon pricing, the Green New Deal) to review the mix of energy sources and related infrastructure assets.

1 Munich Re, "Tropical cyclones causing billions in losses dominate nat cat picture of 2019." web, Munich Re 2019.

The growing physical and transition risks of climate change make corporations re-evaluate their current infrastructure assets and reallocate corporate capital. Building, operating, and financing environmentally-friendly and climate-resilient infrastructure assets can deliver not only positive environmental impacts but also a monetary value, which is linked to the stewardship of capital. Indeed, 42% of global coal plants are already unprofitable, and running a current coal plant costs 36% than building a new renewable power plant. This is not a story of the future: it is based on 2018's data. And by 2040, 72% at risk of becoming unprofitable due to a combination of falling renewable energy costs, carbon pricing, and air pollution regulations.[2]

Today, however, asset owners, operators, and investors underestimate the implications of the inevitable and irreversible shift toward a low-carbon and climate-resilient future because they fail to evaluate climate resilience in a holistic way. For instance, investors are mispricing risks associated with their energy investments in the value of the related financial contracts. This indicates that the value of "stranded assets" might not be fully reflected in the value of investors' portfolios. Asset owners may lose value under a disordered transition to a low-carbon economy if they are unable to adapt their business and their portfolio management strategy.

This problem requires an urgent and holistic response: the rising climate risks cannot be managed by simply rising insurance risks (e.g., raising premiums or withdrawing cover). Instead, the risks must be addressed via a fundamental change to climate risk assessment and management. As Ramboll highlights in its 2020 report, "a fundamental part of preparing for the future – and enabling sustainable business operations – is truly understanding the risks of climate change."[3]

Therefore, we propose this study to discuss and investigate the following topics:

- How do asset owners, operators, and investors assess the future trajectory of climate risks?
- Whether and which frameworks and tools are available to evaluate the climate resilience of infrastructure assets? Do they efficiently inform decisionmakers on making strategic capital deployment and management decisions?
- Is there a need to look at a stressed case for climate risks, and if so, how could this be done?

Theoretical and Practical Points of Departure

1. ***The industry needs a climate risk assessment tool that can assess the climate resilience of infrastructure assets in a financial value.***

Current climate risk assessment models (e.g., integrated global system modeling [IGSM], dynamic integrated climate-economy [DICE] model) do not yet demonstrate the monetary value of designing and incorporating enhanced climate resilience for long-term infrastructure assets. There is a severe gap between climate risk models and financial risk models, while these two categories of risks are intimately connected. Notably, the CIO of AustralianSuper highlights that the biggest barrier is "taking climate scenarios and transforming them into a model that is useful from an investment perspective, that is, integrating them into a valuation model so that different climate scenarios provide more specific insight for analysts on a company-by-company basis."

2 Carbon Tracker Initiative, "Powering down coal: Navigating the economic and financial risks in the last years of coal power." Tech report, Carbon Tracker Initiative 2018.

3 Ramboll, "Reporting the risks – a key to climate change resiliency." web, Ramboll 2020.

We thus assess the performance of infrastructure assets at the cash flow level, thereby making granular estimates of the timing and magnitude of risks borne by the changing climate. This information provides immediate, actionable data to a decisionmaker on the financial benefits of designing and building climate-resilient infrastructure. We view this as a substantial benefit to design companies in the AEC industry, as they can proactively develop expertise, and hence competitive advantages, in climate-resilient infrastructure design. Furthermore, using our research findings, design companies will be equipped with a methodology to articulate precisely how much financial value climate-resilient design provides to project owners and investors.

2. ***Asset owners should be able to dynamically simulate multiple climate scenarios and estimate overall impacts.***

While asset owners have varying key assumptions and objectives, they are not well-equipped to build and test climate scenarios tailored to their own needs. The climate scenarios provided by Intergovernmental Panel on Climate Change (IPCC), International Energy Agency (IEA), and Environmental Protection Agency (EPA), for instance, are at a macroeconomic level. Although asset owners may refer to these scenarios, many of them do not take immediate action based on them. Asset owners should incorporate climate risks more comprehensively by reflecting their in-depth knowledge from developing and operating assets. Moreover, they should consider not only the physical risks of climate change but also transition risks borne by the evolving regulatory response.

Our customizable methodology can simulate multiple climate scenarios developed by the user. Instead of assessing a single climate risk factor (e.g., temperature rise, water scarcity), our model simulates scenarios with combined risk factors: for instance, when the temperature rises, then it is highly likely that the water supply becomes scarce and fuel costs rise. The owners and operators of infrastructure assets can directly benefit from this methodology as they can better understand which risks and parameters have the greatest potential to affect costs and performance in the long term.

3. ***Asset owners with currently available assessment tools do not fully leverage advanced data that is becoming widely available, such as asset-level data.***

Asset owners and operators are increasingly dependent on analytic data provided by external sources, most of which calculate the resilience score (normalized 0-100) of the overall "portfolio."[4] But, these approaches may overlook valuable implications. It is especially not easy to investigate the impact of climate risks on the value of "individual assets." Assessing asset-level cash flow is challenging because the spectrum of cash flow projection varies widely depending on asset profile, regional circumstances, market awareness, and financial contracts, all of which need to be taken into account while related data is limited. This is a critical barrier that prevents corporations from making informed decisions about the risks and opportunities related to different energy sources, being that the structure and assessment of project financing in this context is very complex.

Through our new approach, asset owners are not only able to estimate a lumpsum probability of default (or the total value of an asset) but also be able to assess the size and time of the losses by the given default. Data on the potential timing, magnitude, and frequency of these climate-driven risks will allow owners and operators in the AEC industry to invest in and develop infrastructure that is resilient in terms of multiple climate metrics. For example, asset owners may seek to estimate

4 Four Twenty Seven, "Scenario Analysis for Physical Climate Risk: Equity Markets." web, Four Twenty Seven 2019.

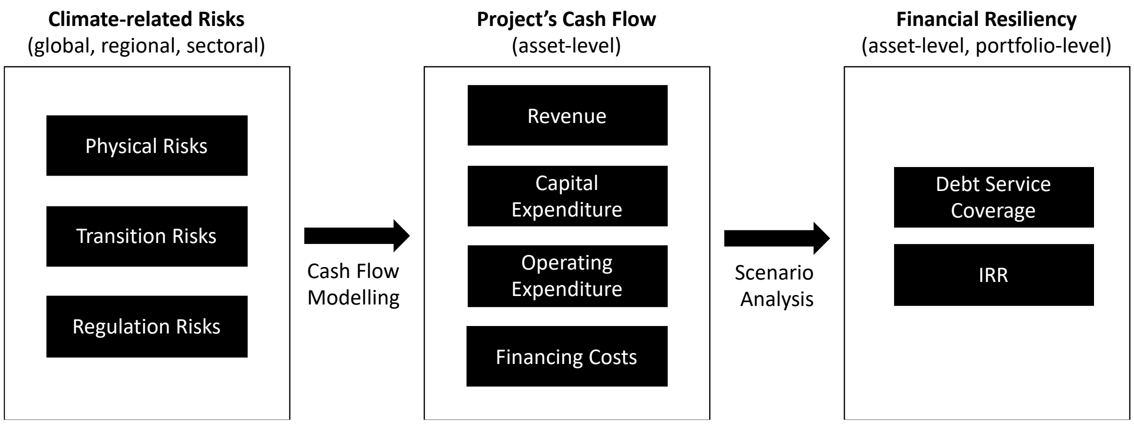
the required investment to make their corporate campuses, data centers, and R&D facilities more resilient to flood risks and weather events. They can choose to evaluate metrics such as optimal levels of insurance to purchase and energy-efficiency features to incorporate.

Research Methods and Work Plan

In this proposed project, we will demonstrate how to assess the financial resilience of energy infrastructure projects to climate change on an asset-by-asset basis. We will integrate multiple climate data and scenarios into a valuation model. As we highlight the variations across assets, this one-year study will focus on three utility-scale electricity generation facilities (i.e., downstream energy assets) in the U.S.: natural gas, coal, and solar PV power plants. However, the methodology that we demonstrate in this study is applicable to a broad range of infrastructure assets in any location. The research team plans to expand this research to the following years to cover different types of energy assets in broader geographical regions.

Using cash flow modeling and stress test methodologies, we will estimate the selected asset's financial default risks that are exposed to specific climate-related risk scenarios. Through this new approach, we are not only able to calculate a lumpsum probability of default (or the total value of an asset) but also be able to assess the size and time of the losses by the given default.

The proposed assessment consists of three parts (see the below flowchart):



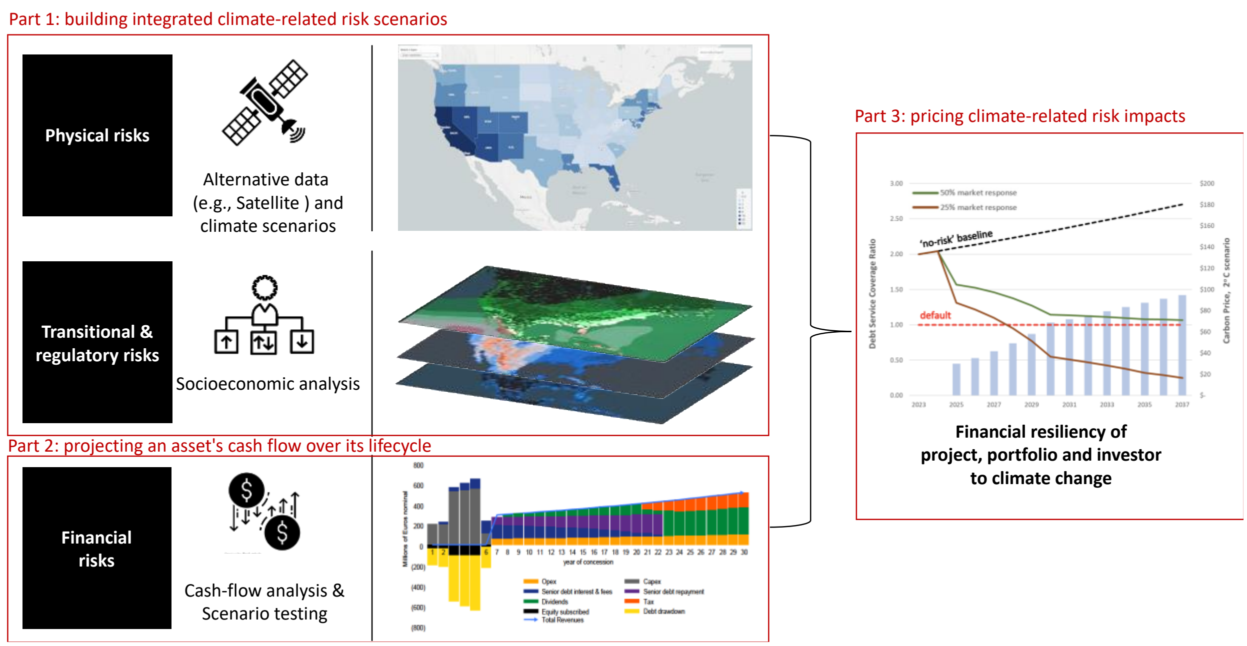
Part 1. Selection of climate risk variables and scenario building: We will build climate risk scenarios (physical, transition, and regulatory risks) that are particularly relevant to the selected asset. The selection of risk variables and their estimates is mostly based on existing literature: estimates of single and combined risk scenarios are computed by a number of existing climate-risk assessment models such as IGSM and DICE models.

Part 2. Cash flow modeling over the project lifecycle: We will price climate-related risk scenarios in the value of the project's cash flow. We consider the dynamic relation among four components of cash flow analysis in evaluating default conditions of an asset: revenues, capital expenditures (CAPEX), operational costs (OPEX), and financing costs.

Part 3. Pricing climate-related risk impacts: We will estimate the asset's probability of financial default due to climate risk scenarios, assess the size and time of the losses by the given default, and calculate the default conditions and negative/positive impacts on their portfolios. Since we analyze the financial resilience of an individual asset, we select an asset of focus by specifying its energy source (e.g., natural gas, coal, nuclear, wind, solar, etc.), sector (e.g., upstream, midstream and downstream), asset class (e.g., debt, bonds, equities), geographical location and project period. These specifications are critical to determining whether and how much the asset is vulnerable to climate risks.[5]

Expected Results: Findings, Contributions, and Impact on Practice

The below figure visualizes the expected output of our assessment model. As such, we aim to develop an innovative, ready-to-use climate risk assessment methodology under uncertainty that will allow any asset owner to price their climate risks for energy investments at the level of the projects' cash flows, and to inform their portfolio and asset management strategies. This is a clear added value to the existing methodologies. In addition, the methodology is flexible enough to be tailored to various types of infrastructure assets.



In particular, the project will develop a ready-to-use climate risk and opportunities' pricing tool to:

- Assess individual energy projects' exposure to climate risk under feasible climate transition risk scenarios and economic trajectories for fossil fuel/renewable energy sectors produced by Integrated Assessment Models.
- Price climate transition risks in the value of individual energy projects' cash flows that could include different types of assets and energy sources, from coal to solar. For doing so, we will develop new, climate-enhanced financial pricing models that are downscaled at the cash flow level. We will consider the specific country's economic and energy market conditions, projects' financial characteristics at the asset level (e.g. loans, bonds, equity), investor's risk aversion and the portfolios' management strategy.

[5] To clarify, we do not use the actual case. Instead, we will identify the most conventional case for each asset type by specifying asset profile, capital structure, and financial terms and conditions, and set it as a base case for our scenario testing. We will also set the geographical location and time period of cash flow projections consistent, as we understand spatial and temporal conditions can extensively influence the degree of financial vulnerability to climate-related risks.

- Calculate the probability of default and assess the potential largest gains/losses at the level of individual project and portfolio by including climate among traditional financial risk metrics, such as the Climate Value at Risk (VaR).

Developing this methodology is a natural extension of the climate stress-testing research that stems from the European Commission's funded project on Financial Systems Simulation and Policy Modelling (SIMPOL). Currently, financial regulation moves precisely in this direction, notably through the G20 Task Force on Climate-related Financial Disclosure (TCFD) and the Network for Greening the Financial System's recommendations (NGFS). This evolution of regulation is creating a major demand by financial actors for quantitative indicators about their climate financial risk exposure that this proposed research is in a unique position to satisfy.

We expect our study outcome will benefit multiple stakeholders in the AEC industry, of course, including the CIFE community. Here, we highlight potential ways CIFE members can leverage and gain value from our research:

- **Designers, developers and constructors:** The ability to estimate the timing and impact of climate risks, and hence the direct financial benefits of investing in resilience, will empower design companies and contractors to gain a competitive position by proactively developing further expertise in climate-resilient infrastructure design. CIFE member companies that have substantial expertise in infrastructure and renewable energy development, such as Swinerton, Mortenson, Obayashi Corporation, and MWH Constructors, can strongly complement their operational capabilities with the capacity to price the benefits (when and how much) of climate-resilient infrastructure.

- **Asset owners and operators:** The customizable nature of our methodology will enable asset owners and operators to create reliable scenarios and simulate their unique perspectives on future conditions. Through the use of cash flow analysis, our model can assess the impact of climate risks on future operational costs, maintenance needs, and asset performance in a granular manner. This can be particularly valuable for CIFE's asset owners and operators such as Google, Gilead, and South32, who own and build corporate campuses, R&D facilities, data centers, power plants, warehouses, and natural resources. They can leverage the data, both from their own assets and also other alternative sources, to adequately assess climate risks as they invest in the built environment and evaluate upfront capital expenditures to develop climate-resilient infrastructure.

- **Decisionmakers and consultants:** The ability to transform climate risk impacts into the financial metrics that users care about will empower decisionmakers to make strategic decisions, such as purchasing insurance or implementing energy-efficient design features or flood and storm protection. Our methodology can benefit CIFE companies such as Ramboll and WSP, who have both increasingly encouraged companies to report climate-related financial data and proactively manage climate risks (e.g., coastal flooding risks).

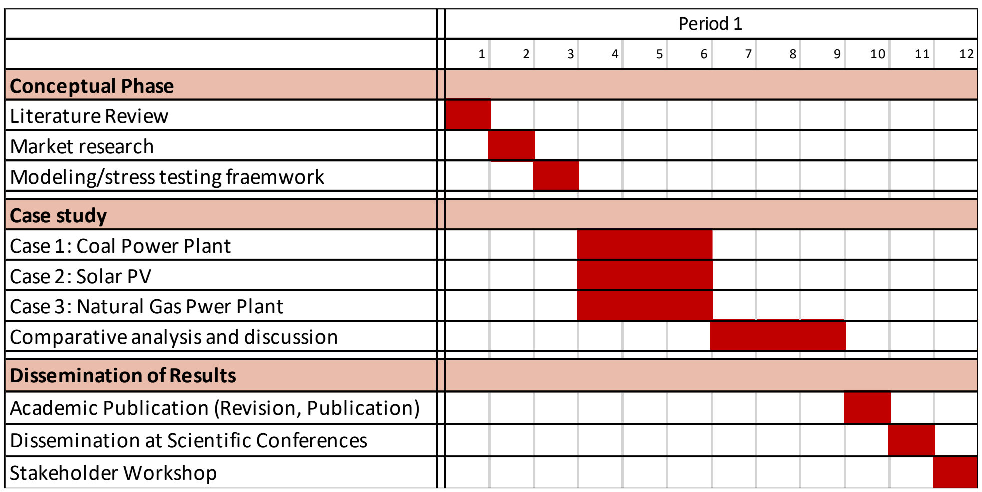
Industry Involvement

- **Immediate industry involvement:** As we emphasize that material climate risk factors should vary by the asset, it is critical to specify key inputs depending on asset types, locations, and financial contracts. We plan to interact closely with CIFE members to validate that our assumptions and scenarios represent industry practice. We will also actively communicate with

CIFE members to understand their current climate risks assessment practices and any barriers for them to effectively and efficiently manage climate risks.

- **Industry involvement in the medium/long term:** As mentioned, we plan this research as a multi-year project. Its first-year milestone, which we propose for CIFE's seed grant, will focus on building a novel methodology and validating it with three cases. In the meantime, we will develop a study that empirically assesses the concept using historical data. Any similar empirical study on asset-level does not exist mainly due to the lack of data availability and access. For instance, asset-level (or regional) climate data has been extremely challenging to capture and access – yet recently, the advanced technologies are contributing to improving this data issue. Also, financing terms and conditions of individual energy assets and projects (e.g., leverage, margin, tenor, and other special financing conditions) are proprietary and thus kept as private. At this point, we are working with development finance institutions (e.g., Inter-American Development Bank and European Investment Bank) on accessing this data: these institutions recognize the benefits of doing so, as it allows them to reevaluate their climate risk exposure. We expect to partner with CIFE members on this empirical validation as well.

Research Milestones and Risks



The success of the project relies on the demand for indicators of exposure to climate financial risks in the analysis of energy investments. Currently this demand is increasing following the changes in the regulatory framework. Our innovation will still help the growing market of asset owners who are committed to addressing climate change because of reputational issues and clients' demand.

Next Steps

- On-campus research collaboration with the Sustainable Finance Initiative and Stanford Energy Club (with potential funding opportunities)
- Global research collaboration with John Weyant (Stanford University), Irene Monasterolo (Vienna University of Economics and Business), Roberto Marco (University of Genoa)
- Research collaboration with think tanks, including the International Network for Sustainable Financial Policy Insights Research and Exchange (INSPIRE), Climate Policy Initiative (CPI), Spatial Finance Initiative (SFI) at University of Oxford (with potential funding opportunities)
- Academia-industry collaboration with development finance institutions including Inter-American Development Bank and European Investment Bank (and CIFE members, if possible)

Budget

Sponsor:	CIFE
Submission Type:	New
Budget Preparation Date:	3/24/2020
Budget Start Date:	10/1/2020
Project Name:	-
Department:	Civil Engineering
Principal Investigator:	Ram Rajagopal
Administrator:	Roosmery Yang

			Period 1		Period 2	All Periods
		From	10/1/2020		10/1/2021	10/1/2020
		To	9/30/2021		12/31/2021	12/31/2021
Personnel Salaries						
Faculty						
Rajagopal, Ram	Academic	1.0%	1,648	1.0%	566	2,214
Total Faculty Salaries			1,648		566	2,214
Graduate Students						
TBA	Academic	50.0%	35,082	50.0%	11,694	46,776
	Summer	0.0%	-	0.0%	-	-
Total Graduate Student Salaries			35,082		11,694	46,776
Research Staff						
Soh Young In	Calendar	13.2%	13,343	0.0%	-	13,343
Total Research Staff Salaries			13,343		-	13,343
Total Salaries			50,073		12,260	62,333
Benefits						
Faculty			503		173	676
Graduate			1,789		596	2,385
Research Staff			4,076		-	4,076
Total Benefits			6,368		769	7,137
Total Salaries and Benefits			56,441		13,029	69,470
Other Direct Costs						
Tuition						
TBA	Academic	50.0%	22,670	50.0%	7,860	30,530
	Summer	0.0%	-	0.0%	-	-
Total Tuition			22,670		7,860	30,530
Total Other Direct Costs			22,670		7,860	30,530
Total Direct Costs			79,111		20,889	100,000
Less						
Tuition			(22,670)		(7,860)	(30,530)
Modified Total Direct Costs			56,441		13,029	69,470
Total Amount Requested			79,111		20,889	100,000

Rates Used in Budget Calculations

Benefit Rates

Faculty:	FY 1 30.55%;	FY 2 30.55%;	FY 3+ 30.55%;
Graduate:	FY 1 05.10%;	FY 2 05.10%;	FY 3+ 05.10%;
Research:	FY 1 30.55%;	FY 2 30.55%;	FY 3+ 30.55%;

Indirect Cost Rates