# FAIRification of Energy System Models: The Example of AMIRIS

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## 1 Introduction

Two criticisms are often associated with energy system models. First, many models are so complex that they are not reproducible outside the developer's group. Just the parametrization of the model requires days and special knowledge. Second, many models cannot be validated by external users, since core data is missing or is internal.

The solution may be a combination of *transparency* through FAIR data and the transition from closed model building to *open-source*. This presentation demonstrates

- the process of switching from closed to open source for the agent-based model AMIRIS,
- the FAIRification of its data by linking it to the Open Energy Ontology and the enrichment with metadata, and
- community building as well as the publication in open journals like JOSS.

## 2 Agent-based modelling in energy systems analysis

Energy research is dominated by optimization approaches. However, they are less suited to capture the behavior of heterogeneous actors and market imperfections. Agent-based simulations (ABM) are ideally suited to do just that. Yet, there are few mature ABM within the domain of energy systems analysis for two reasons. First, since energy systems change very fast, it is hard to keep models up to date. Second, just to provide basic functionalities like communication between agents, high-speed through parallelization, and input-output management requires a lot of effort and time. One solution is to make models open source, providing the basic functionality and build on that basis with external developers expanding the model.

For this reason, we have created the FAME framework (https://gitlab.com/fame-framework/) [1] and AMIRIS (https://gitlab.com/dlr-ve/esy/amiris/amiris) [2] and made them open source for reproducibility and transparency reasons. This translated into four main steps:

1. *Making the model and the data openly available*
2. *Switching from closed data sources to open ones*
   For example, the Germany example on the GitLab repository of AMIRIS uses only openly available data from ENTSOE, OPSD, etc.
3. *Enriching the data with metadata and making it ontology-compliant*
   One important step to make our model more transparent is to add metadata and links to an ontology, which is described in more detail in the next section.
4. *Open source community-building efforts and publications*

## 3 Fairification of FAME and AMIRIS

Adding meta data requires substantial effort for more complex models like AMIRIS, since the existing code base has to be changed to be able to handle metadata. The goal was to provide meta data in a fully automatic workflow without the user having to put time and effort in meta data input – since this often results in no meta data input at all.

The implementation is done in FAME-IO (https://gitlab.com/fame-framework/fame-io) [3], the input and output manager for the FAME framework. The existing structure consists of agents (e.g. electricity exchange, demand trader, power plant operators, or conventional and renewable traders), see Figure 1:

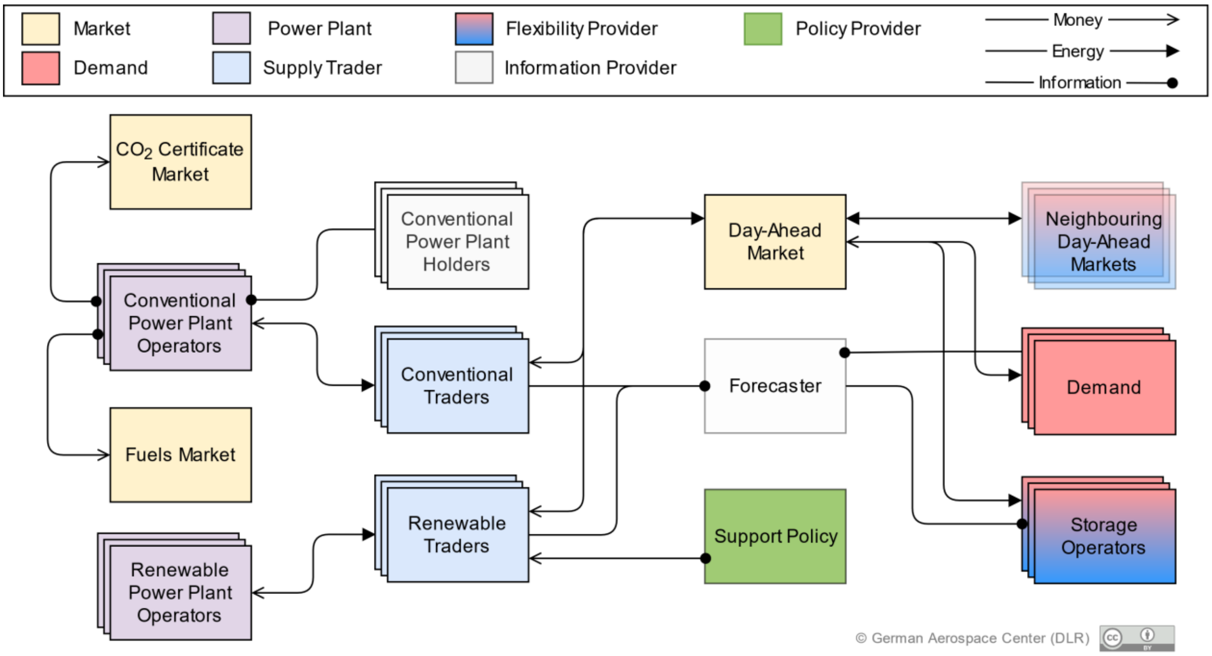


**Figure 1.** Overview about the agent-based simulation AMIRIS

Each agent has a (large) number of attributes which characterize it. These attributes are specified before the simulation begins in a human-readable YAML-file. By providing the appropriate time series and characteristics like efficiencies, capacities, or operation & maintenance costs, each agent is parametrized. Interactions between agents are handled via contracts, also specified via YAML-files.

The new workflow introduces the possibility to add meta data information to each attribute for every agent that is used in the simulation. Figure 2 shows a clipping of hundreds of similar lines:

```yaml
Agents:
  - Type: EnergyExchange
    Id: 1
    Attributes:
      DistributionMethod: SAME_SHARES
      GateClosureInfoOffsetInSeconds: 11
    MetaData:
      Description: "The energy exchange represents the day-ahead energy market with one clearing
      OEONearestConcept: http://openenergy-platform.org/ontology/oeo/OEO_00020065

  - Type: CarbonMarket
    Id: 3
    Attributes:
      OperationMode: FIXED
      Co2Prices: 80
    MetaData:
      Description: "The CarbonMarket sells CO2 emission allowances, determines their prices and
      OEONearestConcept: http://openenergy-platform.org/ontology/oeo/OEO_00020075
```


**Figure 2.** Excerpt of a YAML-file annotated with meta data and Open Energy Ontology links

Two things are important to note. First, the number of meta data annotations is unlimited. This provides room for later extension based on yet unknown future needs. Second, there is an Open Energy Ontology Link for every attribute in AMIRIS. The Open Energy Ontology (https://openenergy-platform.org/ontology/) is the *de facto* standard in energy systems analysis [4]. Hence, we took care to introduce the terminology of our model AMIRIS and of our field more generally – electricity markets – into the OEO. This makes it possible for other modelers to agree on concepts and to share data without errors. These links now provide a huge benefit in interoperability with other models, because the interfaces are defined via the OEO terms.

From a software engineering perspective, the introduction of meta data were light-weight, with no slow-down of the input and output operations. All results including the meta data are collected in one single file to avoid clutter. In addition, all changes are unit-tested, and will soon be published in FAME-IO 1.9.

## 4 Community building and publication strategy

An open source strategy does not only consist of clean code in an open repository. To enable the community to use it, it also has to be (a) well-documented, (b) response times to user queries in forums like openmod (https://openmod-initiative.org/) have to be fast, and (c) easy examples to get started have to be provided. We have implemented all three measures. For example, the energy system in Germany in 2019 with all the open reference data needed to reproduce our results is available, enabling users to parametrize other countries after this prototype – which has already happened, e.g. for Spain.

Besides open source software and open data as described above, there is the problem of making the research itself accessible. Most high-impact journals are behind paywalls, making it hard for many persons to access the research built upon the open source software like AMIRIS. Hence, to increase transparency, our strategy is to publish in open journals whenever possible.

## 5 Conclusion

We showcase AMIRIS as an example of making an energy model more transparent in all its aspects. The process of going open-source is described, the switch from closed to open data is demonstrated, and the community building and publication strategy is explained. In particular, the technical steps of meta data enrichment and ontology building are described in more detail, to make it easier for other researchers to also make that transition and make our research field as a whole more transparent and more reproducible. As a concrete result, AMIRIS model runs now automatically produce metadata and are linked to the Open Energy Ontology.

## 6 References

[1] C. Schimeczek *et al.,* "FAME-Core: An open Framework for distributed Agent-based Modelling of Energy systems," *JOSS*, vol. 8, no. 84, p. 5087, 2023, doi: 10.21105/joss.05087.

[2] C. Schimeczek *et al.,* "AMIRIS: Agent-based Market model for the Investigation of Renewable and Integrated energy Systems," *JOSS*, vol. 8, no. 84, p. 5041, 2023, doi: 10.21105/joss.05041.

[3] F. Nitsch, C. Schimeczek, U. Frey, and B. Fuchs, "FAME-Io: Configuration tools for complex agent-based simulations," *JOSS*, vol. 8, no. 84, p. 4958, 2023, doi: 10.21105/joss.04958.

[4] M. Booshehri *et al.,* "Introducing the Open Energy Ontology: Enhancing data interpretation and interfacing in energy systems analysis," *Energy and AI*, vol. 5, p. 100074, 2021, doi: 10.1016/j.egyai.2021.100074.