

Task-Based Semantic Framework for Organizing Energy Research

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Abstract. Effective discovery and reuse of research software in the energy domain require rich, standardized metadata, yet software purpose is typically expressed as free text and cannot be processed automatically. We introduce the Open Energy Task Ontology, which formalizes software purpose through semantically defined research tasks organized hierarchically from abstract to highly specific activities. Tasks are represented as ontological classes with clear definitions, goals, and semantic relations, enabling machine-readable categorization, workflow construction, and automated identification of compatible software components. Beyond software, tasks serve as a unifying metadata layer for datasets, publications, researchers, and organizations, supporting cross-object discovery and integration. A prototype hierarchy, initial workflow implementations, and integration into existing knowledge-graph infrastructures demonstrate the potential of a task-centric approach to harmonize metadata and enhance interoperability in energy research.

Keywords: Research Data Management, Task Ontology, Open Energy Ontology (OEO), Research Software Metadata, Knowledge Graph Integration, Automated Discovery, Workflow Modeling, Semantic Interoperability, Knowledge Representation, Linked Data

Extended Abstract

Effective management, discovery, and reuse of research software in the energy domain crucially depend on rich and standardized metadata [1], [2], [3]. Among these, the “purpose” or “scope” of a software package is one of the most important pieces of information [4]. Today, such information is typically captured as free-text entries [5], [6], [7], which require human interpretation and cannot be processed or categorized automatically. This limitation hinders automated discovery, categorization, combination, and topic-driven cross-linking to datasets, publications, and researchers.

To address this challenge, we propose the Open Energy Task Ontology, an approach that formalizes the purpose of research software through tasks: semantically defined activities within energy research that can be organized hierarchically, ranging from abstract tasks (e.g., “Wind Resource Assessment”) to specific actions (e.g., “Turbine Placement” or “Power Gen-

eration Simulation"). Tasks are defined as ontological classes with clear, human-readable definitions and associated goals representing the intended outcomes, rather than mere keywords, enabling machine-readable categorization and logical reasoning. They are interconnected through relationships such as predecessor/successor, contains/part-of, alternative-for, and can be applied across multiple granularities. By chaining multiple tasks, researchers can construct workflows that capture complex sequences of activities. These workflows can be implemented and executed through software packages, with task relationships enabling automated suggestions of compatible components and alternative solutions.

The utility of tasks extends beyond software. A task-centric metadata model enables a wide range of applications. Software can declare the tasks it implements and the purpose it serves, while task relationships help identify compatible components, upstream and downstream steps, and alternative solutions. For example, we have implemented and published a multi-step workflow for wind-potential assessment that illustrates how tasks can structure complex processing pipelines [8]. Datasets can be annotated as inputs or outputs for specific tasks, which supports targeted dataset discovery and integration within task-based workflows. Textual resources such as publications and tutorials can reference the tasks they describe or discuss, turning tasks into a formalized semantic anchor for scientific literature and educational materials. Tasks also offer a way to characterize researchers' skills and expertise, facilitating the discovery of individuals capable of performing or supervising specific research activities. Finally, research organizations and projects can be associated with the tasks they pursue, providing a structured overview of task-specific activities across the community. In this way, tasks act as semantic glue, harmonizing heterogeneous metadata types and enabling powerful cross-object discovery: one can query, for example, "Which datasets support the Turbine Placement?", "Which software implements this task?", "Who has expertise in this task?", or "Which publications explain this task?". The task-centric approach also forms a natural foundation for domain-specific metadata standards such as ERSmeta [9], and is likewise compatible with more general frameworks for software-interface metadata such as DataDesc [10], into which these principles can be seamlessly integrated.

The current status of the Open Energy Task Ontology includes a prototype hierarchy of tasks, several examples integrated into the Open Research Knowledge Graph [11], and the previously mentioned workflow demonstrating task-based structuring of research software [8]. To ensure conceptual consistency and interoperability, the ontology reuses established ontological concepts and hierarchies, for example those from the Open Energy Ontology [12]. While the ontology is still in its conceptual phase, these initial results highlight the potential of tasks as a central organizing principle in energy research, with the capacity to fundamentally transform how software, data, and expertise are discovered, connected, and reused across the field.

At the NFDI4Energy 2026 conference, we aim to present this concept to the community, illustrate its applications, and gather feedback on the proposed hierarchical task structure and its semantic relationships. Our goal is to explore community perspectives, identify opportunities for collaboration, and critically assess the overall approach. By involving the research community early on, we hope to collaboratively explore the full potential of task-based metadata for software, data, text publications, and expertise in energy research.

Data availability statement

The data supporting this study are not yet available as the project is ongoing. Data will be made available by the authors upon completion of the study.

Author contributions

Conceptualization: P.K., M.S., O.K., S.F., and J.G.; writing – original draft: P.K.; writing - review & editing: P.K., M.S., O.K., S.F., J.G., T.H., and J.M.W.;

Competing interests

The authors declare that they have no competing interests.

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References

- [1] Leipzig, J., Nüst, D., Hoyt, C. T., Ram, K., and Greenberg, J. (2021). The role of metadata in reproducible computational research. *Patterns* 2.
- [2] Wierling, A., Schwanitz, V. J., Altinci, S., Bałazinska, M., Barber, M. J., Biresselioglu, M. E., Burger-Scheidlin, C., Celino, M., Demir, M. H., Dennis, R. et al. (2021). Fair metadata standards for low carbon energy research—a review of practices and how to advance. *Energies* 14, 6692.
- [3] Ferez, S., and Nieße, A. (2023). Towards improved findability of energy research software by introducing a metadata-based registry. *ing. grid* 1.
- [4] Chang, M., Lund, H., Thellufsen, J. Z., and Østergaard, P. A. (2023). Perspectives on purpose-driven coupling of energy system models. *Energy* 265, 126335.
- [5] The CodeMeta Project. Codemeta Terms. <https://codemeta.github.io/terms/>.
- [6] Garijo, D., Ratnakar, V., Gil, Y., and Khider, D.. The software description ontology. Revision: 1.9.0. <https://w3id.org/okn/o/sd/1.9.0>.
- [7] bio.tools. bio.tools. <https://bio.tools>.
- [8] Pelser, T., Weinand, J. M., Kuckertz, P., and Stolten, D. (2025). Ethos.reflow: an open-source workflow for reproducible renewable energy potential assessments. *Patterns* 6.
- [9] Ferez, S. (2025). ERSmeta (V0.9). Zenodo. <https://doi.org/10.5281/zenodo.17465772>
- [10] Kuckertz, P., Göpfert, J., Karras, O., Neuroth, D., Schönau, J., Pueblas, R., Ferez, S., Engel, F., Pflugradt, N., Weinand, J. M. et al. (2024). Datadesc: A framework for creating and sharing technical metadata for research software interfaces. *Patterns* 5.
- [11] Auer, S., Oelen, A., Haris, M., Stocker, M., D’Souza, J., Farfar, K. E., Vogt, L., Prinz, M., Wiens, V., and Jaradeh, M. Y. (2020). Improving access to scientific literature with knowledge graphs. *Bibliothek Forschung und Praxis* 44, 516–529. <https://doi.org/10.1515/bfp-2020-2042>.
- [12] Booshehri, M., Emele, L., Flügel, S., Förster, H., Frey, J., Frey, U., Glauer, M., Hastings, J., Hofmann, C., Hoyer-Klick, C. et al. (2021). Introducing the open energy ontology: Enhancing data interpretation and interfacing in energy systems analysis. *Energy and AI* 5, 100074.