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Technical - Series for PISSA members

TOPIC 1

Solar Rooftop and Ground-Mounted Productivity Enhancements: Best Practices and Implementation Guide & Financial Considerations.

Sub Topic 1.1:

Implementation Roadmap (Rooftop & Ground-Mounted)

This chapter outlines the key stages involved in implementing rooftop and ground-mounted solar PV projects, from early assessment through commissioning and operations. While the roadmap reflects industry best practices, real-world project execution is often challenged by **tight timelines, coordination complexity, and fluctuating component costs**.

To make this chapter more practical and experience-driven, it is proposed to use the implementation roadmap as a **discussion framework** and invite inputs from members based on their on-ground experience.

Rather than expanding the number of questions, the discussion can initially focus on **two core aspects** that directly impact project success: **time efficiency** and **cost optimization—without compromising quality**.

Focus 1: Reducing Implementation Time While Maintaining Quality

Each phase of the implementation roadmap—assessment, design, permitting, procurement, construction, and commissioning—offers opportunities to improve execution speed. Members are invited to share their views on:

- Which specific steps in the implementation process tend to consume the most time in practice?
- Where can activities be executed in parallel instead of sequentially?
- How can early-stage planning, standardization, or decision-making reduce delays later in the project?
- What proven practices help shorten timelines **without compromising safety, technical standards, or long-term performance**?

The objective is to identify **process improvements**, not shortcuts, that increase efficiency while preserving best-in-class quality.

Focus 2: Cost Optimization Without Compromising Quality

Component prices (modules, inverters, steel, trackers) are subject to market volatility and are often outside direct project control. However, several **implementation-stage decisions** can influence overall project cost without degrading quality. Members are encouraged to comment on:

- Which stages of the implementation roadmap offer the greatest opportunity for cost optimization through better planning or execution?
- Where can costs be reduced through design optimization, standardization, logistics planning, contracting strategy, or construction efficiency—rather than cheaper materials?
- Which cost-cutting measures are safe and sustainable, and which typically lead to higher long-term losses?
- How can quality control be protected while managing budget pressures?

The intent is to distinguish between **smart cost management** and **false economies** that undermine system reliability and lifetime value.

Phase 1: Assessment and Feasibility

Common to both rooftop and ground-mounted systems:

- Energy yield assessment using site-specific solar resource data.
- Preliminary system sizing, DC/AC ratio selection, and technology screening.
- High-level financial feasibility and LCOE estimation.

Additional requirements for ground-mounted systems:

- **Land acquisition or lease assessment**: Title verification, land-use classification, right-of-way access, and long-term lease security.
- **Zoning and permitting review**: Local land-use approvals, setback requirements, aviation or defense clearances (where applicable).
- **Grid proximity and evacuation feasibility**: Distance to substation, available capacity, and preliminary interconnection studies.

Deliverable: Go/no-go feasibility report with land, grid, and financial risk screening.

Phase 2: Site Investigation and Detailed Studies

Rooftop systems:

- Structural assessment of roof load capacity and waterproofing condition.

- Detailed shading analysis using 3D modeling.

Ground-mounted systems (expanded):

- **Geotechnical investigation**: Boreholes, soil stratification, bearing capacity, pile drivability, soil resistivity, and flood risk assessment.
- **Topographic and boundary surveys**: Accurate grading design, drainage planning, and row layout optimization.
- **Environmental and social impact assessment (EIA/ESIA)** where required by regulation or project size.
- **Hydrology and drainage studies** for flood-prone or monsoon-affected sites.

Deliverable: Bankable site investigation package supporting final civil and structural design.

Phase 3: Engineering Design and Permitting

Common activities:

- Electrical system design (SLD, protection schemes, grounding).
- Mechanical layout and equipment specification.
- Submission for statutory permits and utility interconnection approval.

Ground-mounted additions:

- **Foundation and civil design** tailored to soil conditions (driven piles, screw piles, concrete footings).
- **Tracker system engineering**: Wind tunnel validation (if required), fatigue analysis, and row-to-row spacing optimization.
- **Drainage, road, and fencing design** for long-term site accessibility and security.
- **Environmental permit compliance** and mitigation plan implementation.

Deliverable: Approved construction-ready design and permits.

Phase 4: Procurement and Logistics

Common activities:

- Vendor qualification and technical compliance checks.
- Factory acceptance testing (FAT) for major equipment.

Ground-mounted additions:

- Bulk logistics planning for modules, steel, trackers, and transformers.
- Quality audits of tracker manufacturing and galvanization processes.
- Spares strategy for trackers, drives, and control systems.

Deliverable: Fully mobilized supply chain with QA-approved equipment.

Phase 5: Construction and Installation

Rooftop systems:

- Mounting, module installation, electrical integration, and waterproofing verification.

Ground-mounted systems (expanded):

- **Civil works execution**: Piling, foundations, grading, roads, and drainage.
- **Tracker installation and alignment** with strict tolerance control.
- **Cable trenching, laying, and backfilling** with marker and protection systems.
- Continuous QA/QC inspections for pile verticality, torque, and structural alignment.

Deliverable: Mechanically and electrically complete plant.

Phase 6: Commissioning and Optimization

Common activities:

- Electrical testing, insulation resistance, protection relay testing.
- Inverter and monitoring system commissioning.

Ground-mounted additions:

- **Tracker calibration and stow verification** under multiple wind scenarios.
- **Backtracking optimization** to minimize inter-row shading losses.
- Validation of SCADA data, weather stations, and tracker availability KPIs.

Deliverable: Commissioned system meeting ≥95–105% of modeled performance.

Phase 7: Operations, Maintenance, and Continuous Improvement

Common activities:

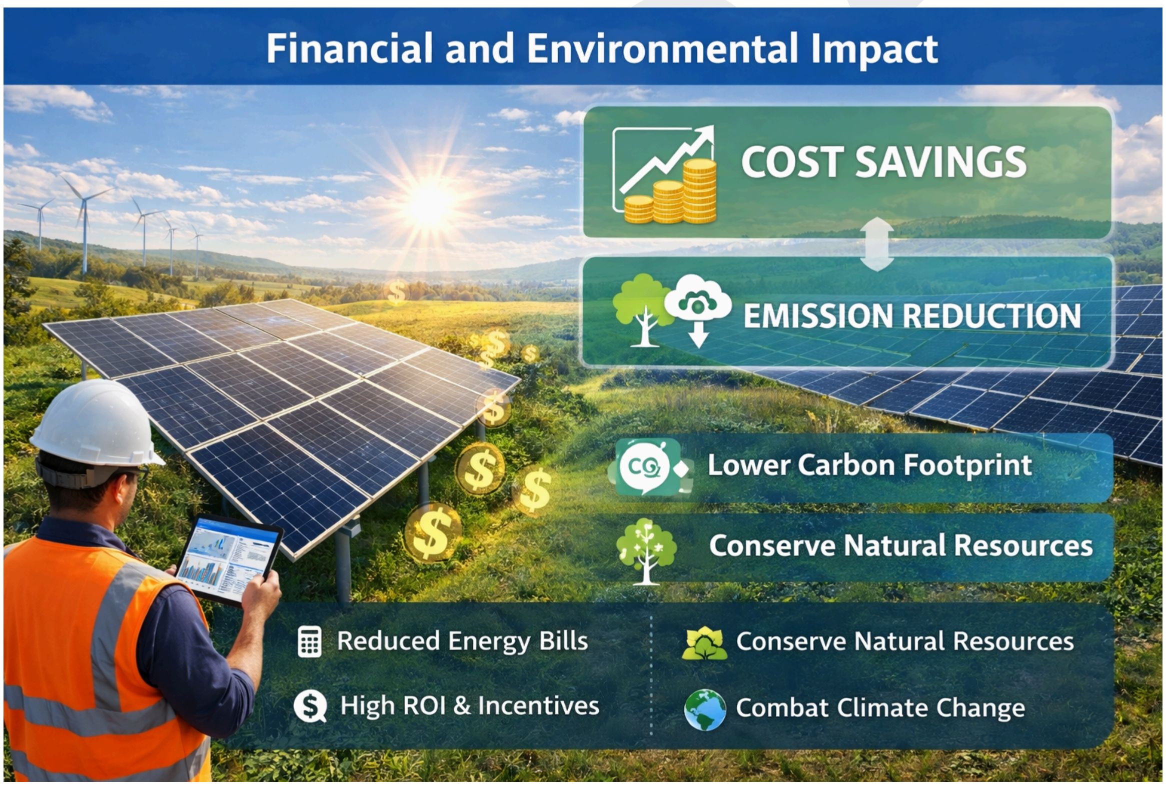
- Preventive maintenance scheduling and performance monitoring.
- Annual performance ratio and degradation assessment.

Ground-mounted additions:

- Vegetation management and erosion control programs.
- Periodic foundation, tracker, and road inspections.
- Data-driven optimization of cleaning frequency and tracker algorithms.

Sub Topic 1.2 :

Financial and Environmental Impact



2.1 Return on Investment (ROI)

Typical trends and structural differences:

Rooftop systems:

- Higher installed cost per watt ($/W) due to smaller scale, customized engineering, and rooftop access constraints.

- Faster permitting and interconnection timelines, especially for residential and small C&I projects.
- Returns are often capped by limited roof area rather than capital availability.
- Strong hedge against retail electricity tariffs; ROI closely linked to net-metering policy stability.

Ground-mounted systems:

- Lower $/W at scale due to standardized design, bulk procurement, and construction efficiency.
- Longer development timelines driven by land, environmental, and grid approvals.
- Higher absolute returns due to larger system size and higher annual energy yield per MW.
- Revenue profile often linked to long-term PPAs or merchant market exposure.

Indicative financial comparison (illustrative):

- Rooftop (C&I, 500 kW–1 MW): IRR typically 10–16%, payback 4–7 years.
- Ground-mounted (utility-scale, >5 MW): IRR typically 12–20%, payback 5–8 years, with higher total cash generation over project life.

2.2 Lifetime Value Optimization

Maximizing lifetime value requires focusing on factors that disproportionately influence long-term energy delivery and cost stability.

Rooftop systems:

- Sensitive to inverter reliability, roof integrity, and access-related O&M costs.
- Long-term value protected by preventive maintenance and early fault detection.

Ground-mounted systems: Ground-mounted plants exhibit **greater sensitivity** to the following drivers:

- **O&M quality**: Poor maintenance compounds across thousands of modules and structures, leading to rapid PR degradation.
- **Tracker uptime and availability**: Each 1% drop in tracker availability can reduce annual generation by 0.7–1.0%.
- **Cleaning automation and soiling control**: Automated or robotic cleaning significantly stabilizes PR in dusty regions and reduces water dependency.

- **Civil and structural durability**: Foundations, roads, and drainage directly affect long-term operability and access.
- **Spare parts and response strategy**: Delayed tracker or inverter repairs can create cascading generation losses.

Key insight: A 1–2% improvement in annual PR for a ground-mounted plant typically delivers **greater lifetime value** than a similar percentage CAPEX reduction.

2.3 Environmental Benefits

Solar PV systems deliver substantial lifecycle environmental benefits, with differences in scale and land interaction between rooftops and ground-mounted projects.

Rooftop systems:

- Utilize existing built surfaces with minimal incremental land impact.
- Reduce transmission and distribution losses through point-of-use generation.
- Particularly effective for urban decarbonization and peak-load reduction.

Ground-mounted systems:

- Deliver **higher annual MWh per MW installed** due to optimal orientation, bifacial gain, and tracking.
- Enable significantly larger absolute carbon offsets per project.
- Environmental performance is closely linked to responsible site selection and land-use planning.

Land-use and sustainability considerations:

- Prefer low-productivity, non-agricultural, or dual-use land (e.g., agrivoltaics).
- Implement biodiversity management plans (native vegetation, pollinator-friendly ground cover).
- Design drainage and soil protection measures to prevent erosion and habitat degradation.

Carbon impact comparison (indicative):

- Rooftop solar: Highest carbon benefit per square meter of land impacted.
- Ground-mounted solar: Highest total carbon reduction per project, with proper mitigation.

Conclusion and Key Recommendations

For optimal solar productivity in Haryana, both rooftop and ground-mounted systems require careful design, quality equipment, and structured operations:

1. Site Design:

- Rooftop: Conduct thorough shading analysis (essential); optimize orientation and tilt; ensure roof structure supports system lifetime.
- Ground-mounted: Select locations with minimal shading; consider soil conditions and drainage; optimize tilt and row spacing to minimize self-shading and facilitate maintenance.

2. Equipment Selection:

- Choose high-efficiency Mono-PERC or Bifacial panels.
- Specify quality inverters (≥10-year warranty, ≥97% efficiency); consider microinverters if partial shading exists.
- For ground-mounted systems, use robust mounting structures resistant to wind loads and corrosion.

3. Thermal Management:

- Ensure adequate rear ventilation for panels.
- Consider reflective roof coatings in hot climates for rooftops; for ground-mounted, allow sufficient airflow beneath panels.
- Select temperature-optimized panels to minimize performance loss in high heat.

4. Cleaning and Maintenance:

- Implement data-driven cleaning schedules (bi-monthly baseline for Haryana).
- Conduct semi-annual visual inspections and annual electrical testing.
- Ground-mounted systems may require additional vegetation control and structural inspection.

5. Monitoring and Performance:

- Install energy metering and inverter monitoring; track Performance Ratio (PR).
- Investigate deviations >5% immediately to maintain energy yield.

6. Quality Assurance:

- Prioritize component certification and third-party inspection.
- Avoid cost-cutting that creates long-term liabilities.
- Demand performance warranties for panels, inverters, and mounting structures.

7. Ongoing Operations & Maintenance (O&M):

- Commit to structured maintenance programs (~$150–300/kW annually).
- Maintaining PR of 78–82% yields 1–3% additional energy recovery over system life.

8. Financial Outlook:

- Well-designed rooftop and ground-mounted systems in Haryana achieve 5–8 year payback with government incentives.
- Expected IRR of 7–12% over a 25-year lifetime.
- Significant environmental benefits: carbon offset of 150–200 tons CO_2 per system.

Value added comments - invited from PISSA members

PISSA technical Team invites value added comments and ways of enhancement specially toards the execution, material handling and management of project specially keeping in mind the ever changing technological, policy, product and finacial constraints of ensuring profitability for the EPC's.