An Analysis of Engineering, Procurement And Construction (EPC)-Contracts Based on Renewable Energy

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Abstract- *EPC contracts are increasingly being adopted as the most preferred form of private sector delivery mechanism for most large infrastructure projects. EPC contracts have significant importance when it comes to delivering renewable power projects because they lead to the effective management of the engineering, procurement, and construction phases. This paper aims to discuss the EPC contracts in renewable energy in details with focus on the legal structures, risk distribution, and project delivery factors influence the efficiency of such projects. This paper does a good job of exploring the peculiarities of renewable energy like wind, solar, and hydroelectric power systems, particularly regarding legal relationships that deal with technical and/or contractual and/or regulatory and/or sustainability requirements. This paper acknowledges how EPC contracts can help reduce the majority of risks, including time, cost, and performance guarantee issues, more so in renewable energy. Based on case studies, the paper assesses the effectiveness of EPC agreements in improving project results and outlines suggestions to improve contract design for better project performance in renewable energy markets.*

Keywords- Engineering, Procurement, and Construction (EPC), Renewable Energy Projects, EPC Contracts, EPC Contract Taxonomy.

I. INTRODUCTION

The global market for oil has been experiencing a drop since 2018, putting pressure on the EPC firms in Asia and Europe. Thus, investors and owners must save 40–50% of Capital Expenditure (CAPEX). This is because decreased productivity for EPC Contractors results in decreased profit margins, loss, and bad cost performance, which lowers global competitiveness[1]. Due to the worldwide spread of the COVID-19 virus, which put pressure on Indonesia's domestic construction sector and made it difficult to carry out EPC projects with budgets (CAPEX) issued before 2018, the country's steel material costs hit a 19.43% increase. The contractor's ability to provide cutting-edge solutions that incorporate modern integrated designs, suitable construction quality, and methods—all while optimising construction costs—is crucial for the project's continued smooth operation and for meeting the demands of 21st-century emerging technologies [2]. The EPC model, in which the contractor is liable for the design, is compatible with this option. Figure 1 shows the applications of EPC.

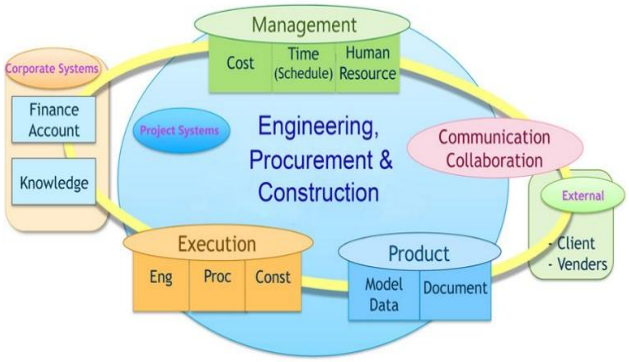

Fig. 1 Applications of Engineering, Procurement, and Construction (EPC)

According to a study that ranked the Engineering (E) phase's planning and designing as the most important activity in terms of project performance, the TOPSIS method—a multi-attribute decision-making technique—was used to rank project risk variables in a sample of large-scale residential construction projects in Iran [3]. Because it is the first step in an EPC project, design is both crucial and potentially dangerous for the project's final outcome. The EPC contract is structured as a lump sum, meaning that the contractor is held fully accountable for any costs that may come from their design. The design is built upon the contractor's proficiency in FEED, which in turn forms the basis for the EPC's detailed design, which in turn generates the construction document [4].

EPC (Engineering, Procurement, and Construction) contracts in renewable energy projects involve a comprehensive agreement where a single contractor manages the entire process of project delivery. These comprise the architectural and engineering of the project, for instance, the

designing of the solar farms, wind, or hydropower projects, procurement of some of the materials and equipment, and construction of the power project up to the stage of generation. Most of the time, the project owner relies on the EPC contractor to handle all of their requirements in a "one-stop shop" manner, and the contractor is obligated to complete the project within a certain time window and budget. This model is popular within the renewable energy industry because it shares most of the risk with the contractor instead of the owner.

In renewable energy development EPC contracts play a major role in technical, regulatory and financial success of the projects. The contractor also takes responsibility for regulating environmental issues and linking renewable equipment to current grid networks. The EPC contractor closely controls the engineering, procurement, and construction aspects of a project which is significant when developing renewable energy generation projects as many of the solutions are large-scale and require sophisticated integration. This contract structure is popular due to its ability to streamline complex projects and ensure that renewable energy systems are delivered on time and within budget.

Structure of the Study

The following paper is structured as: Section II provide the overview of EPC, Sections III and IV give the arrangement and comparison with other contract models, and Sections V and VI provide the EPC Contracts in Renewable Energy Projects and Challenges and Opportunities of EPC. Last Sections VII and VIII discussed the existing work on this and conclusion with future work.

II. ENGINEERING, PROCUREMENT AND CONSTRUCTION (EPC)-CONTRACT

EPC contracts cover a wide range of activities, including detailed engineering design, procurement, construction, and even the commissioning and handover phases of large-scale projects [5]. High-complexity problems may be solved by EPC projects by using an integrated design, procurement, and construction process. The general contractor in an EPC project assumes complete responsibility for the project's design, execution, and completion in addition to managing a wide range of risks from organisational, socio-political, economic, and environmental perspectives [6].

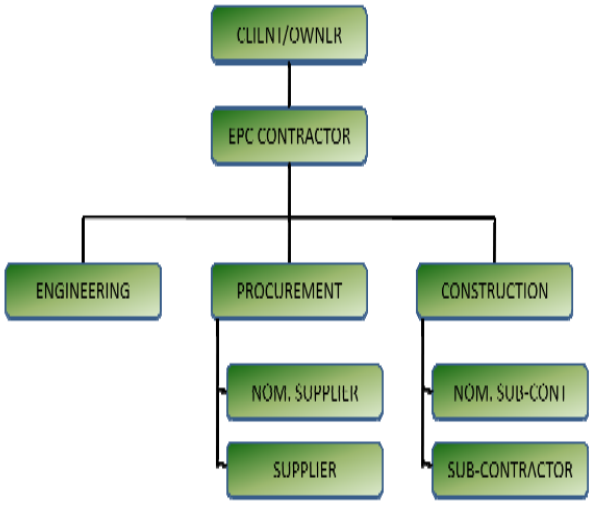

Fig. 2 Typical EPC Project

The EPC project is shown in Figure 2. Power plants, manufacturing facilities, infrastructure, gas development, and industrial plant building are all examples of EPC projects. Construction delivery systems have improved, making EPC contracts more popular worldwide. Allocating employer risk to the major contractor is one reason. Engineering (design), procurement, and construction (execution) are all the contractor's responsibilities, but the employer wants certainty of increased costs and schedules.

A. Phases of EPC-CONTRACT

EPC contracts consist of two distinct phases: development and implementation. Figure 3 illustrates four distinct periods.

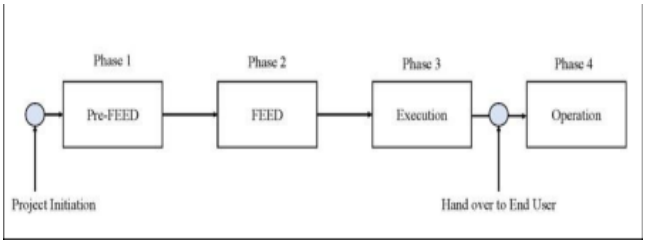

Fig. 3 Four different phases in EPC contracting process

The development phase encompasses Phases 1 and 2 of Pre-Front End Engineering Design (FEED), whereas the implementation phase comprises Phases 3 and 4 of Execution and Operation. The Development Phase typically encompasses planning activities such as inquiry, scope definition, job bundling, and contract award. The Phase 2 (FEED stage) includes activities such as facility design, layout development, vendor inputs, HSE effect evaluation, and conceptual design estimation while Figure 3 illustrates the four distinct steps involved in the EPC contracting process.

B. Types of EPC-CONTRACTS

Definitions of EPC from many sources lead to the conclusion that it is a notion in project management that includes planning, acquiring, and building [7]. Figure 4 shows the fundamental framework of an EPC contract using a power project as an example; however, in practice, the specific structures could vary from project to project [8]. Project management, engineering, materials and equipment, civil works, transportation and installation, commissioning, and foundation and site infrastructure works are all usual components of an EPC contract's scope, along with scheduling and performance guarantees for the entire solution. Usually, the customer handles the fuel supply arrangements, electrical connections, and plant permissions. A customer's scope of work often includes site preparation (levelling, clearing, etc.). Contractors are becoming more risk-averse.

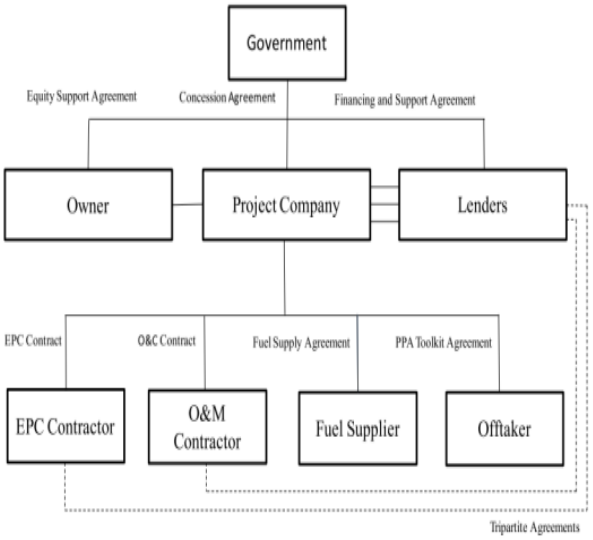

Fig. 4 Basic Structure in an EPC Contract

The EPC Performance Indicators were as follows: Poor design, poor project planning, bad estimation, incomplete design, improper involvement of stakeholders without provision for dispute resolution, loss of reputation, delivery of goods that were outdated, poor site supervision, poor project control, changes in implementation of projects, delays in the delivery of building materials on the site, improper quality of building materials, redo of inadequate works, inefficient or inadequate equipment or machinery sub-contract [3]. Understanding the potential risks associated with the contract's application is essential for assessing the EPC contract's productivity.

1) Lump Sum EPC Contracts

A wide variety of tasks, including but not limited to procurement, management, execution, design, research, and maintenance, may be included in lump sum contracts [9]. The extent of the task, however, may be difficult to adequately describe. In order to achieve these goals and ensure that a lump sum contract is the most efficient option, the owner must be very clear about it. Frequently, the cost of assembling bids is imposed on contractors. It can take significant work and money to refine a proposal to the point where a competitive lump sum fee can be offered. This preparation expense is an expense that is added to the bid. There are projects where owners choose to pay contractors. Contractors may only be successful in winning a small percentage of the bids they submit. Hence, many would argue that the owner should pay for the bidding process [10]. A project should pay for its own expenses and not transfer them to other initiatives, according to solid financial theory. In order to make the bidding papers as complete as possible, it is recommended that the owner do a site survey when required. Since, there is a chance they will win the tender, tenderers could be hesitant to spend on-site research. Proprietors could be hesitant to provide guarantees for the information on their websites to prevent possible conflicts if the content turns out to be incorrect. However, if the site information is not guaranteed, the tenderer may increase its price to account for uncertainties.

2) Cost-Plus EPC Contracts

A cost-plus contract is one in which the contractor gets paid by the customer in addition to the cost of executing the task. In addition to project overhead, labour, and material costs, the price also includes a charge that covers business overhead and profit. The client may pay fees in the form of a set charge, a percentage of the total amount expended, or by using a formula that combines the two [11]. An advantage and a risk are both represented by the cost-plus contract's adaptability to unforeseen shifts in material and labour consumption [12]. But this flexibility also provides a greater burden to the owner as to monitor the whole construction work from financial point of view as the contractor has less stake from financial risk perspective and not much economic motivation to perform that work efficiently.

III. EPC CONTRACTING ARRANGEMENT

EPC contracting requires a comprehensive scope specification throughout the project's engineering phase [13]. A combination of collaboration and information in EPC projects involves numerous professionals with significant workloads. Engineering-Procurement-Construction phases overlap due to the intricacy of EPC contract schedules[14]. Phase overlapping in EPC contracts leads to insufficient

information and limited supplier involvement in long-term equipment planning and design [15].

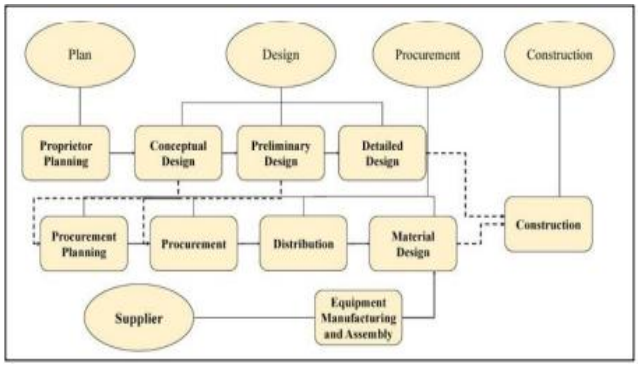

Fig. 5 Activities in Implementation of Engineering, Procurement and Construction phases

The EPC contract was complex and risky due to multi-disciplinary involvement. In oil and gas projects, various engineering disciplines are involved, such as Chemical, Mechanical, Piping, Instrument, Electronic, Electrical/Power, IT/Telecommunication, Civil, Infrastructure, Structural (onshore and offshore), and Subsea Engineering. High integration of disciplines raises risk [16]. Without integration between disciplines, project modifications and variations can lead to delays and failure [17] supported by stating that the engineering and construction industry's inflexibility and lack of customer responsiveness cause adjustments and rework. Poor portfolio management, interpersonal conflicts, financial and supplier market uncertainties, and insufficient engineering design planning at project commencement and FEED stage are factors that contribute to EPC contract difficulties. In addition, poor contractor selection can impact project quality, cost, and schedule later in the cycle [18]. Delays in completion, cost overruns, subpar quality, and an excess of claims and counterclaims were all results of these problems.

A. EPC Contract Taxonomy

Taxonomy is a classification system that arranges the links between ideas in a certain topic via a hierarchical structure [19]. Prior to the introduction of taxonomies, no research had been conducted on lexicons and ontology-based building contracts. Another option was to expand the current lexical dictionary with the terms used in the glossary [20]. It is not possible to classify this earlier research on building contracts using expert analysis. Consequently, without lexical analysis by domain, the vocabulary is constrained when building a lexicon. We addressed this shortcoming by first organising the EPC contract taxonomy via a workshop that aimed at SMEs with 10–20 years of EPC expertise. This study makes use of an EPC contract taxonomy that divides Class 1 into seven subclasses. The taxonomy of EPC contracts is shown in Figure 6.

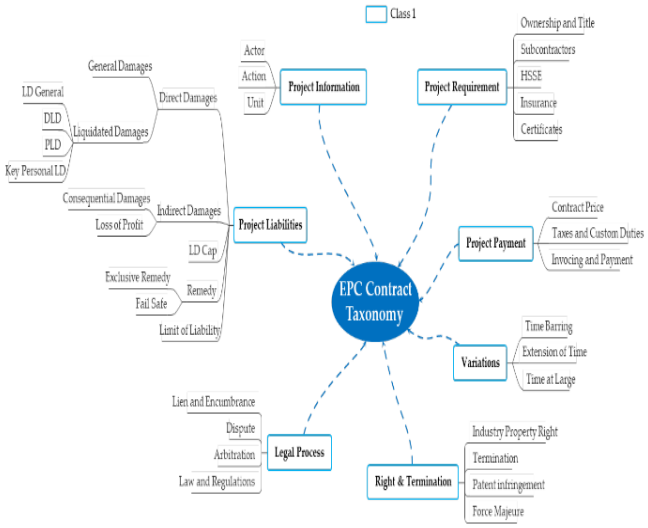

Fig. 6EPC contract Taxonomy

Executives from EPCs, academics, and EPC attorneys made up seven of the SMEs that took part in the program. A gold standard for SA model verification was also developed with the help of these SMEs. The model exam covers details for SMEs. Class 1 was established for a total of seven categories, which include:

- Details on the project, including its scope and any other relevant information regarding the contract.
- Project needs to meet contractual obligations.
- Compensation for damages and contractor responsibility are project liabilities.
- Project payment for progress.
- Changes in construction are one example of a variation.
- Rights concerning projects and contract terminations.
- Disputes between owners and contractors are part of the legal process.

IV. COMPARISON WITH OTHER CONTRACT MODELS

This section contrasts the EPC model with the D&B and BOT models, which stand for "design and build" and "build, operate, transfer," respectively.

A. Build-Operate and Transfer

Public infrastructure services may be provided via partnerships between private enterprises and the government under the BOT model. The private sector engagement strategy entails forming a project company to handle the financing, planning, construction, and operation of a facility for a certain

amount of time before returning it to the government [21]. Project sponsors provide funds for the project via loans and equity donations. Because BOT projects are funded on a project finance basis, which leaves project company members with little to no liability, they vary from conventional financing. Lenders look to the project's ability to generate money as a guarantee [22]. The idea of BOT was used to fund huge construction projects infrastructure without direct governmental support Loan guarantee and is often employed by Developed and developing nations for decades [23]. In BOT, the model itself a private model or structure investment for infrastructure development Often reserved for the public sector.

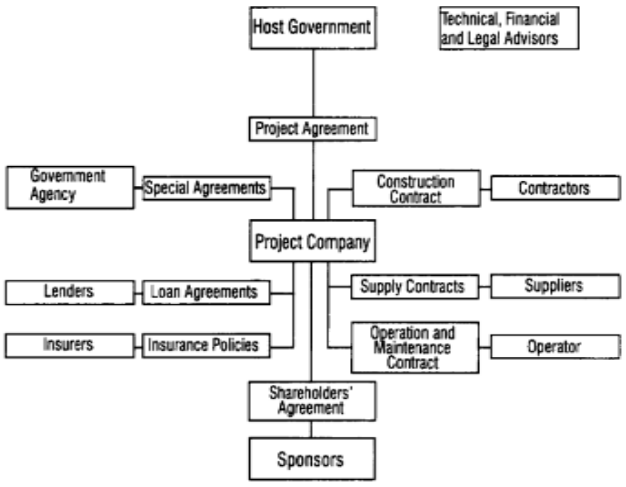

Fig. 7 Structure of a BOT Project

Contracts in BOT projects may be less effective with a weak legal foundation, according to UNIDO BOT principles in Figure 7. When building and operating infrastructure under a BOT model, the government receives investment rights from the host country or the private sector for a certain period of time. Government engagement in the BOT model may vary according to project type, size, complexity, and the economic and legal restrictions of the host country. Taxation, labour, immigration, customs, and currency convertibility laws are needed by the government. The host government addresses contract enforcement, private ownership, security, taxation, foreign exchange remittance, and profit [24]. Project approval comes from the host nation. To approve a project, the administration procurement technique is chosen, and bidders' feasibility and economic viability are evaluated. Some researchers believe that successful BOT projects require a developed economic-financial-legal framework, avoiding delays, project management skills, thorough feasibility, healthy partnerships, stability, political support, facilities, sponsors, acceptable inflation, currency exchange, and interest rate. As a result, host nations will need to find their own unique BOT model to implement infrastructure projects. Countries that have implemented BOT projects successfully generally credit win-win situations. Project sponsors struggle to manage BOT projects. Complex and time-consuming project development may cost locals. BOT projects have high financial risk, long bidding competition, extensive negotiations, and low opportunity costs. BOT sponsors should learn from successful projects and legal problems to take reasonable risks and be adaptable.

B. Design and Build

Delivering construction projects in a different way includes the Design and Build (D-B) process. It's a kind of procurement where one party has a contractual responsibility for both project design and project construction. The goal of design and build projects is to integrate the design and building processes into one organisation, hence resolving the issue of distinct procedures. Typically, the only company involved is the construction contractor, who has the authority to hire consultants directly under their supervision or may hire designers on-site. The main distinction is that the organisation does not contact the building's designer but rather informs the contractor directly. The employer has the option to hire a quantity surveyor or architect to evaluate the contractor's plan and keep an eye on the progress of the project. A wise business owner will always desire an outside opinion. Construction time and money should be saved since the contractor's evolving design is more likely to be suitable to their organisation's and methodology's demands. There are those who believe that the contractor's construction skills, rather than the employer's design needs, will dictate the design. The employer should save money with the finished building because of reduced on-site manufacturing expenses and a shorter design and construction time overall [25]. Even when the price of any required independent architectural assistance is taken into consideration, there should still be some purported savings on the design fees.

V. EPC CONTRACTS IN RENEWABLE ENERGY PROJECTS

This section gives a brief description of EPC contracts in renewable energy projects with reference to their features, sustainability and environmental issues, indices of performance, challenges, and risks relating to regulation and policy.

How EPC Contracts Differ in Renewable Energy Projects?
--Integration of Renewable Technologies:

- Renewable energy often involves niche technologies particle in installation of solar PV panels, wind mills and battery power for energy storage. To compensate for these

conditions, EPC contracts for these projects must incorporate use of these technologies; these technologies are comparatively less standardised and more variable than conventional energy technologies like fossil fuels and nuclear energy.

- Energy from renewable sources: The design and technical stages. Renewable technology know-how and how they are affected by conditions of the environment like irradiance and wind for EPC contracts.

Focus on Sustainability and Environmental Compliance:

- Many renewable energy projects are usually subjected to numerous environmental standards and sustainability goals. To promote the standards of environmental requirements in the EPC contracts certain features can be incorporated such as, Environmental assessment, sustainable environmental construction and environmental compliance related to local and international norms.
- The aspect of carbon emission reduction during the construction and the operational phase is more emphasised, the decisions regarding procurement and construction methods being influenced.

Variable Energy Output and Performance Metrics:

- Renewable resources possesses a high variability in their production because the generation depends on certain natural occurrences in the society like the amount of sun or wind. Maturity of energy output is another factor that should be taken into consideration whilst developing performance criteria related to EPC contracts within the renewable energy industry. Such figures often include performance bonds referring to the capacity factors or estimated energy production and not specific outputs.
- The performance guarantees that holders demand in renewable energy may require complex calculations to estimate power generation over a period.

Specific Challenges in Renewable Energy EPC Contracts-Site Selection and Environmental Impact:

- The decision making scope of a site for renewable energy is a critical decision because the amount of energy produced depends on this location. EPC contracts should address the challenges that one is bound to face when identifying suitable locations for the generation of energy which takes into account the strengths as well as the surrounding environment and society.
- Environmental impact studies are especially important in renewable energy projects such as wind and hydroelectric power; these affect wildlife, ecosystems and populations significantly.

Regulatory and Policy Uncertainty:

- The renewable energy sector usually carries serious risks of changes in legal regulations and policies greatly affecting the viability and profitability of proposed projects. EPC contracts must entail provisions which seek to capture variation in policy where such scenarios can be dealt with by provisions such as changes in subsidy rates, tariffs or any environmental legislation.
- Regulatory approvals and policies may act as a source of risk; they may prove unreliable and this may eventually lead to delay, cost increase or project cancellation while the latter is an obvious form of risk that has to be managed in a contract.

VI. CHALLENGES AND OPPORTUNITIES OF EPC IN RENEWABLE ENERGY

In this section are captured the challenges as well as the opportunities. The issues of technicality, contractual, and project progression of renewable technology in EPC.

Technical Challenges- Integration of Renewable Technologies:

- **Complexity in Design:** RE schemes often require the use of multiple technologies to achieve the desired functionality, including solar PV systems, wind generators, and energy storage systems. The process of merging them conveniently and getting the ideal performance of these technologies may be complicated and needs professional input and innovative solutions.
- **Technology Maturity:** There is still development in some forms of renewable energy, which causes issues in their efficiency, durability, and service provisioning. This may have effects on the EPC design and execution phase of contracts outworn above.
- **Grid Connectivity:** Integrating RE sources in existing grids has challenges like; maintaining grid integrity, managing varying energy production, and ensuring compliance with grid codes as well as standards. Viable grid connection project might be delayed and may lead to high costs such as the following.

Contractual Challenges- Performance Guarantees:

- **Uncertain Output:** New generation power generation projects often depend on unpredictable natural sources like light and wind. The issue of diverse levels of

performance results in conflicts in the utilisation of contracts between the project owners and the EPC contractors with the scope of contractual obligations.

- **Warranty and Liability Issues:** Maintenance of the installed system's long-term performance is a challenging venture. Warranty claims may be in question, particularly, inasmuch the performance of the contractor is suboptimal, due to exogenous factors, for instance, conditions of the physical environment or innovative challenges.

Project Delays:

- **Regulatory Approvals:** Project schedules can be altered, possibly from the period waiting for permission and endorsement from the right authorities. These various possible delays have to be taken into account in EPC contracts, since they lead to increased costs and, most importantly, contractual penalties.
- **Supply Chain Disruptions:** The investment in renewable energy sources sometimes relies on imported input, particularly, solar cells, wind turbines, and batteries. Problems in these supply chains can happen due to geopolitical problems, transportation issues or other factors, which results in project delivery delays and pressures to the contractual relations.

VII. LITERATURE REVIEW

This section provides the existing work on Engineering, Procurement and Construction (EPC).

In, Pícha, Tomek and Löwitt, (2015) research aims to promote common knowledge by identifying the important provisions and hazards that cause the majority of conflicts in EPC contracts. It then gives an explanation of these circumstances. Furthermore, the EPC contract scheme identified the critical success elements for project completion. The EPC contracting scheme has the potential to be very effective for electricity projects, particularly when the contractor has a thorough understanding of all contract legalities, including risk allocation[8].

In, Tsolas, (2020) gives a way to benchmark EPC power plant projects in advance utilising a two-stage DEA process. The study's goal is to evaluate the efficiency of a group of twelve natural gas-fired power plant projects, both domestic (based in Greece) and international (OCPP and CCPP with single and multi-shaft configurations), using a series two-stage DEA model–an improvement over single-stage DEA. Stage 1 evaluates the EPC mode's performance, while Stage 2 evaluates the plant's yearly operating efficiency. The EPC mode exhibits lesser performance compared to operational efficiency, based on the obtained data[26].

In, Liu et al., (2021) developed and verified a theoretical framework using information from a large-scale EPC hydropower project to assess the relationships between these factors and the success of such projects. By methodically mapping the effects of EPC hydropower project success on design capabilities, design management, and partnerships, this research provides theoretical support for the concept that design-related activities may be structured both inside and across organisations[27].

In, Zhao, (2011) Engineering procurement efficiency was enhanced by the use of the EPC model, which incorporates supply and critical chains. A comprehensive model of an EPC contract is presented in this study. After a thorough examination of the supply chain and key chain application methods in the EPC contract model, a strategy for particular applications was proposed, drawing on a mix of buying theory and the EPC model[28].

Therefore, Sangroungrai, Sukchareonpong and Witchakul, (2018) An essential strategy for cutting costs and saving time is efficient project scheduling. Projects of any size often make use of PERT, or the Program Evaluation and Review Technique, as a means of controlling and managing the scheduling of various tasks. Finding the longest route in a network diagram or the quickest time to accomplish a project are two common uses of the CPM. The study's stated goal was to find the best way to use PERT and CPM in conjunction with the Crystal Ball simulation add-in for Microsoft Excel to shorten the length of complicated projects and increase the assurance of their completion. A monthly reduction in the total cost of project management will be achieved by shortening the length of the project. This article found that by combining PERT and CPM with the Crystal Ball add-in for Microsoft Excel, project length could be reduced from 356 days to 312 days and completion assurance could be increased from 24.49% to almost 100%[29].

Table 1 provides a structured overview of the relevant work on EPC contracts and project management, highlighting the aim, achievements, limitations, and areas for future research.

Table. 1 Summarising the key information from these studies

Reference	Aim	Achievements	Drawbacks	Future Work
[8]	Identify significant provisions and dangers that cause conflicts in EPC contracts, and outline conditions for successful project completion.	Defined key clauses leading to disputes and provided clarity on risk allocation, showing EPC contracts work well when contractors understand legal aspects	Limited to contract-related factors without exploring operational efficiency or cost management	Explore integration of EPC contracts with modern project management techniques like BIM or digital twins.
[26]	Propose a two-stage DEA model for benchmarking EPC power plant projects	Evaluated performance of domestic and international natural gas power plants, showing a gap between EPC mode performance and operational efficiency	Limited to natural gas power plants, excluding renewable energy projects or other technologies	Apply the two-stage DEA model to renewable energy projects and analyse the impact of new technologies like battery storage
[27]	Investigate the causal link between partnership, design management, design capacity, and EPC hydropower project performance.	Established a conceptual model linking partnering, design management, and project performance for large-scale EPC hydropower projects	Focused on hydropower, excluding other types of renewable energy projects like solar or wind	Extend the model to other renewable energy sectors and validate using additional data from different projects.
[28]	Analyse the use of supply networks and critical chains in EPC contracts to increase procurement efficiency.	Provided a complete EPC contract model and demonstrated how supply chain optimisation can enhance procurement	Limited scope focusing on procurement, lacking insights into construction or operational phases	Explore integration of advanced procurement technologies, such as AI-driven supply chain management, to further optimise efficiency
[29]	Apply PERT and CPM methods with simulation software to optimise project scheduling in EPC projects.	Demonstrated how using PERT, CPM, and simulation software (Crystal Ball) can reduce project duration and improve completion certainty.	Focused solely on scheduling aspects without considering other project management components like cost control or risk management	Investigate integration of real-time data from construction sites into PERT and CPM models for dynamic project scheduling adjustments.

VIII. CONCLUSION & FUTURE WORK

The analysis of EPC contracts in the renewable energy sector reveals that well-structured agreements are vital for the successful delivery of projects, as they streamline coordination and reduce risks associated with engineering, procurement, and construction activities. Proper delimitation of responsibilities, risk sharing, and practical obligation terms are critical factors that cover most of the challenges including; delay in project implementation, increase in costs, and regulatory concerns. Targeting, result- and technology-based EPC contracts that reflect the specific character of renewable energy projects form the sound basis for sustainable and efficient energy delivery. In light of the ongoing trend toward

the development of renewable energy, it is necessary to constantly update EPC mechanisms that respond to innovations and adjustments to legislation. Thus, the EPC model can also promote innovation and efficiency in the renewable energy sector by learning lessons from previous contracts and contract management through cooperatives.

This study could be succeeded by other research works to investigate how the adoption of emerging technologies including; Artificial Intelligence, Digital Twins, and Blockchain can be harnessed fully in managing EPC contracts effectively for renewable energy projects. Finally, more work could enhance lifecycle management when concepts of sustainability and circular economy are introduced into contract solutions. Other potential research topics include the derivation of target risk models for hybrid renewable systems and the modification of contracts for decentralised energy projects. Lastly, the incorporation of Environmental, Social and Governance (ESG) factors into EPC contracts could help make sure that projects subscribe to more all-encompassing sustainability standards.

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