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Abstract
This article explores the intersection of occupational safety and renewable energy development in conflict-affected regions. As global demand for clean energy rises, wind and solar projects are increasingly deployed in politically unstable or post-conflict zones. These environments pose unique risks to workers, from physical threats due to violence to psychological stress and logistical challenges. This study investigates how occupational risk is assessed and managed in such contexts, drawing on case studies, interviews, and safety frameworks. It proposes a conflict-sensitive safety management model tailored to renewable energy infrastructure.

Keywords
Safety; renewable energy; risks; psychological stress.

I. Introduction

Background and Rationale. The global transition to renewable energy is accelerating, driven by the urgent need to mitigate climate change, reduce dependence on fossil fuels, and promote sustainable development. Wind, solar, and hybrid energy systems are increasingly deployed not only in stable regions but also in fragile and conflict-affected areas where energy access is limited or disrupted [1]. These projects are often supported by international development agencies, humanitarian organizations, and private investors seeking to rebuild infrastructure and foster resilience in post-conflict societies [2]. However, the deployment of renewable energy infrastructure in conflict zones introduces a complex array of occupational risks. Workers in these environments face not only the conventional hazards associated with construction and energy systems, such as electrical accidents, falls, and equipment failure, but also risks amplified by political instability, violence, and weak institutional oversight [3]. These include threats from armed groups, unexploded ordnance, psychological trauma, and disrupted supply chains. Despite these challenges, there is a notable gap in the academic literature and policy frameworks addressing occupational safety in such high-risk contexts [4].

Problem Statement. While occupational health and safety (OHS) is a well-established field in industrialized settings, its application in conflict-affected renewable energy projects remains underexplored. Existing safety protocols often fail to account for the dynamic and volatile nature of conflict environments, where standard risk assessments may be inadequate or inapplicable [5]. Moreover, the intersection of conflict dynamics, local labor practices, and international project management creates a unique and urgent need for context-sensitive safety strategies. This research addresses a critical gap by proposing a novel Conflict-Resilient Safety Management (CRSM) model, specifically designed for renewable energy infrastructure operating in conflict zones. The model integrates principles from the High Reliability Theory, Conflict Sensitivity, Resilience Engineering and Feedback Loops to offer a comprehensive framework for managing occupational risks in volatile environments.

Research Objectives and Questions. This article aims to investigate how occupational risks are identified, assessed, and managed in renewable energy projects operating in conflict-affected regions. The central research questions are: What are the primary occupational risks faced by workers in these projects? How do conflict dynamics influence the effectiveness of safety management systems? What strategies and frameworks can enhance worker safety in such volatile environments?

Summary of Contributions. Drawing on case studies from Iraq, South Sudan and Ukraine, as well as interviews and safety frameworks, this study presents key findings that highlight how occupational risks are amplified by weak governance, corruption and inadequate healthcare infrastructure. The Conflict-Resilient Safety Management (CRSM) model offers a structured, adaptive approach to mitigate these risks through decentralized decision-making, resilience planning and continuous learning. These insights are intended to be practically implemented in high-risk renewable energy projects. Building on the foundational concepts introduced in the previous section, the following chapter presents the theoretical underpinnings that guide this study.

II. Theoretical Framework

The complexity of occupational safety in conflict-affected renewable energy projects demands a multidisciplinary theoretical approach. This chapter introduces and synthesizes three key frameworks: High Reliability Theory, Conflict Sensitivity, and Resilience Engineering, to construct a conceptual model that addresses the unique challenges of managing occupational risk in volatile environments.

A. High Reliability Theory (HRT)

High Reliability Theory (HRT) explains how organizations operating in high-risk environments maintain safety through vigilance, decentralization, and continuous learning [7]. In conflict zones, renewable energy projects face unpredictable threats such as violence, infrastructure sabotage, and political instability. HRT principles, such as preoccupation with failure and deference to expertise, are essential for maintaining safety under such conditions.
In eastern Ukraine, a solar farm implemented decentralized decision-making and daily safety briefings. Site supervisors were empowered to halt operations during nearby shelling incidents, preventing injuries and equipment damage [7].

B. Conflict Sensitivity

Conflict sensitivity involves understanding how interventions interact with local conflict dynamics and adapting accordingly [8]. It ensures that safety planning accounts for social tensions, power imbalances, and potential triggers of violence. Example: In Kenya’s Kakuma Refugee Camp, renewable energy projects were adapted to avoid exacerbating tensions between refugee and host communities. Hiring practices and energy distribution were modified to ensure equitable access, thereby reducing conflict [8].

C. Resilience Engineering

Resilience Engineering focuses on building systems that can adapt to disruption and continue functioning safely [9]. It emphasizes flexibility, redundancy, and learning loops-critical in conflict zones where conditions change rapidly. In South Sudan, a hybrid microgrid project used modular designs and trained local technicians to maintain operations during road blockades and political unrest. Redundant supply routes and flexible system configurations ensured continuity [10].

D. Conflict Sensitivity

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E. Feedback and Adaptation Loops

Feedback loops allow safety systems to evolve based on real-time data and worker input. This is vital in conflict zones, where static protocols may quickly become obsolete [11]. A wind project in Afghanistan used mobile apps for anonymous safety reporting. Weekly reviews led to changes in shift schedules and evacuation protocols based on recent conflict flare-ups [11].

F. Conceptual Model: Conflict-Resilient Safety Management

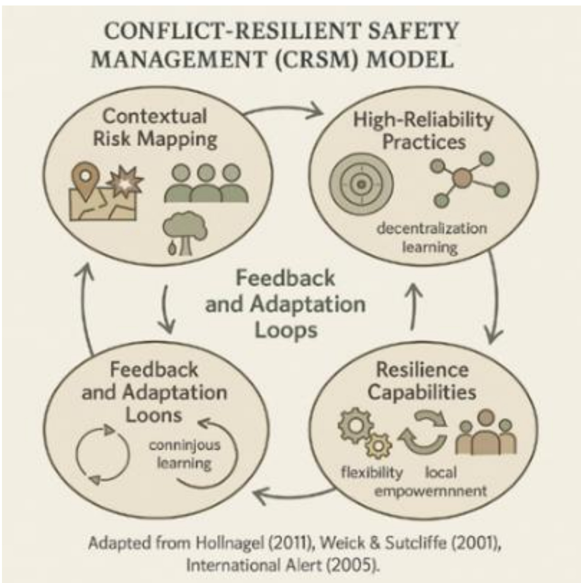

Fig. 1. Visual representation of the CRSM model

The CRSM model integrates the above theories into a unified framework for managing occupational safety in conflict-affected renewable energy projects. It includes:

• Contextual Risk Mapping - Identifies socio-political and environmental hazards
• High-Reliability Practices - Embeds vigilance and decentralized decision-making
• Resilience Capabilities - Builds adaptive capacity through flexible planning
• Feedback and Adaptation Loops - Enables continuous learning and system updates

III. Contextual Overview

This chapter provides a comparative overview of three conflict-affected countries – Iraq, South Sudan, and Ukraine – where renewable energy projects are being implemented amid political instability and security risks. It outlines the geopolitical context, renewable energy potential, and the key stakeholders involved in project development and safety governance.

A. Country Profiles and Energy Contexts

Iraq has experienced decades of conflict, including the U.S. invasion, sectarian violence, and the rise of ISIS. Although relatively more stable today, it remains vulnerable to regional tensions and internal unrest [12]. Iraq has set a target to generate 20% of its electricity from renewables by 2030. Despite high solar irradiance and wind potential, progress is slow, with only one major solar project launched as of 2025 [13]. Political interference, corruption, and dependence on Iranian gas hinder energy diversification [12].

South Sudan, since gaining independence in 2011, has been plagued by civil war, ethnic violence, and humanitarian crises. Security remains fragile [14]. With only 8.4% of the population having access to electricity, South Sudan has vast potential for off-grid solar and hybrid systems. Its lack of legacy infrastructure presents an opportunity to leapfrog into renewables. Infrastructure deficits, poverty, and climate-related shocks (e.g. floods) complicate energy deployment [15].

The ongoing war with Russia has devastated Ukraine's energy infrastructure. Over half of its electricity production capacity has been destroyed [14]. Ukraine has significant wind and solar potential, particularly in the southern regions. Prior to the war, it had one of the fastest-growing renewable sectors in Eastern Europe. Post-2022, reconstruction efforts have prioritized decentralized and resilient energy systems, including microgrids and hybrid renewables. Challenges: active conflict zones and military targeting of infrastructure, displacement of skilled labor and technical personnel, regulatory uncertainty and disrupted supply chains, psychological stress and trauma among energy workers.

The highlight of how each country has distinct but overlapping barriers in deploying renewable energy under conflict conditions is summarized in figure 2.

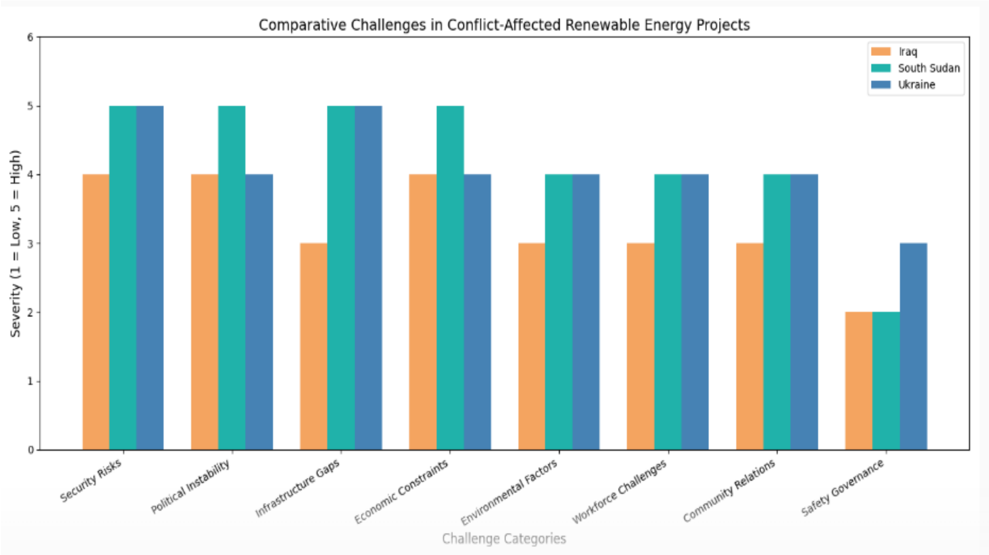

Fig. 2. Comparative challenges in Conflict-affected renewables Energy project

IV. Occupational risk and safety management in conflict - affected renewable energy projects

A, Types of occupational risks

Physical risks. Workers in conflict zones face direct physical threats such as: Landmines and unexploded ordnance (UXO) common in post-conflict areas like South Sudan and Afghanistan [16]; Armed attacks or sabotage, renewable infrastructure is often targeted due to its symbolic and strategic value; Poor infrastructure, inadequate roads and emergency services increase accident rates.

Table 1. Physical risk incidents in conflict zones

Country	Type of risk	Incident rate (per 100 workers / year)
Afghanistan	UXO related injuries	12.4
South Sudan	Armed attacks	8.7
Democratic Republic of Congo	Infrastructure failure	10.1

Psychological risks. Conflict environments exacerbate mental health challenges: Chronic stress and PTSD (post-traumatic stress disorder). Up to 30-70% of workers in war zones report symptoms [17]; Isolation, Remote locations and security restrictions limit social interaction; Trauma exposure, witnessing violence or displacement events. Formula for psychosocial risk index (PRI):

$$\text{PRI} = \frac{(S+T+1)}{3} \qquad (1)$$

Where:
S – Stress level (1 – 10)
T – Trauma exposure (1 – 10)
I – Isolation score (1 – 10)
Scores for stress (S), trauma exposure (T), and isolation (I) are derived from structured worker surveys. Each parameter is rated on a scale from 1 to 10, based on self-reported experiences and validated through interviews with field security and safety officers.

Operational risks. Operational disruptions are frequent due to: Supply chain breakdowns border closures, embargoes, or attacks on logistics [18]; Delays in construction due to security threats or lack of skilled labor; Communication failures, infrastructure damage affects coordination.

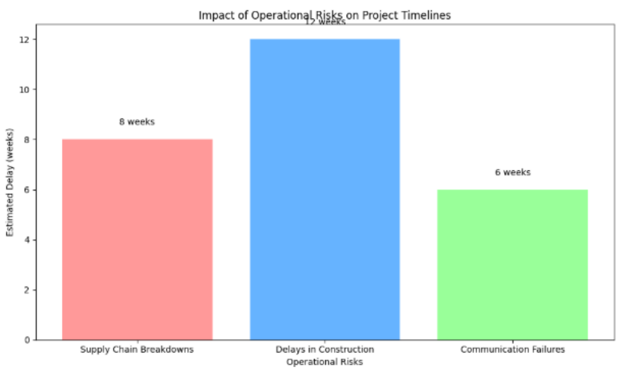

Fig. 3. Impact of operational risks on project timelines in conflict-affected renewable energy projects

Key insights. Delays in construction: have the highest estimated impact, causing up to 12 weeks of delay due to security threats and labor shortages. Supply chain breakdowns (e.g. border closures, attacks) can delay projects by around 8 weeks. Communication failures: due to infrastructure damage, may result in a 6-week delay.

Environmental risks. Environmental conditions in conflict zones often include:

Table 2. Environmental Stressors in Renewable Energy Sites

Location	Climate risk	Accessibility	Environmental degradation
North Mali	High	Low	High
Eastern Ukraine	Medium	Medium	Medium
Yemen Highlands	High	Very low	high

In conflict-affected renewable energy projects, occupational risks are not only shaped by direct threats but are significantly amplified by systematic weaknesses in governance, corruption, and healthcare infrastructure. These amplifiers exacerbate the severity and frequency of workplace hazards, reduce the effectiveness of mitigation strategies, and increase workers' vulnerability.

Weak Governance. Weak governance manifests in the inconsistent enforcement of safety regulations, fragmented oversight and limited institutional capacity to manage risks. In South Sudan, the absence of a coherent regulatory framework for labor and energy infrastructure has led to a near-total lack of enforcement of occupational standards. Many renewable energy projects operate in legal grey zones, relying on ad hoc agreements with local governments. In Iraq, overlapping jurisdictions between federal and regional governments create confusion over regulatory responsibilities, delaying inspections and enforcement. In Ukraine, while governance structures are more deployed, the ongoing war has diverted administrative capacity away from civilian infrastructure oversight, weakening the enforcement mechanism.

Corruption. Corruption undermines occupational safety by distorting procurement, inspection, and enforcement processes: Bribery in inspections allows contractors to bypass safety protocols, leading to substandard construction and unreported hazards [20]. Diversion of safety funds intended for PPE, training, or emergency response towards non-operational uses in common in both Iraq and South Sudan, where transparency mechanisms are weak [21]. In Ukraine, corruption risks have increased in areas under temporary occupation or near the front lines, where informal power structures influence project operations [20].

Table 3. Corruption Impact on safety compliance

Country	Bribery in inspection	Safety Fund Diversion	Compliance Score (0-10)
Iraq	High	High	4
South Sudan	Very High	Very High	3
Ukraine	Medium	Medium	6

Corruption Amplification Factor (CAF) can be determined:

$$CAF = B + D - C \qquad (2)$$

Where:
B = Bribery Index
D = Diversion Index
C = compliance score.

Higher CAF indicates greater corruption impact. The Bribery Index (B) and Diversion Index (D) are qualitative assessments scored 1 to 10, based on expert interviews, NGO Reports, and transparency audits. The Compliance Score (C) is a numerical rating (0-10) derived from documented adherence to safety protocols, inspection records, and third-party evaluations.

Lack of Medical Facilities. The absence of adequate medical infrastructure in conflict zones significantly increases the fatality and morbidity rates of occupational incidents. In South Sudan, there are fewer than 0.15 physicians per 1000 people, and many rural project sites are over 100 km from the nearest clinic [22]. In Iraq, faces a shortage of trauma care facilities in areas affected by the past insurgencies, with many hospitals still under reconstruction [23]. In Ukraine, while urban centers have robust medical systems, frontline regions suffer from destroyed infrastructure and overwhelmed emergency services [22]. The below visualization supports that medical infrastructure deficiencies significantly amplify occupational risks in conflict-affected renewable energy projects. South Sudan's extreme response time (180 minutes) highlights the urgent need for mobile clinics and trauma-ready field units in remote project areas.

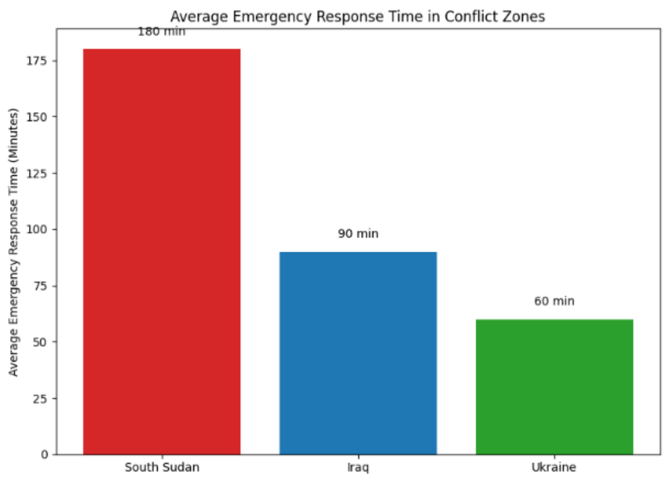

Fig. 4. Average Emergency response time in conflict zones, comparing South Sudan, Iraq and Ukraine.

In response to the risks identified, the following chapters explore current safety management strategies tailored to conflict zones.

V. Safety management strategies in conflictaffected renewable energy projects

In conflict-affected regions such as Iraq, South Sudan, and Ukraine, safety management in renewable energy projects requires a hybrid approach that blends conventional occupational safety practices with conflict-sensitive innovations. This chapter explores current practices, identifies persistent challenges, and highlights emerging innovations tailored to high-risk environments.

A. Current practices

Use of private security. In conflict-affected regions, private security firms are often indispensable to the operation of renewable energy projects. These firms fill the vacuum left by weak or absent state security forces and are tasked with protecting both personnel and infrastructure. Their roles typically include: Perimeter defense - Installation and monitoring of surveillance cameras, motion sensors, and physical barriers such as fencing and checkpoints. Escort services - Armed or unarmed escorts for engineers, technicians, and supply convoys travelling to and from remote or high-risk project sites. Threat intelligence - Gathering and analyzing local security data to anticipate risks such as insurgent activity, theft, or sabotage. In Iraq, solar energy projects in Anbar province have contracted local security firms with deep knowledge of tribal dynamics. These firms not only provide physical protection but also act as intermediaries with local communities, reducing the likelihood of attacks or sabotage [24]. While private security can enhance safety, it also introduces ethical and operational challenges, including: Accountability gaps in the event of misconduct; Escalation risks if security personnel are perceived as partisan; Cost burdens that can divert funds from core safety infrastructure.

Remote Monitoring and Automation. To reduce personnel exposure to physical and conflict-related hazards, renewable energy projects in conflict zones are increasingly adopting remote monitoring and automation technologies. These systems allow for real-time oversight and control of infrastructure with minimal on-site presence. Key technologies:

Drones - used for aerial inspections of wind turbines and solar panels, drones can detect structural damage, overheating or unauthorized access without requiring human inspectors to enter dangerous areas.

SCADA Systems (Supervisory Control and Data Acquisition): These centralized platforms allow operators to monitor and control energy production, defect faults, and adjust system parameters remotely. SCADA systems are particularly valuable in Ukraine, where frontline regions are inaccessible due to the ongoing conflict.

IoT Sensors: Internet of Things (IoT) devices are embedded in turbines, solar panels and substations to monitor: Structural integrity (e.g., vibration, tilt); Environmental conditions (e.g., temperature, wind speed); Energy output and efficiency. These sensors enable predictive maintenance, reducing downtime and preventing catastrophic failures. In Ukraine, wind farms near Mykolaiv have integrated IoT sensors with satellite uplinks to maintain operational visibility even during periods of shelling or power grid instability [25]. Benefits: Reduced personnel risk in high-threat areas; Faster response times to technical issues; Improved data accuracy for performance optimization. Challenges: Cybersecurity vulnerabilities: Remote systems are susceptible to hacking, especially in regions with active cyber warfare. Connectivity issues: In South Sudan and parts of Iraq, poor internet infrastructure can limit the effectiveness of real-time monitoring.

Emergency Evacuation Plans. In conflict-affected renewable energy projects, emergency evacuation planning is a critical component of occupational safety management. These plans are designed to ensure the rapid and safe withdrawal of personnel in the event of armed conflict, natural disaster, or technical failure. Key Components of Evacuation Plans:

- Evacuation Routes and Rally Points (Predefined escape routes are mapped and regularly updated based on evolving security conditions. Rally points are established at safe distances from project sites, often near UN or NGO compounds.)
- Emergency Communication Systems (Satellite phones, encrypted radios, and mobile apps are used to maintain communication during evacuations. In Ukraine, some wind farms have integrated Starlink terminals to ensure connectivity during blackouts or cyberattacks.)
- Evacuation Drills and Training (Regular drills are conducted to familiarize staff with procedures. Drills include simulations of armed attacks, landmine encounters, and medical emergencies.)

C. Challenges

Despite the implementation of safety strategies, renewable energy projects in conflict zones face persistent and systemic challenges that undermine occupational safety. These challenges are often interlinked with broader issues of governance, infrastructure, and social dynamics.

Limited Access to Training. Access to safety training is a foundational element of occupational risk management. However, in conflict-affected regions, training is often sporadic, underfunded, or entirely absent. South Sudan lacks formal institutions for technical and safety training in the renewable energy sector. Most workers are hired locally with minimal prior experience, and training is often delivered informally or on-the-job, if at all. In Iraq, logistical barriers such as road insecurity, curfews, and militia checkpoints hinder the delivery of training programs to remote or high-risk areas. Trainers often require armed escorts, which increases costs and reduces frequency. Ukraine has seen many training centers in frontline regions damaged, repurposed for humanitarian use, or rendered inaccessible due to active conflict. Workers may be unaware of basic safety procedures, such as lockout/tagout protocols, PPE use, and emergency response procedures. This increases the likelihood of preventable accidents, especially during maintenance or installation phases. A 2023 incident in a solar installation in Jonglei State, South Sudan, resulted in two fatalities due to improper grounding of electrical equipment-an error linked to a lack of formal training. This root cause highlights a systematic gap in workforce competency and underscores the urgent need for standardized safety education in emerging solar markets to prevent avoidable fatalities.

Cultural and Language Barriers. Multinational teams are common in renewable energy projects, especially those funded by international donors or operated by foreign firms. However, while cultural and linguistic diversity enriches, it can also introduce safety risks. Language mismatches between expatriate engineers and local laborers can lead to miscommunication of safety instructions, especially during emergencies. Cultural norms may discourage workers from reporting hazards, questioning authority, or admitting a lack of understanding.

Inconsistent Enforcement of Safety Protocols. Even when safety protocols exist, their enforcement is often inconsistent due to fragmented governance, lack of oversight, or shifting control of territory. In Iraq, overlapping jurisdictions between federal, regional, and tribal authorities create confusion over who is responsible for enforcing labor and safety laws. This leads to patchy inspections and selective compliance. South Sudan suffers from a near-total absence of regulatory enforcement in rural areas. Safety standards are often determined by the implementing agency or contractor, with little external accountability. In Ukraine, enforcement varies significantly between government-controlled areas and contested zones. In some frontline regions, safety inspections are suspended entirely due to security concerns.

Innovations. In response to the complex safety challenges in conflict-affected renewable energy projects, a range of innovative strategies have emerged. These innovations aim to enhance worker protection, improve communication, and adapt safety practices to volatile and resource-constrained environments.

Mobile Safety Apps. Mobile applications are transforming how safety is managed in remote and high-risk project sites. These tools offer real-time, decentralized, and user-friendly platforms for safety communication and training. Key Features: Incident Reporting: Workers can instantly report hazards, injuries, or security threats. Geofenced Alerts, apps can trigger location-based warnings (e.g., proximity to conflict zones or minefields). Digital Training Modules, interactive safety training can be accessed on demand, even in low-bandwidth environments. Offline

Functionality, crucial in areas with unreliable internet, such as rural South Sudan or frontline zones in Ukraine.

Community-Based Safety Liaisons. In fragile contexts, community engagement is not just a social responsibility, it is a safety imperative. Community-based safety liaisons serve as trusted intermediaries between project teams and local populations. Early Warning Systems provide real-time intelligence on local conflict dynamics, environmental hazards, or community tensions. Cultural Mediation helps adapt safety protocols to local customs and languages, improving compliance and trust. Dispute Resolution can de-escalate conflicts between workers and residents, especially over land use or access.

Conflict-Sensitive Safety Training. Traditional safety training often fails in conflict zones because it overlooks the social, political, and psychological realities of the environment. Conflict-sensitive training addresses this gap by integrating contextual awareness into safety education. Core Modules could contain: Conflict Awareness (understanding local power dynamics, armed group behavior, and conflict triggers); De-escalation Techniques (nonviolent communication, negotiation, and situational judgment); Trauma-Informed First Aid (psychological first aid and care for blast or gunshot injuries). Delivery Methods:

• Blended Learning: Combining in-person workshops with mobile-based modules.
• Peer-to-Peer Training: Empowering local workers to train others in their language and cultural context.
• Scenario-Based Drills: Simulations of conflict-related emergencies (e.g., evacuation under fire, checkpoint navigation).

VI. Conclusion

Occupational safety in conflict-affected renewable energy projects demands a paradigm shift from conventional models to adaptive, context-sensitive frameworks. Through the lens of Iraq, South Sudan, and Ukraine, this study has shown that safety risks are shaped not only by direct threats, such as violence, landmines, and infrastructure failure, but also by systemic amplifiers like weak governance, corruption, and inadequate healthcare.

To address these challenges, the Conflict-Resilient Safety Management (CRSM) model integrates High Reliability Theory, Conflict Sensitivity, Resilience Engineering, and Feedback Loops into a unified approach. This model emphasizes vigilance, decentralization, adaptability, and continuous learning, principles essential for operating safely in volatile environments. The analysis of current practices and innovations, ranging from private security and remote monitoring to mobile safety apps and community-based liaisons, demonstrates that effective safety management must be both locally grounded and technologically enabled. Ultimately, ensuring worker protection in conflict zones is not only a technical challenge but a socio-political imperative, requiring collaboration, flexibility, and a deep understanding of the local context.

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APPENDIX A: VISUAL AIDS AND DATA APPENDICES

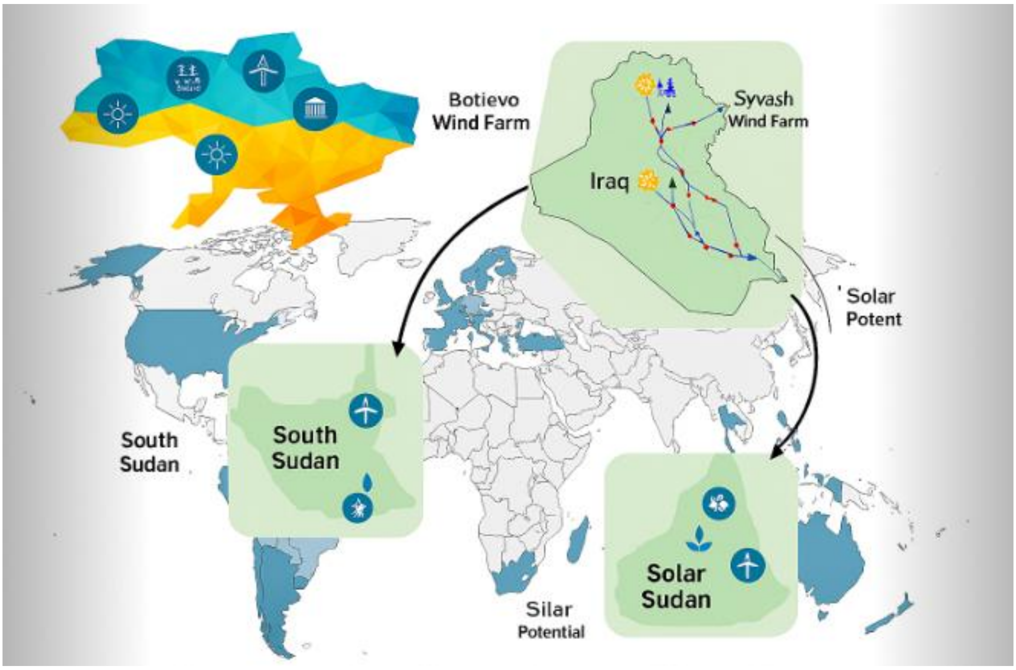

Fig. A1. Map of Renewables in Iraq, South Sudan, and Ukraine

Fig. A2. Infographic: Conflict-Resilient Safety Management (CRSM) Model Overview

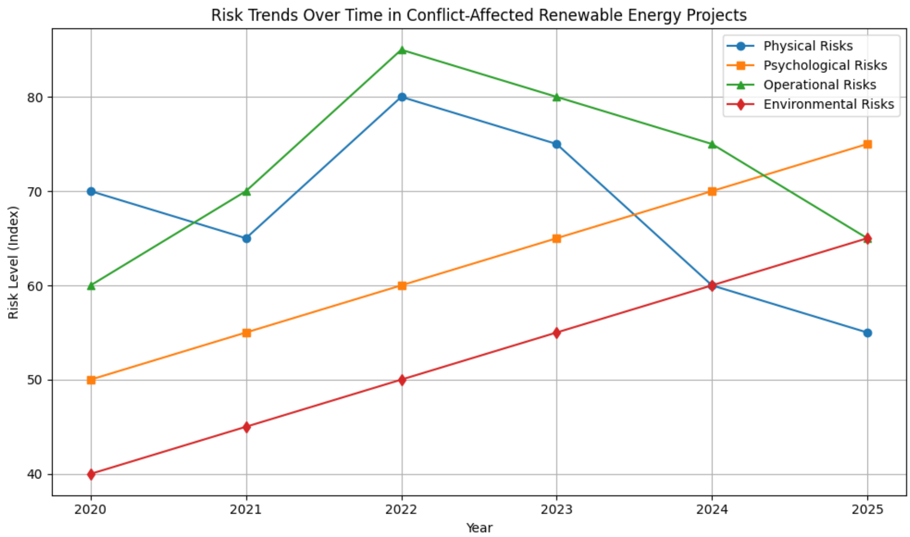

Fig. A3. Chart: Risk Trends Over Time in Conflict-Affected Renewable Energy Projects

Physical Risks peaked in 2022 (80) but declined steadily to 55 by 2025, likely due to improved security measures and remote monitoring.

Psychological Risks show a continuous upward trend, reaching 75 in 2025, reflecting cumulative stress and trauma exposure.

Operational Risks spiked in 2022 (85) during major conflict escalations, then decreased as resilience strategies were implemented.

Environmental Risks steadily increased from 40 to 65, indicating growing climate-related stressors and accessibility issues.

APPENDIX B: INTERVIEW METHODOLOGY

1. Description of Interview Methodology

Sampling Strategy:
A purposive sampling approach was used to identify participants with direct experience in renewable energy projects located in conflict-affected regions. Selection criteria included:
- Minimum of 1 year of field experience in Iraq, South Sudan, or Ukraine.
- Roles in safety management, engineering, logistics, or community liaison.
- Representation from both international and local stakeholders.

Interview Format:

Interviews were semi-structured, allowing flexibility to explore emergent themes while maintaining consistency across core questions. Each session lasted between 45 and 60 minutes and was conducted via secure video conferencing platforms due to security and accessibility constraints.

Ethical Considerations:

- Informed consent was obtained from all participants.
- Anonymity and confidentiality were guaranteed.
- Sensitive topics (e.g., trauma, corruption) were approached with care, and participants could skip questions.
- Ethical approval was granted by the doctoral ethics committee of the National University of Science and Technology POLITEHNICA Bucharest.

2. Sample Interview Questions

1. What are the most frequent safety risks you encounter in your current project?
2. How does the local conflict environment affect your ability to implement safety protocols?
3. Can you describe a situation where safety procedures had to be adapted due to conflict dynamics?
4. What role do local communities play in shaping safety outcomes?
5. How do you manage psychological stress among workers in high-risk zones?
6. What kind of training or support do workers receive regarding emergency evacuation?
7. Have you observed any corruption-related challenges in safety enforcement?
8. What technologies or innovations have helped improve safety in your project?
9. How do you communicate safety instructions across language or cultural barriers?
10. What improvements would you recommend for future safety management in conflict zones?

3. Participant Demographics

Table 1

Role	Gender	Country of Origin
Safety Manager	Male	Iraq
Field Engineer	Female	Ukraine
Logistics Coordinator	Male	South Sudan
Community Liaison	Female	South Sudan
NGO Safety Advisor	Male	Denmark

Renewable Energy Consultant	Female	Romania
Site Supervisor	Male	Ukraine
Trauma Care Nurse	Female	Iraq

4. Summary of Qualitative Findings

- Decentralized Decision-Making: Empowering local supervisors to halt operations during conflict events was cited as a critical safety measure.
- Psychological Stress: PTSD and chronic stress were prevalent, especially among local workers. Mobile apps and peer support networks were helpful.
- Corruption and Governance Gaps: Safety compliance was often undermined by bribery and diversion of funds, particularly in Iraq and South Sudan.
- Community Engagement: Projects that employed community liaisons reported fewer incidents and better local cooperation.
- Training Deficits: Lack of formal safety training was a recurring issue, especially in South Sudan. Peer-to-peer and mobile-based training were seen as promising alternatives.
- Technology Use: IoT sensors, drones, and SCADA systems were praised for reducing physical exposure and improving monitoring.
- Evacuation Planning: Regular drills and satellite communication were essential, but infrastructure damage and access restrictions remained major barriers.

APPENDIX C: CRSM MODEL TOOLKIT

1. Step-by-Step Implementation Guide

This guide outlines the four key steps for implementing the CRSM model in conflict-affected renewable energy projects.

Step 1: Contextual Risk Mapping
- Conduct socio-political and security risk assessments.
- Use GIS mapping and conflict analysis frameworks.

Step 2: High-Reliability Practices
- Establish decentralized decision-making protocols.
- Conduct daily safety briefings and empower 'stop-work authority'.

Step 3: Build Resilience Capabilities
- Design redundancy in supply chains and energy systems.
- Prepare mobile medical units and backup communication systems.

Step 4: Feedback and Adaptation Loops
- Deploy mobile apps for incident reporting.
- Schedule weekly risk review meetings.

2. Practitioner Checklist

□ Risk map completed and updated weekly.
□ Local security liaison appointed.
□ Emergency evacuation plan tested.
□ Mobile safety reporting system active.
□ Redundant supply routes identified.

3. Monitoring & Evaluation Template

Indicator	Traget	Frequency
% of staff trained in CRSM	100%	Quarterly
# of safety incidents	<2	Monthly
Average. evacuation time (min)	<45	Quarterly

APPENDIX D: SAMPLE CALCULATIONS AND RAW DATA

Sample Calculation for Psychosocial Risk Index (PRI): Using hypothetical values for S, T, and I.

Formula: PRI = $\frac{(S+T+1)}{3}$
Where:
S= Stress level (1–10)
T = Trauma exposure (1–10)
I = Isolation score (1–10)
Example:
S = 8, T = 7, I = 6
PRI =$\frac{(S+T+I)}{3}$ = 7

Sample Calculation for Corruption Amplification Factor (CAF): Using example values for B, D, and C.

Formula: CAF = B + D – C

Where:
B = Bribery Index (1–10)
D = Diversion Index (1–10)
C = Compliance Score (0–10)
Example:
B = 7, D = 6, C = 4
CAF = 7 + 6 – 4 = 9

Raw Data Tables: Placeholder for structured data used in risk analysis.

Table 2

Psychosocial Risk Survey Results

Participant ID	Stress (S)	Trauma (T)	Isolation (I)
P001	8	7	6
P002	6	5	7
P003	9	8	8
P004	5	4	6

Table 3
Corruption Risk Assessment

Region	Bribery Index (B)	Diversion Index (D)	Compliance Score (C)
Iraq	7	6	4
South Sudan	8	7	3
Ukraine	5	4	6

Sensitivity Analysis: Description of how changes in input parameters affect PRI and CAF outcomes.

Psychosocial Risk Index (PRI) is sensitive to increases in any of the three parameters.
For example:
If Stress increases from 6 to 9 while Trauma and Isolation remain constant at 7:
PRI = $\frac{(9+7+7)}{3}$ = 7.67

Corruption Amplification Factor (CAF) is most sensitive to reductions in Compliance Score (C). For example:
If Compliance drops from 6 to 3 while Bribery and Diversion remain at 7 and 6:
CAF = 7 + 6 – 3 = 10

APPENDIX E: SAMPLE CALCULATIONS AND RAW DATA

Iraq – Conflict Sensitivity & Governance Challenges
Security firms with tribal knowledge acted as intermediaries, reducing sabotage risks and improving local trust. Overlapping jurisdictions and bribery in inspections undermined safety compliance, highlighting the need for CRSM's feedback and adaptation mechanisms. In Iraq, the integration of local security actors and adaptive safety planning illustrates how CRSM can navigate fragmented governance and corruption. These measures improved operational safety despite systemic challenges.

South Sudan – Resilience Engineering & Community Engagement
Modular microgrid designs and local technician training allowed operations to continue during road blockades and unrest. Community-based safety liaisons helped mediate tensions and adapt safety protocols to local customs. South Sudan's reliance on modular infrastructure and community liaisons reflects the CRSM model's resilience and conflict-sensitive dimensions. These strategies ensured continuity and reduced friction with local populations.

Ukraine – High Reliability & Feedback Loops

Ukraine's energy infrastructure has been heavily targeted during the war, making contextual risk mapping essential. Wind farms near Mykolaiv empowered site supervisors to halt operations during shelling, demonstrating decentralized decision-making and preoccupation with failure—key High Reliability Theory principles. Mobile apps allowed anonymous safety reporting, leading to real-time adjustments in evacuation protocols and shift schedules. These practices exemplify the CRSM model's emphasis on adaptive safety, enabling rapid response to evolve threats and minimizing worker exposure.