An Introduction to Engineering, Procurement, and Construction (EPC) Contracts for Climate Projects

The role of EPC contracts in accelerating the deployment of infrastructure projects involving early-stage climate technology

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October 2024

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Acknowledgments

I extend my thanks to Mark Reuss at Spring Lane Capital and to my colleague Dan Matross, both of whom reviewed this paper and shared their comments on EPC contracts.

Here is further reading on the intersection of climate projects and EPC contracts:

- "Industrial & Energy Technology Project Finance: A Startup and Developer's Guide to Scaling and Commercial Success" (New Energy Risk)
- "Successful projects depend on the business" (Project Management Institute)
- "Engineering, Procurement and Construction (EPC) contracts in the solar sector" (PwC)

Executive Summary

As the world faces the urgent challenge of transitioning to a decarbonized economy, deploying innovative climate hardware that is less polluting than legacy technologies has become imperative. Large-scale climate technology infrastructure projects are essential for reducing and eliminating emissions. Engineering, procurement, and construction (EPC) contracts play a vital role in the successful execution of these projects. This paper examines the importance of well-structured EPC contracts in enabling the efficient deployment of emerging climate technology infrastructure.

- EPC contracts are agreements that shift responsibility for project planning, management, and construction to the contractor. These arrangements offer a single point of accountability, integration of design and construction processes, and performance guarantees. However, EPC contracts also have limitations, such as reduced owner control over design details and risk of contractor default or delay.
- EPC contractors are construction firms with significant resources and capabilities to deliver large projects. They typically support large and expensive projects that involve repeat clients and proven technologies. Because EPCs usually operate on thin margins, these project characteristics limit risk and enable profitability.
- Unlike traditional contracts that shift most or all project-related risks to the EPC contractor (known as lump sum turnkey), contracts for emerging climate technology projects will likely involve more thoughtful and creative allocation of risk and responsibility. Several initial steps, collectively known as front-end loading, can help a project owner evaluate benefits and risks before negotiating and signing an EPC contract. With greater project definition, an EPC contractor can provide the project owner with an accurate cost estimate and enable them to make a final investment decision.
- Entrepreneurs and investors might commit significant capital and time to deploying climate technology and building projects. Detailed understanding of EPC contract strengths and limitations, pricing arrangements, and cost estimates is valuable. Knowing the model for how projects have been built can facilitate better cost and timeline estimations and accelerate decarbonization efforts.

This paper is the third in a series from CREO that describes important deployment tools for infrastructure projects involving emerging climate technology. The first two papers addressed climate offtake agreements and financial risk transfer solutions, such as insurance and hedges. In addition, CREO's framework for first-of-a-kind (FOAK) projects helps developers demonstrate that components of their project have been done before and thus are less risky to finance. CREO also compiled strategies that developers adopt to scale up, de-risk, and finance climate projects.

Comments on this paper or related inquiries are welcome. Please direct queries or comments to Kobi Weinberg (kweinberg@creosyndicate.org).

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Introduction

Achieving net zero emissions by 2050 requires a significant increase in financing and deployment of emerging climate hardware technologies.[1] This transition to a low-carbon economy necessitates widescale production and adoption of sustainable energy, fuel, and materials, carbon capture and storage, and other emissions-reducing innovations. Building the infrastructure to deploy emerging climate technologies is a complex undertaking involving significant financial resources, technical expertise, and project management prowess. Projects involving emerging climate technology that has not been tested or used at scale are especially risky, making it difficult to attract essential financing and customer demand.

Engineering, procurement, and construction (EPC) contracts, where a single contractor is responsible for all elements of design, procurement, construction, and commissioning, have emerged as the preferred method for executing large infrastructure projects.[2,3,4] These contracts, if properly negotiated and performed, can speed deployment, lessen project risk, and help attract critical financing. Despite the widespread use of EPC contracts in certain industries, members of the climate community – including technology innovators, accelerators, funders, and advocates – are often unfamiliar with them. This paper describes EPC contracts, their advantages and disadvantages, when to use them, and how to negotiate them.

Despite their importance in building critical climate infrastructure, securing a high-standard or bankable EPC contract can be challenging. An EPC contractor might be unable or unwilling to provide desirable price, schedule, or performance guarantees for a new climate infrastructure project because of greater technical, financial, and operational risks. Hence, this paper also reviews the steps and structures a project developer or owner can adopt to better define a project's scope and increase its bankability.

1 EPC Contracts and EPC Contractors

1.1 EPC Contracts

An engineering, procurement, and construction (EPC) contract is an agreement between a project owner and a single contractor that is responsible for delivering a complete and operational facility.[5] The EPC contractor carries out the detailed engineering and design of the project, procures all the necessary equipment and materials, and performs construction to deliver a functioning facility or asset to the client.[6] This structure contrasts with other contractual arrangements where the owner may manage design and procurement separately from construction or may divide construction responsibilities among multiple parties.

EPC contracts are common in infrastructure, industrial, and energy projects, where the owner seeks a single point of responsibility for project delivery. For large-scale climate technology projects, EPC contracts can play a crucial enabling role. They allow project owners to transfer key risks to contractors with the expertise and resources to manage them. EPC contracts can also accelerate project delivery by integrating and overlapping design and construction activities. As more companies look to decarbonize hard-to-abate industries (e.g., steel, cement, aviation, shipping) and deploy more sustainable assets, partnering with an experienced EPC contractor can be essential for success.

The idea of having one contractor provide a complete solution for these types of projects dates to the early 20th century.[7] However, it was in the 1970s and 1980s that EPC contracting gained prominence, particularly in the energy sector.[8,9] The oil embargo in the early 1970s disrupted supplies to Western countries, prompting them to expand domestic production. Seeking EPC contractors' expertise in comprehensive project delivery, the oil and gas industry adopted EPC contracts for constructing refineries, pipelines, and offshore platforms. In the 1990s, the use of EPC contracts expanded into power generation, mining, and industrial infrastructure projects.[10] Today, the EPC model is the dominant contracting approach for large-scale, complex projects across sectors.

Ideally for most project owners, an EPC contract shifts all responsibility for project planning, management, and construction to the contractor. The contractor's duties fall into five primary categories:[11]

- **Engineering**. Detailed plans, designs, and specifications for the project.
- **Procurement**. Materials, equipment, and technology sourcing and purchasing.
- **Construction**. Construction management and oversight of the installation of equipment and infrastructure.
- **Project management**. Coordination of all project aspects, including scheduling, budgeting, and quality control, which ensure the project is completed on time and within budget.
- **Commissioning (facility start-up).** Verification that installed systems and equipment operate according to design specifications and meet performance standards.

The contractor is usually required to finish and deliver the project in turnkey condition (i.e., ready for immediate use) by a certain date and within a specific budget. While the terms "EPC contract" and "turnkey contract" are often used interchangeably, a turnkey contract technically involves an extra step of project commissioning and start-up. Many EPC contractors recently, however, are not signing turnkey contracts and are instead adopting other arrangements. (See the "Types of EPC Contracts" section.) EPC contracts also do not always include commissioning, which entails running, testing, and adjusting each system to ensure the project performs as stipulated. After commissioning, the project should be ready to commence operations. Once the project is operational, the project manager can ramp-up production to full commercial-scale and test the plant's performance at steady-state production (sometimes called the "Bankers' Test").

1.2 EPC Contractors

An EPC contractor may be a single company or a consortium of firms with complementary capabilities.[12,13,14] EPC contractors usually have in-house engineering and project management resources and a network of subcontractors and suppliers. Many are large organizations generating billions of dollars in annual revenue and employing thousands or tens of thousands of people, including engineers with various specialties, design and supply chain professionals, regulatory and government experts, and finance and risk managers. Several EPC contractors have begun to support climate-related projects. Figure 1 lists some leading EPC contractors in climate projects.

Figure 1: Leading EPC Firms for Emerging Climate Infrastructure Projects.[15]

Many emerging climate projects (i.e., non-wind, non-solar) are too small for EPCs to undertake. In a CREO dataset of 60 demonstration and commercial climate projects fundraising in 2023 and 2024, the median project cost was $58 million, and more than 60% of the projects cost less than $100 million.[16,17] While this cost may seem significant, it might not necessarily attract EPC contractors because not all the capital raised goes directly to the EPC and these contractors typically have tight profit margins.

In contrast to tech companies, whose net profit margins are in the high teens or low twenties, EPCs typically have 1-3% net profit margins. EPCs are able to operate profitable businesses on these lower margins because the projects they support are large, expensive, and involve repeat clients and technologies. Fluor Corporation, a publicly traded EPC firm, had a net profit margin of 2.62% in Q2 2024.[18] With tight margins, these firms might avoid projects with significant risk and limited scale. EPC firms are structured and incentivized to take big projects with clients that have proven technologies and are likely to be repeat customers.

2 Advantages and Drawbacks of Using EPC Contracts for Climate Technology Infrastructure Projects

An owner needs to evaluate whether an EPC contract is an appropriate structure for a project. These arrangements offer a single point of accountability, integration of design and construction processes, and usually performance guarantees. However, EPC contracts have potential drawbacks, such as reduced owner control over design details and risk of contractor default or delay. The suitability of an EPC contract depends on multiple factors, such as project complexity, owner capabilities, and risk allocation preferences.[19] This section describes the main advantages and limitations of EPC contracts (which Tables 2 and 3, respectively, summarize).

2.1 Advantages of EPC Contracts

EPC contracts have become popular because they offer owners multiple advantages:

- **Risk allocation and mitigation.** Climate technology infrastructure projects often involve novel designs, unproven equipment, and first-time component integrations. These features amplify the risks of cost overruns, delays, and performance shortfalls. A well-crafted EPC contract explicitly allocates these risks between the project owner and contractor.[20] The contractor generally assumes risks related to cost, schedule, and performance, which they can hedge through equipment warranties.[21] This arrangement motivates EPC contractors to implement rigorous risk management practices.
- **Accelerated project delivery.** EPC contracts can significantly compress infrastructure project timelines. Design, procurement, and construction activities can be fast-tracked, overlapped, or run concurrently. Getting climate technology projects operating faster accelerates decarbonization and allows project owners to seize time-sensitive government funding, prove technology performance and scalability, and attract additional private financing. EPC contracting can shorten schedules more than other construction approaches.[22]
- **Performance guarantees and warranties.** A performance guarantee or “wrap” in an EPC contract increases certainty that a climate technology and project will function as planned. These guarantees motivate contractors to meet output, efficiency, and emissions reduction targets, as their compensation is tied to performance. EPCs sometimes require multi-year warranties on emerging climate technologies that assign underperformance or failure risk to technology providers. These assurances enhance bankability and increase confidence in projected attributes and financial returns.[23,24] Table 1 summarizes how EPC contracts can mitigate project risks and enhance bankability.

Table 1: EPC Contracts Can Mitigate Risks Affecting Project Bankability.

Project Risk	EPC Contract Mitigant
Price	A fixed completion price
Performance	Guarantee with liquidated damages
Responsible party	Single point of responsibility
Schedule	Guaranteed schedule with damages for delay
Security	Payment guarantee or bonding

- **Interface and integration management.** As the central point of responsibility and communication across dozens of suppliers, subcontractors, and consultants, the EPC can ensure all pieces fit and work together. For example, deploying an innovative electrolyzer for green hydrogen production requires seamlessly integrating the technology with the plant and supporting infrastructure. An EPC firm is best positioned to select compatible components, manage integration, and validate overall system operation.
- **Cost and change management.** EPC contracts sometimes use open-book costing and set target prices to align owner and contractor incentives.[25] In these contract structures, savings or overages relative to the target price are shared. These agreements reward contractors for timely surfacing of potential changes and enable active management of contingency budgets. Target price contracting promotes transparency and flexibility to adapt designs as climate technologies rapidly evolve.
- **Benefits to securing financing.** Large-scale projects tend to be expensive, and their riskiness, especially if they involve new technology, can make securing financing especially difficult. EPC contracts offer several advantages for securing project finance. By wrapping multiple project elements into a single point of responsibility, EPC arrangements enhance the bankability of projects. The risk transfer and performance guarantees inherent in EPC contracts provide greater certainty over cost, schedule, and revenue outcomes. This predictability is crucial for securing debt and equity financing, as well as grants. With an EPC contract, lenders can often offer more favorable terms as the contractor’s balance sheet provides additional security. The contractor’s track record and financial stability are key considerations in the financing process.

Table 2: Benefits of EPC Contracts.

Reason	Description
Single point of responsibility	The EPC contractor assumes responsibility for all aspects of the project, including design, engineering, procurement, construction, commissioning, and testing. The project owner needs to communicate and coordinate with only one entity. If a problem arises, the owner can hold one party accountable. The EPC contractor bears all project-related risks.
Fixed contract price	If pricing is lump sum, the EPC contractor is responsible for cost overruns but benefits from cost savings. The contractor has limited options to claim extra time/costs.
Fixed completion date	The project completion date is guaranteed either as a fixed date (e.g., by January 1) or a fixed period after the contract starts (e.g., within 365 days). If the project is not finished on time, the contractor often pays (or reduces the price by) a specified sum. This pre-determined amount provides certainty for both parties, simplifies dispute resolution, and deters breach of contract.[26]
Performance guarantees	The project owner earns revenue by operating the facility. Performance guarantees help ensure that the facility is ready on time and operates as required – in terms of output, efficiency, and reliability. Guarantees can include penalties for failing to meet various standards.
Performance security or bonds	It is normal for the contractor to provide performance security to the project owner in case it does not comply with its obligations under the contract. Performance security is a financial arrangement where the project owner can file a claim against a performance bond, bank guarantee, or letter of credit to recover damages or hire a different contractor.
Defects liability	Contractors are required to repair defects within a certain period (e.g., 12-24 months) after performance testing is completed.

2.2 Limitations of EPC Contracts

EPC contracts have tradeoffs. While these contracts are popular for large-scale infrastructure projects, they have limitations, especially when applied to projects involving emerging climate technologies.

- **Dependence on a single contractor.** The heavy dependence of project owners on an EPC contractor for an entire project can be particularly risky. A contractor facing problems, such as financial struggles, overcommitment, personnel changes, or difficulty meeting the project's technical requirements, can delay or jeopardize the project. Replacing the contractor mid-way may be hard due to the specialized nature of the technology and the contract’s comprehensive scope. A contractor's monopoly on project-specific knowledge and expertise can put the owner at a disadvantage in negotiations or dispute resolutions, affecting the long-term operation and maintenance of the project.
- **Inflexibility in the face of technological uncertainty.** EPC contracts might operate on a fixed-price, turnkey basis, which assumes a high degree of certainty about the project's scope, costs, and timeline. However, emerging climate technologies are often

characterized by rapid technological advancements, uncertain performance in real-world conditions, and evolving regulatory landscapes. This mismatch can lead contractors either to overprice bids to account for unknown risks or to underestimate costs, potentially resulting in disputes or project failures.

- **Risk allocation challenges.** Traditional EPC contracts place most of the project risk on the contractor. While this can work for well-established technologies, it becomes problematic with emerging climate technologies. Contractors may be unwilling to accept risks associated with unproven technologies, a situation that can lead to higher bids or reduced competition among contractors. Alternatively, contractors might take on risks they cannot adequately manage, potentially leading to financial distress or project abandonment.
- **Limited flexibility for design changes.** EPC contracts typically limit the owner's ability to change designs after the contract is signed. However, in the fast-evolving field of climate technology, new, more efficient solutions may emerge during the project lifecycle, and regulatory requirements may change, necessitating design modifications. The inability to incorporate these changes can result in a less effective or outdated solution upon project completion.
- **Challenges in performance guarantees.** EPC contracts often include performance guarantees, but they can be problematic for emerging technologies. Limited historical data makes setting realistic performance targets difficult. The complexity of new systems might also lead to unforeseen interactions affecting performance. As a result, contractors may offer overly conservative guarantees, potentially limiting the technology's full potential.
- **Inadequate provisions for collaboration and innovation.** The inherent tension in traditional EPC contracts can stifle the collaboration necessary for successful implementation of new technologies. These contracts often result in limited knowledge-sharing between the owner and contractor and reduced opportunities for joint problem-solving. This can lead to potential missed opportunities to optimize the technology during implementation.
- **Significant upfront investment requirements.** EPC contracts require significant upfront investment in engineering and design before construction begins. For climate technologies still under development, paying for these preliminary steps can be particularly challenging. When product specifications are not firmly set due to the evolving nature of technology, investors and financial institutions may be hesitant to commit substantial resources. This scenario can be a Catch-22, where funding is needed to finalize designs, but final designs are needed to secure funding. This situation can stall promising climate technology projects before they even begin. The long tendering period of EPC contacts and the initial engineering phase can also delay the project.
- **Higher total costs due to risk premiums.** Contractors' risk premiums for emerging climate technology projects are likely to raise total costs. Given the uncertainty of new technologies, contractors often inflate their prices to cushion against potential unforeseen challenges or performance issues. This approach, while rational from the contractor's perspective, can significantly increase the overall project cost. Higher costs may make some climate technology projects economically unviable or less attractive than more established and polluting alternatives.

Table 3: Limitations of EPC Contractors.

Limitation	Description
Single point of responsibility	Dependence on one contractor is risky.
Inflexibility	EPC contracts assume a high degree of certainty about project scope, costs, and timeline. This is mismatched with the rapidly evolving nature of emerging climate technologies, leading to potential disputes or project failures.
Risk allocation	The contractor bears most project risks. This can lead to higher bid prices, reduced competition, or contractors assuming risks they cannot manage, potentially resulting in financial distress or project abandonment.
Limited design flexibility	EPC contracts typically restrict design changes after signing. This can result in outdated or less effective solutions, as new technologies or regulatory requirements may emerge during the project lifecycle.
Performance guarantee challenges	Limited historical data for new technologies makes setting realistic performance targets difficult. Contractors may provide overly conservative guarantees, potentially limiting the technology's full potential.
Lack of collaboration	The adversarial nature of EPC contracts can stifle necessary collaboration and knowledge-sharing between owners and contractors, potentially missing opportunities to optimize the technology during implementation.
Upfront investment requirements	Significant upfront investment in engineering and design is required before construction. For evolving climate technologies, securing funding for these preliminary steps can be challenging, potentially stalling promising projects.
Higher costs due to risk premiums	Contractors often inflate prices to cushion against uncertainties associated with new technologies. This can significantly increase overall project costs, making some climate technology projects economically unviable.
Limited contractor expertise	Many firms lack experience with emerging climate technologies. This can lead to unrealistic bids, project delays, suboptimal performance, and increased costs due to learning curves.

EPC contracts are an important tool for project development and deployment. They offer certainty to owners and financiers and transfer project delivery risks to contractors. To implement crucial climate innovations, especially in first-of-a-kind projects, project owners will likely need to accept more risk or higher prices. However, EPC contracts and contractors can also evolve beyond their heritage model to accelerate emerging climate technology deployment.

While EPC contracts have an established place in traditional industries, their need for adjustment becomes more apparent when applied to projects involving emerging climate technologies. The industry should consider more flexible contractual models that allow for equitable risk-sharing, promote collaboration and knowledge exchange, provide mechanisms for incorporating technological advancements and design changes, and offer realistic and adaptable performance guarantees. Owners can, for example, mitigate design risks through collaborative contracting models that involve technology providers earlier in the design process. Addressing contractual limitations, whether by modifying EPCs or looking at other arrangements, can facilitate the rapid and effective deployment of emerging climate technologies, crucial in meeting decarbonization goals.

There are also steps that EPC contractors can take to mitigate risks. For example, EPC firms can deepen their climate project capabilities by training and teaching existing employees, hiring new technology experts, and learning from corporate venture investments. Governments can also work with EPCs to pay for or insure riskier projects.

3 Types of EPC Contracts

3.1 Pricing Arrangements

EPC contracts are sometimes categorized by the pricing scheme they use. Most EPC contracts have lump sum or reimbursable pricing, or a combination of both.

Lump Sum Turnkey (LSTK). This “fixed cost” pricing scheme is best suited for projects with well-defined scopes and minimal anticipated changes. Contractors agree to deliver the project on a certain schedule for a fixed price, regardless of the actual cost of the work.[27] They assume most of the financial risk and are incentivized to optimize designs and execution plans to minimize costs. While emerging climate technology project owners might prefer a lump sum contract to avoid surprise costs, contractors will inflate initial prices to hedge the risks of unfamiliar technology and processes. For a first-of-a-kind climate technology project, the benefits of this integrated, turnkey approach likely come at a significant premium.

Additionally, LSTK limits flexibility to accommodate scope changes. Changes in project scope requested after the EPC contract is signed, known as change orders, can result in 10-15% markup for overhead and profit.[28] For these reasons, the reimbursable contract might be more cost-effective for some developers but risk the climate project’s ability to meet bankability requirements.

Reimbursable. Under a cost reimbursable contract, also known as a “cost-plus” or “time and materials” contract, a client reimburses the contractor for the actual costs incurred plus a fee for overhead and profit. The fee is typically a percentage of the total project cost. It could also be a fixed amount or a combination of a fixed percentage and a fixed amount. Contracts might also include additional fees, either percentage or lump sum, if certain performance measures, deployment milestones, or other targets are achieved by a certain date.

With a cost reimbursable contract, a client bears more financial risk but has greater visibility into, and control over, costs. Cost reimbursable contracts are favored when the project scope is fluid or the technology is unproven. They allow for adaptability but may reduce the contractor's motivation to minimize costs. Cost reimbursable contracts often include incentives for the contractor to meet cost and schedule targets. Some contracts allow reimbursable pricing to be converted, at the contractor’s discretion, to lump sum. A contractor might accept this pricing transition once it has been involved with the project long enough to learn about the costs, risks, and new efficiencies.

Reimbursable contracts with a price cap are known as EPC-GMAX contracts. Under this arrangement, the total cost of the project, including the fee, is capped at a guaranteed maximum. If the total cost exceeds the guaranteed maximum, the contractor loses money. If the total cost is less than the guaranteed maximum price, the contractor profits.

Target Cost. Target cost contracts combine the flexibility of reimbursable arrangements with the cost management incentives of a lump sum agreement. With a target cost agreement, the project owner and contractor agree to a target price. If actual costs are lower than the target, the contractor receives a bonus. If costs exceed the target, the contractor bears a portion of the overrun. Target cost contracts share risk and reward between parties, promoting collaboration to optimize project outcomes. They are well-suited for projects with moderate scope uncertainty. However, setting appropriate targets and gainshare or painshare mechanisms can be challenging and may lead to disputes if not clearly defined.

Deciding which arrangement to use. Whether a project owner pursues a LSTK or reimbursable pricing arrangement depends on several factors. Table 4 summarizes these considerations. Because first-of-a-kind projects involving emerging climate technology include significant uncertainty and thus require flexibility, EPCs will likely either not offer LSTK contracts or offer them only with a sizeable premium. This creates an obvious tension between the expectations of lenders for project financing and the developer's EPC contract options. Over time, once an EPC builds and commissions projects with the same or similar technology, it is likelier to offer LSTK contracts.

Table 4: Reimbursable vs. Lump Sum EPC Contracts: Considerations for a Project Owner.

Factor	Lump Sum Turnkey (LSTK)	Reimbursable
Pricing structure	Fixed price for entire scope	Actual cost-plus fee
Pricing risk allocation	Contractor bears pricing risk	Owner bears pricing risk
Flexibility/change management	Less flexible to changes	Easier to accommodate changes
Cost transparency	Less visibility into costs	High visibility into costs
Contractor motivation	Incentivizes contractor efficiency to maximize profit	Does not inherently incentivize cost savings
Typical use cases	Well-defined projects; repetitive or standardized work	Complex or unfamiliar projects with unknowns; fast-track projects
Project owner involvement to monitor costs	Less involvement required to monitor costs	Requires more oversight and involvement to monitor costs
Project definition	Requires well-defined scope	More flexible; better accommodates uncertainty
Contractor selection	Often focuses on lowest price	May prioritize qualifications and collaboration
Cost certainty for owner	More certainty	Less certainty
Contract terms	"Fixed price"	"Cost-plus" or "time and materials"

Even projects involving well-established climate technology face risks. For example, some EPC contractors endured heavy losses from solar projects, particularly in Australia, due to factors including grid connection delays and constraints and supply chain delays from COVID. As a result of such problems, some project necessities, like construction insurance, have become more expensive and harder to obtain.[29]

3.2 Arrangements That Divide Responsibility

A defining feature of EPC contracts is that one contractor is responsible for building a structure and getting it ready for operation. Sometimes, contracts are modified to divide responsibility.

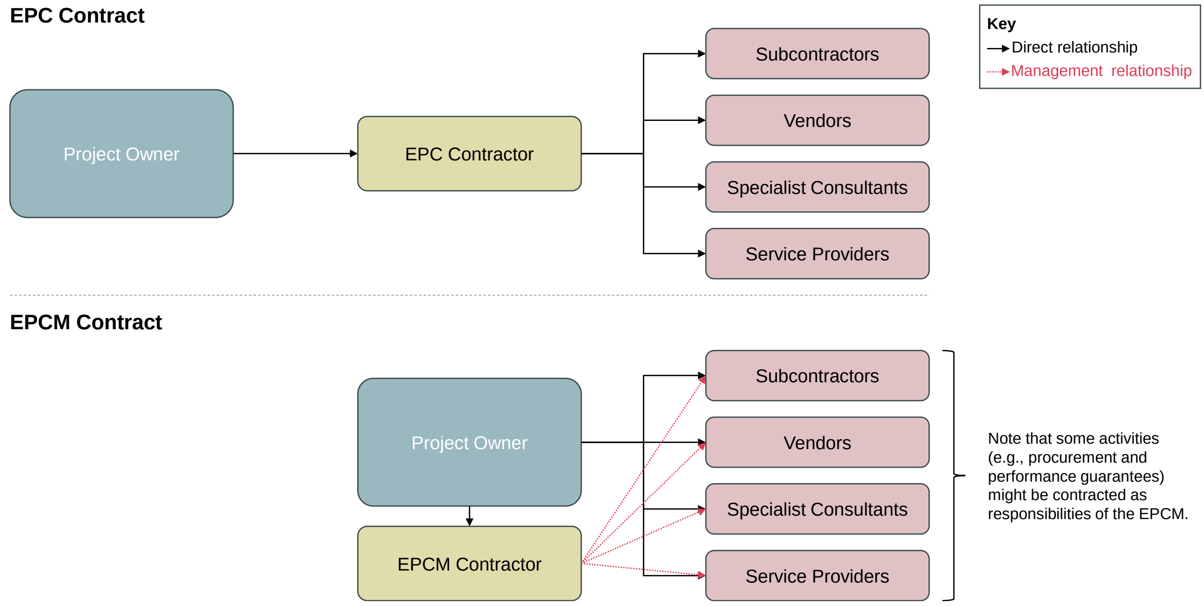
This section describes two common variations of EPC contracts: the engineering, procurement, and construction management (EPCM) contract and the split EPC contract.[30]

Engineering, Procurement, and Construction Management (EPCM). This agreement gives the project owner more control than a traditional EPC. Like an EPC contract, an EPCM agreement also involves a third-party developer that manages project delivery. The contractor performs design and procurement and manages construction on behalf of the client but does not directly execute construction work.[31] EPCM contracts allow a client to maintain greater control over the project and potentially save on contractor risk premiums. However, the client assumes more interface and performance risk. EPCM contracts are often used when clients have strong in-house project management capabilities or want to perform some construction activities themselves.

EPCM and EPC contracts differ in three primary ways:

- **Responsibility.** In an EPC contract, the contractor performs most construction itself and is responsible for all phases of the project. The owner can direct any claims and disputes about the project to the EPC contractor. Under an EPCM contract, the contractor does not directly perform construction work. Rather, it serves as a general contractor, subcontracting and managing construction on the owner's behalf. This arrangement can be useful for complex projects where the owner wants more control, when a contractor does not have all the required construction capabilities, or when the scope is not completely defined. Because several entities perform the work, disputes can involve multiple parties, and resolving them can take longer and be more costly than under an EPC contract. Figure 2 compares the responsibilities under EPC and EPCM contracts.
- **Flexibility.** An EPCM agreement enables the project owner to be more involved with decision-making throughout the project lifecycle. However, this involvement requires a greater time commitment and higher risk retention for the project owner (i.e., less risk is transferred through the EPCM contract).
- **Pricing.** EPC contracts usually have lump sum pricing, while EPCM agreements more commonly use reimbursable or guarantee maximum pricing. Under an EPCM arrangement, the project owner pays subcontractors directly for materials, equipment, and construction. The owner pays the EPCM only for its direct costs, which are primarily the labor of engineering and supervisory services. The margin on labor that EPCM contractors charge varies with the risk they assume (which is usually low), the project's size (small projects usually have higher margins), and macroeconomic conditions (e.g., charging lower prices when inflation is high and there is less construction).

Figure 2: EPC vs. EPCM Contractor Project Management Structure.



The EPCM structure offers project owners more control over a project in exchange for accepting more risk from the contractor. Table 5 summarizes key factors differentiating EPC and EPCM contracts.

Table 5: EPC and EPCM Contract Comparison.[32]

Factor	EPC	EPCM
Accountability	Contractor fully accountable	Owner has multiple points of accountability
Construction/ performance risk	Contractor bears risk	Owner and contractor bear risk
Time	Fixed date for completion	No fixed completion date
Price	Fixed price contract	Schedule of rates or cost-plus
Procurement	Contractor responsible for procurement	Contractor procures as agent for the owner
Quality/performance guarantee	Contractor guarantees performance of completed facility	Contractor does not guarantee performance
Project control	Contractor in control	Project owner in control
Defective works/ services	Contractor to rectify defects	Contactor assists owner to manage rectification of defects

Split EPCs. These contracts divide a project into two or more EPC packages, often split by discipline (e.g., civil works, mechanical, and electrical). This structure allows parallel execution but requires careful coordination. A split EPC can accelerate schedules and allow the use of specialized contractors for different packages. This arrangement is frequently used on mega-projects or when different technologies are involved (e.g., wind turbine supply and installation are contracted separately from electrical grid interconnection). However, split EPCs can lead to disputes over scope boundaries and dilute single-point responsibility.

Split EPC contract structures are also commonly used for projects in Europe and emerging markets like the Middle East and South Asia. The arrangement involves an offshore construction contract and an onshore construction contract. The offshore contractor typically provides design and engineering services, and it supplies foreign equipment and materials. The onshore contractor installs the offshore equipment when it arrives onshore, supplies needed local material and equipment, and assumes responsibility for construction and commissioning. A split EPC contract adds complexity, but it can lower the total project price by (1) avoiding onshore taxes on offshore equipment and services, and (2) reducing the cost of complying with local licensing regulations.[33]

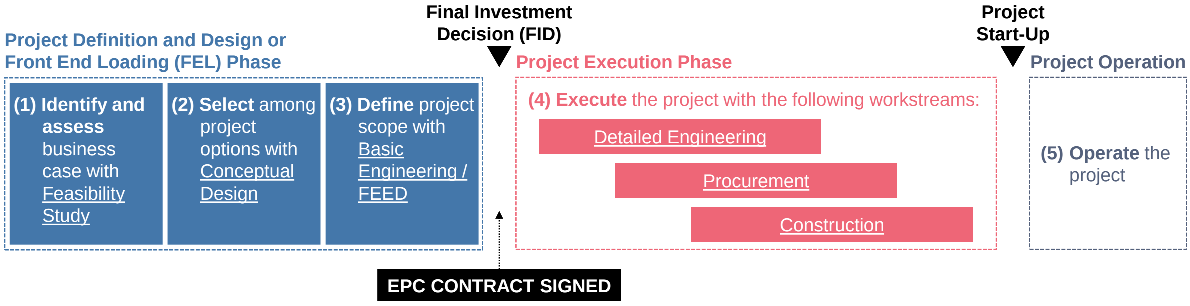
Split EPCs are not always feasible. Some countries restrict which firms can perform activities like engineering and design services.

4 Evaluating Projects Before Entering EPC Contracts

An EPC contract is a critical but expensive commitment. Owners must decide whether an EPC arrangement is appropriate and refine the project's scope and budget.

Project development typically goes through three phases: project definition and design, project execution, and project operation. This paper focuses on the first phase (the blue boxes in Figure 3), after which project owners are ready to sign an EPC contract.

Figure 3: Three Phases of Project Development.



4.1 The Project Definition and Design Phase

The project definition and design phase focuses on evaluating a project's feasibility and planning the project in detail. This phase is often called **front-end loading (FEL)** because it dedicates significant effort to planning, design, and preparation at the early stage of the project, "loading up" the front end with key decisions and planning. FEL should yield more predictable and successful project outcomes, reduced lifecycle costs, and improved stakeholder satisfaction.

FEL is a structured and comprehensive project management method that involves careful planning to make critical decisions early in the project when design changes are easier and less expensive to make. Planners look for potential points of failure or commercial challenges so a project can "fail fast" before substantial capital and effort are committed. After developing, structuring, and executing the engineering process in FEL, a project owner should be able to secure an EPC contract. FEL is an especially important process for big and high-stakes projects in industries such as oil and gas, mining, infrastructure, and power generation.

Before starting the FEL phase, particularly on a commercial-scale project, the climate technology being deployed should be fully developed and have a proven market. To confirm customer demand (sometimes called product-market fit), climate technology developers frequently seek offtake agreements. These contracts allow buyers ("offtakers") to secure a long-term supply of output before a facility is operational. Offtakes ensure that the project will have cash flow.[34]

FEL follows three successive stages:[35]

- FEL-1: Identify and assess project with feasibility study
- FEL-2: Select among project options
- FEL-3: Define project scope with front-end engineering design (FEED)

By progressively defining and refining project parameters from FEL-1 to FEL-3, organizations can make informed decisions, optimize designs, and set realistic expectations for project outcomes. This methodical approach improves the chances of project success and allows companies to prioritize and allocate resources to the most promising initiatives.

After each FEL stage, decision-makers, who can include senior management, board directors, investors, and government entities, can decide to proceed (full approval), modify (conditional approval based on changes), hold (delay until more information or market changes), or cancel (no approval) a project. This process, known as “stage-gating” ensures a disciplined evaluation of a project’s readiness before executing an EPC.[36] Conducting reviews after each FEL stage ensures that project decisions align with major milestones. While reviews at each “gate” make project development more rigorous, they can slow decision-making and may be ill-suited for agile project delivery approaches.

Table 6: Front-End Loading Stages by Goals, Activities, Costs, Deliverables, and Outcomes.[37,38]

Stage	FEL-1	FEL-2	FEL-3
Goal	Identify and assess project options	Select among project options	Define project scope
Activities	● Develop business case and objectives ● Articulate technology strategy ● Identify and screen alternatives to be analyzed in FEL 2	● Begin conceptual screening ● Form core team ● Analyze alternatives ● Select and develop preferred alternative ● Complete the business case ● Business authorization	● Complete basic engineering, estimate, and project execution for selected option ● Confirm business
Approximate % of total FEL cost	6%	27%	67%
Approximate % of total FEL duration	14%	29%	57%
Deliverables	Feasibility study to advance technical design to cost estimate +/- 50%	Conceptual design to advance technical design to approximately +/- 30% cost estimate	Basic engineering / FEED to advance technical design to approximately +/- 10% cost estimate
Outcome	Business case developed	Concept selected	Final investment decision (FID) authorized
Involvement of potential EPC	Minimal, if any. Might provide high-level input, but project owner largely works independently.	Advisory capacity. Might help with preliminary designs and estimates. Owner might engage multiple potential EPCs at this stage.	Much more significant. Participates heavily in detailed engineering studies and planning. Possible pre-EPC services agreement.

Table 6 summarizes the activities at each FEL stage, which are described in detail below.

FEL-1: Concept Selection

FEL-1 starts the project's design. A goal of this stage is to clarify the business opportunity and determine whether it merits additional effort and expense. Project teams brainstorm, conduct preliminary research, perform initial feasibility studies, and develop order-of-magnitude cost estimates. Stakeholders evaluate potential benefits and risks as well as whether sufficient demand for the product exists. While the level of detail at this stage is low, it sets the foundation for subsequent planning efforts. Sometimes this assessment step is called FEL-0.

Expanding on the business concept, FEL-1 is an early-stage assessment of a project's technical and economic viability, including high-level cost estimates and risk analyses.[39] With the support of EPC contractors, owners conduct feasibility studies, assess the market, evaluate technology, and consider any environmental impact. Teams rely on benchmark data, vendor quotes, and engineering judgment to estimate costs and benefits.

The primary FEL-1 deliverable is a comprehensive feasibility report that provides a clear understanding of the project's potential value, challenges, and resource requirements. Feasibility studies should permit a "Class 5" or "Class 4" cost estimates (i.e., +/- 30-50%). (Cost estimate classes are discussed below.) These studies might not capture all project risks, but they are a relatively low-cost way to filter out infeasible projects.

During FEL-1, project owners might begin to lay preliminary groundwork for operating the project. For example, they might enter non-legally binding agreements (e.g., memoranda of understanding or letters of intent) with potential stakeholders, such as offtakers and feedstock suppliers.

FEL-2: Select Among Project Options

In the FEL-2 stage, which is critical for decision-making, owners select the best option among project alternatives. Building on the feasibility study from FEL-1, project teams develop and evaluate multiple options to address the identified business need. This evaluation involves more rigorous technical and economic analyses, including detailed cost-benefit comparisons, risk assessments, and schedule implications for each option. The project team conducts workshops and engages subject matter experts to assess each alternative. It also establishes selection criteria, weighting them according to project and organizational priorities. This stage might also include preliminary vendor engagement and technology assessments.

By the end of FEL-2, the preferred project option will be selected and will serve as the foundation for the next stage. This selection is typically accompanied by a preliminary project execution strategy and a more refined business case.

FEL-3: Project Definition or Front-End Engineering Design (FEED)

FEL-3 is the most detailed and intensive stage of the FEL process. The selected project option is developed with sufficient detail to make a final investment decision. This stage emphasizes project definition and front-end engineering design (FEED). Detailed engineering activities are carried out, including the development of comprehensive process and instrumentation diagrams, equipment specifications, and final plot plans. The project team thoroughly defines an execution strategy, including aspects such as contracting strategy, procurement plans, and construction methodologies. Cost estimates are considerably more reliable, typically within a range of +/- 10-15%. Detailed project schedules are developed, including resource-loaded timelines and critical path analyses. Risk management plans are finalized, and strategies for quality assurance and control are established. Upon competition of FEL-3, FEED materials should permit a “Class 3” or “Class 2” cost estimate and line of sight to a “Class 1” estimate.

Stakeholder engagement is more intense, and the project team seeks formal approvals from regulatory bodies and key project partners. FEL-3 deliverables form the basis for the final investment decision and, if approved, serve as the blueprint for project execution and justification for signing an EPC contract.

4.2 The Final Investment Decision

After completing FEL-3, project owners and developers decide whether to proceed with the project. At this moment – known as final investment decision (FID), authorization for expenditure (AFE), or notice to proceed (NTP) – decision-makers determine whether to authorize full funding for the project and approve awards of major contracts. If the project is authorized, an EPC contract can be signed.

Another useful tool in front-end loading and planning is the Project Definition Rating Index (PDRI). It was developed in the 1990s by the Construction Industry Institute (CII) to address the need for better project scope definition. The comprehensive, easy-to-use PDRI score sheet includes 70 scope definition elements.[40] Each element is weighted based on its relative importance to the other elements. Since the PDRI score relates to risk, areas that need further work can be easily isolated. Each element rating is based on its level of definition, with lower scores indicating better definition and higher project readiness. A PDRI score of 200 or less greatly increases the probability of a successful project. The score also helps teams identify areas needing further development to reduce risk and improve project outcomes.

5 Estimating Project Costs Before Entering an EPC Contract

Realistic and well-documented cost estimates are essential for evaluating, approving, negotiating, and funding projects. Owners typically follow a staged approach, such as front-end loading, to refine cost estimates progressively as the project scope becomes more defined. As a project progresses through each FEL stage, cost estimates improve. Producing these estimates requires robust project definition, industry cost intelligence, and collaboration with contractors and suppliers.[41]

5.1 Categorizing Cost Estimates by Their Accuracy

The Association for the Advancement of Cost Engineering (AACE) *Cost Estimate Classification System* categorizes cost estimates by their accuracy and describes how different types of estimates are used.[42] The system includes five classes of accuracy. Each successive class incorporates more project detail and is more accurate. Categories range from Class 5 (the least precise) to Class 1.

Table 7 summarizes the main characteristics of each cost class. As the table indicates, each category of estimates has different uses.

- The least accurate estimates, *Order of Magnitude estimates* (Classes 5 and 4), are made when limited project detail is available. These high-level cost approximations are used to screen projects and evaluate their feasibility. The estimates are based on historical data from similar projects, capacity factored estimates, and parametric models. Their accuracy range is -30% to +50%. Estimates in this category are sometimes referred to as “Rough Order of Magnitude” or “ROM,” “ballparks,” “blue sky,” or “top-down.”
- *Budget estimates* (Class 3) are developed during the pre-FEED stage to establish an initial control budget. The project is 10-40% defined at this stage, offering more data for estimates. The team uses a combination of methods and sources, such as factored estimates, where the known cost of a similar item is adjusted to the current project using factors such as size or location. Also used are “takeoffs,” which list the materials needed to build an item based upon a design document. The accuracy range of these estimates is higher (-20% to +30%). These figures are sometimes referred to as “budget” or “semi-detailed” estimates.
- The most reliable figures, *definitive estimates* (Classes 2 and 1), are prepared after the FEED step and are used as the basis for EPC contract pricing. At this stage in the FEL process, the project is much better defined (65%-100%). Analysts use firm commercial quotes for major equipment and bulk materials, and detailed estimates for construction labor and indirect costs. The accuracy range is now within fifteen percent (-10% to +15%). This estimate is sometimes called the “firm price” or “bottoms-up” estimate.

As part of these investigations, project teams conduct sensitivity analyses to determine the impact of the main cost drivers and risks. This step includes evaluating the impact of escalation, currency exchange rates, productivity factors, and contingency allowances.

It is worth noting that, despite these estimation methodologies, very large projects are routinely late and over budget. On average, projects whose budgets exceeded $1 billion, commonly referred to as “megaprojects,” are delivered a year behind schedule and 30% over budget.[43] McKinsey estimates that 98% of megaprojects exceed their budgets more than 30%, and 77% of projects take at least 40% longer to deliver than estimated.[44] Many factors contribute to delays and cost overruns, including modifications of the project as it evolves, so original estimates may have been closer for projects as originally conceived.

Table 7: AACE International Cost Classifications and Expected Ranges of Accuracy.[45,46]

AACE Class	ANSI Class	Class Description	Purpose	Preparation Effort.[47]	Typical Data Sources	Project Definition	Range of Accuracy		Other Descriptive Terms
							Low	High	
5	Order of Magnitude	Concept screening	Long-range planning	1	Previous similar event cost	0% to 2%	-50% to -20%	+30% to +100%	ROM (rough order of magnitude); ballpark; blue sky; ratio
4		Study or feasibility	Preliminary budget indication	2-4	Previous similar event cost, with scope adjustments	1% to 15%	-30% to -15%	+20% to +50%	Feasibility; top-down; screening; pre-design
3	Budgetary	Budget authorization	Initial budget approval, funding request	3-10	Detailed material take-offs, historically priced	10% to 40%	-20% to -10%	+10% to +30%	Budget; basic engineering phase; semi-detailed
2	Definitive	Control or bid/tender	Final budget approval	4-20	Detailed material take-offs, mix of historical and commercial pricing	30% to 75%	-15% to -5%	+5% to +20%	Engineering; bid; detailed control; forced detail
1		Check estimate or bid/tender	Control estimate	5-100	Detailed material take-offs, commercially priced	65% to 100%	-10% to -3%	+3% to +15%	Bottoms-up; full detail; firm price

5.2 The Sizes of Projects

Projects vary widely in size and complexity. Most projects involving emerging climate technology are smaller and mid-size. These projects typically cost millions or tens of millions of dollars and should take approximately two to four years to execute after the EPC contract is signed. Over time, more big climate projects will arise, both to achieve key climate goals and to capture economies of scale. Table 8 provides general size categories, with examples of general and climate projects in each.

Table 8: Categories of Project Size by Execution Cost and Duration.

	Estimated Total Project Execution			
Project Size	**Cost (USD)**	**Duration (Years)**	**General Examples**	**Climate Examples**
Small	<$10mn	2-2.75	Equipment upgrades, small building renovations, minor plant modifications	Microgrid installations (see DOE Microgrid Overview), electric vehicle charging networks (e.g., fast-charging hub with 50-60 stations in California)
Medium	$10mn-$100mn	2-2.75	Small- to medium-sized industrial facilities, mid-size commercial buildings	Small solar and wind farms (e.g., solar power plant in Vietnam), small carbon capture facilities (e.g., Climeworks Orca project in Iceland)
Large	$100mn-$1bn	2.5-4.25	Large manufacturing plants, power plants, major infrastructure projects	Sustainable aviation fuel plants (e.g., SkyNRG SAF plant in Washington), geothermal energy wells (e.g., Fervo geothermal complex in Utah)
Complex or Mega	$1bn-$5bn	4-6.5	Nuclear power plants, major oil and gas developments, large-scale urban development projects	Component recycling plants (e.g., Redwood Materials battery plant in Nevada), offshore wind parks (e.g., South Fork wind farm in New York)
Ultra-large	$5bn+	6.5-11.5	Country-wide infrastructure programs, space exploration initiatives, global energy transition projects	Large-scale green steel plants (e.g., H2 Green Steel facility in Sweden), international subsea power cables for renewables (e.g., Xlinks between Morocco and the UK)

5.3 Conclusion

EPC contracts serve a critical function in building infrastructure that commercializes emerging climate technologies. Their chief benefits – appropriate risk allocation, schedule acceleration, performance assurance, and integration management – help overcome key barriers to deploying climate technologies and building first-of-a-kind projects. Although not without limitations, thoughtfully structured EPC contracts are vital to delivering the next generation of climate hardware assets with the necessary speed and efficiency. Governments and private enterprises should prioritize standardizing EPC contracts and expanding the pool of firms equipped to leverage them for emerging climate technology projects.

References

1 Emerging climate hardware technologies include those in hydrogen, sustainable aviation fuel, cement, and steel, carbon dioxide removal, and select others.

2 Jan Pícha, Aleš Tomek, Harry Löwitt. "Application of EPC Contracts in International Power Projects." Procedia Engineering. Volume 123. 2015. Pages 397-404. ISSN 1877-705, https://doi.org/10.1016/j.proeng.2015.10.061.

3 Damian McNair. "EPC Contracts in the power section." 2016. PwC, https://www.pwc.com.au/legal/assets/investing-in-infrastructure/iif-6-epc-contracts-power-feb16-3.pdf.

4 B Baydemir and BB Goksu. "EPC and EPCM Contract Models." 2021. GSI Articletter, https://heinonline.org/HOL/LandingPage?handle=hein.journals/gsiartc25&div=9&id=&page=.

5 George E. Baram. "Project Execution Risks in EPC/Turnkey Contracts and the Project Manager's Roles and Responsibilities." (AACE International Transactions 2005).

6 "Commercial, Document Description – Engineering, Procurement, and Construction Agreements." Bloomberg Law, https://www.bloomberglaw.com/external/document/XFG5HI4K000000/commercial-document-description-engineering-procurement-and-cons.

7 Jan Pícha, Aleš Tomek, Harry Löwitt. "Application of EPC Contracts in International Power Projects." Procedia Engineering. Volume 123. 2015. Pages 397-404. ISSN 1877-705, https://doi.org/10.1016/j.proeng.2015.10.061.

8 "State of Pipelines: Current State of U.S. Pipeline Infrastructure." Energy Infrastructure, https://www.energyinfrastructure.org/pipeline/state-of-pipelines.

9 "Understanding Natural Gas and LNG Options." 2017. US Department of Energy, https://www.energy.gov/sites/prod/files/2017/09/f36/Understanding%20Natural%20Gas%20and%20Lng%20Options_general%20no%20appendix.pdf.

10 Nick Henchie. "Shifting Sands in the Economy and International Procurement Market." 2009. Mayer Brown, https://www.mayerbrown.com/-/media/files/perspectives-events/publications/2009/05/shifting-sands-in-the-economy-and-international-pr/files/newslminingmay09bulletinshiftingsandspdf/fileattachment/newsl_mining_may09_bulletin_shifting_sands.pdf.

11 Here is an EPC template from the World Bank's public-private partnerships unit.

12 Contracting Strategies in the oil and gas industry (Carolin Schramm, Alexander Meißner, Gerhard Weidinger 2010) https://www.italonaweb.com.br/wp-content/uploads/2012/10/3R_Schramm_Nov09.pdf.

13 "The Cooperation Establishment Mechanism of EPC Project Consortium in Context of China: Form the Perspective of Trust (Weiping Jiang and Shanqing Tang, Sustainability 2024) https://www.mdpi.com/2071-1050/15/2/1266#:~:text=Meanwhile%2C%20reputation%2C%20reciprocity%20and%20communication,consortium;%20trust;%20intention%20to%20cooperate.

14 Few enterprises have adequate design *and* construction capabilities. To meet contract requirements and compete with other EPCs, firms might form a consortium and partner with firms that have complementary skillsets or expertise. The consortium chooses one organization to be the leader, who serves as the single point of contact for the client.

15 This figure is illustrative and does not contain a comprehensive grouping of EPC firms involved with climate projects.

16 Demonstration facilities can prove that a technology works at scale and quell concerns about scale, yield, availability, cost predictability, serviceability, and customer satisfaction. First-of-a-kind facilities are intended to be profitable, prove a technology's commercial performance, and establish a track record for future projects.

17 Kevin Biehl and Kobi Weinberg. "Six Insights in Climate Technology Project Development." 2024. CREO, https://www.dropbox.com/scl/fi/oedj25rpcfywt8yvt485i/2024_CREO_Six_Insights_in_Climate_Technology_Project_Development.pdf?rlkey=veirxafyl66tlwt4qrmy7npzr&e=2&st=297bvmbl&dl=0.

18 "Fluor Corporation (FLR)." Yahoo Finance, https://ca.finance.yahoo.com/quote/FLR/key-statistics/. Accessed 22 Sep. 2024.

19 Jonathan Hosie. "EPC Contracts: Controlling cost blowouts on mining developments." 2015. Mayer Brown, https://www.mayerbrown.com/Files/Publication/35328234-d6f9-49c7-bbe8-964945bb9158/Presentation/PublicationAttachment/96527455-174f-4e1a-9a9c-9a1d66e9bde3/EPC_contracts_jan15_hosie.pdf.

20 Jonathan Hosie. "Treatment of key risks under EPC contracts." 2016. Mayer Brown, https://www.mayerbrown.com/-/media/files/perspectives-events/publications/2016/10/treatment-of-key-risks-under-epc-contracts/files/art_hosie_treatment-of-key-risks/fileattachment/art_hosie_treatment-of-key-risks.pdf.

21 Richard S. Robinson, Esq. "Warranties in Construction Contracts: Contractor's Drafting Considerations." 2015. Thomson Reuters, https://www.pecklaw.com/wp-content/uploads/2022/05/Warranties_in_Construction_Contracts_Contractots_Drafting_Consideration...-3.pdf.

22 Fred Rahbar and Andrew Avalon. "Schedule Optimization in FEED Project Management." https://www.long-intl.com/articles/schedule-optimization/.

23 In assessing project bankability, lender credit committees evaluate risk allocation between the contractor and project owner. They focus on the ability, or lack thereof, of the EPC to claim additional costs or time extensions.

24 "Engineering, Procurement and Construction (EPC) contracts in the solar sector." 2024. PwC, https://www.pwc.com/m1/en/blogs/pdf/epc-contracts-in-solar-sector.pdf.

25 Roosevelt R. Huggins. "ARPA-E Nuclear Heat Workshop: Power Plant and Industrial Facility Development." 2023. Black & Veatch, https://arpa-e.energy.gov/sites/default/files/ARPA-E%20-%20NHES%20-%20Day%202%20-%20EPC%20Panel%20-%20Huggins%20-%20B%26V.pdf.

26 Liquated damages are usually expressed as a rate per day. The value represents the estimated extra costs incurred (e.g., extra insurance, supervision fees, and financing charges) and losses suffered (revenue forgone) for each day of delay.

27 Fluor Corporation Form 10-K https://s203.q4cdn.com/957337755/files/doc_financials/2023/q4/2023-10K.pdf.

28 Grace Ellis. "What are Change Orders?" 2022. Autodesk, https://www.autodesk.com/blogs/construction/change-order/.

29 "Engineering, Procurement and Construction (EPC) contracts in the solar sector." 2024. PwC, https://www.pwc.com/m1/en/blogs/pdf/epc-contracts-in-solar-sector.pdf.

30 There are other variations of EPC contracts and structures. More information can be found in New Energy *Risk's* *Industrial & Energy Technology Project Finance* and White & Case's *Building the New*.

31 Phil Loots and Nick Henchie. "Worlds Apart: EPC and EPC Contracts: Risk issues and allocation." 2007. Mayer Brown, https://www.fidic.org/sites/default/files/epcm_loots_2007.pdf.

32 David Strickland. "Building the new: Creative solutions for procuring major energy projects." 2022. White & Case, https://www.whitecase.com/sites/default/files/2022-03/energy-projects-cover-infographic-final.pdf.

33 EPC Contracts in the oil and gas sector (PwC Report, Damian McNair January 2016) https://www.pwc.com.au/legal/assets/investing-in-infrastructure/iif-5-epc-contracts-oil-gas-feb16-3.pdf.

34 Read CREO's *An Introduction to Climate Offtake Agreements* to learn more.

[35] Some people include a FEL-0 to label project concept design. Most EPCs, however, typically include this activity in FEL-1. FEL-2 and FEL-3 are sometimes combined.

[36] Adrián Muiño and Fabián Akselrad. "Gates to Success: Ensuring the Quality of the Planning." 2009. Project Management Institute, https://www.pmi.org/learning/library/gates-success-tollgate-methodology-6842.

[37] Pam Wertz. "Mitigating Risks of Early Commitment in New Energy Projects." 2023. *Journal of Petroleum Technology*, https://jpt.spe.org/mitigating-risks-of-early-commitment-in-new-energy-projects.

[38] Adrián Muiño and Fabián Akselrad. "Gates to Success: Ensuring the Quality of the Planning." 2009. Project Management Institute, https://www.pmi.org/learning/library/gates-success-tollgate-methodology-6842.

[39] Frank R. Parth. "Successful projects depend on the business." 2015. Project Management Institute, https://www.pmi.org/learning/library/successful-projects-depend-on-business-9898.

[40] "Project Definition Rating Index: Industrial Project." 2014. Pages 43-50. Construction Industry Institute, https://ocw.snu.ac.kr/sites/default/files/ASSIGNMENT/Week%204_PDRI_Industrial.pdf.

[41] US Army Corps of Engineers. "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study." 2000. US Environmental Protection Agency, https://semspub.epa.gov/work/05/918808.pdf.

[42] The AACE (Association for the Advancement of Cost Engineering) was founded in 1956 by several cost estimators and cost engineers.

[43] McKinsey Capital Projects & Infrastructure Practice. "The art of project leadership: Delivering the world's largest projects." 2017. McKinsey & Company, https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/the%20art%20of%20project%20leadership%20delivering%20the%20worlds%20largest%20projects/the-art-of-project-leadership.pdf.

[44] Sriram Changali, Azam Mohammad, and Mark van Nieuwland. "The construction productivity imperative." 2015. McKinsey & Company, https://www.mckinsey.com/capabilities/operations/our-insights/the-construction-productivity-imperative.

[45] Shoshanna Fraizinger. "Estimating As It Pertains to Risk Management." 2021. AACE International, https://source.aacei.org/2021/04/28/estimating-as-it-pertains-to-risk-management/.

[46] "Cost Estimate Classification System – as Applied in Engineering, Procurement, and Construction for the Process Industries." 2020. AACE International, https://www.pathlms.com/aace/courses/2928/documents/3803.

[47] Typical degree of effort relative to least cost index of 1. If the range index value of "1" represents 0.005% of project costs, then an index of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.