International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

The MESSAGE$_{ix}$ modeling framework and other state-of-the-art tools for integrated scenario analysis

Daniel Huppmann, Volker Krey, Matthew Gidden, Oliver Fricko, Keyan Riahi, 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

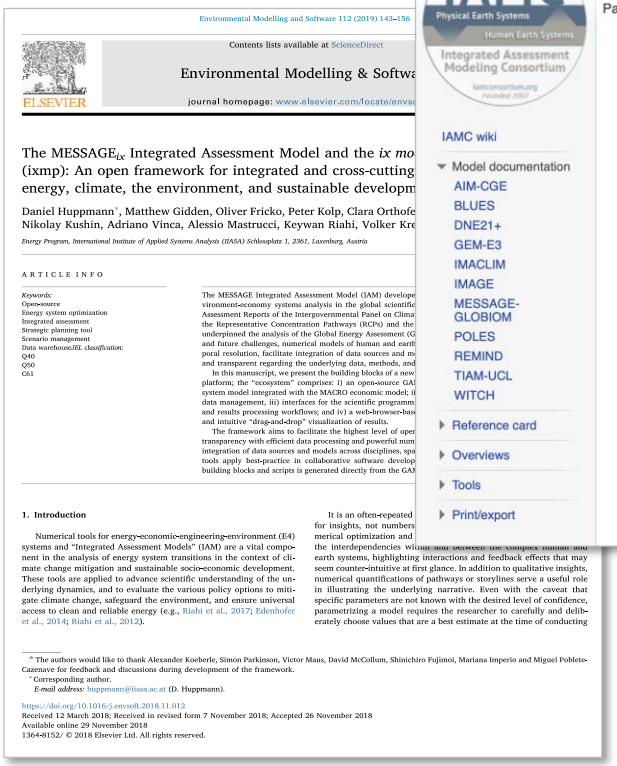
⇒ Provide ways for new users to contribute their work
e.g., GitHub "pull requests"

⇒ Create incentives ("carrots and sticks") for all stakeholders to collaborate

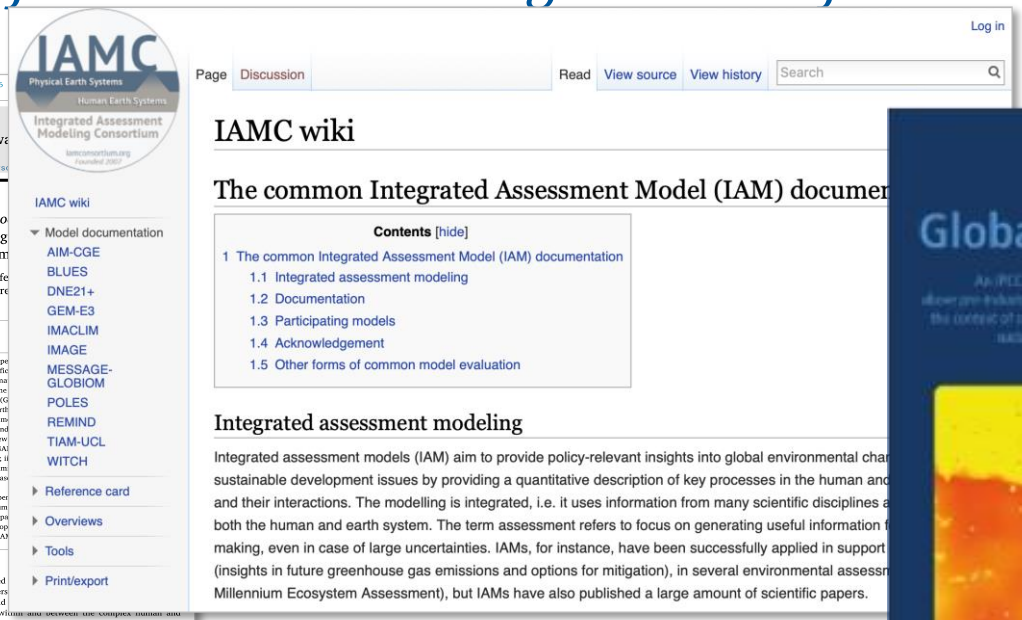
- *Institutions*: provide the necessary environment for researchers to collaborate effectively
- *Experienced users*: answer questions from new users in a timely manner, provide feedback, make suggestions for improvement
- *New users*: once you have figured out the first steps, make suggestions for improving the documentation and tutorials

The first step to capacity building is transparency

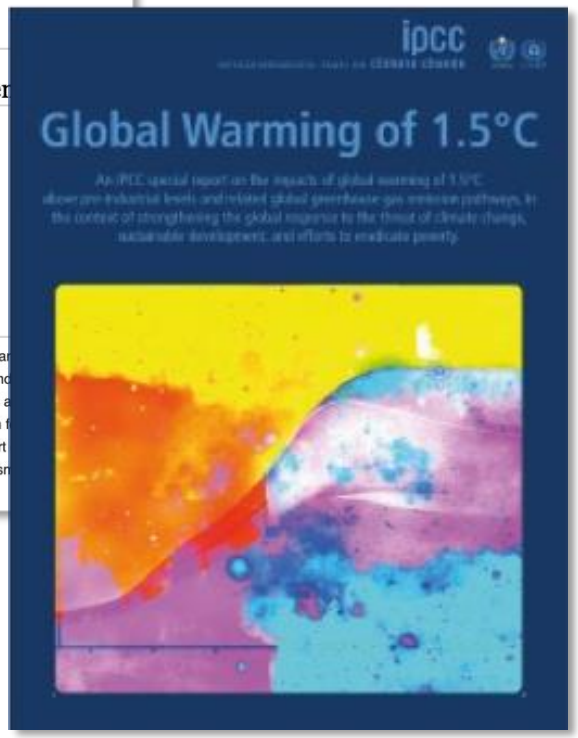
Model & tool documentation need to consider user experience and provide information at the "right" level of detail



Model framework documentation
Huppmann et al. (2019)



Model documentation wiki
www.iamcdocumentation.eu
hosted by PBL

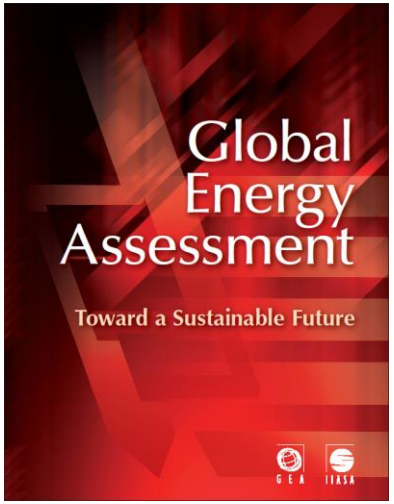


Detailed model documentation
in the Annex of Chapter 2
SR15, IPCC (2018)

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

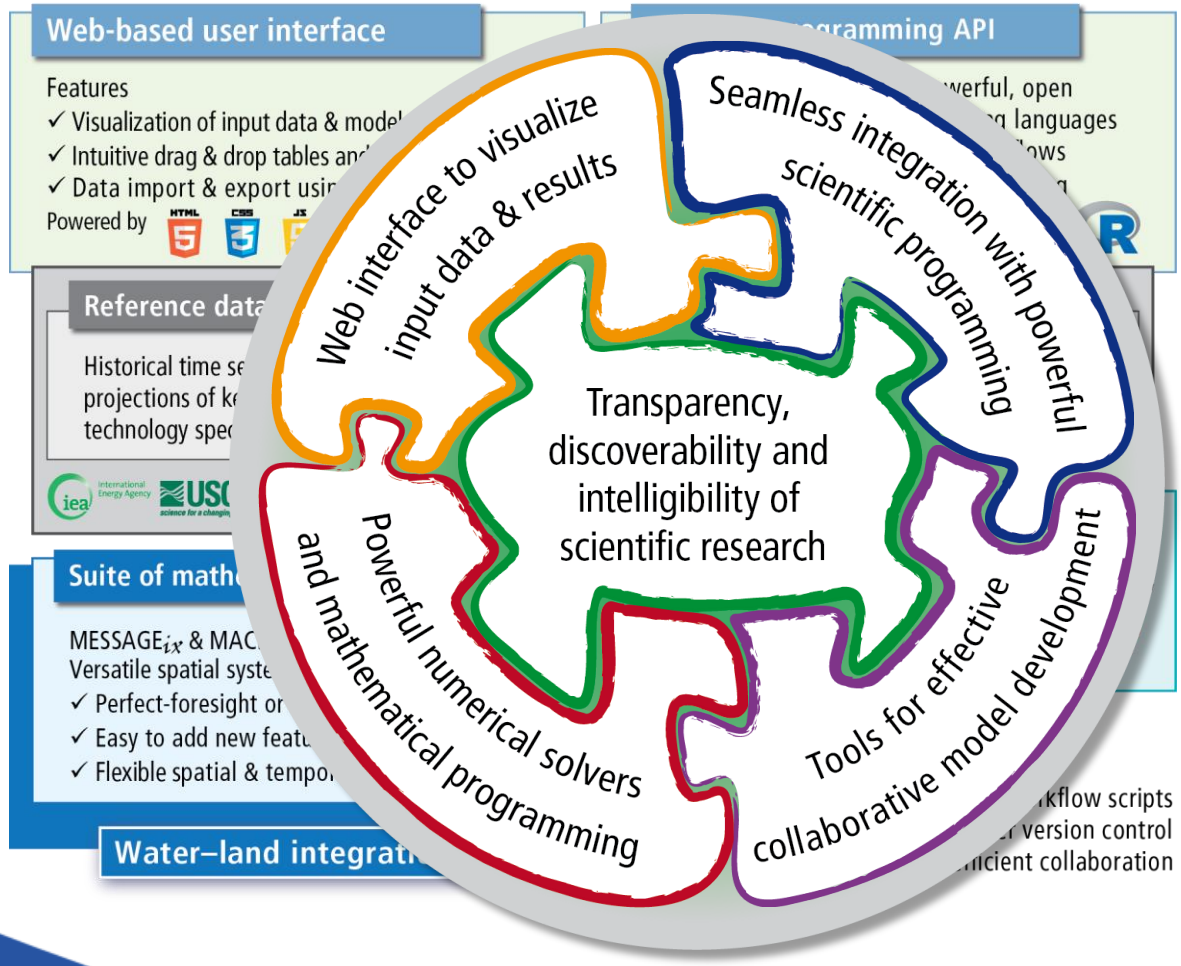


The analysis of the Global Energy Assessment (GEA, 2012) was supported by MESSAGE scenarios.

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

The new MESSAGE$_{ix}$ framework

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



Documentation:
messageix.iiasa.ac.at

GitHub repository (download):
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

IIASA cooperation and capacity building

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

Example 1:

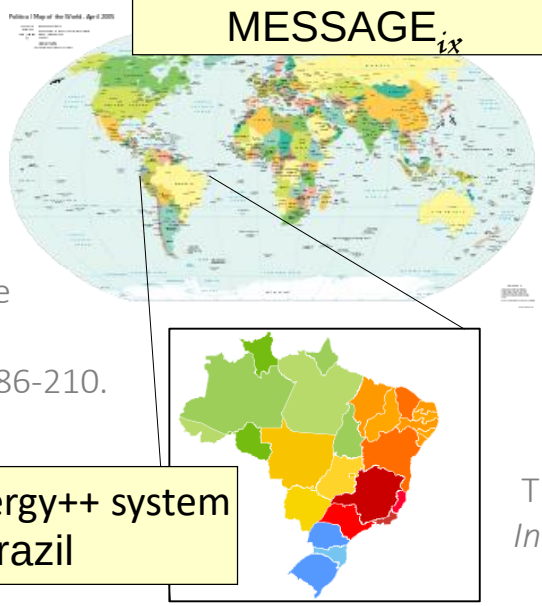
Collaboration with the research group of Prof. Dr. Roberto Schaeffer

Energy Planning Program, COPPE, Universidade Federal do Rio de Janeiro

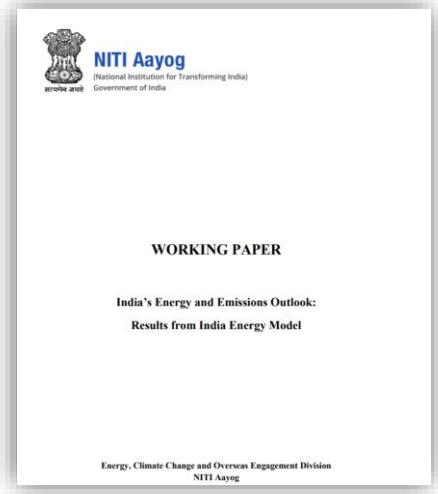
de Lucena et al. (2010) Least-cost adaptation options for global climate change impacts on the Brazilian electric power system. *Global Environmental Change* 20(2):342-350. doi: 10.1016/j.gloenvcha.2010.01.004

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

Global energy++ system
MESSAGE$_{ix}$



Detailed sub-national energy++ system
MESSAGE$_{ix}$-Brazil



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

Example 2:

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

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

- 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

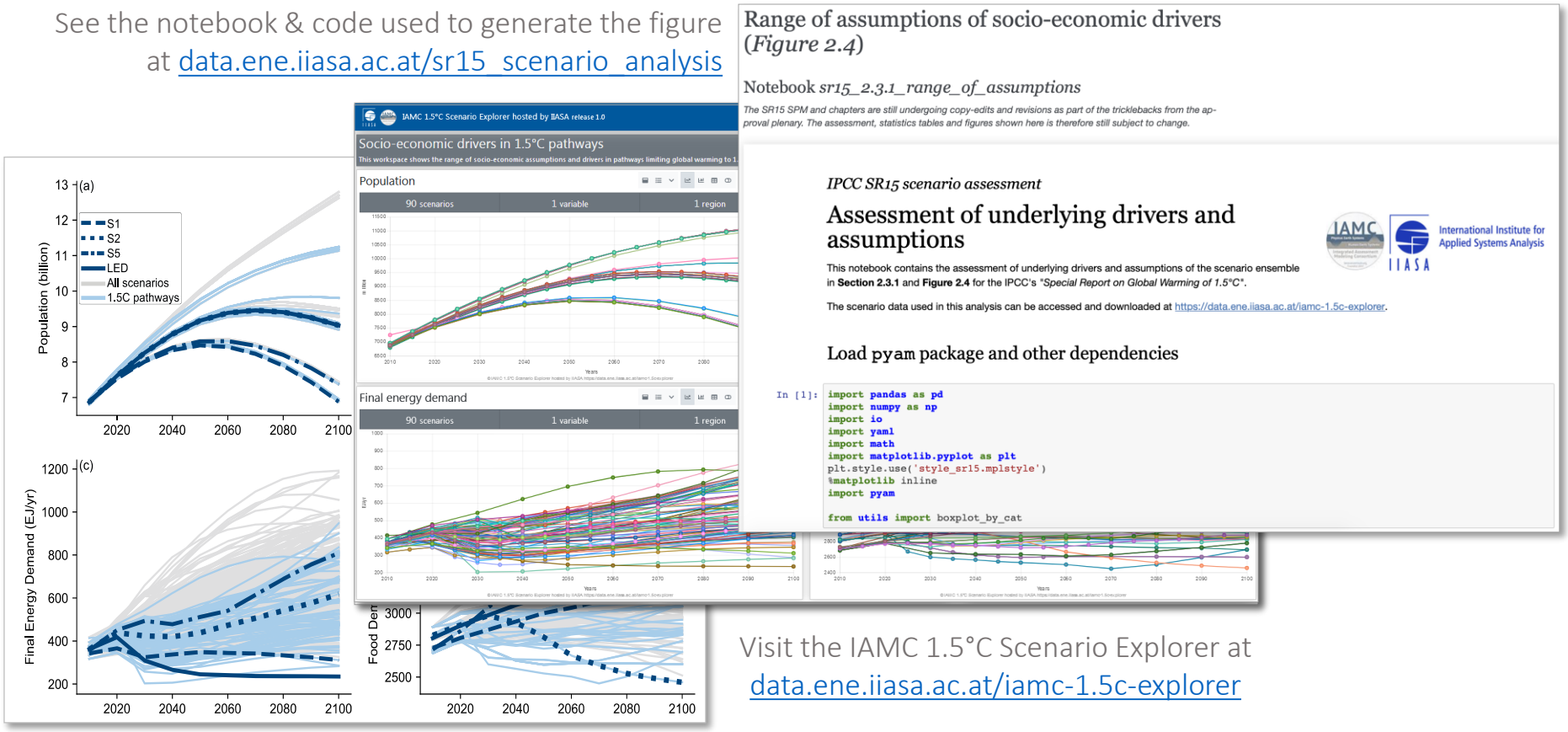
⇒ Implemented using best-practice of open-source, collaborative science

⇒ 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



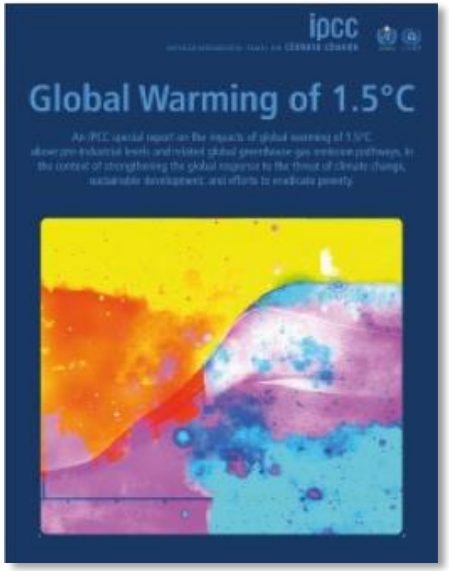
Visit the IAMC 1.5°C Scenario Explorer at data.ene.iiasa.ac.at/iamc-1.5c-explorer

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

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
  - ⇒ 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



SR15, IPCC, 2018

- Assessment and generation of figures & tables using notebooks
  - ⇒ Rendered notebooks: data.ene.iiasa.ac.at/sr15_scenario_analysis
  - ⇒ GitHub repository: github.com/iiasa/ipcc_sr15_scenario_analysis
  - ⇒ Based on open-source package *pyam*: 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

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$_{ix}$

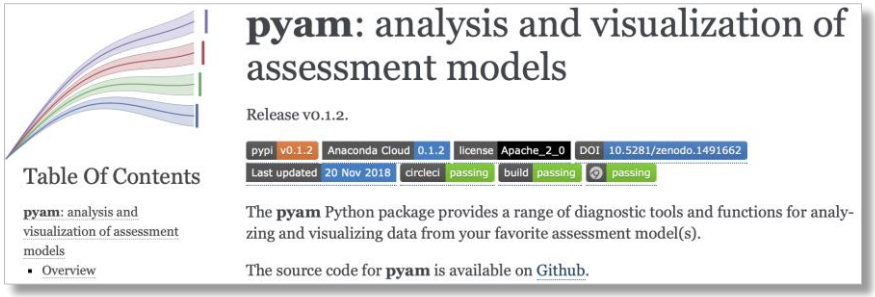
  An open-source framework for integrated energy systems++ assessment

  ⇒ 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

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Thank you very much for your attention!

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