Photovoltaic System MBSE Project: AI-Assisted Conceptualization Phase Update

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22 May 2025

Outline

- Project Overview & Objectives
- MBSE Approach & Lifecycle
- MBSE Workflow Integration with AI Agents
- Conceptualization Phase – Key Activities
- Summary, Conclusions & Next Steps

Ethical, Standards-Based Solar Power System

- Exceed IEC, IEEE, and ISO standards.
- Deliver reliable, low-cost renewable power.
- Cut emissions and support the circular economy.
- Ensure ethical sourcing and fair labour.
- Create lasting value for all stakeholders.

MBSE Process Key Outputs

- Conceptualization → Needs & Mission Definition
- Requirements Definition → System Requirements Baseline
- Architecture Definition → Architecture Models & Interfaces
- Design → Detailed Design & Executable Models
- Verification & Validation → Test Cases & V&V Plan
- Integration & Test → Verified System & Issue Reports
- Implementation Support → Coordinate with Developers
- Operations & Maintenance → Performance Monitoring & Support Plan
- Retirement & Disposal → Decommissioning Plan & Reuse/Recycle Report

Conceptualization Workflow

Task	Input	Output
1.01	Strategic goals	Initial stakeholder list
1.02	Initial stakeholder list	Comprehensive stakeholder list
1.03	Comprehensive stakeholder list	Stakeholder engagement plan
1.04	Stakeholder engagement plan	Raw stakeholder needs
1.05	Stakeholder engagement plan	User stories
1.06	Stakeholder engagement plan	Stakeholder goals
1.07	Stakeholder engagement plan	Operational task list
1.08	Stakeholder engagement plan	Scope documentation
1.09	Stakeholder engagement plan	Stakeholder concerns
1.10	Raw stakeholder needs	Categorized needs list
1.11	Categorized needs list	Structured needs list
1.12	Stakeholder goals	System mission statement
1.13	System mission statement	System objectives
1.14	System mission statement	Success measures
1.15	Success measures	Key performance indicators
1.16	Key performance indicators	Parametric models
1.17	Operational task list	Use case descriptions
1.18	Use case descriptions	Use case diagrams
1.19	Operational task list	OpsCon outline
1.20	OpsCon outline	Operations Concept document
1.21	Scope documentation	System-of-interest (SOI) definition
1.22	System-of-interest definition	System context diagram
1.23	System context diagram	External interface list
1.24	Stakeholder concerns	Initial risk list
1.25	Initial risk list	Updated risk register
1.26	System mission statement	Risk prioritization criteria
1.27	Risk prioritization criteria	Prioritized risk list

Conceptualization Workflow

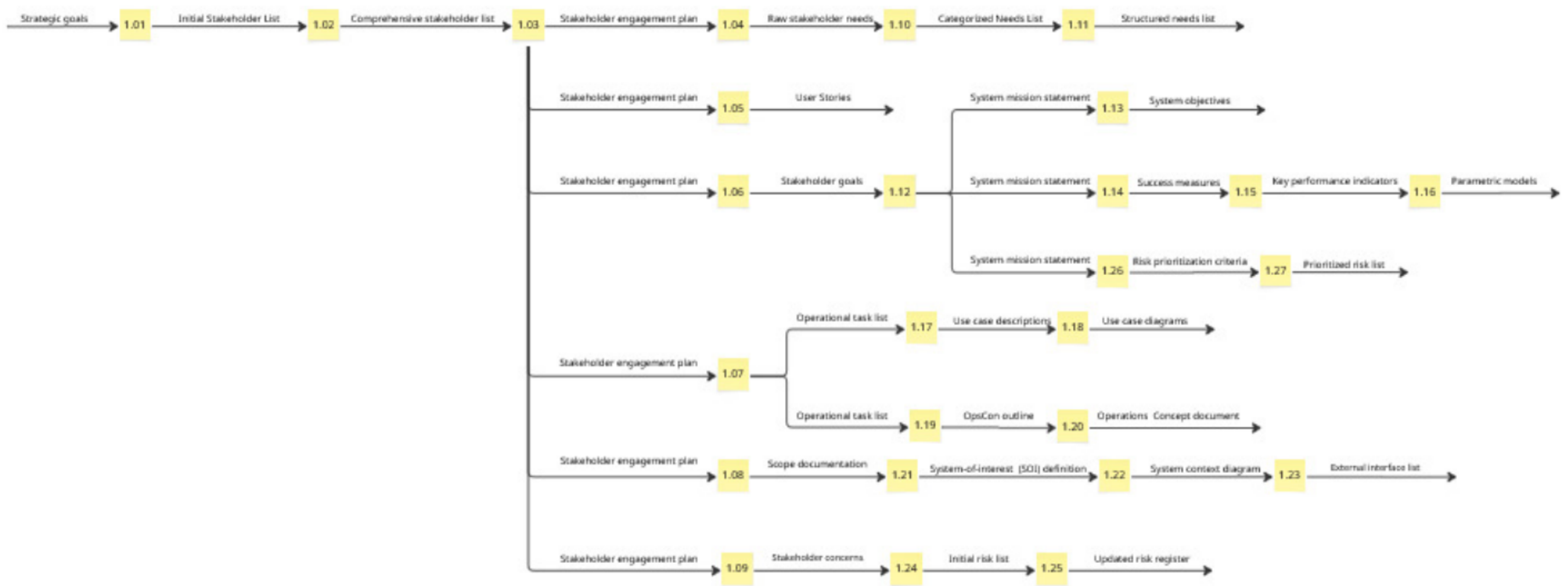
Strategic Goals => Comprehensive Stakeholder List =>

Stakeholder Engagement Plan => Stakeholder Goals =>

System Mission Statement => Success Measures =>

Key Performance Indicators => Parametric Models

Conceptualization Workflow



AI in the Workflow

Prompt: “I’m going through an MBSE process one step at a time to design a {…}. [*Upload Input*] Please conduct this task {*Convert Input into Output*}”

Then, validate the AI output.

Prompt: “Provide this output in a downloadable Sysml v2 metamodel-compliant code file.”

[Save the code]

Why SysML v2 is Critical for AI-Driven MBSE

Unified semantics let AI reason over models reliably.

Inputs/outputs are machine-recognizable.

SysML v2 text format enables automation.

One schema spans all phases of MBSE.

Built-in traceability supports impact analysis.

Conceptualization Workflow

Identify Stakeholders

Elicit Stakeholder Needs

Analyze and Structure Needs

Define System Mission

Identify Success Criteria

Define Use Cases

Draft OpsCon

Identify System Boundaries

Define External Interfaces

Identify Initial Risks

Prioritize Risks

Key Stakeholder Categories

- Standardization & Certification
- Government & Regulation
- Technical & Engineering
- Manufacturing & Supply Chain
- Deployment & Operations
- Monitoring & Verification
- End-of-Life & Circular Economy
- Community & Ethical Interests
- Financial & Investment Agencies

Top-Level Needs Summary

- Regulatory Compliance
- Modular, Verifiable Design
- Ethical Circular Supply Chain
- Safe, Cost-Effective Operation
- Financial Viability
- Environmental Impact Reduction
- Equitable Community Benefits

System Mission Statement

Design, deliver, operate, and retire a photovoltaic power system that meets international standards, delivers reliable and cost-effective renewable energy, supports the circular economy, reduces environmental impact, ensures ethical and equitable practices, and creates transparent, long-term value for all stakeholders across its lifecycle.

Key Success Measures

- ***Environmental***
  - ≤ 20 g CO_2-e/kWh lifecycle intensity (≥ 85% reduction vs 2025 grid baseline)
  - ≥ 95% material recovery at end-of-life (ISO 14040/44)
- ***Economic***
  - LCOE ≤ \$0.04/kWh (including EOL costs)
  - ROIC ≥ 12% by Year 5 (audited cash flows)
- ***Technical Performance***
  - ≥ 99.5% availability over 25 years (IEC 61724-2 class A)
  - Full certification to IEC/IEEE/ISO standards; zero major non-conformities
  - ≥ 50 MWh ancillary services/MW/year (IEEE 2800 compliant)
- ***Social & Ethical***
  - 0 LTIs per 1 million work-hours
  - 100% ethical sourcing compliance with 60-day corrective closure
  - Net Promoter Score (NPS) ≥ +85 within 2 years of operation

Operations Concept

Purpose & Scope

- Full lifecycle: from conceptualization to decommissioning. Applies to utility, commercial, and residential PV systems. Aligns with IEC, IEEE, and ISO standards

System Highlights

Modular, grid-interactive PV with adaptive inverters, Ethical supply chain and circular economy integration, Targets: ≥ 80% energy yield (P90), ≤ 24-month carbon payback, ≥ 95% recycling rate

Lifecycle Phases

Design: Requirements traceability, carbon screening, Build: Ethical sourcing, factory testing, system commissioning, Operate: Predictive analytics, corrective O&M, ESG reporting, Retire: Take-back program, certified recycling, data archiving.

Key Metrics

Carbon intensity, energy yield, workforce diversity, land-use efficiency, cybersecurity compliance

Data & Security

IEC 62443-aligned cybersecurity; zero-trust architecture, ISO 27001-compliant data governance; blockchain traceability

Governance & Validation

ESG audits, third-party certifications, and SysML v2-based verification

Key Use Cases

- **IEC – Safety & Performance Compliance**
  - *Concept Alignment, PDR, CDR*
  - Standards traceability, design validation, and build approval
- **IEEE – Architecture & Interoperability**
  - *System Architecture Validation, Interface Freeze*
  - Confirm functional safety, cybersecurity, and interface conformance
- **ISO – Sustainability & Lifecycle Assurance**
  - *Concept Sustainability Assessment, Lifecycle Performance Review*
  - ESG metrics, LCA modelling, and risk mitigation integration
- **Environmental Agencies – Permitting Process**
  - *Feasibility Clearance, Permitting Approval*
  - Early impact screening and formal regulatory approval

System Context Overview

System Boundary (Internal Subsystems)

PV Module Assembly – Converts sunlight to DC power
Balance of System – Converts and routes power to the grid
SCADA Stack – Real-time monitoring, control, analytics
Site Civil Works – Structural integrity and access
Reverse Logistics – Enables ≥ 90% recycling at end-of-life

External Actors & Interfaces

Utility Grid Operator – Power dispatch at PCC, IEEE 1547 compliance
Third-Party Storage Assets – Optional power coupling
Remote O&M Provider – Monitoring and maintenance via SCADA
Regulators & Certifiers – Standards compliance evidence
Investors & Financiers – ESG & ROI reporting
Local Communities & NGOs – Engagement, oversight, and transparency

Primary Flows

Energy – Solar DC → Grid AC; import during maintenance
Data – Telemetry, controls, ESG, compliance
Materials – Inbound spares, outbound recyclable assets
Authority – Permits, audits, certifications

Key Assumptions

Standards: IEC, IEEE, ISO baseline compliance
Excludes grid upgrades, trading platforms, and carbon-credit monetization

Key Risk Categories

- **Standards & Certification**
  - R01: IEC non-compliance blocks certification
  - R02: IEEE interconnection failures delay grid access
  - R03: ISO sustainability misalignment undermines ESG credibility
- **Technical & Safety**
  - R13: Electrical design faults → fire risk
  - R15: Cyber vulnerabilities degrade power quality
  - R19: Integration mismatches disrupt functionality
- **Environmental & End-of-Life**
  - R07: Lifecycle emissions/waste breaches
  - R26: E-waste mishandling causes fines
  - R28: PV landfill violations damage reputation
- **Financial & Market Access**
  - R36: Yield or cost shortfalls threaten investor returns
  - R39: Carbon-credit failure nullifies revenue
  - R45: Lack of Fair-Trade certification limits ESG capital
- **Social & Regulatory**
  - R42: Ignoring Indigenous rights halts permits
  - R44: Unethical sourcing prompts public backlash

Concept Phase Summary

✓ ***Concept Phase Accomplishments***

- Stakeholder needs, mission, success criteria, OpsCon, and use cases drafted. System boundaries, interfaces, and risks are defined. Sustainability and ethics are embedded in the concept

✓ ***MBSE Artifacts Produced***

- SysML conceptual model (needs, use cases), Draft Concept of Operations (OpsCon), Concept-level requirements and risk register, Successful AI-assisted modelling trial

✓ ***Review & Validation in Progress***

- Concept Review initiated before Requirements Definition phase, Feedback requested from the Sustainability Working Group, Focus: sustainability alignment, ethical design, community impact, lifecycle compliance

Next Steps

✓ ***Phase 2: Requirements Definition***

- Translate validated concept into System Requirements Baseline
- Use AI agents to assist with drafting and traceability of requirements
- Initiate high-level architecture work in parallel to assess feasibility

✓ ***Support Requested from Sustainability Working Group***

- Endorsement of sustainability objectives for organizational alignment
- Assistance refining metrics and thresholds (e.g., carbon, recyclability)
- Guidance on ethical supply chain and community engagement practices
- Participation in design reviews to maintain sustainability alignment

Conclusion

- Concept phase completed with clear system definition and embedded sustainability principles

- Project is well-positioned to enter requirements definition with a strong foundation

- AI-assisted modelling enhanced the quality, traceability, and efficiency of conceptual artifacts

Thank you for your attention.

I would be happy to take questions at this time.

Or you can reach me at:

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