The MESSAGE\textsubscript{ix} IAM and the “\textit{ix} modeling platform” for integrated and \textit{x}-cutting analysis

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The MESSAGE model at IIASA
What we talk about when we talk about MESSAGE

• The MESSAGE model was developed at IIASA since 1982
• It is a (usually linear) systems optimization model coupled with a macro-economic equilibrium problem
• The framework can be used for large-scale energy-system- and integrated-assessment modeling
• The name “MESSAGE” is used for...
  – the ”software” aka the model generator aka the framework
  – the dataset of the global IAM instance used at IIASA, usually referred to as “MESSAGE\textsubscript{ix}-GLOBIOM”

Recent publications:
• LowEnergyDemand: Grubler et al., Nature Energy, 2018
• Scenarios for the CD-LINKS project: McCollum et al., Nature Energy, 2018
The MESSAGE$_{ix}$ framework
An integrated modeling platform for $x$-cutting analysis

*Goal*: Develop a platform for streamlined modeling
... using state-of-the-art tools for data processing,
... building versatile & powerful mathematical models,
... and applying best practice of collaborative research
The new MESSAGE framework
An integrated modeling platform for x-cutting analysis

Goal: Develop a platform for streamlined modeling
... using state-of-the-art tools for data processing,
... building versatile & powerful mathematical models,
... and applying best practice of collaborative research

Vision: Facilitate integration of models & scientific analysis
... between different disciplines and fields, including economics, engineering, geophysical, social sciences
... across spatial and temporal levels of disaggregation
... guaranteeing the highest level of transparency and scientific reproducibility for a wide audience
The new MESSAGE framework
It’s all about the data...

All modeling & scientific analysis hinges on data availability
... reference data required for calibration and verification
... version-controlled input data is crucial for development
... standardized data processing tools and a common data interface facilitates efficient workflows
The new MESSAGE framework
Supported by a high-performance database architecture

The platform...

... is based on a Java interface as gateway to the data

... supports both an ORACLE database backend for high-performance, heavy-use modeling and local, file-based databases for working “on the fly”
The new MESSAGE_\text{ix} \textit{framework} \\
A simple gateway for researchers and a wider audience
The new MESSAGE$_{ix}$ framework

Interfaces to scientific programming for advanced users

In [1]: `import ixmp as ix`

In [2]: `# launch the IX modeling platform using the local default database
mp = ix.Platform(dbtype='HSQLDB')`

In [3]: `model = "Austrian energy model"

#-----------------------------------------
# load package
source(file.path(Sys.getenv("IXMP_R_PATH"), "ixmp.R"))

#-----------------------------------------
# launch the IX modeling platform
mp <- Platform()

#-----------------------------------------
# specify the model and scenario name
model <- "canning problem"
scen <- "standard"

#-----------------------------------------
# load a datastructure from the database
ds <- mp$DataStructure(model, scen)

#-----------------------------------------
# retrieve the demand as a dataframe
demand <- ds$par("demand")

Scientific programming API

Seamless integration with powerful, open and flexible scientific programming languages
✓ Efficient implementation of workflows
✓ Standardized interface for data processing

Web-based user interface

Features
✓ Visualization of input data & model results
✓ Intuitive drag & drop tables and graphs
✓ Data import & export using MS Excel

Powered by

Database infrastructure

Supports both a centralized data hub and local databases to work "on the fly"
Powered by

ix Modeling Platform

Reference data
Historical time series, projections of key drivers, technology specifications, etc.

Data processing
Downscaling & aggregation, harmonization across sources

Model data
Structured input data, complete model results, standardized reporting
The new MESSAGE\textsubscript{ix} framework
Connected to high-performance numerical programming

The platform has an interface to GAMS, a versatile software for mathematical programming & optimization. MESSAGE\textsubscript{ix} is the first model fully integrated in the \textit{ix} modeling platform...

**Suite of mathematical models**

MESSAGE\textsubscript{ix} & MACRO
Versatile spatial systems-economic model

✓ Perfect-foresight or recursive-dynamic approach
✓ Easy to add new features & extensions
✓ Flexible spatial & temporal detail

**Water–land integration**

**Web-based user interface**
- Visualization of input data & model results
- Intuitive drag & drop tables and graphs
- Data import & export using MS Excel

**Scientific programming API**
- Seamless integration with powerful, open and flexible scientific programming languages
- Efficient implementation of workflows
- Standardized interface for data processing

**ix Modeling Platform**
- Reference data
  - Historical time series, projections of key drivers, technology specifications, etc.
- Data processing
  - Downscaling & aggregation, harmonization across sources
- Model data
  - Structured input data, complete model results, standardized reporting

**Database infrastructure**
- Supports both a centralized data hub and local databases to work "on the fly"

Powered by
- GAMS
- Python
- R
- Oracle
- Java
- Nexus
- The World Bank
- USGS
- CARMA
The new MESSAGE framework
Implementing tools for comprehensive documentation

The platform ensures transparency and intelligibility of code through “auto-documentation” of all codes & packages

Detailed documentation web pages of the mathematical equations are generated automatically from LaTeX mark-up in the GAMS code
The new MESSAGE framework is geared towards best-practice in collaborative research.

The platform facilitates collaborative model development through comprehensive data version control by moving to “script-based” data processing & analysis using full version control of all model codes and scripts. It implements “continuous integration” automated unit-testing of new features to ensure stable codebase.
The new MESSAGE framework
Facilitating transparency and reproducibility of research
A new model integration methodology
An example of the platform’s “raison-d’être”

Current project: Develop “nesting” methodology of sub-national models within the global IAM framework
A simple tutorial – MESSAGE$_{ix}$ Austria
Developing a stylized energy system model

- The public release of the framework includes several tutorials to guide new users into using the framework
- The MESSAGE$_{ix}$ Austria tutorial develops a stylized model using IEA statistics and other techno-economic data
- The tutorial illustrates how to use MESSAGE$_{ix}$ for policy and scenario analysis
More information on MESSAGE\textsubscript{ix}

Our aim is to develop an open and vibrant community

- Released under an APACHE 2.0 open-source license
- Currently used for teaching at TU Wien & Politecnico Milano
- Framework documentation and mathematical formulation:
  MESSAGE\textsubscript{ix}.iiasa.ac.at
- Community forum and mailing list hosted as Google group:
  groups.google.com/d/forum/message\_ix
- Open-source code hosted on GitHub:
  www.github.com/iiasa/message\_ix
- Scientific reference:
Thank you very much for your attention!