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

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Capacity-building Hub @ COP 24, Katowice, Poland
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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

Daniel Huppmann, Capacity-building Hub @ COP24, Katowice, December 12 2018
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

The MESSAGEix Integrated Assessment Model and theMESSAGEix (MESSAGEix): An open framework for integrated and cross-cutting energy, climate, the environment, and sustainable development. Daniel Huppmann, Matthew Glidden, Oliver Fröhlich, Peter Kulp, Giacomo Bertossio, Nicholas Blosin, Adriano Costi, Alexei Matysin, Kiyoomi Iida,钤呂克Naveau, Jean-Pierre (PBL) Veldkamp. International Institute for Applied Systems Analysis (IIASA), Vienna, Austria.

IAMC wiki

The common Integrated Assessment Model (IAM) documentation

1. The common Integrated Assessment Model (IAM) documentation

Integrated assessment modeling

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

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

Model documentation wiki

www.iamcdocumentation.eu
hosted by PBL

Model framework documentation

Huppmann et al. (2019)

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

The analysis of the Global Energy Assessment (GEA, 2012) was supported by MESSAGE scenarios.
The new MESSAGE\textsubscript{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:

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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

delucena et al. (2010) Least-cost adaptation options for global climate change impacts on the Brazilian electric power system.  
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.  
doi: [10.1016/j.techfore.2015.05.006](https://doi.org/10.1016/j.techfore.2015.05.006)

**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:

- 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

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

```python
import pandas as pd
import numpy as np
import xl
import matplotlib.pyplot as plt
plt.style.use('style_grill-agleyile')
import 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

The MESSAGEix modeling framework and other state-of-the-art tools for integrated scenario analysis
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:

- 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

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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\textsubscript{x}**
  An open-source framework for integrated energy systems++ assessment
  ⇒ [https://messageix.iiasa.ac.at](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/](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](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](http://gains.iiasa.ac.at/models)
Thank you very much for your attention!

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