Snapshot of - GEM-E3

Archive of GEM-E3, version: _092019

Contents

Reference card - GEM-E3

The reference card is a clearly defined description of model features. The numerous options have been organized into a limited amount of default and model specific (non default) options. In addition some features are described by a short clarifying text.

Legend:

☐ not implemented

☑ **implemented**

☑ **implemented (not default option)**

About

Name and version GEM-E3 _092019

Model link	https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/gem_e3_long_en.pdf
Institution	Institute of Communication And Computer Systems (ICCS), Greece, https://www.iccs.gr/en/.
Documentation	GEM-E3 documentation consists of a referencecard and detailed model documentation
Process state	published

Model scope and methods

Model documentation: Model scope and methods - GEM-E3

Model type	☐ Integrated assessment model	☑ **CGE**
	☐ Energy system model	☐ CBA-integrated assessment model
Geographical scope	☑ **Global**	☐ Regional
Objective	The GEM-E3 model is a multi-regional, multi-sectoral, recursive dynamic hybrid computable general equilibrium (CGE) model which provides details on the macro-economy and its interaction with the environment and the energy system. It incorporates micro-economic mechanisms and institutional features within a consistent macro-economic framework.	
Solution concept	☐ Partial equilibrium (price elastic demand)	
	☐ Partial equilibrium (fixed demand)	
	☑ **General equilibrium (closed economy)**	
Solution horizon	☑ **Recursive dynamic (myopic)**	☐ Intertemporal optimization (foresight)
Solution method	☐ Simulation	☑ **Optimization**
Temporal dimension	Base year:2014, time steps:5, horizon: 2100	
Spatial dimension	Number of regions:46	
Time discounting type	☐ Discount rate exogenous	☐ Discount rate endogenous
Policies	☑ **Emission tax**	☑ **Capacity targets**
	☑ **Emission pricing**	☐ Emission standards
	☑ **Cap and trade**	☐ Energy efficiency standards
	☑ **Fuel taxes**	☐ Agricultural producer subsidies
	☑ **Fuel subsidies**	☐ Agricultural consumer subsidies
	☑ **Feed-in-tariff**	☐ Land protection
	☑ **Portfolio standard**	

☐ Pricing carbon stocks

Socio-economic drivers

Model documentation: Socio-economic drivers - GEM-E3

Population	☑ **Yes (exogenous)**	☐ Yes (endogenous)
Population age structure	☐ Yes (exogenous)	☐ Yes (endogenous)
Education level	☐ Yes (exogenous)	☑ **Yes (endogenous)**
Urbanization rate	☐ Yes (exogenous)	☐ Yes (endogenous)
GDP	☐ Yes (exogenous)	☑ **Yes (endogenous)**
Income distribution	☐ Yes (exogenous)	☐ Yes (endogenous)
Employment rate	☐ Yes (exogenous)	☑ **Yes (endogenous)**
Labor productivity	☑ **Yes (exogenous)**	☐ Yes (endogenous)
Total factor productivity	☑ **Yes (exogenous)**	☐ Yes (endogenous)
Autonomous energy efficiency improvements	☑ **Yes (exogenous)**	☐ Yes (endogenous)

Macro-economy

Model documentation: Macro-economy - GEM-E3

Economic sector

Industry	☐ Yes (physical) ☐ Yes (economic)	☐ Yes (physical & economic)
Energy	☐ Yes (physical) ☐ Yes (economic)	☐ Yes (physical & economic)
Transportation	☐ Yes (physical) ☐ Yes (economic)	☐ Yes (physical & economic)
Residential and commercial	☐ Yes (physical) ☐ Yes (economic)	☐ Yes (physical & economic)

Agriculture	☐ Yes (physical) ☐ Yes (economic)	☐ Yes (physical & economic)
Forestry	☐ Yes (physical) ☐ Yes (economic)	☐ Yes (physical & economic)
Other economic sector	☑ **other** *Note: GEM-E3 represents 29 sectors: Agriculture,Coal,Crude Oil,Oil,Gas,Electricity supply,Ferrous and non ferrous metals,Chemical Products,Other energy intensive,Electric Goods,Transport equipment,Other Equipment Goods,Consumer Goods Industries,Construction,Transport (Air),Transport (Land),Transport (Water),Market Services,Non Market Services,Coal fired,Oil fired,Gas fired,Nuclear,Biomass,Hydro electric,Wind,PV,CCS coal,CCS Gas*	

Macro-economy

Trade	☑ **Coal** ☑ **Oil** ☑ **Gas** ☐ Uranium ☐ Electricity ☑ **Bioenergy crops** ☑ **Food crops**	☑ **Capital** ☑ **Emissions permits** ☐ Non-energy goods ☑ **All other major traded economic activities (40 economic sectors)** ☑ **Energy goods**

Note: The model links all countries and sectors through endogenous bilateral trade transactions.

Cost measures	☑ **GDP loss** ☑ **Welfare loss** ☐ Consumption loss	☐ Area under MAC ☐ Energy system cost mark-up ☑ **Equivalent Variation**
Categorization by group	☐ Income ☐ Urban - rural ☑ **Technology adoption** ☐ Age	☐ Gender ☐ Education level ☐ Household size
Institutional and political factors	☐ Early retirement of capital allowed ☐ Interest rates differentiated by country/region ☐ Regional risk factors included	☐ Technology costs differentiated by country/region ☐ Technological change differentiated by country/region ☐ Behavioural change differentiated by country/region

☐ Constraints on cross country financial transfers

Resource use

Coal	☑ **Yes (fixed)** ☐ Yes (supply curve)	☐ Yes (process model)
Conventional Oil	☐ Yes (fixed) ☐ Yes (supply curve)	☐ Yes (process model)
Unconventional Oil	☑ **Yes (fixed)** ☐ Yes (supply curve)	☐ Yes (process model)
Conventional Gas	☑ **Yes (fixed)** ☐ Yes (supply curve)	☐ Yes (process model)
Unconventional Gas	☑ **Yes (fixed)** ☐ Yes (supply curve)	☐ Yes (process model)
Uranium	☐ Yes (fixed) ☐ Yes (supply curve)	☐ Yes (process model)
Bioenergy	☐ Yes (fixed) ☐ Yes (supply curve)	☑ **Yes (process model)**
Water	☐ Yes (fixed) ☐ Yes (supply curve)	☐ Yes (process model)
Raw Materials	☐ Yes (fixed) ☐ Yes (supply curve)	☑ **Yes (process model)**
Land	☐ Yes (fixed) ☐ Yes (supply curve)	☐ Yes (process model)

Technological change

Energy conversion technologies	☐ No technological change ☐ Exogenous technological	change ☐ Endogenous technological change
Energy End-use	☐ No technological change ☐ Exogenous technological	change ☐ Endogenous technological change
Material Use	☐ No technological change ☑ **Exogenous technological**	**change** ☐ Endogenous technological change
Agriculture (tc)	☐ No technological change ☐ Exogenous technological	change ☐ Endogenous technological change
Other technological change	☑ **Other: Total factor productivity, Labour productivity, Capital productivity are all exogenous.**	**Semi-endogenous TFP for clean technologies based on learning by doing and learning by research**

Energy

Model documentation: Energy - GEM-E3

Energy technology substitution

Energy technology choice

- ☐ No discrete technology choices
- ☐ Logit choice model
- ☐ Production function
- ☐ Linear choice (lowest cost)
- ☐ Lowest cost with adjustment penalties

Energy technology substitutability

- ☑ **Mostly high substitutability**
- ☐ Mostly low substitutability
- ☐ Mixed high and low substitutability

Energy technology deployment

- ☑ **Expansion and decline constraints**
- ☐ System integration constraints

Energy

Electricity technologies

- ☐ Coal w/o CCS
- ☑ **Coal w/ CCS**
- ☑ **Gas w/o CCS**
- ☑ **Gas w/ CCS**
- ☑ **Oil w/o CCS**
- ☐ Oil w/ CCS
- ☑ **Bioenergy w/o CCS**
- ☐ Bioenergy w/ CCS
- ☑ **Geothermal power**
- ☑ **Nuclear power**
- ☑ **Solar power**
- ☑ **Solar power-central PV**
- ☐ Solar power-distributed PV
- ☐ Solar power-CSP
- ☑ **Wind power**
- ☑ **Wind power-onshore**
- ☑ **Wind power-offshore**
- ☑ **Hydroelectric power**
- ☐ Ocean power

Hydrogen production

- ☐ Coal to hydrogen w/o CCS
- ☐ Coal to hydrogen w/ CCS
- ☐ Natural gas to hydrogen w/o CCS
- ☐ Natural gas to hydrogen w/ CCS
- ☐ Oil to hydrogen w/o CCS
- ☐ Oil to hydrogen w/ CCS
- ☐ Biomass to hydrogen w/o CCS
- ☐ Biomass to hydrogen w/ CCS
- ☐ Nuclear thermochemical hydrogen
- ☐ Solar thermochemical hydrogen
- ☐ Electrolysis

Refined liquids

- ☐ Coal to liquids w/o CCS
- ☐ Coal to liquids w/ CCS
- ☐ Gas to liquids w/o CCS
- ☐ Gas to liquids w/ CCS
- ☐ Bioliquids w/o CCS
- ☐ Bioliquids w/ CCS
- ☐ Oil refining

Refined gases

- ☐ Coal to gas w/o CCS
- ☐ Coal to gas w/ CCS
- ☐ Oil to gas w/o CCS
- ☐ Oil to gas w/ CCS
- ☐ Biomass to gas w/o CCS
- ☐ Biomass to gas w/ CCS

Heat generation

- ☐ Coal heat
- ☐ Natural gas heat
- ☐ Oil heat
- ☐ Biomass heat
- ☐ Geothermal heat
- ☐ Solarthermal heat
- ☐ CHP (coupled heat and power)

Grid Infra Structure

Electricity	☐ Yes (aggregate)	☐ Yes (spatially explicit)
Gas	☐ Yes (aggregate)	☐ Yes (spatially explicit)
Heat	☐ Yes (aggregate)	☐ Yes (spatially explicit)
CO2	☐ Yes (aggregate)	☐ Yes (spatially explicit)
Hydrogen	☐ Yes (aggregate)	☐ Yes (spatially explicit)

Energy end-use technologies

Passenger transportation

- ☑ **Passenger trains**
- ☑ **Buses**
- ☐ Light Duty Vehicles (LDVs)
- ☑ **Electric LDVs**
- ☐ Hydrogen LDVs
- ☑ **Hybrid LDVs**
- ☑ **Gasoline LDVs**
- ☐ Diesel LDVs
- ☑ **Passenger aircrafts**

Freight transportation

- ☑ **Freight trains**
- ☑ **Heavy duty vehicles**
- ☑ **Freight aircrafts**
- ☑ **Freight ships**

Industry

- ☑ **Steel production**
- ☑ **Aluminium production**
- ☑ **Cement production**
- ☑ **Petrochemical production**
- ☑ **Paper production**
- ☐ Plastics production
- ☑ **Pulp production**
- ☑ **Other: Equipment goods, Non-metalic minnerals, Consumer goods industries**

Residential and commercial

- ☑ **Space heating**
- ☐ Space cooling
- ☑ **Cooking**
- ☐ Refrigeration
- ☐ Washing
- ☐ Lighting

Land-use

Model documentation: Land-use - GEM-E3

Land cover

- ☐ Cropland
- ☐ Cropland irrigated
- ☐ Cropland food crops
- ☐ Cropland feed crops
- ☐ Cropland energy crops
- ☐ Forest
- ☐ Managed forest
- ☐ Natural forest
- ☐ Pasture
- ☐ Shrubland
- ☐ Built-up area

Agriculture and forestry demands

- ☐ Agriculture food
- ☐ Agriculture food crops
- ☐ Agriculture food livestock
- ☐ Agriculture feed
- ☐ Agriculture feed crops
- ☐ Agriculture feed livestock
- ☐ Agriculture non-food
- ☐ Agriculture non-food crops
- ☐ Agriculture non-food livestock
- ☐ Agriculture bioenergy
- ☐ Agriculture residues
- ☐ Forest industrial roundwood
- ☐ Forest fuelwood
- ☐ Forest residues

Agricultural commodities

- ☐ Wheat
- ☐ Rice
- ☐ Other coarse grains
- ☑ **Oilseeds**
- ☐ Sugar crops
- ☐ Ruminant meat
- ☐ Non-ruminant meat and eggs
- ☐ Dairy products

Emission, climate and impacts

Model documentation: Emissions - GEM-E3, Climate - GEM-E3, Non-climate sustainability dimension - GEM-E3

Greenhouse gases

- ☑ **CO2 fossil fuels**
- ☐ CO2 cement
- ☐ CO2 land use
- ☑ **CH4 energy**
- ☐ CH4 land use
- ☑ **CH4 other**
- ☑ **N2O energy**
- ☐ N2O land use
- ☑ **N2O other**
- ☐ CFCs
- ☑ **HFCs**
- ☑ **SF6**
- ☐ PFCs

Pollutants

- ☐ CO energy
- ☐ CO land use
- ☐ CO other
- ☐ NOx energy
- ☐ NOx land use
- ☐ NOx other
- ☐ VOC energy
- ☐ VOC land use
- ☐ VOC other
- ☐ SO2 energy
- ☐ SO2 land use
- ☐ SO2 other
- ☐ BC energy
- ☐ BC land use
- ☐ BC other
- ☐ OC energy
- ☐ OC land use
- ☐ OC other
- ☐ NH3 energy
- ☐ NH3 land use
- ☐ NH3 other

Climate indicators

- ☐ Concentration: CO2
- ☐ Concentration: CH4
- ☐ Concentration: N2O
- ☐ Concentration: Kyoto gases
- ☐ Radiative forcing: CO2
- ☐ Radiative forcing: CH4
- ☐ Radiative forcing: N2O
- ☐ Radiative forcing: F-gases
- ☐ Radiative forcing: Kyoto gases
- ☐ Radiative forcing: aerosols
- ☐ Radiative forcing: land albedo
- ☐ Radiative forcing: AN3A
- ☐ Radiative forcing: total
- ☐ Temperature change
- ☐ Sea level rise
- ☐ Ocean acidification

Note: GEM-E3 model does not include climate indicators.

- ☑ **Bioenergy with CCS**
- ☐ Reforestation

Carbon dioxide removal	☑ **Afforestation**	☑ **Direct air capture**
	☐ Soil carbon enhancement	☐ Enhanced weathering
Climate change impacts	☐ Agriculture	☐ Economic output
	☐ Energy supply	☐ Built capital
	☐ Energy demand	☐ Inequality
Co-Linkages	☐ Energy security: Fossil fuel imports & exports (region)	☐ Air pollution & health: Health impacts of air Pollution
	☑ **Energy access: Household energy consumption**	☐ Food access
		☐ Water availability
	☐ Air pollution & health: Source-based aerosol emissions	☐ Biodiversity

Model Documentation - GEM-E3

Table of contents

- Gaseous fuels
- Liquid fuels
- Solid fuels
- Grid, pipelines and other infrastructure
- Energy end-use
- Transport
- Residential and commercial sectors
- Industrial sector
- Other end-use

- **Energy demand**
- **Technological change in energy**

Land-use

- **Agriculture**
- **Forestry**
- **Land-use change**
- **Bioenergy land-use**
- **Other land-use**
- **Agricultural demand**
- **Technological change in land-use**

Emissions

- **GHGs**
- **Pollutants and non-GHG forcing agents**
- **Carbon dioxide removal (CDR) options**

Climate

- **Modelling of climate indicators**
- **Climate damages, temperature changes**

Non-climate sustainability dimension

- **Air pollution and health**
- **Water**
- **Other materials**
- **Other sustainability dimensions**

Appendices

- **Mathematical model description**
- **Data**

References