

Exploration of Decision Options within Complex Energy-related Workflows

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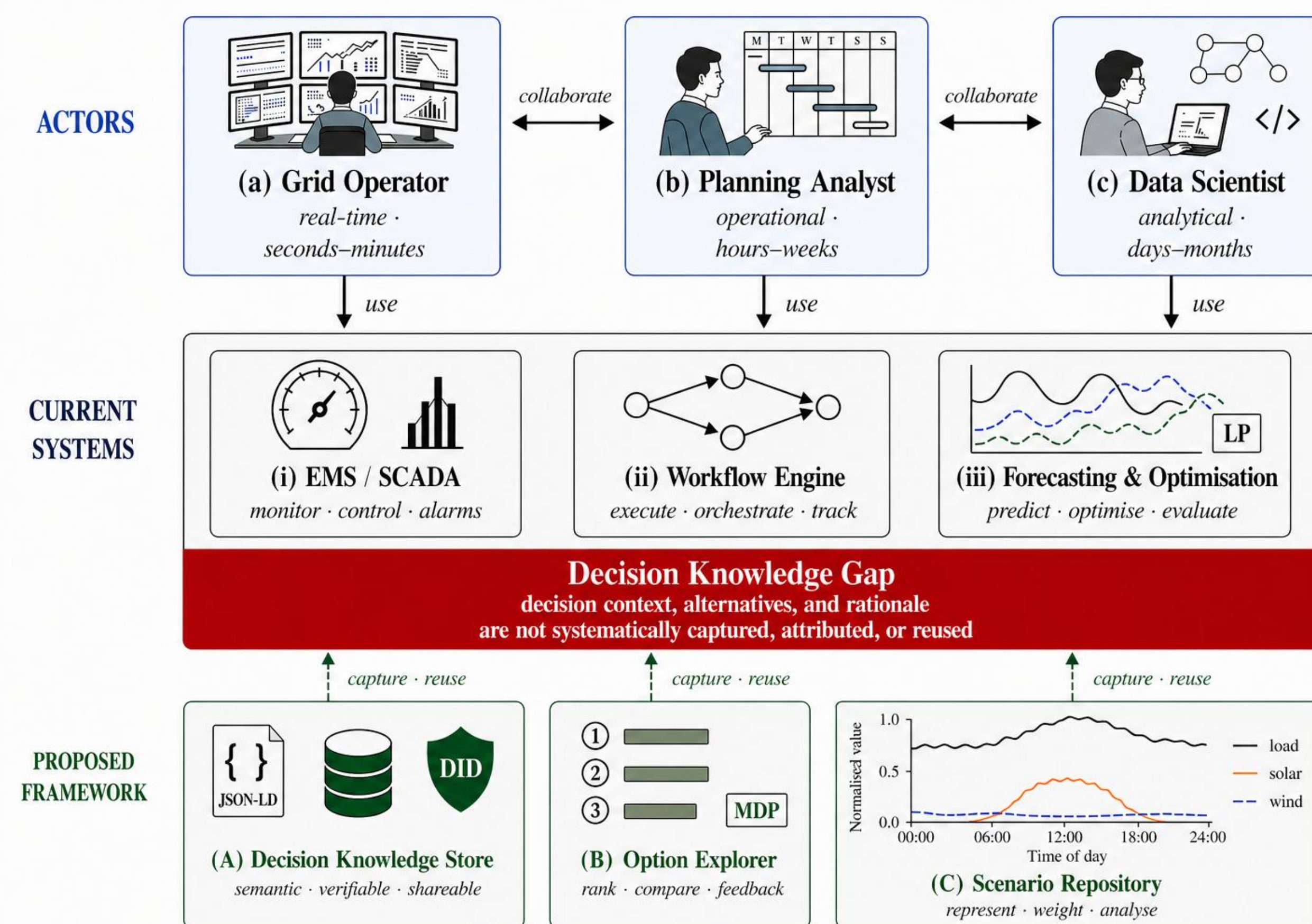
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Introduction

The transition to renewable-rich energy systems has transformed grid operation into a complex decision-making challenge, where operators must continuously evaluate multiple alternatives under uncertainty, time pressure, and competing constraints. While modern energy platforms efficiently execute analytical workflows, they fail to capture the reasoning behind decisions, including context, alternatives, and justification. As a result, valuable decision knowledge remains fragmented, limiting reuse, transparency, and learning across systems and organizations. This work addresses this gap by treating decisions as structured, verifiable, and reusable knowledge, enabling systematic exploration and improved support for energy-related workflows.

Problem

- Decisions are **executed but not captured as reusable knowledge**
- **Decision context** (constraints, alternatives, rationale) remain **implicit and fragmented**
- Limited support for **exploring and comparing multiple decision options**
- Absence of **verifiable, shareable decision records across organisations**



Objective

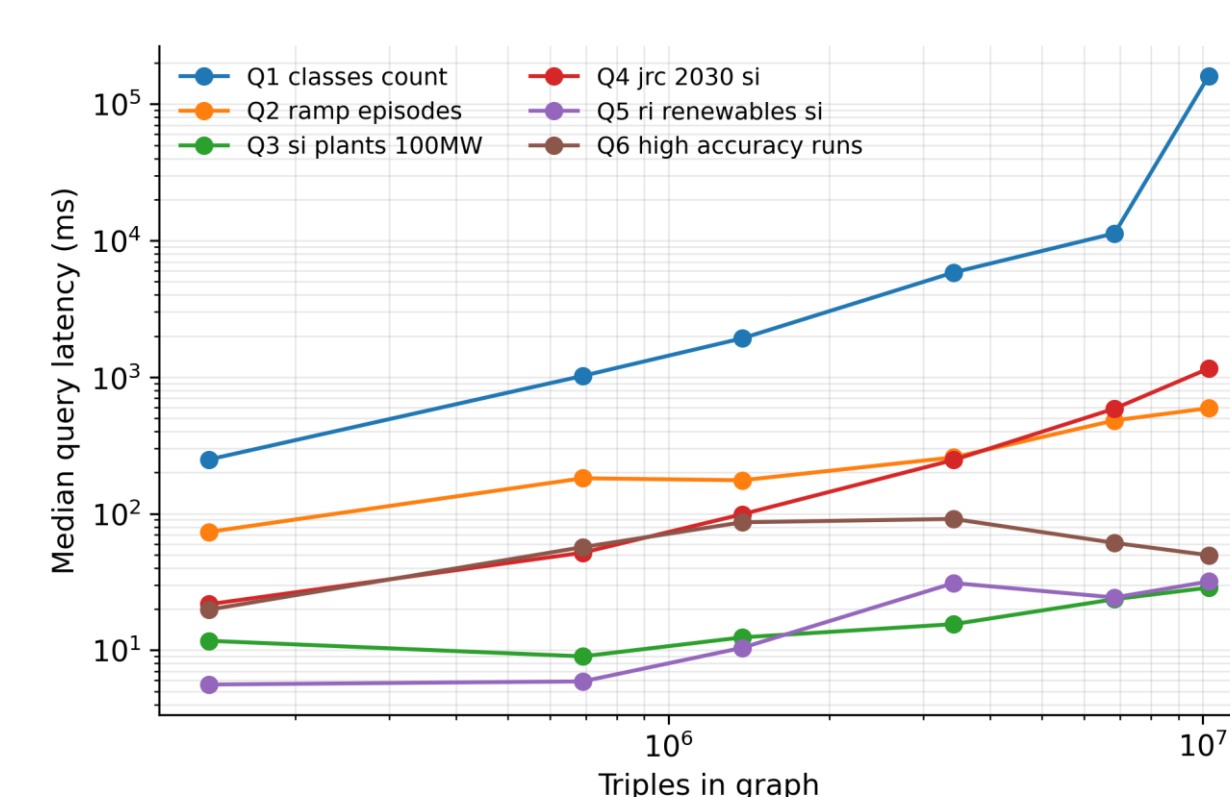
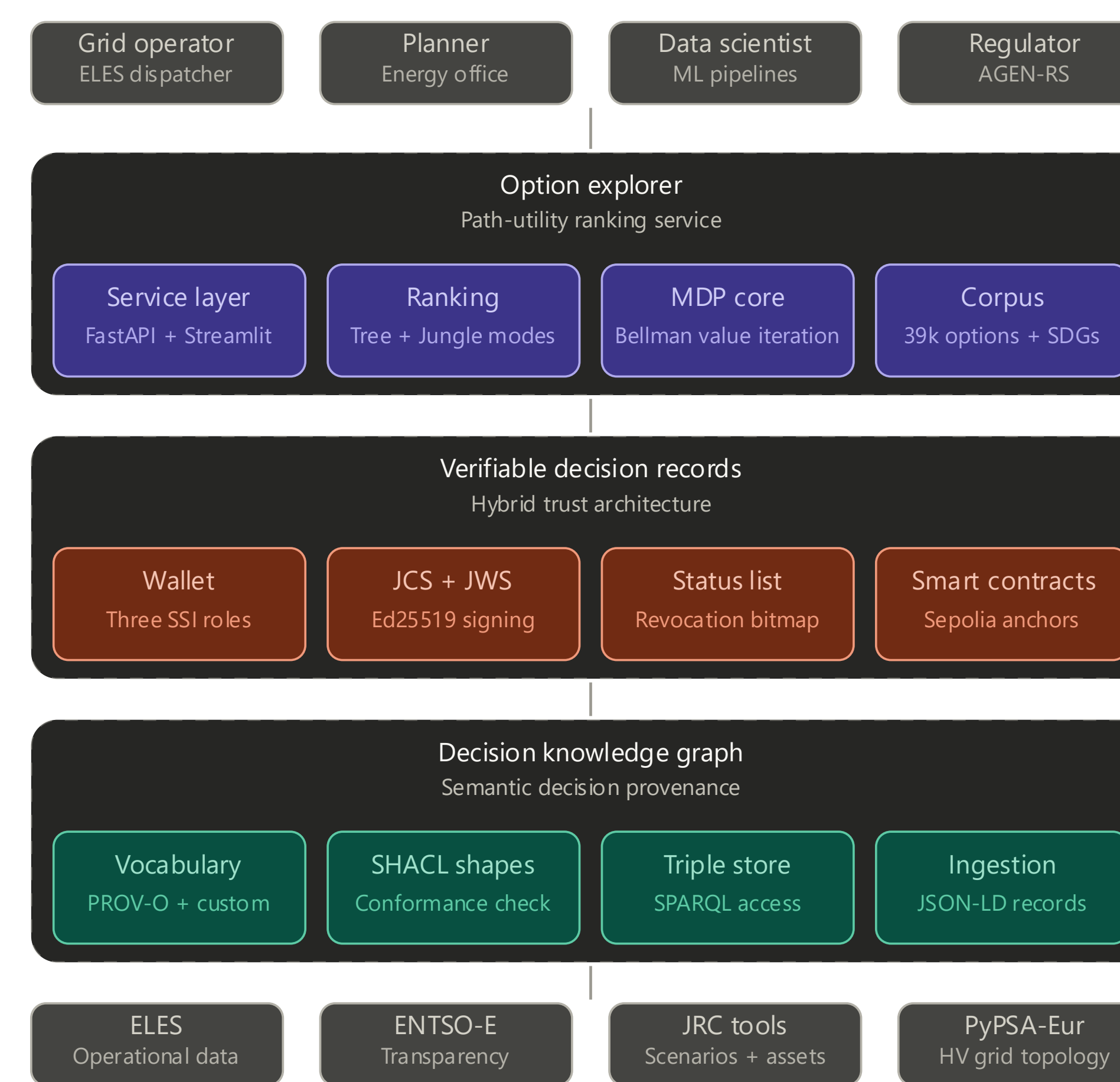
- **Capture decisions** as structured, machine-interpretable records
- **Model decision context** (constraints, options, rationale) explicitly
- **Enable reuse and sharing** of decision knowledge across workflows
- **Ensure verifiability and trust** through cryptographic mechanisms
- **Support ranking of decision options** under uncertainty
- **Integrate decision support** into existing energy workflows

References

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- [2] Miri, P., Stankovski, V., Veljković, K., Kochovski, P. *A Context-aware Decision Support Framework for Scientific Experiment Configuration*. Software: Practice and Experience, 2026. (under review)
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Approach

- 1. Decision Knowledge Graph (DKG)**
 - Captures decisions as JSON-LD records
 - PROV-O backbone + SHACL validation
- 2. Verifiable Decision Records (VDR)**
 - Signed with DIDs & Verifiable Credentials
 - Hybrid trust: off-chain identity, on-chain anchors
- 3. Option Explorer (MDP-based)**
 - Ranks decision alternatives by path utility
 - Combines user constraints + SDG impact + historical transitions

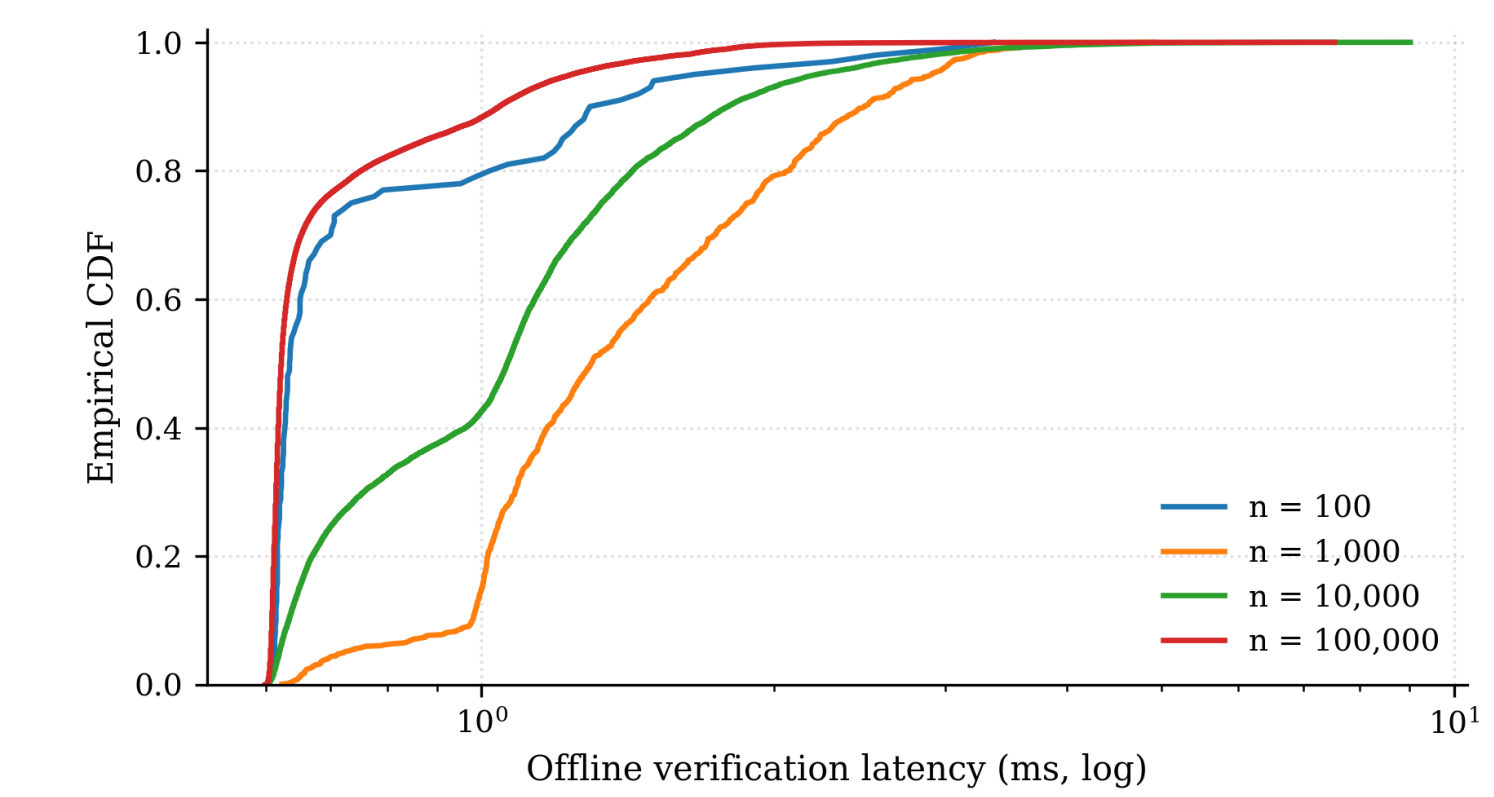


DKG Results

- 255 k records → 3.49 M triples in 135 s
- Selective SPARQL queries < 50 ms at 10 M triples
- 100 % SHACL conformance

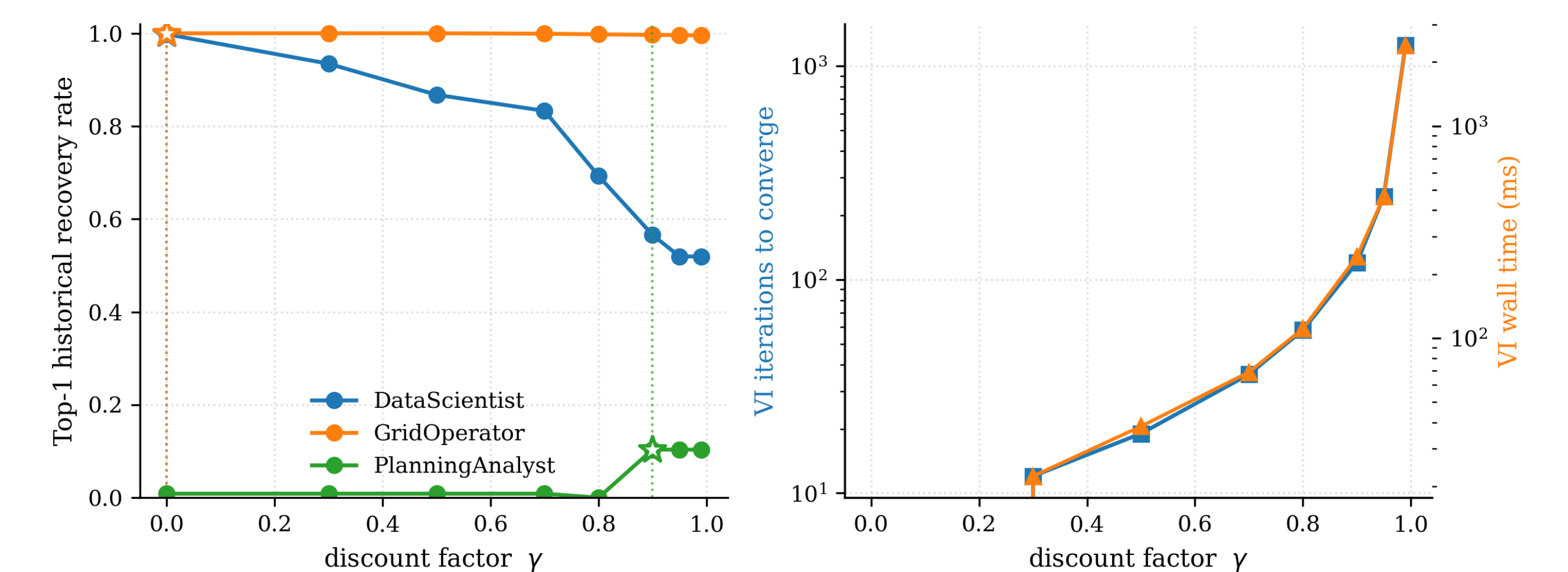
VDR Results

- Median verification **0.6–1.3 ms**, p95 < 3 ms
- On-chain check **~54 400 gas**, flat with batch size
- 100 % revocation detection



Option Explorer Results

- 39 k options ranked sub-second
- Top-1 recovery: GridOp **100 %**, DataSci **99.8 %**, Planner **10.3 %**
- Per-persona Pareto-optimal γ



Conclusion

- Three integrated layers close the decision-knowledge gap in energy workflows
- Validated end-to-end on Slovenian operational data (ELES, JRC, ENTSO-E)
- Cross-organisational trust demonstrated with Ljubljana, AGEN-RS, ELES
- Turns fragmented logs into queryable, signed, ranked decision knowledge



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