MIDAS includes the descriptions of models in use by the Commission in support to the policy cycle. MIDAS is developed and managed by the **Competence Centre on Modelling** of the European Commission.

Find out more at https://knowledge4policy.ec.europa.eu/modelling/about_en
Contact: EU-MIDAS@ec.europa.eu

Factsheet

SWD/2021/611 final

IMPACT ASSESSMENT REPORT Accompanying the document REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement

Supporting model(s)

GAINS, PRIMES

Document based on Ares(2021)4205265

Impact assessment
SWD/2021/611 final

Fact sheet on model contributions

Source: Commission modelling inventory and knowledge management system (MIDAS)

Date of Report Generation: 02/09/2021

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Overview

Title
IMPACT ASSESSMENT REPORT Accompanying the document REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement

Document ID
SWD/2021/611 final

Year of publication
2021

Led by
CLIMA

Model(s) used
GAINS, PRIMES

Additional information on model use for this Impact assessment

The most recent EU reference scenario [1] forms the baseline for this impact assessment. The policy scenarios are developed from the basis of the Climate Target Plan policy scenarios (SWD/2020/176 final).

[1] European Commission, EU Reference Scenario 2020: Energy, Transport ad GHG Emissions: Trends to 2050, Publications Office, Luxembourg, 2021, https://doi.org/10.2833/35750.

GAINS

Full title

Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)

Run for this impact assessment by

International Institute for Applied Systems Analysis

Contributed to

Baseline and assessment of policy options

Helped to assess the following impacts

GAINS models non-CO2 greenhouse gases for diverse sectors such as agriculture, waste, energy and industry and their associated cost for reducing emissions of non-CO2 greenhouse gases (CH4, N2O, F-gases).

PRIMES

Full title

PRIMES Energy System Model

Run for this impact assessment by

Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens

Contributed to

Baseline and assessment of policy options

Helped to assess the following impacts

The PRIMES model and its variants are used to model all aspects of the energy system, including buildings, transport and industry. Regarding greenhouse gas emissions it reports all CO2 emissions from these sectors.

GAINS

Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-Model

Fact sheet

Source: Commission modelling inventory and knowledge management system (MIDAS)

Date of Report Generation: 02/09/2021

Dissemination: Public

Overview

Acronym GAINS
Full title Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-Model

Main purpose
GAINS is an analytical framework for assessing future potentials and costs for reducing air pollution impacts on human health and the environment while simultaneously mitigating climate change through reduced greenhouse gas emissions. It explores synergies and trade-offs in cost-effective emission control strategies so as to maximize benefits across multiple scales.

Summary
The **G**reenhouse gas - **A**ir pollution **In**teractions and **S**ynergies (GAINS) model (http://gains.iiasa.ac.at/) developed by the International Institute for Applied Systems Analysis (IIASA), describes the pathways of atmospheric pollution from its anthropogenic origin to the most relevant environmental impacts (Amann et al. 2011). It brings together information on future economic, energy and agricultural development, emission control potentials and costs, atmospheric dispersion and environmental sensitivities towards air pollution. The model addresses threats to human health posed by fine particulates and ground-level ozone, risk of ecosystems damage from acidification, excess nitrogen deposition (eutrophication) and exposure to elevated levels of ozone, as well as various global and regional climate metrics to calculate warming potential or temperature change. The assessed impacts are considered in a multi-pollutant context, quantifying the contributions of sulphur dioxide (SO2), nitrogen oxides (NOx), ammonia (NH3), non-methane volatile organic compounds (VOCs), primary emissions of particulate matter (PM2.5, PM10), carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), fluorinated gases (HFCs, PFCs and SF6), and black and organic carbon (BC, OC).

The GAINS model can explore cost-effective strategies to reduce emissions of air pollutants and greenhouse gases in order to meet specified environmental targets. It also assesses how specific control measures simultaneously influence different pollutants, permitting a combined analysis of air pollution and climate change mitigation strategies, which can reveal important synergies and trade-offs between these policy areas. The optimization mode of the GAINS model balances emission control measures across countries, pollutants and economic sectors such that user-defined target levels on various environmental impacts are met at least costs.

The GAINS model framework has global coverage with a geographic representation of 180 countries/regions and spanning the period 1990 to 2050 in five-year intervals with extension to 2070 for the European region. The estimation of emissions is combining activity data with emission factors describing alternative sets of pollutant reduction technologies. The emphasis lies on a rich representation of more than a thousand emission source sectors with associated alternative sets of abatement technologies. This allows for identification and quantification of emission sources, exposure levels, and mitigation potentials at a policy relevant level, e.g., by region (EU, country, sub-national, city level), by sector (industry, residential, transport, agriculture), by farm size, by urban/rural contribution. Atmospheric dispersion processes are modeled using a source-receptor methodology that linearly

approximates results of full chemical transport models. Critical load information (characterizing ecosystem sensitivities) are often compiled exogenously and incorporated into the GAINS model framework.

The model can be operated in the 'scenario analysis' mode, i.e., following the pathways of the emissions from their sources to their impacts. In this case the model provides estimates of regional costs and environmental benefits of alternative emission control strategies. The Model can also operate in the 'optimization mode', which identifies cost-optimal allocations of emission reductions in order to achieve specified deposition levels, concentration targets, or GHG emissions ceilings. The current version of the model can be used for viewing activity levels and emission control strategies, as well as calculating emissions and control costs for those strategies.

GAINS is frequently used to provide model input for air pollution and climate policy formulation. For example, GAINS has been used for policy analyses by the European Commission for the EU Reference Scenario (Energy, transport and GHG emissions: trends to 2070) and for the EU Thematic Strategy on Air Pollution and the air policy review (e.g., Amann et al., 2016, 2018; EC, 2019).

Keywords
Air Pollution , climate change , emissions , air pollutant emissions

Model category (thematic)
Climate

Model home page
https://iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html

Ownership & license

Ownership
Sole ownership [3rd party]

Ownership details
International Institute for Applied Systems Analysis (IIASA)

Licence type
Non-Free Software licence. The license has one or more of the following restrictions: it prohibits creation of derivative works; it prohibits commercial use; it obliges to share the licensed or derivative works on the same conditions.

Details

GAINS structure and approach
No information provided

Input and parametrization
GAINS uses externally produced activity scenarios for the macroeconomic, energy sector and agricultural sector developments. These are imported through links to partial equilibrium models, e.g., PRIMES for energy sector developments in Europe, CAPRI for developments in agricultural activity (livestock numbers and fertilizer use) in Europe, and the IEA-WEO and FAO for global energy and agricultural sector scenarios, respectively. In consistency with respective macroeconomic developments, GAINS generates internally projections for waste generation, relevant industry production, and consumption of F-gases. Technology-specific emission factors and cost parameters are developed internally in GAINS through information from literature and from direct dialogues and iterative consultations with stakeholders.

Main output
GAINS estimates emissions, mitigation potentials and costs for the major air pollutants (SO2, NOx, PM, NH3, VOC, BC/OC) and for the six greenhouse gases included in the Kyoto Protocol.

Outputs include emissions, impacts and costs of alternative policy configurations, prescribed or identified as cost-effective.

Spatial - temporal extent
The output has the following spatial-temporal resolution and extent:

Parameter	Description
Spatial Extent / Country Coverage	GAINS has global coverage, distinguishing 180 regions including 48 European countries and 46 provinces/states in China and India.
(Spatial) resolution	Depends on the indicator. Grid resolution for calculating ambient PM2.5 in Europe: 0.125^{o} (longitude) x 0.0625^{o} (latitude), approx. 7x7km. Different resolution in the global domain outside Europe.
Temporal extent	1990 to 2050 with extension to 2070 for the European region
Temporal resolution	Five years intervals

Quality & transparency

Quality

Question	Answer	Details
Models are by definition affected by uncertainties (in input data, input parameters, scenario definitions, etc.). Have the model uncertainties been quantified? Are uncertainties accounted for in your simulations?	yes	Uncertainty is in GAINS handled through: - The use of alternative activity data scenarios reflecting a range of macroeconomic, energy and agricultural sector developments - Extension of sector/technology model resolution to reflect policy relevant implications of e.g., scale, urban/rural differences, etc. on emission factors and costs - Consideration of a wealth of country-specific factors and circumstances in the derivation of emission factors, cost parameters, and emission control strategies.
Sensitivity analysis helps identifying the uncertain inputs mostly responsible for the uncertainty in the model responses. Has the model undergone sensitivity analysis?	yes	Sensitivity analyses are frequently performed on GAINS model results on a case-by-case basis, e.g., by the use of alternative activity data scenarios or by using ranges for emission factors and costs in simulations.
Has the model undergone external peer review by a panel of experts, or have results been published in peer-reviewed journals?	yes	GAINS model results have been presented in numerous peer-reviewed publications and has been evaluated by an external expert panel on a few occasions as part of regular IIASA program reviews.
Has model validation been done? Have model predictions been confronted with observed data (ex-post)?	yes	Modelled ambient PM concentrations at (urban or rural) background level have been validated against observations, see Kiesewetter et al (2015a,b) and Amann, M., Kiesewetter, G., Schoepp, W., Klimont, Z., Winiwarter, W. et al., 2020. Reducing global air pollution: The scope for further policy interventions. Phil. Trns. R. Soc. A. (In press). GAINS bottom-up emission inventory for global methane emissions evaluated against top-down atmospheric measurements of CH4 concentration, see Höglund-Isaksson et al. (2020); Saunois et al. (2020).

References related to external peer-review and publication in scientific journals:

- Höglund-Isaksson, L., Gómez-Sanabria, A., Klimont, Z., Rafaj, P., & Schöpp, W. (2020). Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe –results from the GAINS model. Environmental Research Communications, 2(2), 025004. doi:10.1088/2515-7620/ab7457
- Kiesewetter, G., Borken-Kleefeld, J., Schöpp, W., Heyes, C., Thunis, P., Bessagnet, B., … Amann, M. (2015). Modelling street level PM₁₀ concentrations across Europe: source apportionment and possible futures. Atmospheric Chemistry and Physics, 15(3), 1539–1553. doi:10.5194/acp-15-1539-2015
- Kiesewetter, G., Schoepp, W., Heyes, C., & Amann, M. (2015). Modelling PM2.5 impact indicators in Europe: Health effects and legal compliance. Environmental Modelling & Software, 74, 201–211. doi:10.1016/j.envsoft.2015.02.022

- Saunois, M., Stavert, A. R., Poulter, B., Bousquet, P., Canadell, J. G., Jackson, R. B., … Patra, P. K. (2020). The Global Methane Budget 2000–2017. Earth System Science Data, 12(3), 1561–1623. doi:10.5194/essd-12-1561-2020

Transparency

Question	Answer	Details
Is the model underlying database (i.e. the database the model runs are based on) publicly available?	yes	The GAINS database is publicly available and can be accessed through the GAINS website http://gains.iiasa.ac.at/models/index.html. The information supplied on the GAINS website or parts thereof may be freely used for non-commercial and educational purposes. Data from this site is for informational purposes only, and may only be used as input to other models with explicit permission of IIASA. Information from this site may be reproduced with proper acknowledgment to IIASA, Laxenburg, Austria.
Can model outputs be made publicly available?	yes	Simulation mode results can be produced within the public model framework. Optimization mode results have been made available through peer-reviewed publications.
Is the model transparently documented (including underlying data, assumptions and equations, architecture, results) and are these documents available to the general public?	yes	Amann et al. (2011): general model approach for Europe; Höglund-Isaksson et al. (2018): documentation of methodology for non-CO2 policy scenarios for EU-28, see https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/non_co2_methodology_report_en.pdf; Klimont et al (2017): documentation of methodology for PM emission calculation; Klimont and Winiwarter (2015): documentation of NH3 emission and cost calculation.
Is the model source code publicly accessible or open for inspection?	yes	Can be made available upon request

References related to documentation:

- Nguyen, T. B., Wagner, F., & Schoepp, W. (2011). GAINS – An Interactive Tool for Assessing International GHG Mitigation Regimes. Information and Communication on Technology for the Fight Against Global Warming, 124–135. doi:10.1007/978-3-642-23447-7_12
- Amann, M., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Höglund-Isaksson, L., … Winiwarter, W. (2011). Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications. Environmental Modelling & Software, 26(12), 1489–1501. doi:10.1016/j.envsoft.2011.07.012
- Klimont, Z., Kupiainen, K., Heyes, C., Purohit, P., Cofala, J., Rafaj, P., … Schöpp, W. (2017). Global anthropogenic emissions of particulate matter including black carbon. Atmospheric Chemistry and Physics, 17(14), 8681–8723. doi:10.5194/acp-17-8681-2017
- Klimont, Z., & Winiwarter, W. (2015). Estimating Costs and Potential for Reduction of Ammonia Emissions from Agriculture in the GAINS Model. Costs of Ammonia Abatement and the Climate Co-Benefits, 233–261. doi:10.1007/978-94-017-9722-1_9

The model's policy relevance and intended role in the policy cycle

The model is designed to contribute to the following policy areas

- Climate action
- Public health

The model is designed to contribute to the following phases of the policy cycle

- Formulation

The model's potential

The model is designed to contribute to the following policy areas:

- Climate action through mitigation potentials for non-CO2 GHGs and Black Carbon
- Climate action through harnessing health co-benefits
- Public health through air pollution exposure levels
- Ecosystem protection through critical loads

GAINS is used for policy analyses under the Convention on Long-range Transboundary Air Pollution (CLRTAP), e.g., for the revision of the Gothenburg Protocol, and by the European Commission for the EU Thematic Strategy on Air Pollution and the air policy review, and it was among the models used to inform the EC proposal "A Clean Planet for All" (COM (2018) 773). GAINS is used to assess domestic mitigation potential of non-CO2 GHGs for EU climate policy analyses. Scientists and government agencies in many nations (e.g., in Europe, China, India, Vietnam) use GAINS as a tool to assess emission reduction potentials in their regions.

In "scenario analysis" mode, it follows emission pathways from sources to impacts, providing estimates of regional costs and the environmental benefits of alternative emission control strategies.

In "optimization" mode, GAINS identifies cost-optimal portfolios of emission control measures for achieving specified targets, such as absolute emission limits, or health impacts.

Previous use of the model in ex-ante impact assessments of the European Commission

Use of the model in ex-ante impact assessments since July 2017.

In the Year	GAINS contributed to the Impact assessment called	Led by	By providing input to the	The model was run by	Details of the contribution
2021	Impact assessment accompanying the document Proposal for a regulation of the European Parliament and of the Council: amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement SWD/2021/611 final	CLIMA	Baseline and assessment of policy options	*International Institute for Applied Systems Analysis*	GAINS models non-CO2 greenhouse gases for diverse sectors such as agriculture, waste, energy and industry and their associated cost for reducing emissions of non-CO2 greenhouse gases (CH4, N2O, F-gases).
2021	Impact assessment accompanying the document Proposal for a Regulation of the European Parliament and the Council: amending Regulations (EU) 2018/841 as regards the scope, simplifying the compliance rules, setting out the targets of the Member States for 2030 and committing to the collective achievement of climate neutrality by 2035 in the land use, forestry and agriculture sector, and (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review SWD/2021/609 final	CLIMA	Baseline and assessment of policy options	*International Institute for Applied Systems Analysis*	GAINS was used to assess costs and mitigation potential of non-CO2 greenhouse gases in the agriculture sector.
2021	Impact assessment accompanying the document Directive of the European Parliament and of the Council: amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757 SWD/2021/601 final	CLIMA	Baseline and assessment of policy options	*International Institute for Applied Systems Analysis*	General modelling of ETS strengthening and possible extension to buildings and transport/ all fossil fuel combustion.

2020	Impact Assessment accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition SWD/2020/176 final	CLIMA	Baseline and assessment of policy options	*International Institute for Applied Systems Analysis*	GAINS models non-CO2 greenhouse gases for diverse sectors such as agriculture, waste, energy and industry and their associated cost for reducing emissions of non-CO2 greenhouse gases (CH4, N2O, F-gases).

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- *Klimont, Z., & Winiwarter, W. (2015). Estimating Costs and Potential for Reduction of Ammonia Emissions from Agriculture in the GAINS Model. Costs of Ammonia Abatement and the Climate Co-Benefits, 233–261. doi:10.1007/978-94-017-9722-1_9*

- *Kiesewetter, G., Borken-Kleefeld, J., Schöpp, W., Heyes, C., Thunis, P., Bessagnet, B., … Amann, M. (2015). Modelling street level PM₁₀ concentrations across Europe: source apportionment and possible futures. Atmospheric Chemistry and Physics, 15(3), 1539–1553. doi:10.5194/acp-15-1539-2015*

- *Kiesewetter, G., Schoepp, W., Heyes, C., & Amann, M. (2015). Modelling PM2.5 impact indicators in Europe: Health effects and legal compliance. Environmental Modelling & Software, 74, 201–211. doi:10.1016/j.envsoft.2015.02.022*

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- *Kiesewetter G, Borken-Kleefeld J, Schoepp W, Heyes C, Thunis P, Bessagnet B, Terrenoire E, Gzella A, Amann M. Modelling NO2 concentrations at the street level in the GAINS integrated assessment model: projections under current legislation. ATMOSPHERIC CHEMISTRY AND PHYSICS 14 (2); 2014. p. 813-829. JRC84253*

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- *Amann, M., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Höglund-Isaksson, L., … Winiwarter, W. (2011). Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications. Environmental Modelling & Software, 26(12), 1489–1501. doi:10.1016/j.envsoft.2011.07.012*

PRIMES

PRIMES Energy System Model

Fact sheet

Source: Commission modelling inventory and knowledge management system (MIDAS)

Date of Report Generation: 02/09/2021

Dissemination: Public

Overview

Acronym PRIMES
Full title PRIMES Energy System Model

Main purpose
Energy system model designed to project the energy demand, supply, prices, trade and emissions for European countries and assess policy impacts.

Summary
The PRIMES (Price-induced market equilibrium system) model is being developed by E3Modelling, a spin-off of the E3MLab at National Technical University of Athens (NTUA). The model is suited for medium-term and long-term (up to 2070) projections in 5-year steps and covers all EU Member States, and EFTA (except Lichtenstein) and candidate countries.

PRIMES combines micro-economic foundations of the behavioural modelling with the engineering and energy-system approach, covering all energy sectors and markets at a disaggregated level. The model determines energy prices, energy supply, energy demand, trade, emissions, costs and investment. Furthermore, the model captures the technology learning and economies of scale.

PRIMES can be used for policy analysis and impact assessment. It provides energy sectors, markets and system projections including energy system restructuring, both in the demand and supply sides. The model can support the impact assessment of specific energy, transport and environment policies and measures applied either at the Member State or EU level, including taxation, subsidies, emissions trading system, technology promoting policies, renewable energy sources policies, efficiency promoting policies, environmental policies and technology standards.

PRIMES can be linked to other models such as GAINS and GLOBIOM for a full coverage of sectors when assessing climate or environmental policies.

Keywords
emissions , energy demand , energy supply

Model category (thematic)
Energy

Model home page
https://e3modelling.com/modelling-tools/primes/

Ownership & license

Ownership
Sole ownership [3rd party]

Ownership details
E3Modelling and E3Mlab at NTUA

Licence type
Non-Free Software licence. The license has one or more of the following restrictions: it prohibits creation of derivative works; it prohibits commercial use; it obliges to share the licensed or derivative works on the same conditions.

Details

PRIMES structure and approach

The PRIMES model (Price-Induced Market Equilibrium System) is a large scale applied energy system model that provides detailed projections of energy demand, supply, prices and investment into the future, covering the entire energy system including emissions. The distinctive feature of PRIMES is the combination of behavioural modelling (following a micro-economic foundation of optimisation by agent or sector) with engineering aspects, covering all energy sectors, and with market equilibrium. The model includes a detailed representation of instruments for policy impact assessment related to energy markets, technology adoption and climate mitigation, including market drivers, standards, and targets by sector or overall. It simulates the EU Emissions Trading System in its current form (changes can be simulated). It handles multiple policy objectives, such as GHG emissions reductions, energy efficiency, and renewable energy targets, and provides pan-European simulation of internal markets for electricity and gas.

PRIMES offer the possibility of handling market distortions, barriers to rational decisions, behaviours and market coordination issues and it performs a full accounting of costs (CAPEX and OPEX) and investment in equipment, energy savings and infrastructure. The model covers the horizon up to 2070 in 5-year interval periods and includes all Member States of the EU individually, as well as neighbouring and candidate countries in Europe. PRIMES is designed to analyse complex interactions within the energy system in a multiple agent – multiple markets framework.

Decisions by agents are formulated based on microeconomic foundation (utility maximization, cost minimization influenced by market equilibrium) embedding engineering constraints and explicit representation of technologies and capital vintages; optionally perfect or imperfect foresight for the modelling of investment applies in all sectors. The model allows simulating long-term transformations/transitions and includes non-linear formulation of potentials by type (resources, sites, acceptability etc.) and technology learning.

The PRIMES model is modular and consists of several sub-models (modules), each one representing the behaviour of a specific agent, a demander or supplier of energy. Sub-models link with each other through a model integration algorithm, which determines equilibrium prices in multiple markets and equilibrium volumes, including cap and trade systems (e.g. ETS), which satisfy balancing and policy, e.g. emissions, constraints and policy targets.

Demand modules formulate a representative agent who maximises benefits (profit, utility, etc.) from the energy demand and non-energy inputs (commodities, production factors) subject to prices, budget and other constraints. Constraints relate to activity, comfort, equipment, technology, environment or the fuel availability. In the demand sub-models, the agents may be simultaneously self-producers of energy services (e.g. using a private car, heating using a residential boiler, etc.) and purchasers of marketed energy commodities. The pricing of self-supplied energy services is endogenous and reflects average total costs. The mix of self- supply and the purchasing from external suppliers (e.g. private cars

versus public transportation, residential boiler versus district heating) derives from agent's optimisation, which depends on market conditions where the agents are price-takers.

Supply modules formulate stylised companies aiming at minimising costs (or maximising profits in model variants focusing on market competition) to meet demand subject to constraints related to capacities, fuel availability, environment, system reliability, etc. Supply-side modules determine commodity and infrastructure prices by end-use sector (tariffs) by applying various methodologies by sector as appropriate for recovering costs depending on market conditions and regulations.

Both demand and supply modules are subject to system-wide constraints, mirroring overall targets for example on emissions, renewables, efficiency, import dependency, etc. When binding, constraints convey non-zero shadow prices (dual values) to the demand and supply modules. Hence, the PRIMES model has overall a mixed-complementarity mathematical structure.

Agents are price-takers when being energy demanders and price-makers when being energy suppliers. Optionally, the model can handle non-perfect market competition regimes. The electricity and gas market modules can optionally include explicit companies and apply the Nash-Cournot competition with conjectural variations. Pricing and costing includes taxes, subsidies, levies and charges, congestion fees, tariffs for use of infrastructure etc. Usually, these instruments are exogenous to the model and reflect policy assumptions.

PRIMES follows a descriptive approach concerning factors which influence decisions by private entities, where perceived costs and uncertainty factors play a significant role. Policy measures can reduce uncertainty and decrease perceived costs: such mechanism in the model is often used to simulate policy inducing higher uptake of advanced technology or investment enabling accelerated energy efficiency progress.

The capital formation derives from an economically driven investment and follows a dynamic accounting of equipment technology vintages: equipment invested on a specific date inherits the technical-economic characteristics of the technology vintage corresponding to that date. Capital turnover is dynamic and the model keeps track of capital vintages and their specific technical characteristics. The agent's investment behaviour consists in building or purchasing new energy equipment to cover new needs, or retrofitting existing equipment or even for replacing prematurely old equipment for economic reasons.

The PRIMES model is fully dynamic and has options regarding future anticipation by agents in decision-making. Usually, PRIMES assumes a perfect foresight over a short time horizon for demand sectors and an imperfect foresight over long time horizon for supply sectors. All economic decisions of agents are dynamic and concern both operation of existing equipment and investment in new equipment, both when equipment is using energy and when it is producing energy.

The PRIMES model also includes a detailed numerical model on biomass supply, namely PRIMES-Biomass, which simulates the economics of supply of biomass and waste for energy purposes through a network of current and future processes. The PRIMES-Biomass model is a key link of communication

between the energy system projections obtained by the PRIMES energy system model and the projections on agriculture, forestry and non-CO2 emissions provided by other modelling specialist tools (CAPRI, GLOBIOM/G4M, GAINS).

Computationally, PRIMES solves an EPEC problem (equilibrium problem with equilibrium constraints), which allows prices to be explicitly determined. The overall convergence algorithm simultaneously determines multi-market equilibrium while meeting system-wide constraints.

Input and parametrization

A summary of database sources, in the current version of PRIMES, is provided below:

- Eurostat and EEA: Energy Balance sheets, Energy prices (complemented by other sources, such IEA), macroeconomic and sectoral activity data (PRIMES sectors correspond to NACE 3-digit classification), population data and projections, physical activity data (complemented by other sources), CHP surveys, CO2 emission factors (sectoral and reference approaches) and EU ETS registry for allocating emissions between ETS and non ETS, Process CO2 emisssions
- Technology databases: ODYSSEE-MURE, ICARUS, Eco-design, VGB (power technology costs), TECHPOL – supply sector technologies, NEMS model database, IPPC BAT Technologies
- Power Plant Inventory: ESAP SA and PLATTS
- RES capacities, potential and availability: JRC ENSPRESO, JRC EMHIRES, RES ninja, ECN, DLR and Observer, IRENA
- Network infrastructure: ENTSOE, GIE, other operators
- Other databases: District heating surveys (e.g. from COGEN), buildings and houses statistics and surveys (various sources, including ENTRANZE project, INSPIRE archive, BPIE), JRC-IDEES, update to the EU Building stock Observatory

The model is fully calibrated to match the historical energy balance of the last PRIMES historical year (5-year step modelling: historical points years are 2000, 2005, 2010, 2015, ..) and to capture the more recent evolution since that year.

Main output

The PRIMES model provides, per country represented and for the EU as a whole detailed and comprehensive energy balances of the energy system, related CO2 emissions and detailed economic information associated to the energy system (investments, costs, prices, taxes, ..).

In association with the GAINS model and the GLOBIOM model, it provides comprehensive GHG balances per country represented and for the EU as a whole.

Spatial - temporal extent

The output has the following spatial-temporal resolution and extent:

Parameter	Description
Spatial Extent / Country Coverage	EU Member States plus United Kingdom, Norway, Switzerland, Iceland, Albania, Serbia, Montenegro, Kosovo, Bosnia-Herzegovina, FYROM and Turkey.
(Spatial) resolution	Country level
Temporal extent	Until 2070
Temporal resolution	5 yearly

Quality & transparency

Quality

Question	Answer	Details
Models are by definition affected by uncertainties (in input data, input parameters, scenario definitions, etc.). Have the model uncertainties been quantified? Are uncertainties accounted for in your simulations?	yes	Uncertainties on assumptions can be addressed by producing variants with the model.
Sensitivity analysis helps identifying the uncertain inputs mostly responsible for the uncertainty in the model responses. Has the model undergone sensitivity analysis?	yes	Sensitivity analysis can be produced with the model.
Has the model undergone external peer review by a panel of experts, or have results been published in peer-reviewed journals?	yes	The model has undergone a peer review. See Commission staff working paper: SEC(2011)1569. Results have been published in peer-reviewed journals. The model has been used in multiple peer reviewed publications, that can be found here: https://e3modelling.com/publications/
Has model validation been done? Have model predictions been confronted with observed data (ex-post)?	not_applicable	The model is calibrated on historical data. The model does not do predictions but comparative scenario analysis based on assumptions.

References related to external peer-review and publication in scientific journals:

- No references provided in MIDAS

Transparency

Question	Answer	Details
Is the model underlying database (i.e. the database the model runs are based on) publicly available?	yes	The input data to the model is not published, but it builds on multiple sources, a large number of which being publicly accessible.
Can model outputs be made publicly available?	yes	Selected model outputs are made publicly available. Published outputs are defined by the Commission and are project-specific.
Is the model transparently documented (including underlying data, assumptions and equations, architecture, results) and are these documents available to the general public?	yes	The model documentation is publicly available. The model documentation includes the architecture and logic of the model and its different modules as well as the mathematical formulation.
Is the model source code publicly accessible or open for inspection?	no	The code is not open. However, the mathematical formulations of the model are published in the manual as well as in peer reviewed articles.

References related to documentation:

- No references provided in MIDAS

The model's policy relevance and intended role in the policy cycle

The model is designed to contribute to the following policy areas

- Climate action
- Energy
- Transport

The model is designed to contribute to the following phases of the policy cycle

- Formulation

The model's potential

The PRIMES model is designed to provide long-term energy system projections and system restructuring up to 2070, both in demand and supply sides. The model (including its transport module PRIMES-TREMOVE) can support impact assessment of specific energy, climate, transport and environment policies and measures, applied at Member State or EU level, including price signals, such as taxation, subsidies, ETS, as well as technology promoting policies, RES supporting policies, efficiency promoting policies, environmental policies and technology standards. The PRIMES model is sufficiently detailed to represent concrete policy measures in various sectors, including market design options for the EU internal electricity and gas markets. Policy analysis is based on comparative analysis of policy scenarios against a "baseline" projection.

NOTE *The field 'use of the model in ex-ante impact assessments of the European Commission' focuses on the contributions of the model to the assessment of policy options.*

In addition, please note that the model has also been extensively used in impact assessments to contribute to the construction of the baseline as part of the modelling framework of the EU reference scenario 2016 Energy, transport and GHG emissions : trends to 2050, Luxembourg: Publications Office of the European Union, 2016, doi:10.2833/9127.

The use of the Reference Scenario is reported under 'Additional information' in the entries of the related impact assessments.

Previous use of the model in ex-ante impact assessments of the European Commission

Use of the model in ex-ante impact assessments since July 2017.

In the Year	PRIMES contributed to the Impact assessment called	Led by	By providing input to the	The model was run by	Details of the contribution
2021	Impact assessment accompanying the Proposal for a Regulation of the European Parliament and of the Council: on the use of renewable and low-carbon fuels in maritime transport SWD/2021/635 final	MOVE	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	PRIMES is one of the core models of the modelling framework for energy, transport and greenhouse gas emissions projections. PRIMES-Maritime, a module of PRIMES and PRIMES-TREMOVE transport model, provided the developments in the maritime transport activity, energy use in the maritime sector, the greenhouse gas emissions and air pollution emissions, as well as the associated costs. The PRIMES model also provided an assessment of the biomass feedstock and the electricity consumption for producing synthetic fuels, while ensuring the links with the rest of the energy system.
2021	Impact assessment accompanying the Proposal for a Directive of the European Parliament and the Council: amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 SWD/2021/621 final	ENER	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	The model helped to assess the following impacts: - Significant effects on sectors - Economic growth and employment - Investments and functioning of markets - Impact on jobs - Impact on jobs in specific sectors, professions, regions or countries - Households income and at risk of poverty rates - Emission of greenhouse gases - Economic incentives set up by market based mechanisms - Emission of ozone-depleting substances - Ability to adapt to climate change - Energy intensity of the economy - Fuel mix used in energy production

					- Demand for transport - Vehicle emissions - Energy and fuel consumption - Change in land use
2021	Impact assessment accompanying the Proposal for a Directive of the European Parliament and of the Council: on energy efficiency (recast) SWD/2021/623 final	ENER	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	The model helped to assess the following impacts: - Investment cycle - Markets for Innovation - Innovation for productivity/resource efficiency - Investments and functioning of markets - Emission of greenhouse gases - Energy intensity of the economy - Fuel mix used in energy production - Energy and fuel consumption
2021	Impact assessment accompanying the Proposal for a Regulation of the European Parliament and of the Council: on ensuring a level playing field for sustainable air transport SWD/2021/633 final	MOVE	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	PRIMES is one of the core models of the modelling framework for energy, transport and greenhouse gas emission projections. The PRIMES-TREMOVE model, a module of PRIMES, provided the developments in the air transport activity, the energy use in the aviation sector, the greenhouse gas emissions and air pollution emissions, as well as the associated costs. The PRIMES model also provided an assessment of the biomass feedstock and the electricity consumption for producing synthetic fuels, while ensuring the links with the rest of the energy system. Supporting study: Ricardo et al. , Study supporting the impact assessment of the ReFuelEU Aviation initiative
2021	Impact assessment accompanying the Proposal for a Regulation of the European Parliament and of the Council: on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council SWD/2021/631 final	MOVE	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	PRIMES is one of the core models of the modelling framework for energy, transport and greenhouse gas emission projections. The PRIMES-TREMOVE model, a module of PRIMES, provided the developments in the vehicle fleet and the associated recharging and refuelling infrastructure, as well as the developments in CO2 emissions and air

					pollution emissions. The PRIMES model ensured the links with the rest of the energy system in developing the baseline and the policy scenarios. Supporting study: Ricardo et al. (2021), Impact assessment support study on the revision of the Directive on the Deployment of Alternative Fuels Infrastructure (2014/94/EC) (for details, see the impact assessment report).
2021	Impact assessment accompanying the document Proposal for a regulation of the European Parliament and of the Council: establishing a carbon border adjustment mechanism SWD/2021/643 final	TAXUD	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	The model helped to assess the following impacts: - EU Exports & imports - Investment flows & trade in services - Cost of doing business - Business' capacity to innovate - Market share & advantages in international context - Free movement of goods, services, capital and workers - Competition - Innovation for productivity/resource efficiency - Budgetary consequences for public authorities - Consumer's ability to benefit from the internal market or to access goods and services from outside the EU - Prices, quality, availability or choice of consumer goods and services - Significant effects on sectors - Disproportionately affected region or sector - Impacts on third countries - Goods traded with developing countries - Investments and functioning of markets - Impact on jobs - Impact on jobs in specific sectors, professions, regions or countries - Wages, labour costs or wage setting mechanisms - Emission of greenhouse gases - Sustainable production and consumption - Relative prices of environmental friendly and unfriendly products

					- Polution by businesses - Environment in third countries - Energy intensity of the economy - Fuel mix used in energy production - Energy and fuel consumption
2021	Impact assessment accompanying the document Proposal for a regulation of the European Parliament and of the Council: amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement SWD/2021/611 final	CLIMA	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	The PRIMES model and its variants are used to model all aspects of the energy system, including buildings, transport and industry. Regarding greenhouse gas emissions it reports all CO2 emissions from these sectors.
2021	Impact assessment accompanying the document Proposal for a Regulation of the European Parliament and of the Council: amending Regulation (EU) 2019/631 as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition SWD/2021/613 final	CLIMA	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	The PRIMES model is used to assess the projected evolution of the transport system, as part of the wider energy system, resulting from different policies, including CO2 emission standards for vehicles.
2021	Impact assessment accompanying the document Directive of the European Parliament and of the Council: amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757 SWD/2021/601 final	CLIMA	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	(1) General modelling of ETS strengthening and possible extension to buildings and transport/ all fossil fuel combustion. (2) Extension of emissions trading to maritime transport and alternatives. The PRIMES-Maritime module has been used to assess the impact of the various maritime policy options. PRIMES-Maritime is a specific sub-module of the PRIMES-TREMOVE transport and the overall PRIMES energy systems model aiming to enhance the representation of the maritime sector within the energy- economy-environment modelling nexus.

2020	Impact Assessment accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition SWD/2020/176 final	CLIMA	Baseline and assessment of policy options	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	The PRIMES model and its variants are used to model all aspects of the energy system, including buildings, transport and industry. Regarding greenhouse gas emissions it reports all CO2 emissions from these sectors.
2018	Impact assessment accompanying the document Proposal for a Regulation of the European Parliament and of the Council on: the establishment of a framework to facilitate sustainable investment and; Proposal for a Regulation of the European Parliament and of the Council on: disclosures relating to sustainable investments and sustainability risks and amending Directive (EU) 2016/2341 and; Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2016/1011 on: low carbon benchmarks and positive carbon impact benchmarks SWD/2018/264 final	FISMA	Problem definition	*Energy - Economy - Environment Modelling Laboratory, National Technical University of Athens*	The yearly average investment gap for the period 2021 to 2030 was based on PRIMES projections

Bibliographic references

- *EU reference scenario 2016 : energy, transport and GHG emissions : trends to 2050. - MJ-01-15-793-EN-N*
- *EU energy, transport and GHG emissions, trends to 2050 : reference scenario 2013. - 10.2833/17897*