Syllabus (Ver. 1.0)
Environment and Resources (ENVRES)
ENVRES 260: Implementing & Financing a Decarbonized Economy
Winter Quarter 2021

Course Sessions: Tuesdays and Thursdays from 4:30 pm to 5:50 pm PST
Commencing Tuesday, January 12 and ending Thursday, March 18

Location: All classes via Zoom given the ongoing pandemic.

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Eligible Students: Graduate students only. The Instructors anticipate that there will be a mix of students from Earth, Engineering, GSB, Law and H&S.

Enrollment Process: Solely by application and approval by Instructors. The application form is available at this link: Consent of Program Form

Enrollment Cap: Given the Zoom format, which presents a new teaching experiment for the Instructors, enrollment will be limited to 20 students. The Instructors’ predecessor course (more on which below) was typically substantially oversubscribed even with an enrollment cap of 40, so interested students should be sure to apply timely.

Course Description:

Overview

This is an ambitious course. Most persons who become skilled in the discipline taught by this course do so over many years and surely not over the duration of one academic quarter.
The Instructors have between themselves over a half century and ++$100B worth of hands-on experience developing, financing, acquiring or selling a wide range of projects both in the US and outside the US. The goal of this course is to impart to the students some of the skills, analytical methods and knowledge that sponsors of projects need to have in order to develop and finance successful low-carbon projects that will be financed using non-recourse project financing.

What is meant by “non-recourse project financing”? Or, to shorthand it, “project finance”? Project finance means raising money for a special purpose company (called the “project company”) on a “stand alone” or “non-recourse” basis for the purpose of constructing a “project” (infrastructure asset, power plant, industrial facility, etc.). In other words, there is no independent balance sheet or creditworthy party guarantying the performance of the project company nor the repayment of the project company’s indebtedness. Rather, the repayment of the project company’s indebtedness and the distribution of equity returns to its owners will come out of the cash flows from the operation of the project.

How does a newly-formed shell entity called the project company raise millions or billions of dollars for a project that does not yet exist when no one with a credit-worthy balance sheet is prepared to give any assurances about the overall performance of the project company nor the repayment of the project company’s indebtedness? Well, as much as that description may sound like a very heavy lift, that type of transaction happens every week. Getting such a transaction completed is not magic, but it does require special skills. The US and global markets have developed an art or science (depending on one’s point of view) about how to craft a project that can be project financed. That is what this course intends to (at least begin to) teach.

And there is no small irony in recognizing that the financing tools that enabled a carbon-based economy will also be useful—and essential—to financing a decarbonized economy.

What makes project finance a subject worthy of study?

The transition of the global economy—not just in electricity or even all energy, but across all sectors—to low-carbon systems presents a challenge and a timeframe without precedent in human history. The amount of up-front capital needed in the coming decades to implement the transition to a low-carbon economy will be in the many tens of trillions of dollars. That capital will come from many sources and will be deployed through a variety of financing techniques. Without doubt, project finance will be a large and critical component of that capital and, in effect, will be essential to the successful transition of the global economy to low-carbon systems.

The importance of the cost of capital to fund a project, as distinct from the amount capital to fund a project, is very often underappreciated. When considering any plan or program to address either carbon emissions reductions or carbon removal:

- If it won’t scale, it won’t matter
- If it won’t be economic (as in providing reasonable returns to providers of debt and equity capital for the risks taken), it won’t scale
- If it involves a significant up-front capital investment to produce benefits over many years and cannot attract low-cost capital, it won’t be economic.
As a well-proven and long-standing technique for properly assessing and pricing risks for projects, project financing often offers a path to low-cost capital (at least compared to alternatives) for many types of projects. And sometimes, project finance is the path to obtaining capital at any cost.

How does this course intersect with the transition to a decarbonized economy?

There are so many interesting and different ways to explore the transition to a decarbonized economy. Accordingly, the Instructors wish to be clear about what this course is and is not about.

There are many programs or proposals—whether within NGOs, academia or governments—for the decarbonization of the economy. Examples include: the US Green New Deal, the EC’s European Green Deal, Project Drawdown, the Evergreen Action Plan, Governor Inslee’s 100% Clean Energy for America Plan or his Climate Mission Agenda, a just-released Bill Gates climate plan and others. Of course, perhaps most important in the near term is the future Biden administration’s climate plan which contemplates a decarbonized US electricity sector by 2035 and a decarbonized US economy by 2050.

A great course in the discipline of energy and engineering economic systems might unpack (as in study, compare and critique) these various programs or proposals in terms of how best (at least on paper) to transition to a decarbonized economy (e.g., emphasize or de-emphasize solar, onshore wind, offshore wind, storage, hydropower, geothermal, nuclear, energy efficiency, EVs, hydrogen, etc.) A great course in public policy might unpack the programs or proposals in terms of what mechanisms they propose to implement policy (e.g., what mix of carbon pricing, regulatory mandates, loan guaranties, tax credits, grants, etc.). A great course in political science might unpack the programs or proposals in terms of how they might fare in Congress. A great course in law might examine the extent to which the new administration would be able to effect changes via regulation in the absence of cooperation from Congress or study the tensions between the federal government and the states in their respective jurisdictions and roles as relevant to decarbonization policies.

But unpacking these various high-level programs or proposals—whether from perspectives of energy and engineering economic systems, public policy, political science or law—is not what this course is about. For sure, this course will touch on many of those topics, but its emphasis will be elsewhere. For lack of a better analogy, think of those rather worthy topics as the “macroeconomics” of decarbonization.

Instead, to continue the analogy, think of this course as the “microeconomics” of decarbonization. The contrast between the two is rather sharp. Here below to illustrate the point is just one example: the development of new high-voltage electric transmission lines:

On the “macroeconomics” level (i.e., not this course), the programs or proposals described above will talk about the critical need for significant additional transmission line infrastructure to be built to get large-scale renewable power moved from production locations (windy, sunny or good geothermal areas) to locations where the “load” is, the challenges of building new lines and some policy changes that would help enable the needed transmission infrastructure to be built. The more detailed of such programs or proposals described above might even talk about how many million megawatt miles of transmission need to be built and/or depict some of the origin and destination locations in general terms. They might also name some identified projects that should get built (but not really dive into what it would take for those projects to get built).
On the “microeconomics” level (i.e., this course), by contrast, the focus will be on particular projects. Specifically, to study the development of new high-voltage electric transmission lines, this course would examine whether some specific proposed transmission line could get built. How would the developer get it permitted? What permitting agencies (state and federal) would be involved? What issues does the primary route present? What alternative routes need to be studied? What environmental studies need to be undertaken? What endangered species are anywhere along the routes? Who are all of the potential stakeholders and constituencies? What environmental justice issues does the project present? How would the developer acquire rights of way given that the developer (typically) will not have condemnation authority? Should the developer try to partner with WAPA (a federal agency) to get some condemnation authority? What would be the downsides of doing so? What agreements will be needed with independent transmission system operators or regional transmission organizations? Will the line be AC or DC? If it is AC, will it have excess line losses? If it is DC, how will the inability to tie into the line along the route (i.e., only at each end) affect the buy-in by the affected communities? How many years is the lead time for procurement of major equipment? How backed up are the very limited number of eligible transmission equipment suppliers since a recent federal order required so much already-installed or ordered Chinese-manufactured equipment to be replaced? How, well ahead of the project being ready for financing overall, does the developer finance the 8-figure equipment deposit that is needed to lock down a manufacturing slot? Who can challenge the project, whether people along the route, environmental groups or others? What would be the points of vulnerability (whether legal, practical or political)? What will it take (in time, money, evidentiary showings and/or politics) to overcome the challenges? How long will appeals take? Do the financing and commencement of construction need to wait for appeals to play out? If so, can the developer still meet whatever commitment(s) it made as to when the line would be built and energized? Who would the users of the line be? Do the users of the line even yet exist or are the users some yet-to-be-built set of renewable energy projects? If so, how real are the prospects that those projects will get built and built timely? And even if real, how does one solve that not-so-uncommon chicken-and-egg problem of separate projects being mutually dependent? Who will finance the line (both as to debt and equity)? What financing structure would make sense? What do the economics of the project look like? Are the prospects of succeeding in the development of the line sufficiently attractive to merit pursuing the project?... And so on.

As just this one example illustrates, one need not be an expert in project development to see that there is quite a gulf between the aspirations of an adopted “macro” plan and its commercial implementation on the ground. No matter how impressive a “macro” program may be for the decarbonization of the economy, at the end of the day, the “macro” program only comes to fruition if the “micro” side gets real

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1 The faster the energy transition (and, in the domain of energy and industrial infrastructure, what the Biden plan proposes is fast), the more these sorts of chicken-and-egg problems will arise.

2 And, just to put a finer point on the contrast, the gulf focused on here is not what is takes to get a “macro” plan (1) fully figured out as among its advocates and advisors, (2) adopted through administrative rulemaking processes and past inevitable legal challenges or (3) enabled by Congress with legislation or budgetary appropriations. While those are no small steps, they are not the gulf focused on here. Even with a “macro” plan fully resolved and instantly in place (with whatever requisite regulations, legislation and appropriations in hand), there is still a huge gulf between the “macro” and the “micro”.
projects built. And a lot of them. Nothing will get built unless there is a team of people well skilled at sorting out everything needed to get a project done. As Grandpa would say, “There’s an awful lot of felt between the ball and the pocket.”

This same sharp contrast between the “macro” and the “micro” would apply to any category of low-carbon project studied in this course. This course will apply that same type of very granular “micro” analysis to whatever low-carbon projects are being examined, whether renewable energy, storage, direct air capture, carbon capture or otherwise.

Non-US projects

Studies and reports on climate impacts point out that a successful decarbonization of the US and EU countries would mean very little without a successful global decarbonization. The implementation of decarbonization steps throughout the world will require vast capital investment flows from wealthy economies to developing economies. Much of that capital investment will be in the form of cross-border project finance. Why? The next two decades of energy spending required in developing countries to achieve a low-carbon economy materially exceeds their total current wealth. Cross-border project finance will be imperative to close the gap.

Although most of the projects this course will examine are US projects, most of the content of this course will be valuable for understanding any project—whether in the US or elsewhere. A cross-border component adds a myriad of additional issues to any project. Even before getting to any cross-border issues, this course is already quite fulsome in content. Because of time constraints and surely not as an indication of relative importance, this course will provide only an introduction to the specific issues of cross-border finance. That subject would make for a rather worthy and fulsome course on its own.

In their team projects (more on which below), students can focus (and in the past often have focused) on non-US projects, as and if so decided by the student team.

What students can get from this course

*Project development.* Obviously, if the course succeeds in its goal of teaching the discipline and analytical methods of project finance, the students who wish to pursue low-carbon projects will be aided in their efforts.

*Policy.* Less obviously but notably, students who prefer a career in the policy domain should find the course helpful in analyzing the merits or demerits of policy programs, which are written by very smart and well-meaning people who often have little or no experience in actually getting projects done and who therefore often do not fully appreciate the challenges facing the implementation of their policy.

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3 Of course, there are many elements of any “macro” program that will not have this described dependence on the “micro” side (as in not requiring projects of the sort covered in this course), such as with light transportation policy (e.g., incentives for EVs and fuel economy standards for, or phase-outs of, ICE cars), energy efficiency steps (e.g., tightening standards for lighting, appliances or HVAC equipment) or certain agricultural policy changes (e.g., changing farming practices). But an enormous part (i.e., tens of trillions of dollars globally in the coming decades) of any “macro” program will have this dependency.
prescriptions. A feedback loop of input from the “micro” side into the “macro side” would yield better public policy.  

Clean tech. Students who aspire to a career in clean tech should find some knowledge of project development to be rather useful, particularly if (as is often the case) their intended technology requires deployment via real “steel in the ground” as opposed to deployment via software. The clean tech highway is strewn with the carcasses of companies whose investors, boards and management teams had strong confidence in a particular technology, but an insufficient understanding of what it would take to get commercial projects built.

CEPDF – the predecessor course

In five previous academic years, the Instructors (along with a colleague) taught a very well received course called “Clean Energy Project Development and Finance” at the GSB (GSBGEN 335) and the Law School (LAW 2509). This new course is intended as an evolution of CEPDF by broadening the scope of the types of projects the course will cover (such as industrial decarbonization and carbon removal). The new title is not intended to imply that clean electricity has fallen in importance—to the contrary, it remains a critical component of a decarbonized economy. In fact, there is a staggering large reasonably projectable increase in the demand for clean electricity in future years as clean electricity continues to displace legacy production and as electricity generally finds a greater role in the economy such as in light transportation, building heating and industrial processes. So, this new course continues to have significant content related to clean electricity projects.

The duality of this course

On one level, this course is somewhat timeless and old news. The discipline and analytical methods of project finance have been around for decades and, once learned (albeit no easy task), are a set of skills constituting a way of thinking that can be applied to nearly any project.

On a separate level, this course is very much at the cutting edge. This reframed and broadened course will try to dive into some new (and difficult) topics: industrial decarbonization and carbon dioxide removal. The course will also touch on how new technologies should try to work their way to being accepted by the project finance markets.

Interdisciplinary nature

4 The discipline and analytical methods of project finance can integrate closely with the crafting of government policy. When governments wish to incentivize the development of various types of low-carbon projects, governments in the West rarely pay for projects “whole hog.” Instead, governments provide one or more specific incentives—such as a “feed-in tariff,” a “renewable portfolio standard,” a tax credit, one or more forms of carbon pricing, a loan guaranty, some form of concessionary (subsidized) financing, etc. Governments try to craft enough of an incentive package so that the private sector (often, if not typically, using project finance) will achieve the government’s policy objective of seeing the completion of the desired projects. Importantly, the policy challenge is not solely about crafting the right package of incentives. Rather, governments also need to understand (and then unblock) the obstacles to the successful development of the desired projects that remain even after the adoption of incentives.
The University has sought to emphasize interdisciplinary research and interdisciplinary teaching. This course presents the latter feature on steroids.

The successful development and financing of large projects requires a very broad and interdisciplinary set of very specialized knowledge and skills. In fact, it is hard to think of many businesses that are more interdisciplinary. Any competent person who seeks to lead the development of large projects by necessity needs to know a lot about markets, technology, law and finance.

Naturally then, this course too is very interdisciplinary. Its interdisciplinary nature presents in three ways: (1) the course content by looking at projects holistically and not as any one siloed discipline (engineering, business, finance, law) might, (2) the student mix across many schools at Stanford and (3) the course structure whereby (through a team project—more on which below) the students interact with each other. In that way, the course reflects the real world where the development and financing of projects requires people with different roles and specialties—businesspeople, political people, environmental permitting specialists, lawyers of all sorts, engineers, finance people—to work together in a common effort.

Perhaps this course is so interdisciplinary that a warning label ought to apply. The mix of students from Earth, Engineering, GSB, Law and elsewhere means that inevitably what is new and interesting to one student on topic A may be rather basic and boring to another student and just the reverse on topic B. Hence, the Instructors ask students for some patience in this regard.

Content

The Course Sessions Matrix below lays out the current version of the content of the course broken out by course session. The Instructors will update it from time to time. Please look at Canvas each week to check for updates.

The course will focus on the critical skills needed to evaluate, develop, finance (usually on a non-recourse basis), and complete standalone projects. The course will teach the key building blocks of non-recourse project development and financing for a broad range of technologies. In addition to analyzing key principles, the course will use transaction documents from proposed and operating projects to give students a practical grounding in project development and finance and its application to low-carbon projects.

Course Organization: The course will include: (i) lectures/readings presented and discussed in a seminar format; (ii) various written assignments regarding key readings or concepts, (iii) in-depth group projects (typically four-person teams) presented to the full class as the culmination of the course sessions.

- Lectures: Many of this year’s main lectures will be pre-recorded for students to watch prior to class. We will make these lectures as short and lively as we can. The advantage of pre-recording the lectures is that so doing will allow us to spend our class time on lively discussion. Guest lecturers who are experts in various subjects will join the class at various points.

- Approach to Readings and Documents: Please refer to the Canvas for links to reading assignments and specific questions we will be addressing in particular sessions. The primary course materials include documents from several representative projects. Part of the experience of this class is for students to come across real documents. And the reality is that they are often
long. HOWEVER, please note that the Instructors do not expect students to read or read carefully the entirety of all of the assigned source deal documents. Sometimes students will only need to skim the deal documents. Sometimes students will only need to read specific parts to learn a specific concept—and we will give references to specific pages and definitions to help you. But, even in those situations, it adds to the learning experience for students to have the whole document and not just some highly-curated excerpts. Please check Canvas for updates to reading assignments and for specific guidance on the assigned readings before panicking over the length of some of the deal document portions of readings. Also, we recognize that reading long documents on a computer screen can be difficult. So, we will see if we can arrange for some copies of the documents to be printed out and available for reading at some location.

- **Written Individual Assignments:** We will have various relatively brief written assignments that will be due at the start of certain lecture. These individual assignments are designed to make sure students master the basic quantitative tools and document review skills of project finance.

- **In-Class Seminar Format Discussion:** We will primarily focus our 80-minute class sessions on discussions of the hardest technical, legal, and financing concepts as informed by the lectures, readings, and homework. We hope that the small class size and moving lectures to the pre-recorded format will leave lots of room for every student to participate actively.

- **Team Projects:** The course (lectures, readings and written assignments) will build towards and support team-based projects presented during the last two sessions of the term. In CEPDF, the team projects were a bit hit with the students, at least after an initial period of trepidation. Each project team will analyze the energy project development and finance process for a particular technology, as illustrated by actual projects and informed by key financial, legal, policy, and engineering principles and mechanisms. Students will form four-person multi-disciplinary teams organized by particular technologies as follows:

1. Solar PV (utility scale only, not residential/commercial rooftops), with or without storage
2. Solar thermal
3. On-shore wind
4. Off-shore wind (whether sea-floor-mounted or floating)
5. Geothermal (whether conventional or EGS)
6. Nuclear (whether large or small modular)
7. Storage (battery, pumped storage, hydrogen, gravity or other)
8. Transmission
9. Carbon capture and storage
10. Biomass power
11. Biomass with carbon capture
12. Hydropower (large or mini)
13. Ocean/tidal energy
14. Direct Air Capture (DAC) -- carbon dioxide recovery from atmosphere
15. Ocean CDR-- carbon dioxide removal from the oceans
16. Other, as a student team may propose

In general, for the team projects, we will try to keep comparability across technologies by using a common set of evaluation questions/criteria including: financial feasibility, manageability of
environmental issues, constructability and ability to control cost over-runs, ability to obtain off-takers at prices sufficient to cover expenses and financing, and exposure to carbon limits/taxes. Further information on the team projects will be provided at the second class. In past years we have done our best to honor student preferences on projects, balanced against the need to cover enough different types of technologies to benefit the entire class.

Course Logistics and Administration

Course sessions:

i) Regular attendance via Zoom is mandatory. If you have to miss a class, please notify us prior to that session.

ii) There will be a brief break around the middle of each class.

iii) The class has benefitted in the past from lively participation of students from different schools (Earth, Engineering, GSB, and Law), different professional experiences, and different home-country perspectives. Class participation is part of the grade and is valued. Students who have concerns about public speaking should confer with the instructors as to accommodation.

Grading:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Class Participation</td>
<td>30%</td>
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<tr>
<td>Brief Written Assignments</td>
<td>30%</td>
</tr>
<tr>
<td>Group Project</td>
<td>40%</td>
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</tbody>
</table>

Class Dinner

In the past five years of the CEPDF course, the Instructors hosted a dinner for the class. COVID has put the kibosh on that idea at least for the near term. The Instructors hope to be able to invite all students to a dinner as soon as the law and prudence allow. Hopefully, it can happen in the Spring.
## Course Sessions Matrix

<table>
<thead>
<tr>
<th>Date</th>
<th>Session No.</th>
<th>Primary Topic</th>
<th>Pre-Class Reading or Viewing</th>
<th>Homework or Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>0</td>
<td>Optional pre-reads and previewing(^8)</td>
<td>See posting on Canvas</td>
<td></td>
</tr>
<tr>
<td>Tues 1/12</td>
<td>1</td>
<td>Intro: Micro- vs. Macro-Decarbonization and CDR. The challenge of getting steel in the ground; What we seek to accomplish with this class; Intro to student team projects</td>
<td>None (other than Row 0 above)</td>
<td>None</td>
</tr>
<tr>
<td>Thurs 1/14</td>
<td>2</td>
<td>Technology and cost of energy/capacity. Heat rates, cost of fuel, dispatch, CO2 intensity. Merit order dispatch. How to think about project and system economics -- &quot;Levelized cost&quot; vs. other measures</td>
<td>Lazard cost of power/storage</td>
<td>Problem set on power plant costs, fuels, CO2 emissions</td>
</tr>
<tr>
<td>Tues 1/19</td>
<td>3</td>
<td>Political governance and its implications for project development; U.S. electric power industry regulatory and ownership framework; Legal concepts;</td>
<td>Hoffman intro reading on Project Finance; EEI Cost of Service Regulation; reading on &quot;How Regulated Utilities Make Money&quot;; reading on Dereg &amp; ISOs</td>
<td>None</td>
</tr>
</tbody>
</table>

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\(^5\) This matrix will be subject to regular updates that the Instructors will communicate to the students through postings on Canvas. Note that this Matrix contains a fair amount of topic-specific terminology and the like, all of which will get explained in the readings or class sessions. Accordingly, students who are unfamiliar with the some of the terminology here should not be discouraged, much less conclude for that reason that they are not a fit for this class.

\(^6\) There will be various guest speakers and “cameo topics” in addition to the primary topics. Stay tuned on Canvas.

\(^7\) This column will be supplemented. There will be a fair amount of reading.

\(^8\) Most students are probably keenly interested in the topic of decarbonization, so we provide a list of optional material for reading or viewing either before Winter Quarter starts or over the course of the Quarter.
<table>
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<th>Primary Topic</th>
<th>Pre-Class Reading or Viewing</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Thurs 1/21</td>
<td>4</td>
<td>Finance math, accounting, basic tax. How project finance differs from corporate finance</td>
<td>Brealy &amp; Meyers</td>
<td>Problem set on debt amortization, credit ratios, equity rates of return, Capital Recovery Factors</td>
</tr>
<tr>
<td>Tues 1/26</td>
<td>5</td>
<td>Environmental issues and social license; Permitting—substantive requirements, procedural requirements and challenges</td>
<td>TBD; Record of Decision from project TBD</td>
<td>None</td>
</tr>
<tr>
<td>Thurs 1/28</td>
<td>6</td>
<td>Pro formas; initial feasibility assessment</td>
<td>Solar Case Part I</td>
<td>Solar Case I--Back of Envelope Feasibility--convert windfarm model to solar PV model</td>
</tr>
<tr>
<td>Tues 2/2</td>
<td>7</td>
<td>Critical tasks for advanced feasibility assessment: construction contracts, off-take contracts, resource / market studies, permitting</td>
<td>Solar Case Part II, plus full Independent Engineer reports from 1 or 2 projects</td>
<td>Solar Case II--Incorporate new facts in simple model</td>
</tr>
<tr>
<td>Thurs 2/4</td>
<td>8</td>
<td>Debt market alternatives for decarbonization projects, full life-of-project pro forma modeling</td>
<td>Solar Case Part III, plus readings long-term debt for decarbonization projects &amp; rating agency guidelines</td>
<td>Solar Case III--Use full pro forma (provided) to determine optimal borrowing strategy and to estimate power price to bid</td>
</tr>
<tr>
<td>Tues 2/9</td>
<td>9</td>
<td>Equity markets &amp; bidding price; Previews of student team projects (Teams A, B &amp; C)</td>
<td>Solar Case Part IV</td>
<td>Solar Case IV--Determine optimal leverage, calculate equity returns, make final go/no-go recommendation. Prepare 5-7 minute progress reports (Teams A, B &amp; C)</td>
</tr>
<tr>
<td>Thurs 2/11</td>
<td>10</td>
<td>PPAs &amp; other offtake sales contracts, Contracts for Differences (“CfDs”) and other synthetic offtake agreements; Previews of student team projects (Teams D &amp; E)</td>
<td>Copper Mtn Solar project PPA. [CO2 sales agreement.] Readings on CfDs</td>
<td>Answer questions on Copper Mtn. solar PPA document. Prepare 5-7 minute progress reports (Teams D &amp; E)</td>
</tr>
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<tr>
<td>Tues 2/16</td>
<td>11</td>
<td>EPCs full Session: Dig into Definitions, Rely-upons, LDs, Substantial Completion, Payment Shape &amp; Retainage Challenges of getting newish technologies introduced to project finance</td>
<td>EPC Contract and Exhibits from actual deal; PF Textbook Chapter on EPC; &quot;when things go wrong&quot; reading on failed $7bn project</td>
<td>Answer questions on Natural Gas Combined Cycle construction document</td>
</tr>
<tr>
<td>Thurs 2/18</td>
<td>12</td>
<td>International projects &amp; the overall financing challenge of projects ex-OECD</td>
<td>&quot;Making Green Energy Blue Chip&quot; framing paper</td>
<td>None</td>
</tr>
<tr>
<td>Tues 2/23</td>
<td>13</td>
<td>System Planning: The challenges of integrating intermittent renewables, the conundrums of paying for and choosing when to operate Dispatchable Low-Carbon Power</td>
<td>Paper by SB-100 Study Group (led by CATF and EDF) modeling cost of meeting 2050 climate goals. Reading on &quot;missing money problem&quot; and capacity adequacy issues</td>
<td>None</td>
</tr>
<tr>
<td>Thurs 2/25</td>
<td>14</td>
<td>Storage: Batteries; thermal; pumped storage; hydrogen</td>
<td>Lazard cost of storage V11, excerpts from Law School Seminar paper on storage</td>
<td>Problem set on cost of battery storage.</td>
</tr>
<tr>
<td>Tues 3/2</td>
<td>15</td>
<td>Heavy Industry: Industrial Carbon Capture of combustion and process emissions; electrification; low carbon fuels</td>
<td>White paper on industrial carbon capture; IEA 2020 paper on capture; Columbia paper on industrial heat</td>
<td>None</td>
</tr>
<tr>
<td>Thurs 3/4</td>
<td>16</td>
<td>Negative Emissions: Direct Air Capture (DAC) &amp; Bio-Energy with Carbon Capture and Sequestration (BECCS)</td>
<td>Readings on DAC and BECCS</td>
<td>None</td>
</tr>
<tr>
<td>Date</td>
<td>Session No.</td>
<td>Primary Topic</td>
<td>Pre-Class Reading or Viewing</td>
<td>Homework or Deliverables</td>
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<tr>
<td>Tues 3/9</td>
<td>17</td>
<td>Transportation Zero Carbon Fuels: Aviation, Shipping, Heavy Vehicles</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Thurs 3/11</td>
<td>18</td>
<td>Q&amp;A on student team project presentations (Teams A, B, &amp; C)</td>
<td>Watch pre-recorded student team presentations. Come to class ready to ask questions</td>
<td>Teams A, B, &amp; C pre-record ~30-40 minute presentations and upload same for viewing not later than Tuesday evening 3/9</td>
</tr>
<tr>
<td>Tues 3/16</td>
<td>19</td>
<td>Q&amp;A on student team project presentations (Teams D &amp; E)</td>
<td>Watch pre-recorded student team presentations. Come to class ready to ask questions</td>
<td>Teams D &amp; E pre-record ~30-40 minute presentations and upload same for viewing not later than Friday evening 3/12</td>
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<tr>
<td>Thurs 3/18</td>
<td>20</td>
<td>Wrap-up session: How do we get deep decarbonization done both US and globally?</td>
<td>TBD</td>
<td>None</td>
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