

# The MESSAGE<sub>ix</sub> modeling framework and other state-of-the-art tools for integrated scenario analysis

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and many colleagues

Capacity-building Hub @ COP 24, Katowice, Poland  
December 12, 2018

# Re-designing tools for capacity building

## *From a dichotomy of stylized vs. complex tools and models to frameworks that "grow" with user sophistication*

Researchers tend to develop ever more sophisticated tools

⇒ But this often makes it difficult to use these tools for capacity building...

- *Solution 1*: Use simple, stylized tools for teaching and training, switch to sophisticated tools later on
  - ⇒ This requires that new users "re-learn" and redo a lot of the initial work
- *Solution 2*: Develop tools in a way that they are easy to use across the range of user experience and skill set
  - ⇒ This is a lot of work...

Measures to facilitate that the tool is useful for capacity-building and training

- Ensuring that tools are easy to install and get started
- Implementing features in a modular way, so that users can "plug and play"
- Developing multiple tutorials to get started with each feature
- Improving documentation of tools (software), requirements and dependencies

# Capacity-building is not a one-way street

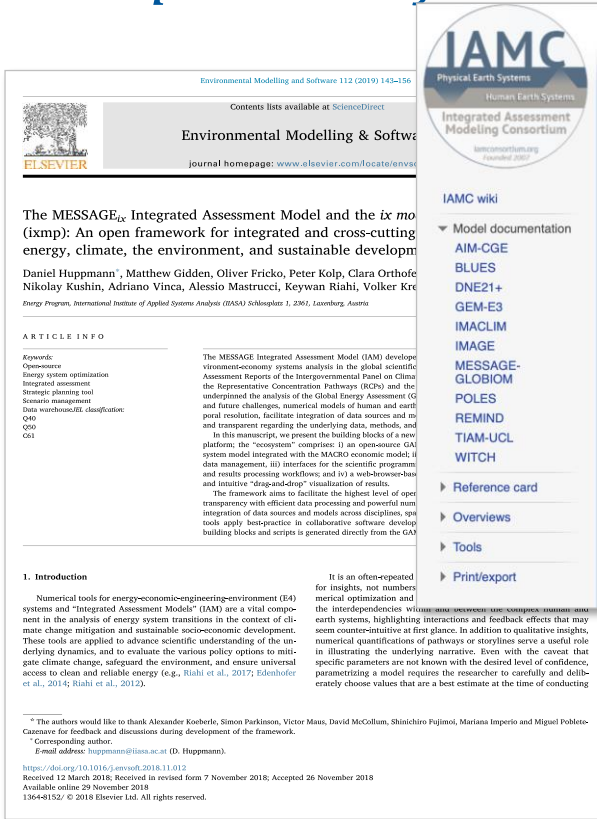
## *Successful collaboration for training and capacity building is a dialogue where both sides contribute and learn*

To go from “throwing a tool over the fence” to successful collaboration requires multiple institutional commitment and enabling technical solutions

- ⇒ Develop an active community forum or mailing list
- ⇒ Provide ways for new users to contribute their work  
e.g., GitHub “pull requests”
- ⇒ Create incentives (“carrots and sticks”) for all stakeholders to collaborate
  - *Institutions*: provide the necessary environment for researchers to collaborate effectively
  - *Experienced users*: answer questions from new users in a timely manner, provide feedback, make suggestions for improvement
  - *New users*: once you have figured out the first steps, make suggestions for improving the documentation and tutorials

# The first step to capacity building is transparency

## Model & tool documentation need to consider user experience and provide information at the “right” level of detail



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The MESSAGE<sub>ix</sub> Integrated Assessment Model and the ix model (ixmp): An open framework for integrated and cross-cutting energy, climate, the environment, and sustainable development

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Strategic planning tool  
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Q10  
Q10

The MESSAGE Integrated Assessment Model (IAM) documents climate-economic systems analysis in the global scientific Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC), the Representative Concentration Pathways (RCPs) and the underpinned the analysis of the Global Energy Assessment (GEA) and future challenges, numerical models of human and earth system interactions, facilitate integration of data sources and methods, and transparent regarding the underlying data, methods, and results processing workflows and (iv) a web-browser-based and intuitive “drag-and-drop” visualization of results.

The framework aims to facilitate the highest level of open transparency with efficient data processing and powerful numerical integration of data sources and models across disciplines, open tools apply best-practice in collaborative software development building blocks and scripts is generated directly from the GCM.

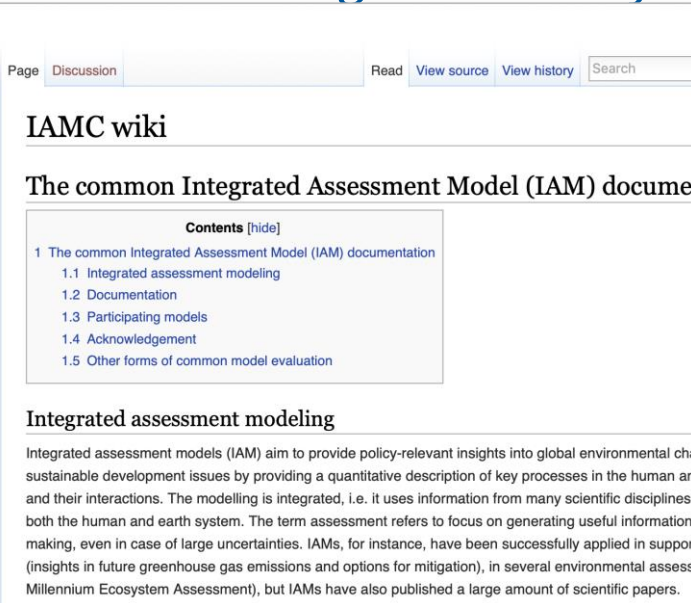
**1. Introduction**

Numerical tools for energy-economic-engineering-environment (E4) systems and “Integrated Assessment Models” (IAM) are a vital component in the analysis of energy system transitions in the context of climate change mitigation and sustainable socio-economic development. These tools are applied to advance scientific understanding of the underlying dynamics, and to evaluate the various policy options to mitigate climate change, safeguard the environment, and ensure universal access to clean and reliable energy (e.g., Riahi et al., 2017; Edenhofer et al., 2014; Riahi et al., 2012).

It is an often-expected for insights, not numbers, numerical optimization and the interdependencies within earth systems, highlighting interactions and feedback effects that may seem counter-intuitive at first glance. In addition to qualitative insights, numerical quantifications of pathways or storylines serve a useful role in illustrating the underlying narrative. Even with the caveat that specific parameters are not known with the desired level of confidence, parameterizing a model requires the researcher to carefully and deliberately choose values that are a best estimate at the time of conducting

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## IAMC wiki

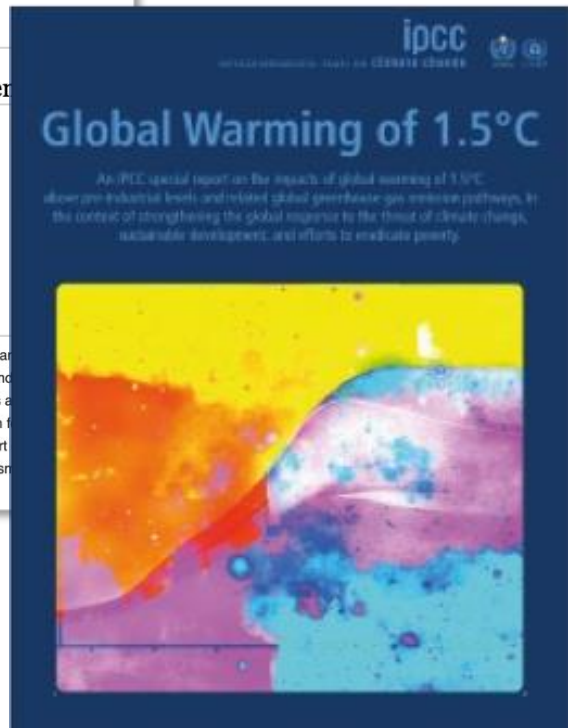
### The common Integrated Assessment Model (IAM) documentation

**Contents [hide]**

- The common Integrated Assessment Model (IAM) documentation
  - Integrated assessment modeling
  - Documentation
  - Participating models
  - Acknowledgement
  - Other forms of common model evaluation

**Integrated assessment modeling**

Integrated assessment models (IAM) aim to provide policy-relevant insights into global environmental change and sustainable development issues by providing a quantitative description of key processes in the human and earth system. The modelling is integrated, i.e. it uses information from many scientific disciplines and their interactions. The term assessment refers to focus on generating useful information for decision making, even in case of large uncertainties. IAMs, for instance, have been successfully applied in support of the Millennium Ecosystem Assessment, but IAMs have also published a large amount of scientific papers.



Model documentation wiki  
[www.iamcdocumentation.eu](http://www.iamcdocumentation.eu)  
 hosted by PBL

Model framework documentation  
 Huppmann et al. (2019)

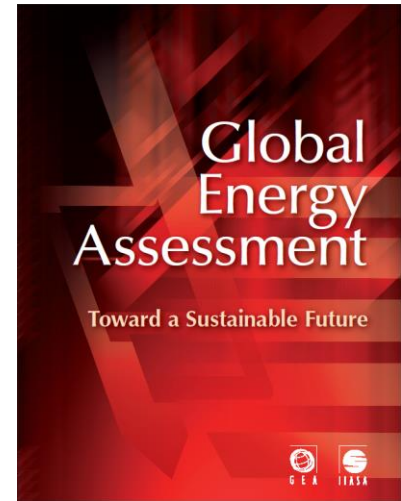
Detailed model documentation  
 in the Annex of Chapter 2  
[SR15](#), IPCC (2018)

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# History and applications of the MESSAGE model

## *Developing an energy systems framework for 40 years...*

- The *Model for Energy Supply Strategy Alternatives and their General Environmental Impact* (MESSAGE) is a linear programming (LP) energy-engineering model
  - ⇒ Developed at IIASA over the past 40 years to represent global & national energy systems for capacity planning and policy analysis
  - ⇒ Current focus at IIASA: integrated assessment of energy system transformation pathways in the context of climate change and sustainable development
  - ⇒ Recently, the MESSAGE energy system model was coupled with the land-use model GLOBIOM to model the interactions between energy, agriculture and food, and bioenergy (Fricko et al., 2017)
- The model generator is distributed by the *International Atomic Energy Agency* to its member countries for planning and analysis



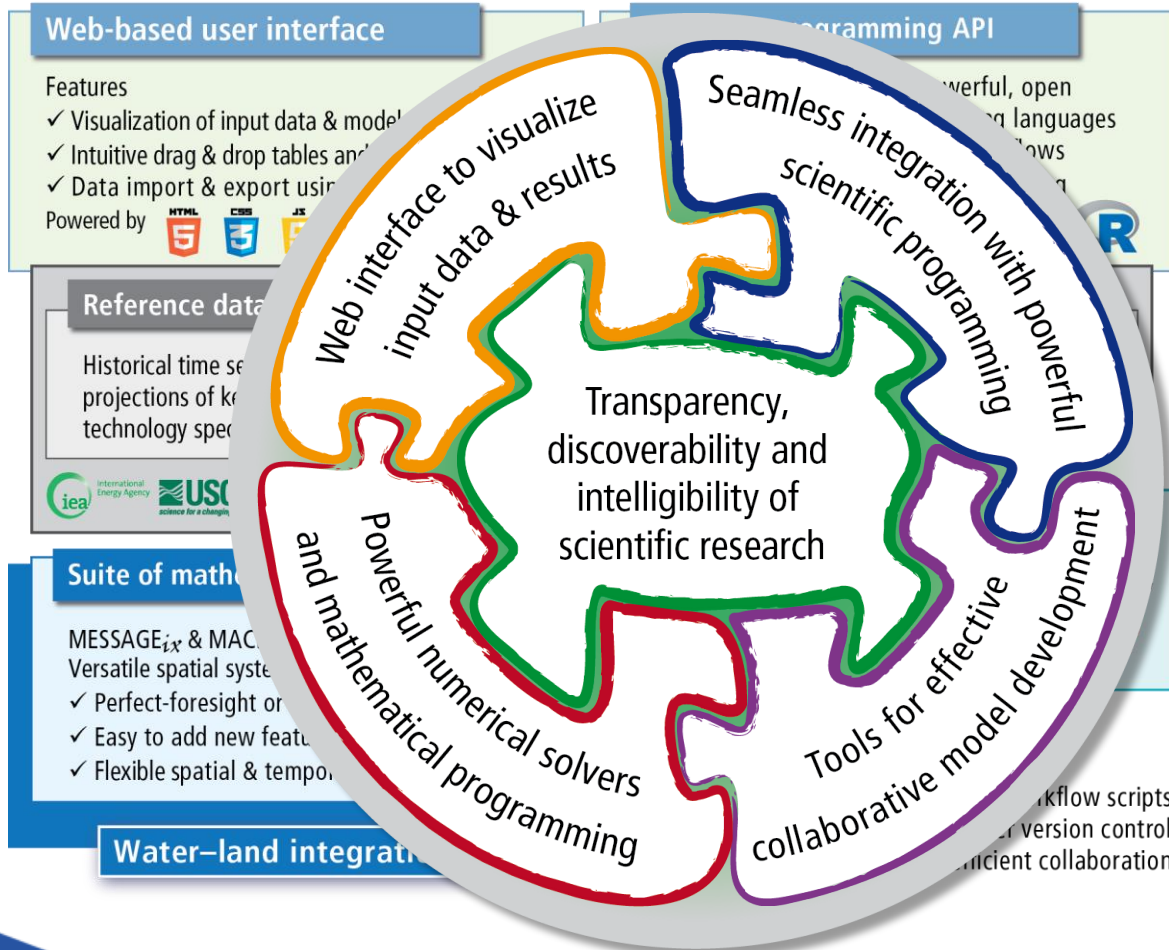
The analysis of the Global Energy Assessment (GEA, 2012) was supported by MESSAGE scenarios.



The IAEA is distributing MESSAGE as part of its capacity-building tools

# The new MESSAGE<sub>ix</sub> framework

*Facilitating transparency and reproducibility of research by implementing best practice of software development*



Documentation:

[messageix.iiasa.ac.at](http://messageix.iiasa.ac.at)

GitHub repository (download):  
[github.com/iiasa/message\\_ix](https://github.com/iiasa/message_ix)

Install via conda and pip

Suite of tutorials to get started

Distributed under the open-source APACHE 2.0 license

Scientific reference:

Daniel Huppmann, et al. (2019).

The MESSAGEix IAM and the ix modeling platform.

*Environmental Modelling & Software* **112**:143-156.

doi: [10.1016/j.envsoft.2018.11.012](https://doi.org/10.1016/j.envsoft.2018.11.012)

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# IIASA cooperation and capacity building

*We are closely collaborating with national modelling teams to develop tools for their domestic research priorities*

## Example 1:

Collaboration with the research group of Prof. Dr. Roberto Schaeffer  
Energy Planning Program, COPPE, Universidade Federal do Rio de Janeiro

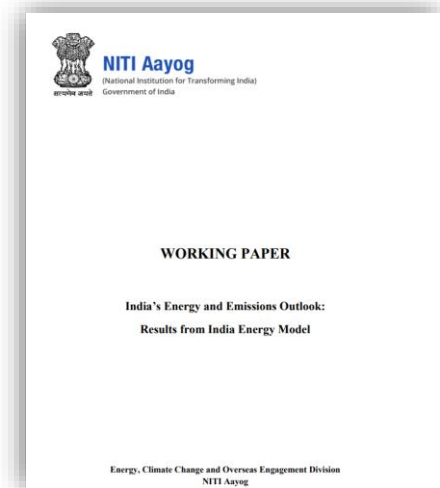
de Lucena et al. (2010) Least-cost adaptation options for global climate change impacts on the Brazilian electric power system. *Global Environmental Change* 20(2):342-350. doi: [10.1016/j.gloenvcha.2010.01.004](https://doi.org/10.1016/j.gloenvcha.2010.01.004)

Herreras Martínez et al. (2015) Possible energy futures for Brazil and Latin America in conservative and stringent mitigation pathways up to 2050. *Technological Forecasting and Social Change* 98:186-210. doi: [10.1016/j.techfore.2015.05.006](https://doi.org/10.1016/j.techfore.2015.05.006)

Global energy++ system  
MESSAGE<sub>ix</sub>



Detailed sub-national energy++ system  
MESSAGE<sub>ix</sub>-Brazil



Thambi, Bhattacharya & Fricko (2018) *India's Energy and Emissions Outlook*. [pure.iiasa.ac.at/id/eprint/15536/](https://pure.iiasa.ac.at/id/eprint/15536/)

## Example 2:

Collaboration with the National Institute for Transforming India (NITI Aayog)

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# The *pyam* package for integrated assessment

## *We developed an open Python package for two applications of analysis and visualization using integrated assessment data*

- Harmonization and plotting of integrated assessment emissions pathways
  - ⇒ Contribution from IAMs to Coupled Model Intercomparison Project Phase 6 (CMIP6)
- Scientific reference:
  - Matthew J. Gidden et al. (2018) A methodology and implementation of automated emissions harmonization for use in IAMs. *Environmental Modelling & Software* 105:187-200. doi: [10.1016/j.envsoft.2018.04.002](https://doi.org/10.1016/j.envsoft.2018.04.002)
- Scenario assessment for the IPCC *Special Report on 1.5°C*
  - ⇒ Completeness checks, data consistency validation, categorization
  - ⇒ Statistical analysis on filtered data and plotting figures for report
  - ⇒ Assessment notebooks published with full report for transparency and reproducibility
- ⇒ Implemented using best-practice of open-source, collaborative science
- ⇒ Multiple tutorials to get users started with the package





# Accessibility of the IPCC SR15 scenario assessment

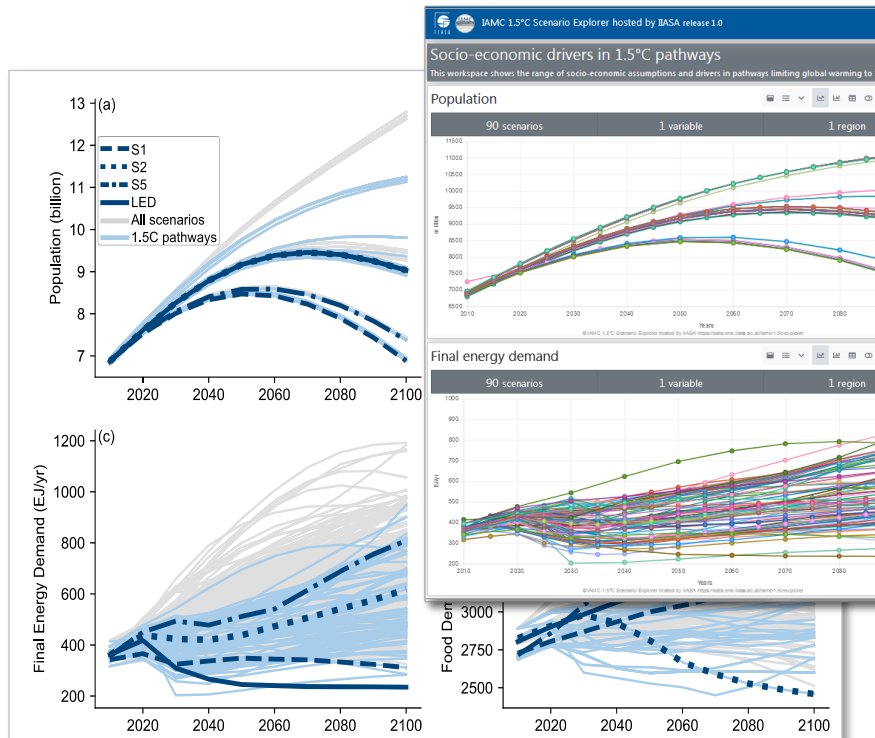
*We developed a suite of tools for researchers and policymakers to better understand the scenario assessment in the IPCC SR15*

See the notebook & code used to generate the figure at [data.ene.iiasa.ac.at/sr15\\_scenario\\_analysis](https://data.ene.iiasa.ac.at/sr15_scenario_analysis)

Range of assumptions of socio-economic drivers (Figure 2.4)

Notebook `sr15_2.3.1_range_of_assumptions`

The SR15 SPM and chapters are still undergoing copy-edits and revisions as part of the tricklebacks from the approval plenary. The assessment, statistics tables and figures shown here is therefore still subject to change.



IPCC SR15 scenario assessment

## Assessment of underlying drivers and assumptions

This notebook contains the assessment of underlying drivers and assumptions of the scenario ensemble in Section 2.3.1 and Figure 2.4 for the IPCC's "Special Report on Global Warming of 1.5°C".

The scenario data used in this analysis can be accessed and downloaded at <https://data.ene.iiasa.ac.at/iamc-1.5c-explorer>.



Load pyam package and other dependencies

```
In [1]: import pandas as pd
import numpy as np
import io
import yaml
import math
import matplotlib.pyplot as plt
plt.style.use('style_sr15.mplstyle')
%matplotlib inline
import pyam

from utils import boxplot_by_cat
```

Visit the IAMC 1.5°C Scenario Explorer at [data.ene.iiasa.ac.at/iamc-1.5c-explorer](https://data.ene.iiasa.ac.at/iamc-1.5c-explorer)

Socio-economic drivers across 1.5°C pathways  
Figure 2.4, SR15, IPCC, 2018

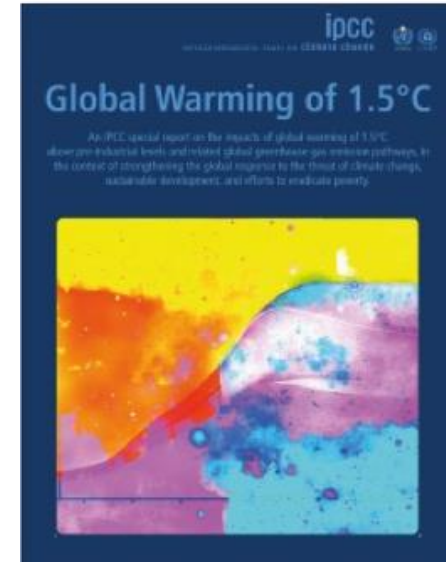
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# A suite of tools to work with 1.5°C scenarios

## *Making it easy to dive into the IPCC scenario assessment*

- A new interactive online scenario explorer
  - ⇒ Website: [data.ene.iiasa.ac.at/iamc-1.5c-explorer](https://data.ene.iiasa.ac.at/iamc-1.5c-explorer)
  - ⇒ Recommended citation of the scenario explorer and data:  
D. Huppmann, E. Kriegler, V. Krey, K. Riahi, J. Rogelj, S.K. Rose, J. Weyant, et al. (2018) *IAMC 1.5°C Scenario Explorer and Data hosted by IIASA*. doi: [10.22022/SR15/08-2018.15429](https://doi.org/10.22022/SR15/08-2018.15429)
- Assessment and generation of figures & tables using notebooks
  - ⇒ Rendered notebooks: [data.ene.iiasa.ac.at/sr15\\_scenario\\_analysis](https://data.ene.iiasa.ac.at/sr15_scenario_analysis)
  - ⇒ GitHub repository: [github.com/iiasa/ipcc\\_sr15\\_scenario\\_analysis](https://github.com/iiasa/ipcc_sr15_scenario_analysis)
  - ⇒ Based on open-source package *pyam*: [software.ene.iiasa.ac.at/pyam](https://software.ene.iiasa.ac.at/pyam)
- Description of the process of compiling, validating and assessing the scenario ensemble, including “the do’s and don’ts” of scenario analysis  
D. Huppmann et al. (2018). A new scenario resource for integrated 1.5 °C research. *Nature Climate Change*, **8**:1027-1030. doi: [10.1038/s41558-018-0317-4](https://doi.org/10.1038/s41558-018-0317-4)



[SR15](https://www.ipcc.ch/reports/special-reports/), IPCC, 2018

# Opening up tools developed at IIASA

*IIASA is making substantial effort to open up its suite of global tools on energy, land use, emissions and climate change*

- MESSAGE<sub>ix</sub>

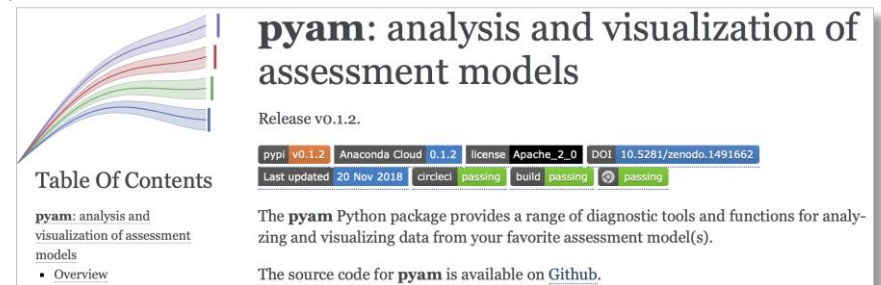
An open-source framework for integrated energy systems++ assessment

⇒ <https://messageix.iiasa.ac.at>

- *pyam*

Open-source Python package for analysis and visualization of integrated assessment models

⇒ <https://software.ene.iiasa.ac.at/pyam/>



- Global Biosphere Management Model (GLOBIOM)

Land-use model for agriculture, forestry, and bioenergy

⇒ Shared with 20+ country teams in the FABLE project, and on track to be released as open source for public use in early 2019

⇒ <http://www.globiom.org>

- GAINS

Framework for modelling emissions of air pollutants and greenhouse gases to minimize their negative effects on human health, ecosystems and climate change

⇒ <http://gains.iiasa.ac.at/models>

*Thank you very much for your attention!*

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