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

GAINS (**G**reenhouse Gas and **A**ir Pollution **IN**teractions and **S**ynergies) model

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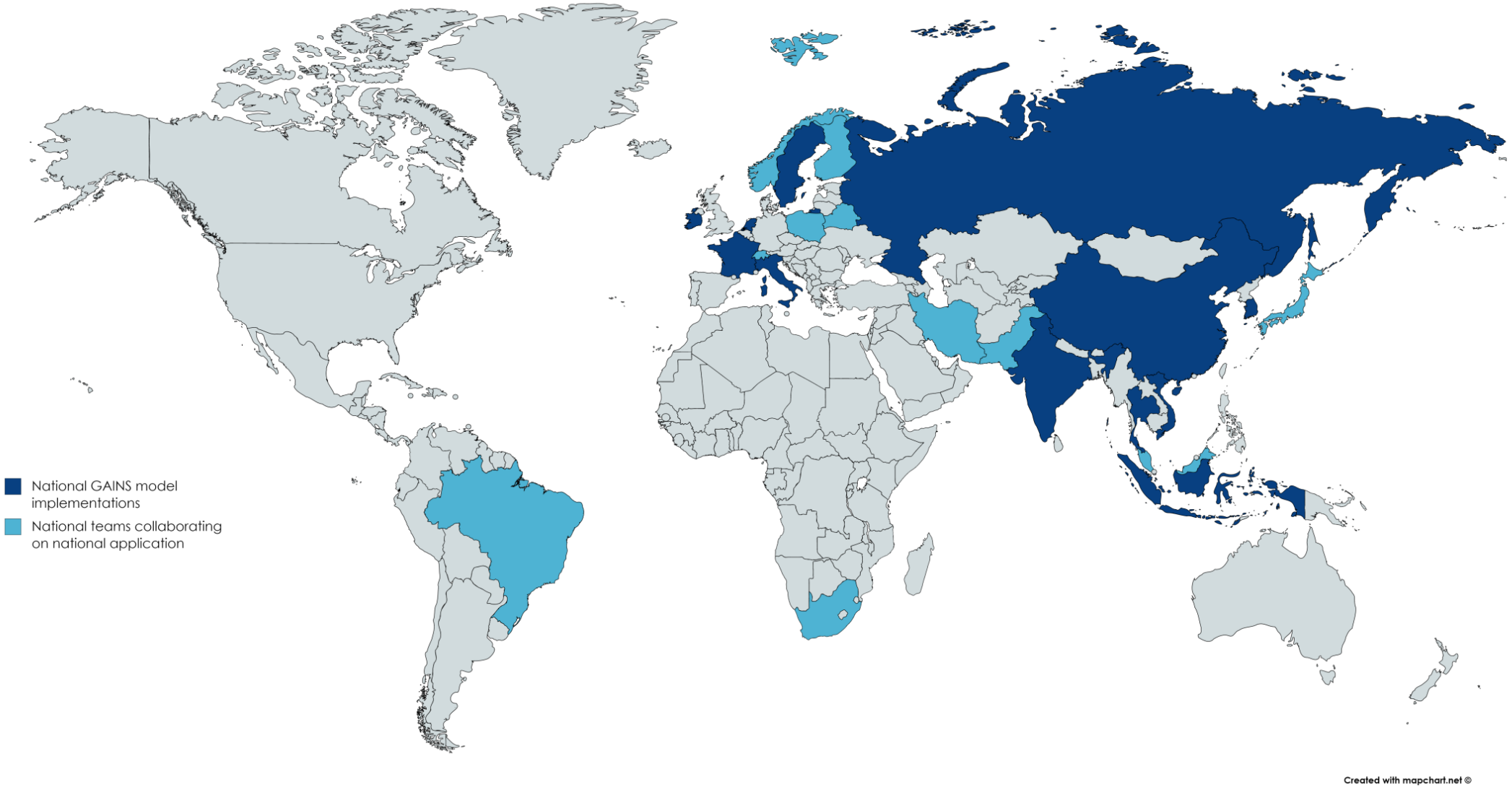
GAINS: A tool for a systematic assessment of the cost-effectiveness of emission control strategies

https://gains.iiasa.ac.at/models/index.html

- GAINS quantifies sectoral emission control potentials and costs,
  - for exogenous (governmental, international agencies) activity projections.
- Search for least-cost mix of mitigation measures to meet air quality and/or GHG targets
- GAINS has global coverage - about 180 regions (several model implementations exist):
  - Europe*, Asia (public free access) and
  - for several countries/regions, e.g., Italy, Sweden, Netherlands, Ireland, Vietnam, South Africa, Hanoi, Beijing, Guateng (SA) (access for projects partners), and
  - global (access for projects partners; sharing results with global/regional modelling community; also CEDS)

* In early 2022, the domain will be extended to include all EECCA countries

GAINS model has been also applied and further developed at the national level



GAINS also applied in several regional and global research activities: e.g., EU funded (ACCENT, CityZen, ECLIPSE), IEA, UNEP/CCAC, GEA, RCP8.5, EMF, SSPs; CEDS

The **GAINS** multi-pollutant/multi-effect framework

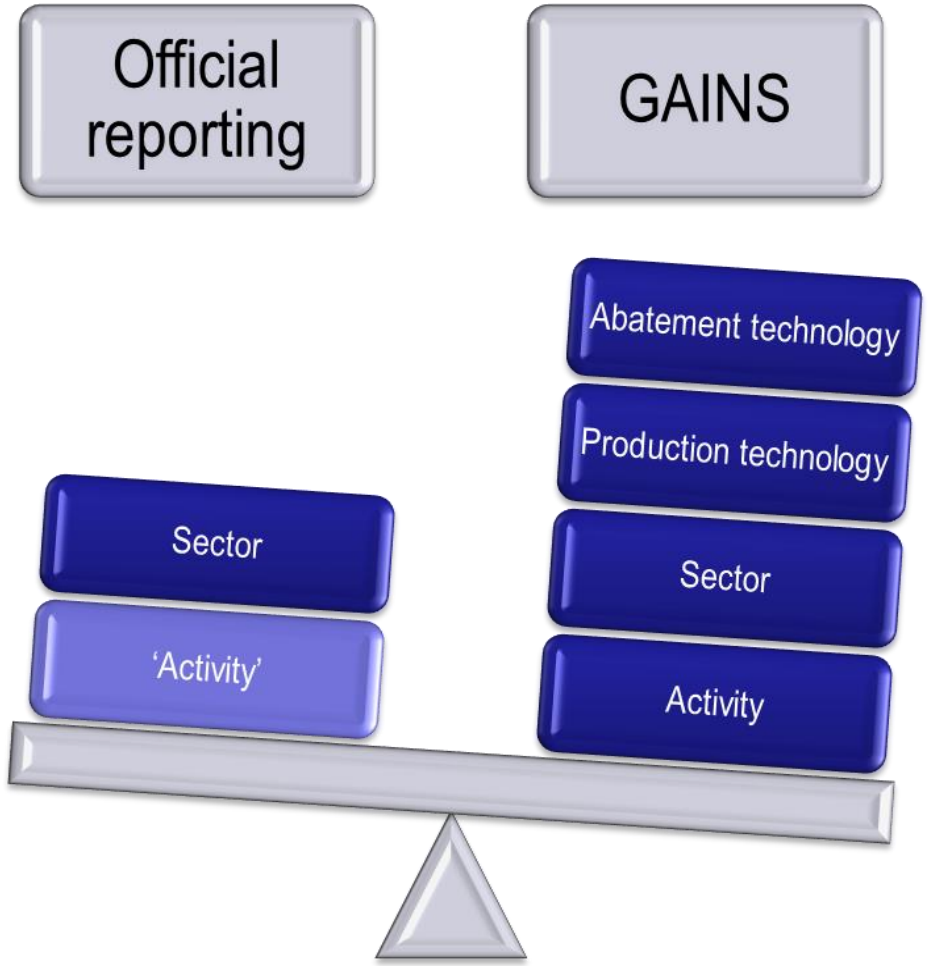
(**G**reenhouse gas and **A**ir pollution **IN**teractions and **S**ynergies)

	PM* (BC, OC)	SO_2	NO_x	VOC	NH_3	CO	CO_2	CH_4	N_2O	HFCs PFCs SF_6
Health impacts: PM (Loss in life expectancy)	√	√	√	√	√					
O_3 (Premature mortality)			√	√		√		√		
Vegetation damage: O_3			√	√		√		√		
Acidification		√	√		√					
Eutrophication			√		√					
Climate impacts: Long-term							+	+	+	+
Near-term forcing	+/-	-	+/-	+	-	+				

* Includes PM2.5, PM10 as well as PM1, TSP; particle number calculation and Hg will be revised in 2023

GAINS model and emission inventories

- GAINS is not an emission inventory model
- We are not reviewing the inventories but use them (and other sources) to validate GAINS estimates; this might also lead to questioning assumptions behind inventories
  - We try to understand and reproduce the inventory (within GAINS source and regional resolution)
  - More and more effort to compare the results of GAINS with ambient measurements to 'validate' the results/assumptions
- GAINS requires often more data than Tier1/2 inventories;



* 'Official reporting' is referring to the high level Tier1/2 submitted/reported inventories

Calculating emissions

Over a 1000 'fuel-technology-emission reduction technology' options when accounting for all pollutants

$$E_i = \sum_{j,k,m} E_{i,j,k,m} = \sum_{j,k,m} A_{i,j,k} ef_{i,j,k} (1 - eff_m) X_{i,j,k,m}$$

i,j,k,m	Country, sector, fuel, abatement technology
E_i	Emissions in country *i*
A	Activity in a given sector
Ef	"Raw gas" emission factor
eff_m	Reduction efficiency of the abatement option *m*
X_m	Implementation rate of the considered abatement measure *m*

Key elements of the emission calculation

- **Activity data [A]** – originates from international (e.g., IEA, FAO, Eurostat, IRF, USGS, etc.), national statistics, local studies, modelling work
- **Emission factors [ef]** (region-specific) originate from peer-reviewed studies, measurement campaigns (some are calculated within the model dependent of data/assumptions about e.g., sulfur, ash content, retention of S in ash, productivity, climatic conditions, etc.)
- **Control measures efficiency [eff]** – real-life performance assessment included where possible, multipollutant aspects (including trade-offs) considered explicitly.
- **Technology application rates [X]** – own interpretation of policy, regional and local assessments, stakeholder consultations, etc.

Source structure (simplified key categories)

- **Several fuels/activities** – coal (5), oil (2), gas, biomass, renewables, electricity, nuclear, steel, aluminum, non-ferrous metals, cement, glass, refining, fertilizers, livestock (>10), waste (>5), paints, etc.

- **Sectors** – power plants (7), industry (boilers and furnaces but also >25 solvent use sectors), fossil fuel production and distribution, residential combustion (several categories for cooking and heating), brick production (several production processes), transport (several categories for road and non-road; high emitters treated explicitly), enteric fermentation, rice production, waste treatment (solid waste and waste water), refrigeration, air conditioning, etc.

- **Control measures** – various desulphurization measures, combustion modification, catalytic and non-catalytic controls, cyclones, ESP and fabric filters, improved stoves, pellet stoves/boilers, EURO stages, solvent substitution, manure storage options, efficient manure application, improved waste management and recycling, etc.

Sour es)

- **Sever** , nuclear, steel, alumin waste (>5), paints,
- **Sector** use sectors), fossil f for cooking and heating gories for road and no on, waste treatm
- **Contr** on, catalytic and nc t stoves/ nt manure applica

Table 2. Residential–commercial sector fuel and source structure in GAINS. The cross indicates the combinations defined in the GAINS model.

Fuels	Non-specific		Three-stone	Fireplace	Stove*	Household boiler		Medium boiler	
		Lighting				Manual	Auto	Manual	Auto
Gaseous fuels	×								
Liquid fuels	×	×							
Charcoal	×								
Coal					×	×	×	×	×
Biomass									
- Fuelwood			×	×	×	×	×	×	×
- Agricultural residue			×		×		×		×
- Dung cake			×		×				

* Distinguishing cooking and heating stoves as separate categories.

Table 3. Mitigation measures distinguished in the residential–commercial sector in GAINS.

Control option	Non-specific		Three-stone	Fireplace	Stove		Household boiler		Medium boiler	
		Lighting			Cooking	Heating	Manual	Auto	Manual	Auto
Improved	×			×	×	×	×			
New				×	×	×	×			
Fan stove					×					
Coal briquettes					×	×				
Hurricane lamp		×								
LED[a] lamp		×								
Pellets						×	×	×	×	×
Cyclone									×	×
ESP[b]						×	×	×		×

[a] Light-emitting diode. [b] Electrostatic precipitator.

GAINS is a collaborative effort

Data needs	Initial IIASA version (international data)	Improved with input from national experts
Base year & projections of economic activities	Data already implemented in GAINS (IEA, FAO, UN, IPCC, etc.)	National data and projections
Emission factors	Current GAINS database (peer reviewed and grey literature)	Refinements based on local measurements
Emission controls; efficiencies, costs	Current GAINS database (peer reviewed and grey literature)	Refinement based on national information
Current/maximum application of emission controls	Current GAINS databases, including published info about legislation	Local information
Atmospheric dispersion	GAINS modelling based on global & regional atmospheric dispersion model	Local fine scale model utilizing local monitoring campaigns; updated with findings from monitoring and source apportionment studies (if available)
Health impacts	Global WHO methodology	Local health statistics

Current status (1) https://gains.iiasa.ac.at/models/index.html

- Current release 4.01
- Modelling period
  - 1990 – 2015 (historical data in five-year intervals)
  - 2008, 2009, 2014, 2016 developed available globally and 2018 for some regions
  - 2020 – 2050 (projections in five-year intervals)
- More detailed info and publications can be found at
  - https://gains.iiasa.ac.at/models/gains_resources.html
- Selected documentation papers
  - Amann et al (2011) https://doi.org/10.1016/j.envsoft.2011.07.012
  - Klimont et al (2017) https://www.atmos-chem-phys.net/17/8681/2017/acp-17-8681-2017.html
  - Gomez-Sanabria et al (2018) https://adgeo.copernicus.org/articles/45/105/2018/
  - Hoglund-Isaksson et al (2020) https://iopscience.iop.org/article/10.1088/2515-7620/ab7457

Current status (2) https://gains.iiasa.ac.at/models/index.html

- Uncertainty in model parameters is not explicitly included in the model
  - Few assessments in the past for European model application
  - Dedicated studies jointly with atmospheric modelling and remote sensing community evaluating results

- Gaps, ongoing and potential extensions
  - Condensables
  - Further improvements for solid waste management – electronic waste
  - NMVOC speciation
  - Temporal distribution (currently annual with few sectors (e.g. residential heating) where regional (grid) specific patterns developed)
  - Second-hand vehicles trade and performance
  - Focus on some regions that have had less data or difficult access to data (Central Asia, Africa, parts of Latin America)
  - Spatial gridding – moving to 0.1 x 0.1 degree globally for all species
  - …