



**Advanced Model Development and Validation for the  
Improved Analysis of Costs and Impacts of Mitigation Policies**



This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 308329.

# How to establish credibility? Evaluation and transparency of energy-economy models

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**ADVANCE final conference**  
Brussels, 24 October 2016

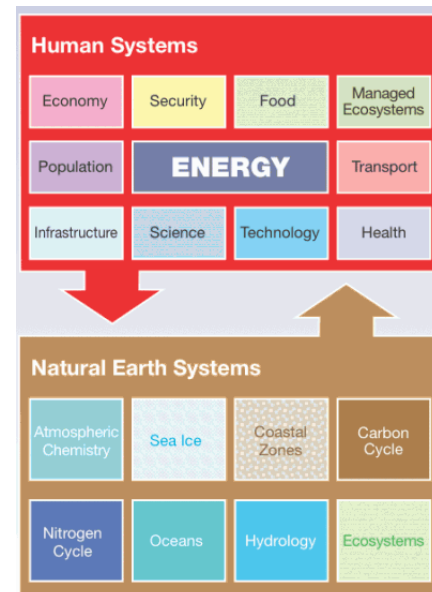
# What is the purpose of IAMs?

## Exploring the option space

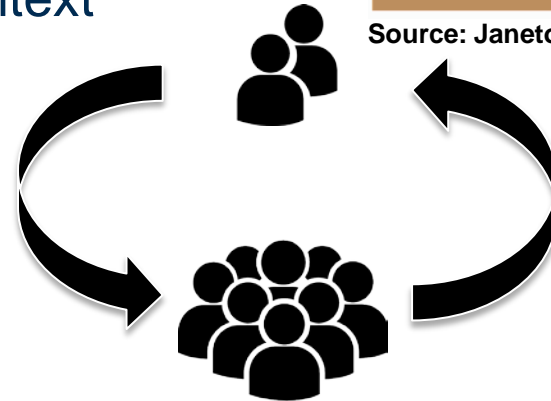
- Develop scenarios for future emissions
- Explore strategies for climate stabilization
- Analyze co-benefits and adverse side effects of mitigation measures
- Explore broader sustainability issues (e.g., water-energy-land nexus) in a climate change context

## Use of IAMs as a reasoning tool

- Problem setting and objectives
- Analysis framing
- Model analysis
- Result evaluation



Source: Janetos, 2009



# **IAM evaluation is an open-ended process of testing, learning & improving a model and its performance**

## **Evaluation criteria for IAMs**

<b><i>appropriateness</i></b>	<b>is model purpose and design consistent with the research question?</b>
<b><i>interpretability</i></b>	<b>are model results clearly interpretable in light of model structure and parameterisation?</b>
<b><i>verifiability</i></b>	<b>are model results repeatable or is model structure accessible to 3<sup>rd</sup> parties?</b>
<b><i>credibility</i></b>	<b>is model seen as <u>good enough</u> for its intended purpose by <u>both users and modellers</u>?</b>
<b><i>usefulness</i></b>	<b>do model insights help understand uncertainties, trade-offs, alternatives?</b>

## Each evaluation method has strengths & weaknesses ... and contributes more to certain evaluation criteria

<u>evaluation method</u>	<i>appropriateness</i>	<i>interpretability</i>	<i>verifiability</i>	<i>credibility</i>	<i>usefulness</i>
historical simulations	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
generalisable historical patterns	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
model intercomparisons	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
diagnostic indicators	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
sensitivity analysis	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
documentation/open access	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

+ ...

# ***Harmonized* Model Documentation**

# ADVANCE documentation specification

## Objective

*harmonized* documentation for larger set of models with two levels of detail

## Structure

- Highly structured **Reference Cards** consisting mostly of tables with predefined categories (~2 pages)
- **Full documentation** based on standardized outline which is adaptable to model type (~30-40 pages)
- Optional **appendices** with details on mathematical formulation and input data (or links to existing material)

## Implementation

- Utilizes **Wiki** platform to allow continuous updating (incl. versioning)
- First Wiki release (hosted by UCL, public since 2015) referenced in ~10 publications

# ADVANCE Wiki Features

## Standardized Outline

- Model scope and methods
- Socio-economic drivers
- Macro-economy [optional]
- Energy
- Land-use [optional]
- Emissions
- Climate [optional]
- Non-climate sustainability dimension [optional]
- Appendices [optional]

## Value added

- One stop repository for model documentation (with links to publications and other documentation)
- Cross-linkages to similar material for other models
- Comparison tables for References Card features
- Public review (2015) highlighted need for improvements along various dimensions

# ADVANCE Wiki Documentation



ADVANCE wiki

Model documentation

- AIM-CGE
- DNE21+
- GEM-E3
- IMACLIM
- IMAGE
- IPETS
- MESSAGE-GLOBIOM
- POLES
- REMIND
- TIAM-UCL
- WITCH

Reference card

- AIM-CGE
- DNE21+
- GEM-E3
- IMACLIM
- IMAGE
- IPETS
- MESSAGE-GLOBIOM
- POLES
- REMIND
- TIAM-UCL
- WITCH

Overviews

- Model comparison
- Model feature matrix

Editor tools

- Guidelines
- Input reference card
- Citation web search

Tools

- What links here
- Related changes

Volker Krey Talk Preferences Watchlist Contributions Log out

Page Discussion

Read

Edit with form

Edit

View history

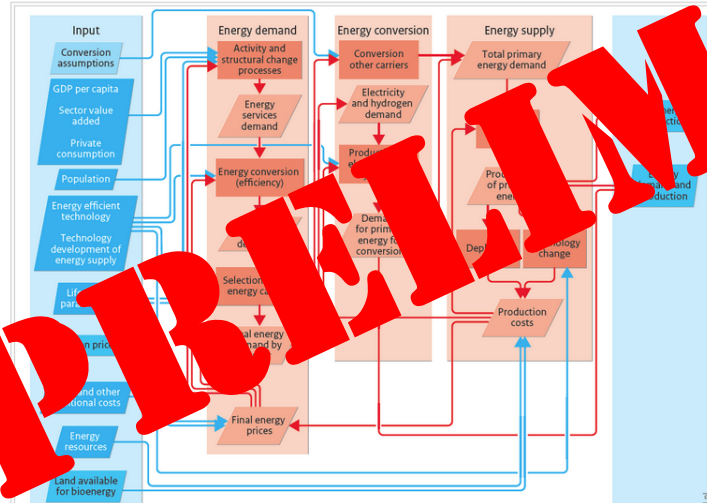
More

Search

## Energy - IMAGE

The Image Energy Regional model, also referred to as TIMER, has been developed to explore scenarios for the energy system in the broader context of the IMAGE global environmental assessment framework<sup>[1][2]</sup>. TIMER describes 12 primary energy carriers in 26 world regions and is used to analyse long term trends in energy demand and supply in the context of the sustainable development challenges. The model simulates long-term trends in energy use, issues related to depletion, energy-related greenhouse gas and other air polluting emissions, together with land-use demand for energy crops. The focus is on dynamic relationships in the energy system, such as inertia and learning-by-doing in capital stocks, depletion of the resource base and trade between regions.

Similar to other IMAGE components, TIMER is a simulation model. The results obtained depend on a single set of deterministic algorithms, according to which the system state in any future year is derived entirely from previous system states. In this respect, TIMER differs from most macro-economic models which let the system evolve on the basis of minimising cost or maximising utility under boundary conditions. As such, TIMER can be compared to energy simulation models such as POLES<sup>[3]</sup> and GCAM<sup>[4]</sup>.



Model documentation - IMAGE	
• Model scope - IMAGE	[+]
• Socio-economic dimension - IMAGE	[+]
• Energy dimension - IMAGE	[+]
• Environmental dimension - IMAGE	[+]
• Technological change in energy - IMAGE	[+]
• Land-use - IMAGE	[+]
• Emissions - IMAGE	[+]
• Climate - IMAGE	[+]
• Non-climate sustainability dimension - IMAGE	[+]
• Appendices - IMAGE	[+]
• References - IMAGE	[+]
Corresponding documentation	
• AIM-CGE	• MESSAGE-GLOBIOM
• DNE21+	• POLES
• GEM-E3	• REMIND
• IMACLIM	• TIAM-UCL
• IMAGE	• WITCH
• IPETS	
Model information	
<b>Institution</b>	PBL Netherlands Environmental Assessment Agency (PBL), Utrecht University (UU)
<b>Concept</b>	The IMAGE framework can best be described as a geographically explicit assessment, integrated assessment simulation model, focusing a detailed representation of relevant processes with respect to human use of energy, land and water in relation to relevant environmental processes.





# ***IAM* Diagnostics**

# Model Diagnostics

## Objective

- Provide methodologies to evaluate IAMs and energy-economic models (global and national) and promote use of diagnostics

## Development of new diagnostic test

- Path dependence
- Sectoral dynamics (electricity, industry, buildings, transport)
- Macro-economy (focus on CGEs)
- Standardized climate model (MAGICC6)  
(utilized in several MIPs including ADVANCE, SSPs, EMF)
- Linking documentation (structure and data) with diagnostic indicators

## Implementation

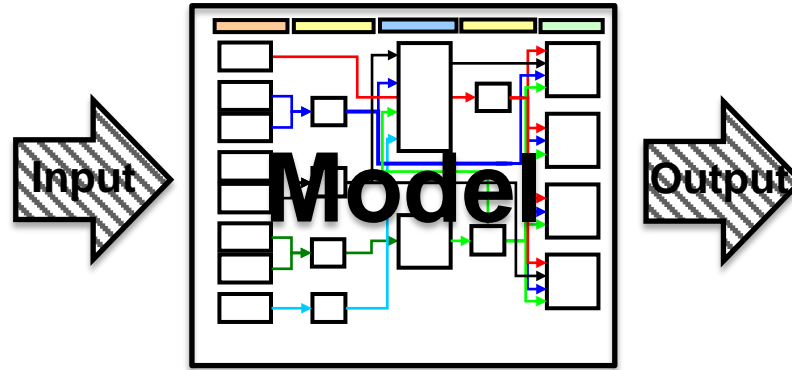
- Development of an automated web-tool for IAM diagnostics, allowing application to a larger set of models

# ADVANCE Diagnostics Exercise

## Simple Scenario Design

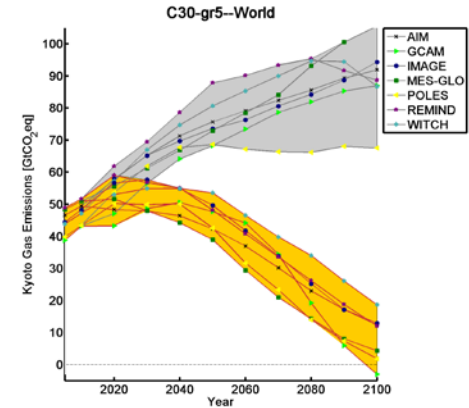
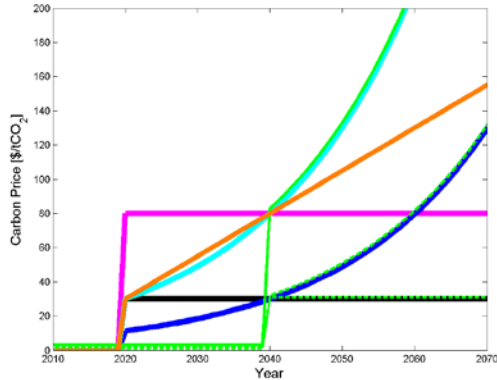
5 mandatory, 6 recommended,  
7 optional model runs

## Model Runs and Submission



## Diagnostic Indicators

GHG emissions response,  
Relative Abatement Index, ...

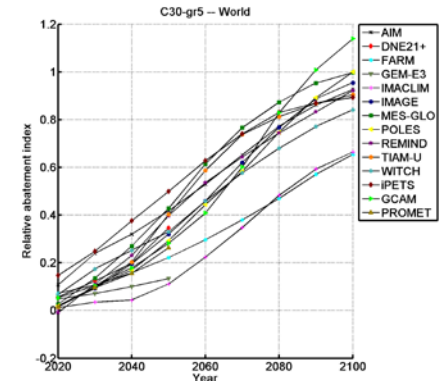


## Model Classification („fingerprint“)

Table 2  
Qualitative description of indicator values across individual models and diagnostic indicators. TBD (To be defined) is shown in places where model data was not available to calculate the particular indicator. A preliminary classification of models based on the combination of indicator values is shown in the rightmost column.

Model	Relative abatement index	CoEI indicator	Transformation index (primary energy)	Cost per abatement value	Classification
AIM-Enduse	Low	Mixed	Mixed	TBD	PE – medium response
DNE21+	Low	Low	Mixed	Low	PE – low response
GCAM	High	Low	High	Medium	PE – high response
GEM-E3	Low	High	TBD	Medium	GE – low response
IMACLIM	Low	High	Mixed	High	GE – low response
IMAGE	High	Low	Mixed	Low	PE – high response
MERGE-ETL	High	Low	High	Low	GE – high response
MESSAGE	High	Low	High	Low	GE – high response
POLES	Mixed	Mixed	Low	Low	PE – medium response
REMIND	High	Low	High	Medium	GE – high response
WITCH	Low	High	Low	Medium	GE – low response

Source: Kriegler et al. 2015



# Automated IAM Diagnostics Web-Tool

ADVANCE Diagnostic Database
Version 1.0

About
Sectors
Series
Scatter
Manage
Download
Admin

Select region(s), scenario(s), and variable to define your query

**(1.) Regions:**

- ☒ Compare
  - ☒ World
    - ☒ World
  - ☐ 5 Regions
    - ☐ Asia
    - ☐ Latin America
    - ☐ Middle East and Africa
    - ☐ OECD 90 + EU
    - ☐ Reforming Economies
    - ☐ Rest of World
  - ☐ Individual Countries
- ☐ AIM/CGE V.2
- ☐ COPPE-MSB\_v1.3.2
- ☐ DNE21+ V.14
- ☐ EPPA6

**(2.) Model/Scenarios:** Filter ...

- ☒ AIM/CGE V.2
- ☒ COPPE-MSB\_v1.3.2
- ☒ DNE21+ V.14
- ☒ EPPA6
- ☒ FARM 3.1
- ☒ GCAM4.2\_ADVANCE
- ☒ GEM-E3\_V1
- ☒ GEM-E3\_V2
- ☒ IMACLIM V1.1
- ☒ IMAGE 3.0
- ☒ IMAGE 3.0.1
- ☒ KEI-Linkages\_2.0
- ☐ MAGICC6
- ☒ MESSAGE V.4
- ☒ MESSAGE-GLOBIOM\_1.0
- ☒ POLES ADVANCE

**(3.) Variables:**

- ☐ Diagnostics
  - ☒ Relative Abatement Index
  - ☐ Transformation Index
  - ☐ Costs per Abatement Value
  - ☐ CtoEI
- ☐ MAGICC6
- ☐ Population
- ☐ GDP
- ☐ Primary Energy
- ☐ Secondary Energy
- ☐ Final Energy
- ☐ Emissions
- ☐ Concentration
- ☐ Forcing
- ☐ Temperature
- ☐ Consumption

**Query Results - Chart Preview:**

**Query Results:**

Region	Model - Scenario	Variable	Unit	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2080	2090	2100
World	AIM/CGE V.2 - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-	0.000	0.001		0.107		0.239		0.320		0.417	0.529	0.652	0.772	0.861	0.926
World	DNE21+ V.14 - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-	0.000	0.000	0.000	0.056	0.090	0.123		0.198		0.345					
World	EPPA6 - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-															
World	FARM 3.1 - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-			0.021	0.072		0.108		0.158		0.221	0.297	0.380	0.470	0.571	0.654
World	GCAM4.2_ADVANCE - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-	0.000	0.000		0.053		0.104		0.178		0.281	0.408	0.601	0.828	1.008	1.139
World	GEM-E3_V1 - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-	-0.000	-0.000	-0.000	0.085	0.111	0.139	0.175	0.210	0.248	0.285					
World	GEM-E3_V2 - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-		0.000	0.000	0.048	0.059	0.072	0.086	0.101	0.117	0.135					
World	IMACLIM V1.1 - DIAG-C30-gr5	Diagnostics Relative Abatement Index	-	0.000	0.000	0.001	0.013	0.030	0.039	0.040	0.046	0.065	0.105	0.205	0.306	0.429	0.535	0.618

**Output Options:**

Microsoft Excel

Portable Network Graphics

Scalable Vector Graphics

**Notes:**

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# Conclusions

- Significant step forward in terms of providing transparent information on IAMs
- Integration of different approaches to enhance model evaluation is important (e.g., linking documentation with diagnostics)
- Ongoing effort to engage the IAM community beyond the ADVANCE consortium partners
  - Documentation: 8 ADVANCE models + 3 external partners
  - Diagnostics: 8 ADVANCE models + 4 external partners + 3 models from wider community
- Continuous, systematic & more prominent evaluation effort is needed to strengthen and maintain confidence in IAMs



**Thanks!**

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