

Snapshot of - MARKAL-India

Archive of MARKAL-India, version: 1.0

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Model Documentation - MARKAL-India

Reference card - MARKAL-India

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	MARKAL-India 1.0
Institution	The Energy and Resources Institute (TERI), India, www.teriin.org .
Documentation	MARKAL-India documentation consists of a referencecard and <u>detailed model documentation</u>
Process state	in preparation

Model scope and methods

Model documentation: Model scope and methods - MARKAL-India

Model type	<input type="checkbox"/> Integrated assessment model	<input type="checkbox"/> CGE
	<input checked="" type="checkbox"/> Energy system model	<input type="checkbox"/> CBA-integrated assessment model
Geographical scope	<input type="checkbox"/> Global	<input checked="" type="checkbox"/> Regional

Objective The model was initially developed to represent the energy related emissions at national level and examine alternative options that could mitigate CO₂ emissions, while keeping in mind the national development priorities. The basic model has been widely used in conjunction with other macroeconomic and biophysical models to examine trade-offs and co-benefits of alternative energy sector trajectories.

Solution concept	<input type="checkbox"/> Partial equilibrium (price elastic demand)	demand)
	<input checked="" type="checkbox"/> Partial equilibrium (fixed	<input type="checkbox"/> General equilibrium (closed economy)
Solution horizon	<input type="checkbox"/> Recursive dynamic (myopic)	<input checked="" type="checkbox"/> Intertemporal optimization (foresight)
	<input type="checkbox"/> Simulation	<input checked="" type="checkbox"/> Optimization

Temporal dimension Base year:2001, time steps:5, horizon: 2051

Spatial dimension Number of regions:1

1. India

Note: Single region national level model

Time discounting type	<input checked="" type="checkbox"/> Discount rate exogenous	<input type="checkbox"/> Discount rate endogenous
Policies	<input checked="" type="checkbox"/> Emission tax <input checked="" type="checkbox"/> Emission pricing <input type="checkbox"/> Cap and trade <input checked="" type="checkbox"/> Fuel taxes <input checked="" type="checkbox"/> Fuel subsidies <input type="checkbox"/> Feed-in-tariff <input checked="" type="checkbox"/> Portfolio standard	<input checked="" type="checkbox"/> Capacity targets <input checked="" type="checkbox"/> Emission standards <input checked="" type="checkbox"/> Energy efficiency standards <input type="checkbox"/> Agricultural producer subsidies <input type="checkbox"/> Agricultural consumer subsidies <input type="checkbox"/> Land protection <input type="checkbox"/> Pricing carbon stocks

Socio-economic drivers

Model documentation: Socio-economic drivers - MARKAL-India

Population	<input checked="" type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Population age structure	<input type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Education level	<input type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Urbanization rate	<input checked="" type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
GDP	<input checked="" type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Income distribution	<input checked="" type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Employment rate	<input type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Labor productivity	<input type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)

Total factor productivity Yes (exogenous) Yes (endogenous)**Autonomous energy efficiency improvements** **Yes (exogenous)** Yes (endogenous)

Macro-economy

Model documentation: Macro-economy - MARKAL-India

Economic sector

Industry **Yes (physical)** Yes (physical & economic) Yes (economic)**Energy** **Yes (physical)** Yes (physical & economic) Yes (economic)**Transportation** **Yes (physical)** Yes (physical & economic) Yes (economic)**Residential and commercial** **Yes (physical)** Yes (physical & economic) Yes (economic)**Agriculture** Yes (physical) Yes (physical & economic) Yes (economic)**Forestry** Yes (physical) Yes (physical & economic) Yes (economic)

Macro-economy

Trade **Coal** Bioenergy crops **Oil** Food crops **Gas** Capital **Uranium** Emissions permits **Electricity** Non-energy goods**Cost measures** GDP loss Area under MAC Welfare loss **Energy system cost mark-up** Consumption loss

Categorization by group

- | | |
|--|--|
| <input type="checkbox"/> Income | <input type="checkbox"/> Gender |
| <input checked="" type="checkbox"/> Urban - rural | <input type="checkbox"/> Education level |
| <input type="checkbox"/> Technology adoption | <input type="checkbox"/> Household size |
| <input type="checkbox"/> Age | |

Note: Urban-rural categorization is explicitly modeled for cooking and lighting in residential sector. It is implicitly modeled in case of passenger movement in transport sector. In other sectors, urban-rural categorization is not used.

Institutional and political factors

- | | |
|--|--|
| <input type="checkbox"/> Early retirement of capital allowed | differentiated by country/region |
| <input type="checkbox"/> Interest rates differentiated by country/region | <input type="checkbox"/> Technological change differentiated by country/region |
| <input type="checkbox"/> Regional risk factors included | <input type="checkbox"/> Behavioural change differentiated by country/region |
| <input type="checkbox"/> Technology costs | <input type="checkbox"/> Constraints on cross country financial transfers |

Resource use**Coal**

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input checked="" type="checkbox"/> Yes (supply curve) | |

Conventional Oil

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input checked="" type="checkbox"/> Yes (supply curve) | |

Unconventional Oil

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input checked="" type="checkbox"/> Yes (supply curve) | |

Conventional Gas

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input checked="" type="checkbox"/> Yes (supply curve) | |

Unconventional Gas

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input checked="" type="checkbox"/> Yes (supply curve) | |

Uranium

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input checked="" type="checkbox"/> Yes (supply curve) | |

Bioenergy

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input checked="" type="checkbox"/> Yes (supply curve) | |

Water

- | | |
|---|--|
| <input type="checkbox"/> Yes (fixed) | <input type="checkbox"/> Yes (process model) |
| <input type="checkbox"/> Yes (supply curve) | |

Raw Materials

- Yes (fixed) Yes (process model)
 Yes (supply curve)

Land

- Yes (fixed) Yes (process model)
 Yes (supply curve)

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

Energy

Model documentation: [Energy - MARKAL-India](#)

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	<input type="checkbox"/> Yes (aggregate)	<input type="checkbox"/> Yes (spatially explicit)
Heat	<input type="checkbox"/> Yes (aggregate)	<input type="checkbox"/> Yes (spatially explicit)
CO₂	<input type="checkbox"/> Yes (aggregate)	<input type="checkbox"/> Yes (spatially explicit)
Hydrogen	<input type="checkbox"/> Yes (aggregate)	<input type="checkbox"/> Yes (spatially explicit)

Energy end-use technologies

Passenger transportation	<input checked="" type="checkbox"/> Passenger trains	<input checked="" type="checkbox"/> Gasoline Two-wheelers
	<input checked="" type="checkbox"/> Buses	<input checked="" type="checkbox"/> Electric Two-wheelers
	<input checked="" type="checkbox"/> Light Duty Vehicles (LDVs)	<input checked="" type="checkbox"/> Gasoline Three-Wheelers
	<input checked="" type="checkbox"/> Electric LDVs	<input checked="" type="checkbox"/> Diesel Three-wheelers
	<input checked="" type="checkbox"/> Hydrogen LDVs	<input checked="" type="checkbox"/> CNG Three-wheelers
	<input checked="" type="checkbox"/> Hybrid LDVs	<input checked="" type="checkbox"/> Electric Three-wheelers
	<input checked="" type="checkbox"/> Gasoline LDVs	<input checked="" type="checkbox"/> CNG Buses
	<input checked="" type="checkbox"/> Diesel LDVs	<input checked="" type="checkbox"/> Electric Buses
	<input checked="" type="checkbox"/> Passenger aircrafts	
Freight transportation	<input checked="" type="checkbox"/> Freight trains	<input checked="" type="checkbox"/> Freight aircrafts
	<input checked="" type="checkbox"/> Heavy duty vehicles	<input checked="" type="checkbox"/> Freight ships
Industry	<input checked="" type="checkbox"/> Steel production	<input checked="" type="checkbox"/> Pulp production
	<input checked="" type="checkbox"/> Aluminium production	<input checked="" type="checkbox"/> Chemicals
	<input checked="" type="checkbox"/> Cement production	<input checked="" type="checkbox"/> Glass
	<input checked="" type="checkbox"/> Petrochemical production	<input checked="" type="checkbox"/> Textile
	<input checked="" type="checkbox"/> Paper production	<input checked="" type="checkbox"/> Fertilisers
	<input type="checkbox"/> Plastics production	<input checked="" type="checkbox"/> Bricks
Residential and commercial	<input type="checkbox"/> Space heating	<input type="checkbox"/> Washing
	<input checked="" type="checkbox"/> Space cooling	<input checked="" type="checkbox"/> Lighting
	<input checked="" type="checkbox"/> Cooking	<input checked="" type="checkbox"/> Water heating
	<input checked="" type="checkbox"/> Refrigeration	

Land-use

Model documentation: [Land-use - MARKAL-India](#)

<input type="checkbox"/> Cropland	<input type="checkbox"/> Cropland irrigated
-----------------------------------	---

Land cover

- | | |
|--|---|
| <input type="checkbox"/> Cropland food crops | <input type="checkbox"/> Natural forest |
| <input type="checkbox"/> Cropland feed crops | <input type="checkbox"/> Pasture |
| <input type="checkbox"/> Cropland energy crops | <input type="checkbox"/> Shrubland |
| <input type="checkbox"/> Forest | <input type="checkbox"/> Built-up area |
| <input type="checkbox"/> Managed forest | |

Agriculture and forestry demands

- | | |
|---|--|
| <input type="checkbox"/> Agriculture food | <input type="checkbox"/> Agriculture non-food crops |
| <input type="checkbox"/> Agriculture food crops | <input type="checkbox"/> Agriculture non-food livestock |
| <input type="checkbox"/> Agriculture food livestock | <input checked="" type="checkbox"/> Agriculture bioenergy |
| <input type="checkbox"/> Agriculture feed | <input checked="" type="checkbox"/> Agriculture residues |
| <input type="checkbox"/> Agriculture feed crops | <input type="checkbox"/> Forest industrial roundwood |
| <input type="checkbox"/> Agriculture feed livestock | <input checked="" type="checkbox"/> Forest fuelwood |
| <input type="checkbox"/> Agriculture non-food | <input checked="" type="checkbox"/> Forest residues |

Agricultural commodities

- | | |
|--|---|
| <input type="checkbox"/> Wheat | <input type="checkbox"/> Sugar crops |
| <input type="checkbox"/> Rice | <input type="checkbox"/> Ruminant meat |
| <input type="checkbox"/> Other coarse grains | <input type="checkbox"/> Non-ruminant meat and eggs |
| <input type="checkbox"/> Oilseeds | <input type="checkbox"/> Dairy products |

Emission, climate and impacts

Model documentation: Emissions - MARKAL-India, Climate - MARKAL-India, Non-climate sustainability dimension - MARKAL-India

Greenhouse gases

- | | |
|---|---------------------------------------|
| <input checked="" type="checkbox"/> CO2 fossil fuels | <input type="checkbox"/> N2O land use |
| <input checked="" type="checkbox"/> CO2 cement | <input type="checkbox"/> N2O other |
| <input type="checkbox"/> CO2 land use | <input type="checkbox"/> CFCs |
| <input checked="" type="checkbox"/> CH4 energy | <input type="checkbox"/> HFCs |
| <input type="checkbox"/> CH4 land use | <input type="checkbox"/> SF6 |
| <input type="checkbox"/> CH4 other | <input type="checkbox"/> PFCs |
| <input checked="" type="checkbox"/> N2O energy | |

Pollutants

- | | |
|---------------------------------------|---------------------------------------|
| <input type="checkbox"/> CO energy | <input type="checkbox"/> SO2 land use |
| <input type="checkbox"/> CO land use | <input type="checkbox"/> SO2 other |
| <input type="checkbox"/> CO other | <input type="checkbox"/> BC energy |
| <input type="checkbox"/> NOx energy | <input type="checkbox"/> BC land use |
| <input type="checkbox"/> NOx land use | <input type="checkbox"/> BC other |
| <input type="checkbox"/> NOx other | <input type="checkbox"/> OC energy |
| <input type="checkbox"/> VOC energy | <input type="checkbox"/> OC land use |
| <input type="checkbox"/> VOC land use | <input type="checkbox"/> OC other |
| <input type="checkbox"/> VOC other | <input type="checkbox"/> NH3 energy |
| <input type="checkbox"/> SO2 energy | <input type="checkbox"/> 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

Carbon dioxide removal

- Bioenergy with CCS
- Reforestation
- Afforestation

- Soil carbon enhancement
- Direct air capture
- Enhanced weathering

Climate change impacts

- Agriculture
- Energy supply
- Energy demand

- Economic output
- Built capital
- Inequality

Co-Linkages

Energy security: Fossil fuel imports & exports (region)

Energy access: Household energy consumption

- Air pollution & health: Source-based aerosol emissions

- Air pollution & health: Health impacts of air Pollution
- Food access
- Water availability
- Biodiversity

Model Documentation - MARKAL-India

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This page was last edited on 7 August 2020, at 16:45.