GAINS release notes

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Release 4.1.1: 24 August 2026

Structural changes (interface version independent)

- The representation of liquid-manure livestock activities has been extended to distinguish between different farm-size classes. Dairy cattle (DL), other cattle (OL), pigs (PL), laying hens (LH) and poultry (OP) can now be represented in five farm-size categories, ranging from small to large farms. Solid-manure livestock activities are not affected by this farm-size differentiation.
  This new structure allows GAINS to account for differences in the applicability, costs and emission characteristics of mitigation technologies across farm sizes. Farm-size shares can vary by country and over time, providing a more detailed representation of structural changes in the agricultural sector.The update introduces the structural framework required for farm-size-specific emission factors, technology application rates and mitigation costs. Existing scenarios remain compatible with the new structure.

- New technology: manure acidification
  Manure acidification has been introduced as a new option for reducing ammonia (NH_3) emissions from livestock manure management. The new technology is integrated into the agricultural mitigation structure and can be represented in combination with the new farm-size classes.

Interface specific changes

- Europe and Scenario Explorer:
  - Health impacts from PM2.5: The calculation of Years of Life Lost (YLLs) has been updated. Now remaining life expectancy is used from UN World Population Prospects 2024 (previously WPP2017). The calculations are done by single-year age steps now, avoiding the 5-year average calculation used previously.

Release 4.1.0: 25 June 2026

Structural changes (interface version independent)

- Hydrogen Structure Update (H_2)
  This release introduces a major structural update of the representation of hydrogen both as a fuel and as a pollutant in GAINS. The update expands the coverage of hydrogen production, transport and distribution, and end-use sectors including industry, power generation, buildings, and transport.

  Hydrogen is now explicitly represented as an emitted pollutant (H2), including fugitive and combustion-related emissions. To avoid confusion with the emitted pollutant, the previous hydrogen fuel category H2 no longer exists in GAINS. and has been replaced by separate representations for pure hydrogen (H2_PURE) and hydrogen blended with methane (H2_CH4_BLEND). In the existing activity pathways and emission vectors, activity H2 has been replaced by H2_PURE, so that all related emissions (NOx) are unchanged.

  For a detailed description of the methodology, assumptions, and implementation, please refer to the **Hydrogen Structure Update Documentation** and the accompanying scientific publication.

  Note that at this point in time, the update only provides the new structure. Public scenarios which use the new elements and allow users to calculate H2 emissions will be made available in due course.

- Gas distribution networks:
  To improve the representation of CH4 leakage rates from gas distribution networks of different materials (i.e., cast iron, steel, PE/PVC, other), the following split into different network material types has been introduced:
  New network types, represented as activities:
  BIOG_CAST_IRON
  BIOG_STEEL
  BIOG_PE_PVC
  BIOG_OTHER
  GAS_CAST_IRON
  GAS_STEEL
  GAS_PE_PVC
  GAS_OTHER
  For domestic (DOM) and transport (TRA_F_CH4) sectors, and aggerated industry (IN) and power (PP) sectors.
- The above change also means that fugitive CH4 emissions from gas distribution networks are now reported separately from CH4 end-use (i.e., combustion) emissions.
  (Outdated activity-sector combinations: GAS – DOM, GAS – TRA_F_CH4, GAS – CON_LOSS)

Interface specific changes

Updates have been made to the Air quality & impacts menus in the following interface versions:

- Europe and Scenario Explorer:
  - Health impacts from PM2.5:
    - The concentration-response function has been updated to follow the recommendations of the HRAPIE-2 assessment by WHO, using the relative risk from Orellano et al (2024), RR=1.095 per 10µgm^{-3} (previously RR=1.08 per 10µgm^{-3} from Chen and Hoek, 2020). Consequently, estimated numbers of premature deaths have increased over previous versions.
    - Population and baseline mortality data has been updated to UN World Population Prospects 2024 (Medium Variant). Since a full life table has not (yet) been available, remaining life expectancy estimates by age groups and for all scenario years, used in the YLL calculation, are still from UN World Population Prospects 2017 as before.
    - The base year for impacts calculated with static demography has been changed from 2010 to 2015, in line with choices made for the ongoing revision process of the UN Air Convention Gothenburg Protocol.
  - Exceedance of empirical critical loads for nitrogen deposition has been added as an ecosystems related impact indicator. The output table is structured like the one for steady state modelled critical loads for eutrophication (CLnutN): Area exceeded as well as AAE are calculated for the aggregated land use classes forests, freshwater, and semi-natural ecosystems. The whole EMEP domain is covered by the receptor map provided by the Coordination Center for Effecs (CCE) under the UN Air Convention along with the critical load data. The lower end of the critical load range is used, consistent with the choice made for the ongoing revision process of the Gothenburg Protocol where AAE is being used as an indicator for risk to biodiversity.
- South Asia:
  - PM2.5 maps and health impact calculations have been updated to now use atmospheric transfer coefficients consistent with the World Bank Flagship Report "Striving for Clean Air: Air Pollution and Public Health in South Asia". These contain a better representation of sector-specific emission changes. Previously, these transfer coefficients were only used in the IGP interface, while the South Asia interface used the global GAINS transfer coefficients. With the update, both interfaces are consistent. With this update, also the natural dust layer has been revised in both interfaces so that now the natural dust estimated by the EMEP CTM is used throughout the domain (previously, satellite derived dust was used west of India). This change affects only Pakistan and Afghanistan. Due to the higher complexity, calculation time is substantially longer with the new transfer coefficients. The effect of this update can be seen by comparing with calculations in the Asia interface which is still based on the global GAINS transfer coefficients.
  - "Blame matrices" have been made available, quantifying the contributions to population-weighted mean ambient PM2.5 in receptor regions from different source regions. Receptors are listed as rows, sources as columns. Three different menus are available, depending on the receptor domain:
    - For the states in the Indo-Gangetic Plain (IGP), the menu "PM2.5 blame matrix: IGP regions" provides a region-to-region matrix of contributions. This is the same menu available in the IGP interface.

- For GAINS regions in India, the menu “PM2.5 blame matrix: Indian receptor regions” calculates contributions by aggregated source categories: same GAINS region (~state), all neighbouring GAINS regions (~states) in India, rest of India, other countries, international shipping, natural background.
- For South Asian regions outside India, the menu “PM2.5 blame matrix: Other receptor regions” calculates contributions to individual GAINS regions from whole countries.

Release 4.03; October 2023

Structural changes (interface version independent)

- High emitters (non-compliant vehicles) have been added as separate categories for diesel (MD) and gasoline (GSL) powered vehicles. Such vehicles are described as vehicle numbers in new activity classes GSL_NV_HE and MD_NV_HE which are derived by applying shares of non-compliant vehicles to the total number of vehicles GSL_NV and MD_NV. A control technology VEH_IM (vehicle inspection and maintenance) has been introduced which eliminates the additional emissions. Details are described in a separate document *Highemitter_formulation_GAINS_v4_03.pdf*.

Interface dependent changes

- Major updates to the GAINS-Europe interface with the extension of the regional domain and new atmospheric transfer coefficients. These have been generated from full year perturbation simulations of the EMEP CTM run at a resolution of 0.3°×0.2° (~22x22km) on the extended EMEP domain. All precursors of PM were reduced individually for each source region (country) by 15%, while NOX emissions were split by soil NOX and all other NOX. The pollutant-specific transfer coefficients have been combined with grid-to-grid tracking of PPM emissions from different release heights for a receptor grid with 0.1°×0.1° (~8 × 11km) resolution to create sector specific transfer coefficients for PPM, SO2 and NOx. For PPM emissions from domestic combustion and road traffic, a local increment based on the uEMEP model run at 100m resolution is included.
- The concentration-response function for PM2.5 has been updated to the systematic review for the WHO 2021 Guidelines, Huangfu & Atkinson (2020).
- Years of life lost (YLLs) have been redefined to show now the annual years of life lost calculated as the age-specific number of premature deaths multiplied with the remaining life expectancy at this age, not integrated over lifetime exposure for the whole population of 2010 as shown in the YOLLs before. YOLLs as calculated in the previous GAINS-Europe definition can be reproduced by multiplying the loss of life expectancy, converted to years, with the population of 2010 as given in a separate column.
- The concentration-response function for O3 (short-term exposure based on the SOMO35 indicator) has been updated to the systematic review for the WHO 2021 Guidelines for short-term exposure to ozone, Orellano et al (2020).

- Archive versions of the main impact calculation menus (PM2.5 health impacts, O3 health impacts, eutrophication and acidification for all ecosystems) using the previous calculations based on GAINS-2012 transfer coefficients and HRAPIE concentration-response functions are available in a separate block of menus below the current impact menus. The last major assessment in which they were used was the EU Clean Air Outlook 2, hence the menus are referred to as CAO2 Archive. For maps, the previous calculation can be selected in the pulldown for the map domain ("28km – CAO2 Archive").
- The GAINS-Europe model now includes the Central Asian countries Turkmenistan (TKME_WHOL), Uzbekistan (UZBE_WHOL), Tajikistan (TAJI_WHOL), Kyrgyzstan (KYRG_WHOL), and Kazakhstan (KAZA_WHOL) and thus covers the European part of the UNECE region.
- Updates to the calculation of PM2.5 health impacts in South Asia, East Asia, Asia, and Global interface: The updated calculation uses GBD2019 concentration-response functions (MR-BRTs) for six causes of death, adding type 2 diabetes to the previous list.

A new version of the ECLIPSE v6 CLE_base scenario (ID: ECLIPSE_V6f) is available which includes the latest structural updates, the latest version of emission vectors and the latest control strategies globally. Note that the activity pathways used in this scenario remain the same as for ECLIPSE v6b, except for the extension to high emitter vehicles.

Release 4.02; June 2022

This release includes the following major updates:

.) Extension of VOC (Volatile Organic Compound) emissions from Agriculture Sources such as:

Animals (Dairy cows, Buffalos, Camels, Horses, Pigs, Other cattle, other poultry, Hens, Sheep, and goats)

Grassland

.) Regional split of the region Former Soviet Union (FSUA_WHOL) into

.) Tajikistan (TAJI_WHOL)

.) Turkmenistan (TKME_WHOL

.) Uzbekistan (UZBE_WHOL)

Release 4.01; September 2021

This is a major update of the model structure as well as elements of interface. It is a result of many strands of development that have taken place since the last version of GAINS that was made public in 2018. The principal features of the online model remain like before and the changes may not be obvious at first sight. Nonetheless, they will affect and, as we believe, improve the work of many users. This release addresses topics of growing

importance such as the urban/rural distinction of activities and respective emissions from residential combustion and municipal waste management (including a much more detailed representation of the waste sector), non-compliant vehicles ("high emitters") as well as explicit representation of international shipping and forest fires scenarios for use in impact assessment.

This is also the first release which is officially numbered. Internally, the existing previous interface version was known as version 3, therefore the numbering starts with 4.01. From now on, the versioning system will distinguish

- major updates which also change the design and functionality of the online model interface (i.e. all regional interfaces) as integer number corresponding to the online interface *version*,
- minor updates of functionality, bug fixes, etc., as *releases* within the same online model version, and might affect only individual regional interfaces.

Release 4.01 is the first release using online interfaces version 4.

Three categories of updates can be distinguished:

- Sectoral structure updated - valid for all regional interfaces. These are described in Section 1 below.
- Regional interface dependent updates are described in Section 2. These concerns mostly the impact calculations, changes in the region structure in GAINS-Europe, and map display/export features.
- Display features – see Section 2. These concern primarily higher spatial resolution of maps than before (0.1° outside Europe). The display can be switched between raster and smoothed contours, and every map can be exported in vector and GIS formats like GeoTIFF.

Available scenarios:
Release 4.01 includes a set of scenarios which have been recently published by IIASA's Pollution Management group (e.g., EU Clean Air Outlook 2, ECLIPSE V6b) which can be used as a starting point for creating user defined scenarios.

Scenarios from previous versions:
Per default, **existing user defined scenarios are not ported** to GAINS version 4 due to the structural changes described below. The previous GAINS interfaces will remain active and accessible for the time being, but no further development is planned and only limited support can be provided by the IIASA team.

We understand that users may be interested to continue working with their existing scenarios in the new interface and make use of the enhanced capabilities of the new GAINS version. Depending on the age of the scenario (in particular, the emission vector used), this may be possible, but needs to be

assessed on a case-by-case basis. Please get in touch with the developers' team (gains.dev@iiasa.ac.at) if you would like to have scenarios converted. We will try to provide assistance for a limited number of cases. Please note, however, that due to the structural changes the previous results will not be reproduced exactly in GAINS$_4$. Note that if your scenarios were developed based on ECLIPSE V4/5 in GAINS-3, we recommend you to directly create new scenarios in GAINS4 based on the available default scenarios rather than convert your scenarios into GAINS4, since ECLIPSE v4/5 are outdated.

1. Structural updates (interface independent)

Topic	**Previous implementation**	**Implementation in the current version of GAINS**
Model Release 4.01		
Municipal solid waste (MSW_xxx)	One sector: WASTE_RES (residential waste)	Multiple sectors specifying waste type and urban/rural residence: MSW_URB_[type] and MSW_RUR_[type] With [type] being: TEX: Textiles PAP: Paper PLA: Plastics WOOD: Wood FOOD: Food MET: Metals GLA: Glass OTH: Other Activity is specified in million tons of waste generated annually. Control options have been extended to include a wide range of different treatment of collected and uncollected waste. Calculations of air pollution and methane emissions have been harmonized.
Residential combustion (DOM_xx)	**Activity**: total DOM sector activity split into import sectors:	**Activity**: Urban-rural split introduced in residential combustion: total DOM activity is distributed into import sectors

	DOM_RES (residential), DOM_COM (commercial), DOM_OTH (other). **Control strategy and emission factors** are specified at the level of sectors like: DOM_STOVE_C, DOM_STOVE_H,… **Sub-structure for activity** splits into cooking and heating stoves for solid fuels: DOM_RES_STOVE_C, DOM_RES_STOVE_H, DOM_COM_STOVE_C, DOM_COM_STOVE_H, DOM_OTH_STOVE_C, DOM_OTH_STOVE_H	DOM_URB, DOM_RUR, DOM_COM, DOM_OTH (Note: DOM_RES=DOM_URB+DOM_RUR does not exist as a separate sector anymore). By default, "urban" and "rural" correspond to UN World Urbanization Prospects 2018 (downscaled to GAINS regions). **Control strategy and emission factors** are specified at the level of sectors as before: DOM_STOVE_C, DOM_STOVE_H,… **Sub-structure for activity** splits into cooking (C) and heating (H) stoves for solid fuels: DOM_URB_STOVE_C, DOM_URB_STOVE_H, DOM_RUR_STOVE_C, DOM_RUR_STOVE_H, DOM_COM_STOVE_C, DOM_COM_STOVE_H, DOM_OTH_STOVE_C, DOM_OTH_STOVE_H
High emitting vehicles	Not included in the online model. Included in gridded global emission products for the atmospheric modelling community, such as the ECLIPSE data sets.	Included in the online model as an approximation to the calculations done for the gridded emission products. New activity classes: MD_NV_HE: non-complying diesel vehicles GSL_NV_HE: non-complying gasoline vehicles The activity is derived from total numbers of vehicles driving with these fuels (MD_NV, GSL_NV) through shares of non-compliant vehicles. Corresponding emission factors are calculated in the emission vector initialization as average over the control technologies applied in a selected representative scenario.
International shipping	In GAINS-Europe domain: Emission-only scenarios for 11 sea regions.	In GAINS-Europe domain: Emission-only scenarios for 13 sea regions as described in Cofala et al. (2018)

	Outside GAINS-Europe: not included in the online model; included in gridded global emission products for the atmospheric modelling community, such as the ECLIPSE data sets.	Outside GAINS-Europe: We included International Shipping as a new element in the scenario meta data (previously "Scenario description") affecting only ambient $PM_{2.5}$ concentrations outside the European domain. Different pre-set storylines can be chosen. A default is allocated to any new scenario.
Forest fires	Included in the natural contributions to ambient PM2.5, constant over time.	Included in the natural contributions to ambient PM2.5. Variable over time, following pre-set storylines which can be selected in the scenario metadata (previously "Scenario description"). A default storyline is allocated to any new scenario.
Cost calculation	All costs specified in Euros 2005. Fixed storyline for wages and energy prices.	All costs specified in Euros 2015. A storyline on wages and fuel prices can be selected in the scenario metadata (previously "Scenario description"). Available storylines are: .) dynamic prices for 2025 .) constant prices based on WEO 2009 .) dynamic prices based on WEO 2009

2. Interface specific changes

Topic	**Interface version**	**Previous implementation**	**Implementation in current version of GAINS**
Model release 4.01			
Model regions	Europe	• 41 regions	• 45 regions

		• Serbia, Montenegro and Kosovo combined as one region SEMO_WHOL.	• SEMO_WHOL split into Serbia (SERB_WHOL), Montenegro (MONT_WHOL), Kosovo (KOSO_WHOL) • Georgia (GEOR_WHOL), Armenia (ARME_WHOL), Azerbaijan (AZER_WHOL) added as model regions
	Global (not public)	• 174 regions • United States: one region (USAM_WHOL) • Africa: only Egypt (EGYP_WHOL), Northern Africa (NAFR_WHOL), South Africa (SAFR_WHOL), and Other Africa (OAFR_WHOL)	• 180 regions, including those in the public interfaces for Europe (changes see above) and Asia. • United States have been split into Mainland (including Hawaii) USAM_MAIN and Alaska USAM_ALAS • Africa has been split into nine regions: Egypt (EGYP_WHOL), South Africa (SAFR_WHOL), Nigeria (NIGE_WHOL), Tanzania (TANZ_WHOL), Kenya (KENY_WHOL), Northern Africa (NAFR_WHOL), Western Africa (WAFR_WHOL), Eastern Africa (EAFR_WHOL), Remaining Southern Africa (RSAF_WHOL). Sudan has been moved from NAFR_WHOL to EAFR_WHOL.
Ambient PM and impact calculations	Europe	• Atmospheric transfer coefficients based on EMEP CTM (~28km resolution) with downscaling to 7km based on CHIMERE CTM. • Life expectancy loss calculated based on life table of UN World Population Prospects 2010 • Premature deaths calculated for 2010 population	• Transfer coefficients (same methodology) extended to include the new regions and updated sea regions. • Life table used for life expectancy loss can be switched between UN World Population Prospects 2010 and 2017 editions. • Premature deaths can be calculated for 2010 population (“static”) and scenario year dependent population.

	East Asia, South Asia	• Atmospheric transfer coefficients based on TM5 CTM (1° resolution) • Life expectancy loss calculated using linear dose-response function	• Atmospheric transfer coefficients based on EMEP CTM (0.5° resolution / 0.1° for low-level sources) • Premature deaths attributable to ambient PM2.5 calculated using integrated exposure-response relationships (IERs) from Global Burden of Disease 2013 / WHO (2016)
	Asia	• Atmospheric transfer coefficients based on EMEP CTM (0.5° resolution), downscaling to urban polygons for low-level primary PM emission sources. • Ambient PM2.5 maps at 0.5° resolution. • No health impact calculations.	• Atmospheric transfer coefficients based on EMEP CTM (0.5° resolution / 0.1° for low-level sources) • Ambient PM2.5 maps at 0.1° resolution. • Premature deaths attributable to ambient PM2.5 calculated using integrated exposure-response relationships (IERs) from Global Burden of Disease 2013 / WHO (2016).