Standardization of scenario data collection via the IAMC data template: past developments and future challenges

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Integrated Assessment Modeling Consortium
Founded 2007

IAMC webinar, 20 June 2023

Overview

- Looking back
  - ⇒ Challenges of scenario data collection
  - ⇒ Development of first IAMC data template
  - ⇒ Revisions and extensions
  - ⇒ Scenario Database/Explorer
  - ⇒ Applications and statistics
- Taking Stock
  - ⇒ Challenges and issues
  - ⇒ Tools around the template
- Looking forward
  - ⇒ Ideas to overcome challenges

Looking Back

Challenge

- After completion of 4th IPCC assessment cycle increasing number of model intercomparison projects and "ex-post" scenario studies (2008/2009)
- Every study used its own data template for collecting scenario data (e.g., long vs. wide table format, different variable names, specific headers)
- Providing scenario data became an increasing workload for modeling teams

Example: EMF22

Goal: international scenarios will explore near-term inefficiencies in international participation on a transition toward stabilizing CO2-equivalent concentrations over the long term

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Required/ Optional	Notes	Category	Variable	Region	Units	Model	Scenario	Level	Overshoot/Stabilization	2000	2010	2020	2030
2	Required		Economics	GDP (MER)	Global	Trillion 2005 U.S. $		Reference	N/A	N/A				
3	Required		Economics	GDP (MER)	Group 1	Trillion 2005 U.S. $		Reference	N/A	N/A				
4	Required		Economics	GDP (MER)	Group 2	Trillion 2005 U.S. $		Reference	N/A	N/A				
5	Required		Economics	GDP (MER)	Group 3	Trillion 2005 U.S. $		Reference	N/A	N/A				
6	Required		Economics	GDP (MER)	United States	Trillion 2005 U.S. $		Reference	N/A	N/A				
7	Required		Economics	GDP (MER)	European Union	Trillion 2005 U.S. $		Reference	N/A	N/A				
8	Required		Economics	GDP (MER)	China	Trillion 2005 U.S. $		Reference	N/A	N/A				
9	Required		Economics	GDP (MER)	India	Trillion 2005 U.S. $		Reference	N/A	N/A				
10	Required		Population	Population	Global	Billion		Reference	N/A	N/A				
11	Required		Population	Population	Group 1	Billion		Reference	N/A	N/A				
12	Required		Population	Population	Group 2	Billion		Reference	N/A	N/A				
13	Required		Population	Population	Group 3	Billion		Reference	N/A	N/A				
14	Required		Population	Population	United States	Billion		Reference	N/A	N/A				
15	Required		Population	Population	European Union	Billion		Reference	N/A	N/A				
16	Required		Population	Population	China	Billion		Reference	N/A	N/A				
17	Required		Population	Population	India	Billion		Reference	N/A	N/A				
18	Required**	9	Economics	Consumption	Global	Billion		Reference	N/A	N/A				
19	Required**	9	Economics	Consumption	United States	Billion		Reference	N/A	N/A				
20	Required**	9	Economics	Consumption	European Union	Billion		Reference	N/A	N/A				
21	Required**	9	Economics	Consumption	China	Billion		Reference	N/A	N/A				
22	Required**	9	Economics	Consumption	India	Billion		Reference	N/A	N/A				
23	Required**	9	Economics	Policy Cost (Area under MAC)	Global	Billion		Reference	N/A	N/A				
24	Required**	9	Economics	Policy Cost (Area under MAC)	United States	Billion		Reference	N/A	N/A				
25	Required**	9	Economics	Policy Cost (Area under MAC)	European Union	Billion		Reference	N/A	N/A				
26	Required**	9	Economics	Policy Cost (Area under MAC)	China	Billion		Reference	N/A	N/A				
27	Required**	9	Economics	Policy Cost (Area under MAC)	India	Billion		Reference	N/A	N/A				

International Scenario Notes | Reference Scenario | Scen_1 Stabilization 2.6 Wm2 | Scen_1 Overshoot 2.6 Wm2 | Sce ...

Example: NIES

Goal: analyze "How mitigation potentials are different? & Why different?" and discuss "How should these potentials be compared one another ?" in the latest bottom-up type studies

(c) Data format of baseline emissions and mitigation potentials

1) Please send GHG emissions in the baseline and mitigation potentials under a certain carbon price in intervention scenarios as much detail as possible in order to compare your results by region and sector with other studies and the IPCC AR4.
2) If you have any proposals of additional data submission rather than the followings, please suggest and send such

Column code	Items
Sector	Your original sectoral classification (or sectors such as Tier 1 to Tier 3. Please see "ReadMe")
Region	Your original regional classification (or regions such as Tier 1 to Tier 3. Please see "ReadMe")
Year	Base year, 2020, and 2030
Gas	Please specily CO2, CH4, N2O, HFCs, PFCs or SF6
Unit	MtCO2, MtCO2 eq., MtC, or MtC eq.
Baseline emissions	Baseline emissions in the base year, 2020, and 2030
Mitigation potentials	Mitigation potentials under a certain carbon price compared with the baseline
	Technological potentials Note1) If you do not calculate or cannot submit mitigation potentials under a certain carbon price for any reason, please send technological potentials without considering limitation of abatement costs.

Comparison step

Note)
If it is difficult to convert the data from your original format to this format, please send the data in your original format. In this case, please give a brief description on how to read your data so that it is possible to understand your data correctly.

Scenario name

Sector	Region	Year	Gas	Unit	Baseline emissions	Mitigation potentials				
						Mitigation potentials under a certain carbon price				Technological potentials
						<0 US$/tCO2	<20 US$/tCO2	<50 US$/tCO2	<100 US$/tCO2	

(a) Basic_Info | (a) Basic_Info(example) | (b)SocioEconomics | (b)SocioEconomics(example) | (c)Emisions&potentials | (c)Emisions&potentials(example) | (d)energy(example)

Example: AIXG

Goal: examine how national and sectoral GHG mitigation potential compares between models used by specific countries for policy-making (i.e. your model input) and global institution models (e.g. OECD, IEA, and others)

			COUNTRY: _____							GLOBAL: _____						
			1990	2000	2010	2020	2030	2040	2050	1990	2000	2010	2020	2030	2040	2050
	GDP	(please provide units, e.g. 2005 USD)														
	Equivalent Variation [1]	Households														
		Government														
	Population	Million people														
	Energy Use	(please provide units)														
	GHG emissions (Absolute MtCO2e)	Energy supply: electric														
		Energy supply: non-electric														
		Transportation														
		Buildings														
		Energy-intensive Industry														
		Other industry														
		Agriculture														
		Forestry														
		Waste														

Model Structure | Baseline | Policy Scenarios

Example: World Development Report 2009

Goal: understand how to energize development without compromising the climate

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1															
2	Energy Investment (World)														
3	**Baseline**	Unit	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	Note	
4	Fossil Extraction	US$2000													
5	Fossil Electricity	US$2000													
6	Non fossil Electricity	US$2000													
7	CCS	US$2000													
8	Hydrogen	US$2000													
9	Bioenergy	US$2000													
10	Other	US$2000													
11	Demand Saving	US$2000													
12															
13	**450 ppmv (CO2-eq.)**	Unit	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	Note	
14	Fossil Extraction	US$2000													
15	Fossil Electricity	US$2000													
16	Non fossil Electricity	US$2000													
17	CCS	US$2000													
18	Hydrogen	US$2000													
19	Bioenergy	US$2000													
20	Other	US$2000													
21	Demand Saving	US$2000													
22															
23	**Diff btw Baseline and 450ppmv (CO2-eq.)**	Unit	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	Note	
24	Fossil Extraction	US$2000													
25	Fossil Electricity	US$2000													
26	Non fossil Electricity	US$2000													
27	CCS	US$2000													
28	Hydrogen	US$2000													
29	Bioenergy	US$2000													
30	Other	US$2000													
31	Demand Saving	US$2000													
32															

primary_energy | electricity | final_energy | **mitigation_investment** | mitigation_wedge

2nd IAMC Annual Meeting in 2009

- Held back-to-back with Asian Modeling Exercise (AME) kick-off meeting in Tsukuba in September 2009
- Small working group established to develop a first version of a "IAMC data template"
- AME took pioneering role for testing first data template (and accompanying scenario database)
- EMF24 followed soon …

Working group


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(NIES)


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(PBL)

First calls in October 2009

- Template specifications
- Variable and region definitions (driven by AME)

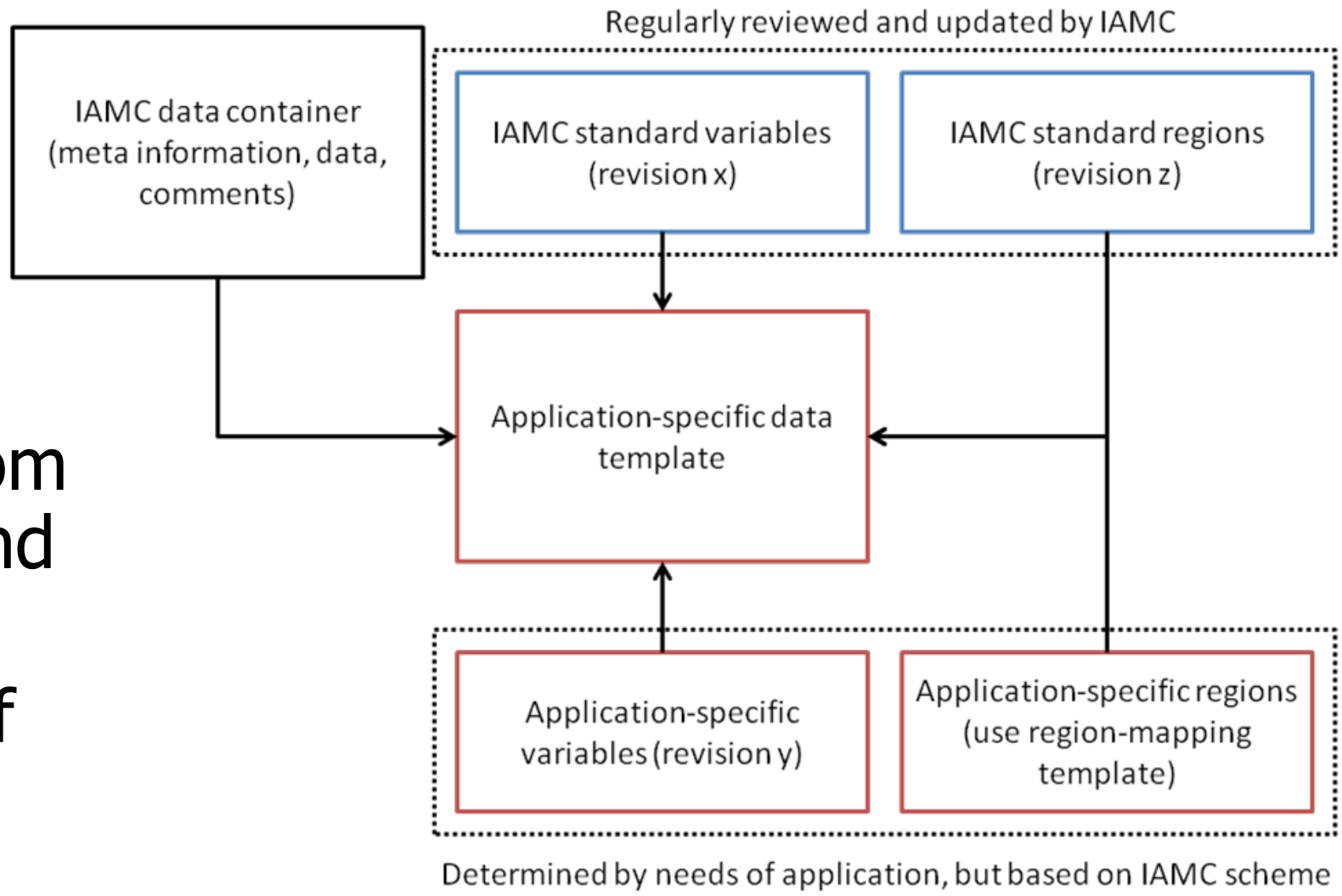
Template requirements

- easy to use for both data suppliers and data analysts
- close enough to existing template structures to ensure acceptability
- machine writable/readable
- highly adaptable to the needs of future modeling comparison projects and data collection efforts
- suitable for small- and large-scale applications, i.e. processing with simple tools (spreadsheets) and databases should be possible

A three-layered approach

- Universal IAMC data container
- Specification of standard Regions, Variables and Units
- Specification of custom Regions, Variables and Units

  ⇒ Specific instance of data template



Template specifications

- File format
  - ⇒ Advanced formats, e.g., XML-based such as SDMX, or others such as GESMES/TS technically preferable
  - ⇒ Comma separated value (csv) files cause problems with different decimal separators, quotation marks, etc.
  - ⇒ Microsoft Excel (xls, xlsx) was least common denominator
- Flexibility
  - ⇒ Hierarchical structure of variables with flexible number of levels via use of separator "|"
  - ⇒ Flexible time steps/years

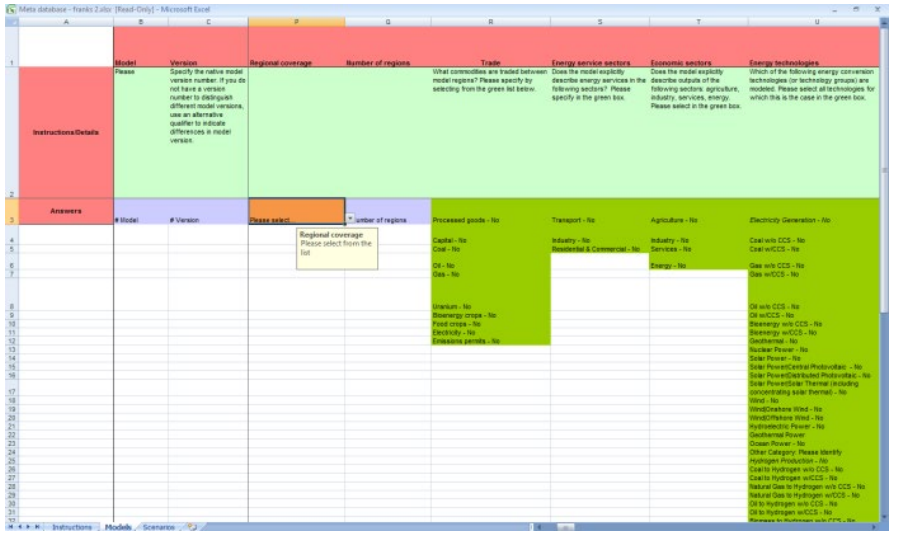
Data Template: Time-series data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Model	Scenario	Region	Variable	Unit	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	210
2				Population|Total	million											
3				Population|Urban	million											
4				Population|Rural	million											
5				GDP|Total|MER	billion US$2005/yr											
6				GDP|Total|PPP	billion US$2005/yr											
7				GDP|Industry|MER	billion US$2005/yr											
8				GDP|Services|MER	billion US$2005/yr											
9				GDP|Agriculture|MER	billion US$2005/yr											
10				Primary Energy|Total	EJ/yr											
11				Primary Energy|Fossil|Total	EJ/yr											
12				Primary Energy|Fossil|w/ CCS	EJ/yr											
13				Primary Energy|Fossil|w/o CCS	EJ/yr											
14				Primary Energy|Coal|Total	EJ/yr											
15				Primary Energy|Coal|w/ CCS	EJ/yr											
16				Primary Energy|Coal|w/o CCS	EJ/yr											
17				Primary Energy|Oil|Total	EJ/yr											
18				Primary Energy|Oil|w/ CCS	EJ/yr											
19				Primary Energy|Oil|w/o CCS	EJ/yr											
20				Primary Energy|Gas|Total	EJ/yr											
21				Primary Energy|Gas|w/ CCS	EJ/yr											
22				Primary Energy|Gas|w/o CCS	EJ/yr											
23				Primary Energy|Biomass|Total	EJ/yr											
24				Primary Energy|Biomass|w/ CCS	EJ/yr											
25				Primary Energy|Biomass|w/o CCS	EJ/yr											
26				Primary Energy|Nuclear|Total	EJ/yr											
27				Primary Energy|Non-Biomass Renewables	EJ/yr											
28				Primary Energy|Hydro|Total	EJ/yr											
29				Primary Energy|Wind|Total	EJ/yr											
30				Primary Energy|Solar|Total	EJ/yr											
31				Primary Energy|Geothermal|Total	EJ/yr											
32				Primary Energy|Ocean|Total	EJ/yr											
33				Primary Energy|Secondary Energy Trade|Total	EJ/yr											
34				Primary Energy|Other	EJ/yr											
35				Secondary Energy|Electricity|Total	EJ/yr											
36				Secondary Energy|Electricity|Coal|Total	EJ/yr											
37				Secondary Energy|Electricity|Coal|w/ CCS	EJ/yr											
38				Secondary Energy|Electricity|Coal|w/o CCS	EJ/yr											
39				Secondary Energy|Electricity|Oil|Total	EJ/yr											
40				Secondary Energy|Electricity|Oil|w/ CCS	EJ/yr											
41				Secondary Energy|Electricity|Oil|w/o CCS	EJ/yr											
42				Secondary Energy|Electricity|Gas|Total	EJ/yr											
43				Secondary Energy|Electricity|Gas|w/ CCS	EJ/yr											
44				Secondary Energy|Electricity|Gas|w/o CCS	EJ/yr											
45				Secondary Energy|Electricity|Biomass|Total	EJ/yr											
46				Secondary Energy|Electricity|Biomass|w/ CCS	EJ/yr											
47				Secondary Energy|Electricity|Biomass|w/o CCS	EJ/yr											

Meta Data: Models and Scenarios

Model

- Model name & version
- Time horizon
- Model type (e.g., general vs. partial equilibrium; recursive-dynamic vs. inter-temporal)
- Cost metrics: GDP & consumption losses/system cost
- …



Scenario

- Part of a bigger exercise? (e.g., EMF27, AMPERE)
- Type: baseline/climate policy/diagnostic
- Climate Target (e.g., none/temperature/radiative forcing/emissions)
- Climate Policy: cap (and trade), price, regional policies
- Status: published (peer-reviewed/non-peer reviewed), preliminary
- …

Revisions and Extensions

Revisions

- Remove of "Total" (2011)
  - ⇒ Primary Energy|Total -> Primary Energy
- Revision of emission variables (SSPs/CMIP6 harmonization, 2015)
  - ⇒ Definitions based on IPCC National Emission Inventory Guidelines (2006)
- Revision of final energy variables (project NAVIGATE, 2022)
  - ⇒ Separation of non-energy use and bunker fuel use
  - ⇒ Reporting of gross carbon flows

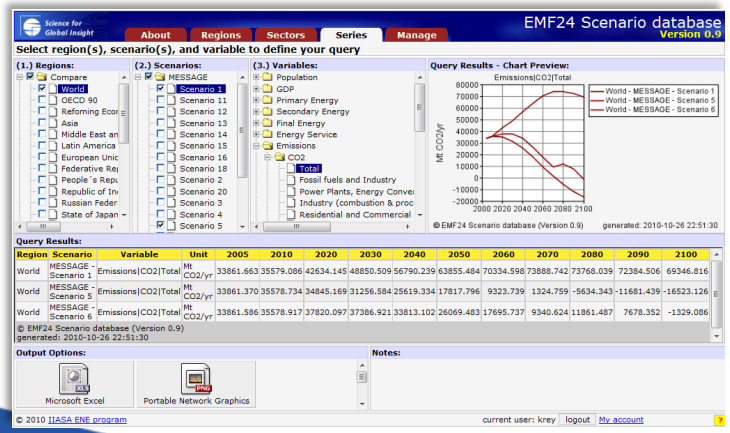
Extensions

- Addition of sub-annual timeslices (project openENTRANCE, 2019/20)
- Countless variables added

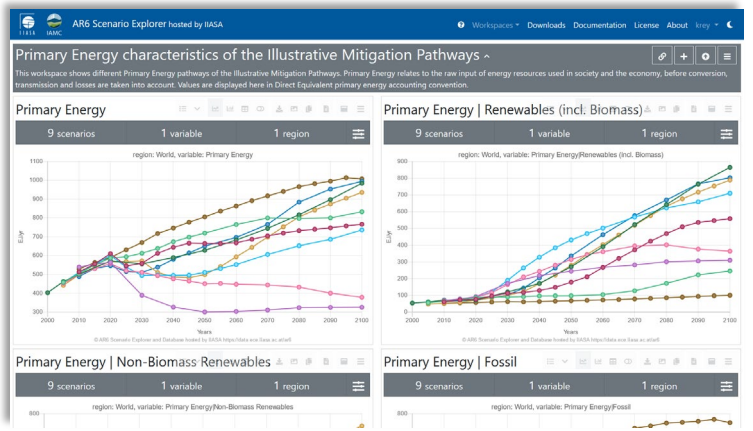
Scenario Database/Explorer

- Interactive web database with user and group management (incl. administrator)
- Automated aggregation to “standard regions”
- Some automated quality checks (model, variable and region names, base year data, variable ranges, additivity)
- Download functionality for database snapshots, data template, etc.
- Data visualization and dissemination to the public

2010-2018



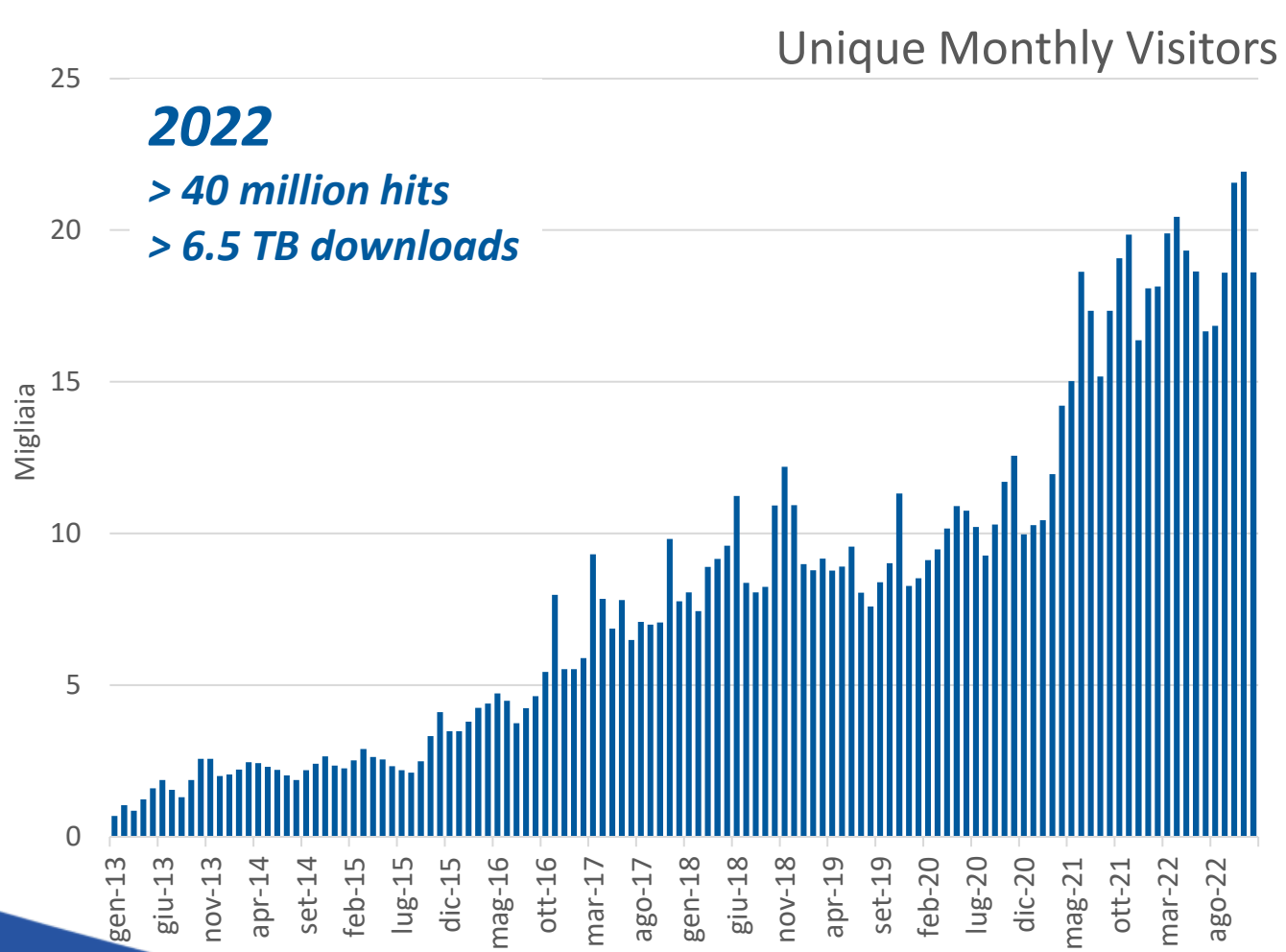
Since 2018



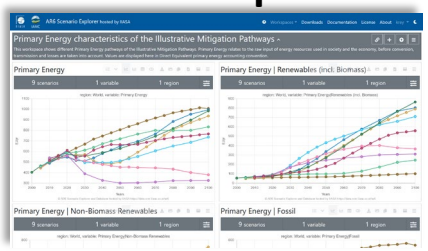
Applications of Template/Databases (incomplete)

- Asian Modeling Exercise (AME)
- Stanford Energy Modeling Forum: EMF24 (US), EMF27 (global), EMF28 (EU), EMF30 (global), EMF32 (US), EMF33 (global), EMF35 (Japan), EMF37 (US)
- IPCC: AR5, SR1.5/SRCCL, AR6
- Global Energy Assessment (GEA)
- Representative Concentration Pathways (RCPs)
- Shared Socio-economic Pathways (SSPs)
- EU Framework Projects: AMPERE, LIMITS, ADVANCE (FP7), CD-LINKS, openENTRANCE, ENGAGE, NAVIGATE, (H2020), ELEVATE, PRISMA, CIRCOMOD, CircEUlar, … (HEU)
- US/EuropeAid: Latin American Modeling Project (LAMP), MILES, COMMIT, COMMITTED, …
- National: SPIPA India, Energy Foundation China, US National Climate Assessment, ARIADNE (Germany), EU Climate Advisory Board, …
- Network for Greening the Financial System (NGFS): Phase 1-4

Scenario Databases: Access statistics

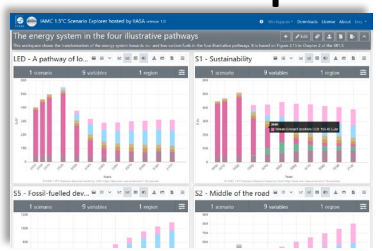


IPCC AR6 explorer



https://data.ece.iiasa.ac.at/ar6/

IPCC SR1.5 explorer

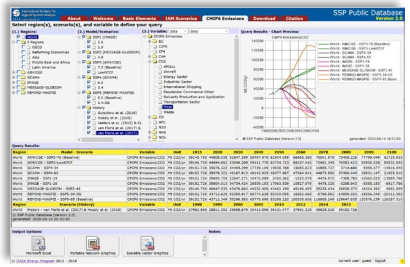


https://data.ece.iiasa.ac.at/iamc-1.5c-explorer/

IPCC AR5 database

https://tntcat.iiasa.ac.at/AR5DB

SSP database



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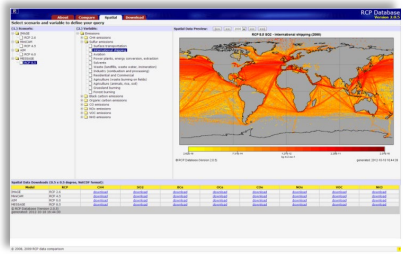
RCP database



http://tntcat.iiasa.ac.at/RcpDb/

NGFS finance pathways

https://data.ece.iiasa.ac.at/ngfs

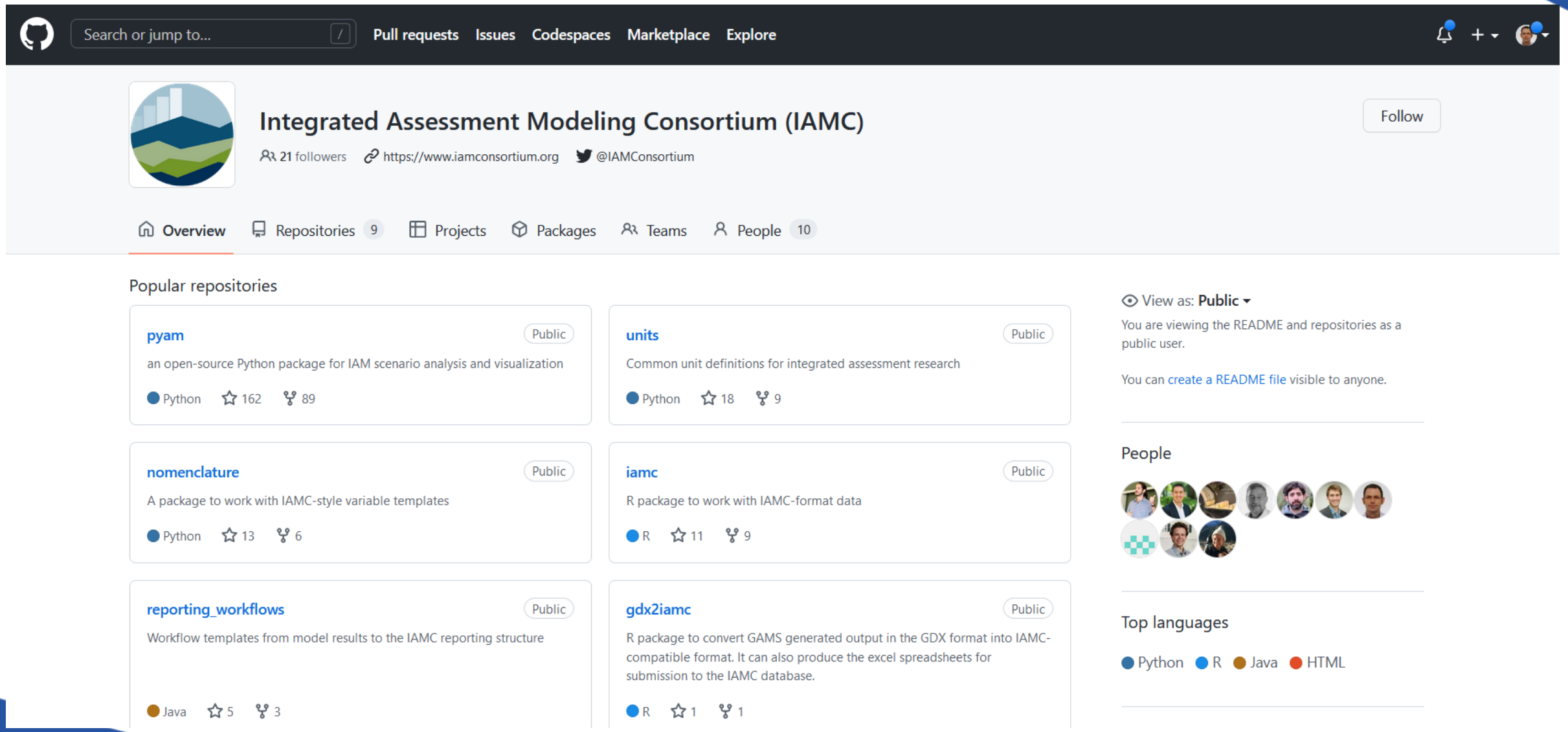
and many more …

Taking Stock

Challenges and Issues

- No strict hierarchy in variables naming
  ⇒ ambiguity, variable name length, no summation rules
- No central approval instance for new variable names
  ⇒ Incompatible variable extensions used in parallel
- Metadata never got fully picked up
  ⇒ Most interesting for assessments, requires manual effort
- Comment functionality, e.g. to document non-compliance with definitions, rarely used
- Automated quality control despite of efforts has large gaps
  ⇒ Limited variable set
  ⇒ Typically not implemented at regional level

Tools to work with IAMC data template



https://github.com/IAMconsortium

Looking Forward

New Scientific Working Group Co-chairs

Additional co-chairs appointed following IAMC Annual Meeting 2022

- Next steps
  - ⇒ Establish data template subgroups that maintain sections independently (but in a coordinated way)
  - ⇒ Establish repositories and develop tools for maintenance of IAMC data template

Ken Oshiro (Kyoto University)

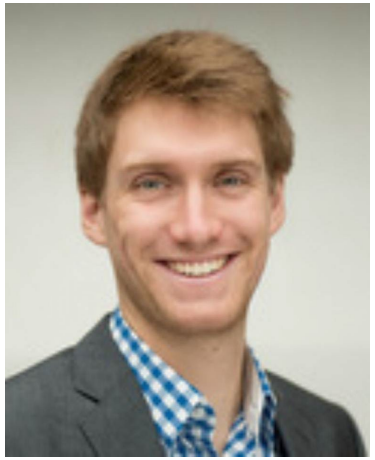
Jessica Strefler (PIK)

Data template subgroup candidates (proposal)

Members ideally align research interest with responsibility for template

- emissions (incl. carbon management, carbon dioxide removal)
- primary energy, secondary energy, energy prices
- industry (incl. non-energy use, materials)
- buildings
- transport (incl. bunkers)
- techno-economic information, energy capacity & investment
- macro-economy (incl. demography, value added, employment, effort sharing, household, governance, policy, trade, energy (trade))
- land (incl. agriculture, food, forestry, land cover, water (agriculture))
- sustainable development goals (incl., air quality, health, resilience, risk, poverty, inequality)

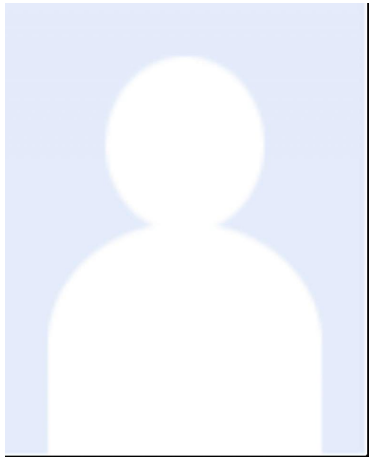
Special Thanks to:



Daniel Huppmann

Philip Hackstock

Edward Byers



Maximilian Wolschlager

Peter Kolp

Thank you very much for your attention!

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