OESM-IE: Open Energy System Modelling for Ireland

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Technical Report WP1-D1

Selection and deployment of open energy system modelling tools and resources

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WP1 summary

WP No. & Title	WP1: Selection and deployment of open energy system modelling tools/resources		
Start Month No.	1	**Finish** Month No.	3
WP Lead:	DCU		
WP Contributors	N/A		
Objective(s)	WP1-O1: Identify and deploy appropriate open modelling tools and datasets		
Description (max 200 words)	Based on the criteria identified by [38], and the directory of open energy system modelling tools and resources (curated by openmod-initiative.org) this WP will evaluate and rank these against the specific objectives of the current project. The most appropriate tools and resources will then be deployed for local use, including any required functional testing/validation, and training for the members of the project team.		
Milestones	WP1-M1: Ranking of open tools/resources completed; preferred tools/resources selected. WP1-M2: Deployment, validation, training on target tools/resourcese completed.		
Deliverables	WP1-D1: Evaluation and ranking of open tools/resources. WP1-D2: Functional local deployment and validation of selected tools/resources.		

Introduction

Energy system transformation can be explored by a wide range of modelling tools and platforms (Connolly, Lund, et al. 2010). Each tool may be suitable for answering specific research questions based on the nature of different projects. An open source energy system modelling may offer reproducibility of computer modelling results by accessing relevant datasets of a specific model. This consequently may address public transparency and further support public interest open development.

A selection process for an open energy system modelling tool is described first. Various open source energy system modelling tools have been categorised through literature review (Hans-Kristian Ringkjøb and Ida Marie Solbrekke 2018). Modelling tools are shortlisted, from which one tool is selected based on specific criteria.

Methodology

The energy system modeling tools are selected by addressing following criteria:

1. open modeling tool is a critical requirement; the models and its source code are required to be open sourced.
2. compatibility with core system components such as energy sources, conversion processes, energy storage technologies.
3. substantial community support to facilitate a modelling tool developer during the developing period. This may also be useful for a new user for further system analyses/modification.

Energy System Modeling Tool Assessment

A list of open source energy system modeling tools are presented in Table 1, adapted from (Hans-Kristian Ringkjøb and Ida Marie Solbrekke 2018).

Table 1: Open source energy system modelling tools

Tool	Platform	Electricity	Storage	GHG	Cost	Transport	Community
BALMOREL	GAMS+Solver	✓		✓		✓	
Calliope	Python	✓	✓	✓	✓		GitHub
DESSTinEE	Excel/VBA	✓			✓	✓	
DIETER	GAMS +Solverver	✓	✓		✓		
EMLab-Generation	Java & Maven	✓		✓	✓		GitHub
EMMA	GAMS/CPLEX	✓			✓		
Energy PATHWAYS	Python	✓	✓	✓	✓		GitHub
ETM2	Online Tool	✓		✓	✓		GitHub
GENESYS	Stand-alone	✓			✓		
GCAM	BOOT, XERCES, JAVA, HECTOR	✓		✓	✓		GCAM community
GridLAB-D	Stand-alone	✓			✓		
NEMO	Python	✓		✓	✓		GitHub
oemof	Python + Solver	✓	✓	✓	✓	✓	GitHub
OpenDSS	Stand-alone	✓					
OSeMOSYS	GNU MatProg	✓	✓	✓	✓	✓	GitHub
PyPSA	Python	✓	✓	✓	✓	✓	GitHub
Renpass	MySQL, R, RMySQL	✓	✓		✓		GitHub
SIREN	Stand alone	✓		✓	✓		
stELMOD	GAMS/CPLEX	✓					
SWITCH	Python	✓		✓	✓		GitHub
Temoa	Python + Solver	✓			✓		GitHub

From the list (Table 1) of open modelling tools, three were shortlisted as potentially suitable platforms: Open Energy Modelling Framework (oemof), Open Source Energy Modelling System (OSeMOSYS) and Python for Power System Analysis (PyPSA). This was based on the availability of a number of energy system components considered essential for the current project. These modeling tools also have a substantial community support in GitHub and/or dedicated community platform. A Python based foundation and its supporting literature are advantageous for oemof and PyPSA. In more detail, the shortlisted platforms are:

- **oemof:** consists of a linear or mixed integer optimization problem formulation library (solph), an input data generation library (feed-in-data), and other auxiliary libraries (S. Hilpert et al. 2018). The solph library is used to represent multi-regional and multi-sectoral (electricity, heat, gas, transport) systems and can optimize for different targets, such as financial cost or CO2 emissions. Furthermore, it is possible to switch between dispatch and investment modes. In terms of scope, oemof can capture the European power system or alternatively it can describe a complex local power and heat sector scheme (Simon Hilpert et al. 2017).
- **OseMOSYS:** intended for national and regional policy development and uses an intertemporal optimization framework. OSeMOSYS provides a framework for the analysis of energy systems over the medium (10–15 years) and long term (50–100 years). It covers most energy sectors, including heat, electricity, and transport (Nnaemeka Vincent Emodi and A.B.M. Rabiul Alam Beg 2019) (Francesco Gardumi and Robbie Morrison 2018).
- **PyPSA:** a free software toolbox for simulating and optimizing electric power systems and allied sectors. It supports conventional generation, variable wind and solar generation, electricity storage, coupling to the natural gas, hydrogen, heat, and transport sectors, and hybrid alternating and direct current networks (Tom Brown and David Schlachtberger 2018). PyPSA itself is written in Python and uses the Pyomo library (Brown et al. 2019).

To select one modelling tool from the three above, some schematic, high level, energy system configurations were formulated, with different potential storage technologies (e.g., heat/electrical/H_2). Several energy system configurations were considered by which, different energy system scenarios could be conceived. These scenarios would be useful to estimate cumulative CO_2 emissions over an extended (multi-decade) decarbonisation transformation. System components were matched to each of the screened modelling tools presented in Table 1. An example schematic system configuration is presented in Figure 1.

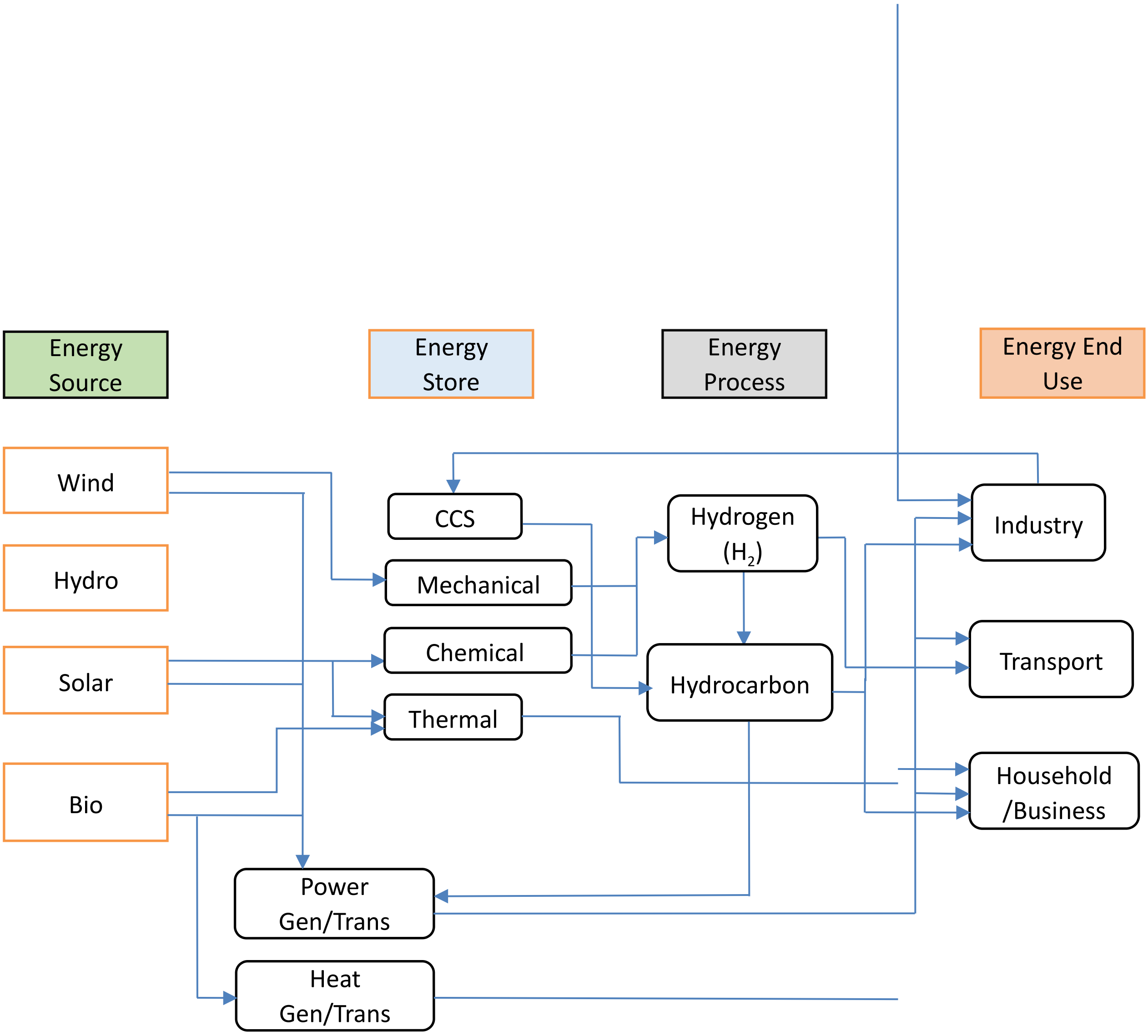

Figure 1: Schematic High-level Energy System Configuration

The input components (i.e. energy sources, energy conversion process, energy storage) in Figure 1 combined with the model's summary outputs (e.g., total cost for energy transition, energy cost per unit and cumulative CO_2 emission from each scenario) were matched with component compatibility of three selected energy modelling tools. PyPSA was judged to be the most suitable modelling tool overall, having most of the components in common (specifically H_2 synthesis, and flexible carbon capture and storage functionality) as shown in Table 2.

Table 2: Open modeling tool selection

	Solar	**Wind**	**Biofuel**	**TES/EES**	**H_2**	**CCS (FF/BE)**	**Fossil Fuel**
Total cost for energy transition	PyPSA OSeMOSYS oemof	PyPSA OSeMOSYS oemof	PyPSA OSeMOSYS oemof	PyPSA OSeMOSYS oemof	PyPSA	PyPSA	PyPSA OSeMOSYS oemof
Energy cost per unit	PyPSA OSeMOSYS oemof	PyPSA OSeMOSYS oemof	PyPSA OSeMOSYS oemof	PyPSA OSeMOSYS oemof	PyPSA	PyPSA	PyPSA OSeMOSYS oemof
Cumulative CO_2			PyPSA OSeMOSYS oemof	PyPSA OSeMOSYS oemof	PyPSA	PyPSA	PyPSA OSeMOSYS oemof

Validation

Long-term energy modelling tools with general computable equilibrium models are difficult to validate due to the change of socio-economic/political events, major technological breakthroughs or any other external factors with time that may affect the structure of an energy system. However, these energy system models may extrapolate possible composition of future energy systems and their pathways to achieve targets that help understanding future market dynamics and preferable energy policies (Hans-Kristian Ringkjøb and Ida Marie Solbrekke 2018).

In contrast to the long-term energy models, the results of power system analysis tools such as PyPSA can be directly tested and validated. Hörsch et.al (Hörsch et al. 2018) validated total line circuit lengths at different voltage levels of PyPSA-Eur model with official statistics from ENTSO-E. The PyPSA-Eur dataset deviate from the ENTSO-E data by a mean absolute error of 15% for 220 kV, 7% for 300 kV and 9% for 380 kV transmission lines. The work assumed the deviation may have accrued due to:

- an approximate representation of ENTSO-E map that does not follow the exact data of each transmission line from which the PyPSA-Eur network is derived;
- incorrect classification of 220 kV lines as 380 kV lines;
- up-to-date PyPSA-Eur model corresponding to recent upgrades to the transmission network relative to the ENTSO-E map.

Prior Work Based on PyPSA

PyPSA is a well presented open energy system modelling tool, with data and results available in various studies, publications and source code hosted on the web based repository service GitHub. Two of the most relevant example energy models based on PyPSA are:

- **PyPSA-Eur-Sec-30:** This a linear model that optimize overall CAPEX and OPEX of an energy system by meeting the technical constraints such as energy demand, intermittency of renewable energy, plant and grid capacity and required CO_2 emission targets. PyPSA-Eur-Sec-30 was used in (Brown et al. 2019) to examine the transitional characteristics of European energy systems with respect to the function of cumulative CO_2 emission budget. This study found, despite of overall transmission expansion, the reduction of 50% CO_2 from the emission in 1999 would be a cost effective option. The modelling tool configurations, input parameters and output data representations can be accessed at: https://www.pypsa.org/animations/pypsa-eur-30/
- **Wind+Hydrogen+Other+Battery+Solar (WHOBS):** This an open-access PyPSA energy modelling tool that uses open data to approximate cost to create a constant "baseload" generation profile from variable renewable energy and storage systems for European countries. Total costs are calculated using projected assumptions for 2020, 2030 and 2050. The modelling tool configurations, input parameters and output data representations of WHOBS model can be accessed at: https://model.energy/

Conclusion

In most of the current energy system models, source-code or datasets are non-accessible making it difficult to reproduce or modify a particular work. As modelling tools have been increasingly contributing to today’s energy policy-making process, the transparency and openness in energy modelling should be further facilitated. This report reviewed 21 energy modelling tools that can model a wide range of energy systems for long/short-term to create different energy system scenarios depending on the purpose of individual developer. The modelling tools are categorized by their software platform and openness along with technical and economic parameters. One open modelling tool/platform had been chosen based on the selected criterion. The purpose was to address the challenges associated with transparency and openness of current energy system modelling.

References

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