# Snapshot of - GCAM-KSA

Archive of GCAM-KSA, version: 1.0

## Contents



# Reference card - GCAM-KSA

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** GCAM-KSA 1.0

| | |
|---|---|
| **Model link** | https://github.com/KAPSARC/gcam-ksa |
| **Institution** | King Abdullah Petroleum Studies and Research Center (KAPSARC), Saudi Arabia, https://www.kapsarc.org/. |
| **Documentation** | GCAM-KSA documentation is limited and consists of a reference card |
| **Process state** | published |

# Model scope and methods

| | | |
|---|---|---|
| **Model type** | ☑ **Integrated assessment model**<br>☐ Energy system model | ☐ CGE<br>☐ CBA-integrated assessment model |
| **Geographical scope** | ☑ **Global** | ☐ Regional |

**Objective**

GCAM-KSA is a global integrated assessment model that explores the interactions among economy, energy, water, land, and climate systems in a single computational platform. It is a modified version of GCAM v6.0. We have separated the Kingdom of Saudi Arabia (KSA) as a separate energy-economy region, i.e., GCAM–KSA includes 33 energy-economy regions (32 original regions plus KSA).

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|---|---|---|
| **Solution concept** | ☑ **Partial equilibrium (price elastic demand)**<br>☐ Partial equilibrium (fixed demand) | ☐ General equilibrium (closed economy)<br>☑ **GCAM solves all energy, water, and land markets simultaneously** |
| **Solution horizon** | ☑ **Recursive dynamic (myopic)** | ☐ Intertemporal optimization (foresight) |
| **Solution method** | ☐ Simulation<br>☐ Optimization | ☑ **Recursive dynamic solution method** |

**Anticipation**

GCAM-KSA is a dynamic recursive model, meaning that decision-makers do not know the future when making a decision today. After it solves each period, the model then uses the resulting state of the world, including the consequences of decisions made in that period - such as resource depletion, capital stock retirements and installations, and changes to the landscape - and then moves to the next time step and performs the same exercise. For long-lived investments, decision-makers may account for

future profit streams, but those estimates would be based on current prices. For some parts of the model, economic agents use prior experience to form expectations based on multi-period experiences.

**Temporal dimension**

Base year:2015, time steps:5-year, horizon: 2100

**Spatial dimension**

Number of regions:33

1. USA
2. Canada
3. Mexico
4. Australia_NZ
5. Japan
6. South Korea
7. EU-12
8. EU-15
9. European Free Trade Association
10. Europe_Non_EU
11. Europe_Eastern
12. Russia
13. China
14. Taiwan
15. Central Asia
16. South Asia
17. Southeast Asia
18. Indonesia
19. India
20. Pakistan
21. Middle East
22. Africa_Eastern
23. Africa_Northern
24. Africa_Southern
25. Africa_Western
26. South Africa
27. Argentina
28. Brazil
29. Central America and Caribbean
30. Colombia
31. South America_Northern
32. South America_Southern
33. Saudi Arabia

**Time discounting type**

☐ Discount rate exogenous

☐ Discount rate endogenous

**Policies**

☑ **Emission tax**
☑ **Emission pricing**
☑ **Cap and trade**
☑ **Fuel taxes**
☑ **Fuel subsidies**
☑ **Feed-in-tariff**
☑ **Portfolio standard**
☑ **Capacity targets**
☑ **Emission standards**
☑ **Energy efficiency standards**
☑ **Agricultural producer subsidies**
☑ **Agricultural consumer subsidies**
☑ **Land protection**
☑ **Pricing carbon stocks**

# Socio-economic drivers

| | | |
|---|---|---|
| **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

## Economic sector

| | | |
|---|---|---|
| **Industry** | ☐ Yes (physical)<br>☐ Yes (economic) | ☑ **Yes (physical & economic)** |
| **Energy** | ☐ Yes (physical)<br>☐ Yes (economic) | ☑ **Yes (physical & economic)** |
| **Transportation** | ☐ Yes (physical)<br>☐ Yes (economic) | ☑ **Yes (physical & economic)** |
| **Residential and commercial** | ☐ Yes (physical)<br>☐ Yes (economic) | ☑ **Yes (physical & economic)** |

| | | |
|---|---|---|
| **Agriculture** | ☐ Yes (physical)<br>☐ Yes (economic) | ☑ **Yes (physical & economic)** |
| **Forestry** | ☐ Yes (physical)<br>☐ Yes (economic) | ☑ **Yes (physical & economic)** |

## Macro-economy

| | | |
|---|---|---|
| **Trade** | ☑ **Coal**<br>☑ **Oil**<br>☑ **Gas**<br>☑ **Uranium**<br>☑ **Electricity** | ☑ **Bioenergy crops**<br>☑ **Food crops**<br>☐ Capital<br>☑ **Emissions permits**<br>☐ Non-energy goods |
| **Cost measures** | ☐ GDP loss<br>☐ Welfare loss<br>☐ Consumption loss | ☑ **Area under MAC**<br>☐ Energy system cost mark-up |
| **Categorization by group** | ☑ **Income**<br>☑ **Urban - rural**<br>☐ Technology adoption<br>☐ Age | ☐ Gender<br>☐ Education level<br>☐ Household size |
| **Institutional and political factors** | ☑ **Early retirement of capital allowed**<br>☑ **Interest rates differentiated by country/region**<br>☑ **Regional risk factors included**<br>☑ **Technology costs** | **differentiated by country/region**<br>☑ **Technological change differentiated by country/region**<br>☑ **Behavioural change differentiated by country/region**<br>☐ Constraints on cross country financial transfers |

## Resource use

| | | |
|---|---|---|
| **Coal** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Conventional Oil** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Unconventional Oil** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Conventional Gas** | ☐ Yes (fixed) | ☐ Yes (supply curve) |

☑ **Yes (process model)**

| | | |
|---|---|---|
| **Unconventional Gas** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Uranium** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Bioenergy** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Water** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Raw Materials** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |
| **Land** | ☐ Yes (fixed)<br>☐ Yes (supply curve) | ☑ **Yes (process model)** |

### Technological change

| | | |
|---|---|---|
| **Energy conversion technologies** | ☐ No technological change<br>☑ **Exogenous technological change** | ☐ Endogenous technological change |
| **Energy End-use** | ☐ No technological change<br>☑ **Exogenous technological change** | ☐ Endogenous technological change |
| **Material Use** | ☐ No technological change<br>☑ **Exogenous technological change** | ☐ Endogenous technological change |
| **Agriculture (tc)** | ☐ No technological change<br>☑ **Exogenous technological change** | ☐ Endogenous technological change |

# Energy

### Energy technology substitution

| | | |
|---|---|---|
| **Energy technology choice** | ☐ No discrete technology choices<br>☑ **Logit choice model**<br>☐ Production function | ☐ Linear choice (lowest cost)<br>☐ Lowest cost with adjustment penalties |
| **Energy technology substitutability** | ☐ Mostly high substitutability<br>☐ 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**<br>☑ **Coal w/ CCS**<br>☑ **Gas w/o CCS**<br>☑ **Gas w/ CCS**<br>☑ **Oil w/o CCS**<br>☑ **Oil w/ CCS**<br>☑ **Bioenergy w/o CCS**<br>☑ **Bioenergy w/ CCS**<br>☑ **Geothermal power**<br>☑ **Nuclear power** | ☑ **Solar power**<br>☑ **Solar power-central PV**<br>☑ **Solar power-distributed PV**<br>☑ **Solar power-CSP**<br>☑ **Wind power**<br>☑ **Wind power-onshore**<br>☑ **Wind power-offshore**<br>☑ **Hydroelectric power**<br>☐ Ocean power |
| **Hydrogen production** | ☑ **Coal to hydrogen w/o CCS**<br>☑ **Coal to hydrogen w/ CCS**<br>☑ **Natural gas to hydrogen w/o CCS**<br>☑ **Natural gas to hydrogen w/ CCS**<br>☑ **Oil to hydrogen w/o CCS**<br>☑ **Oil to hydrogen w/ CCS** | ☑ **Biomass to hydrogen w/o CCS**<br>☑ **Biomass to hydrogen w/ CCS**<br>☑ **Nuclear thermochemical hydrogen**<br>☑ **Solar thermochemical hydrogen**<br>☑ **Electrolysis** |
| **Refined liquids** | ☑ **Coal to liquids w/o CCS**<br>☑ **Coal to liquids w/ CCS**<br>☑ **Gas to liquids w/o CCS**<br>☑ **Gas to liquids w/ CCS** | ☑ **Bioliquids w/o CCS**<br>☑ **Bioliquids w/ CCS**<br>☑ **Oil refining** |
| **Refined gases** | ☑ **Coal to gas w/o CCS**<br>☑ **Coal to gas w/ CCS** | ☑ **Oil to gas w/o CCS**<br>☑ **Oil to gas w/ CCS** |

| | | |
|---|---|---|
| | ☑ Biomass to gas w/o CCS | ☑ Biomass to gas w/ CCS |
| **Heat generation** | ☑ Coal heat | ☑ Geothermal heat |
| | ☑ Natural gas heat | ☑ Solarthermal heat |
| | ☑ Oil heat | ☑ CHP (coupled heat and power) |
| | ☑ Biomass heat | |

## 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 | ☑ Passenger aircrafts |
| | ☑ Buses | ☑ CNG Buses |
| | ☑ Light Duty Vehicles (LDVs) | ☑ CNG Three-wheelers |
| | ☑ Electric LDVs | ☑ Electric Buses |
| | ☑ Hydrogen LDVs | ☑ Electric Two-wheelers |
| | ☑ Hybrid LDVs | ☑ Fuel-cell LDVs |
| | ☑ Gasoline LDVs | ☑ Diesel Three-wheelers |
| | ☑ Diesel LDVs | ☑ LPG/CNG LDVs |
| **Freight transportation** | ☑ Freight trains | ☑ Freight ships |
| | ☑ Heavy duty vehicles | ☑ Fuel-cell HDVs |
| | ☑ Freight aircrafts | ☑ Hybrid HDVs |
| **Industry** | ☑ Steel production | ☑ Plastics production |
| | ☑ Aluminium production | ☐ Pulp production |
| | ☑ Cement production | ☑ Other Industries |
| | ☑ Petrochemical production | ☑ Fertilisers |
| | ☐ Paper production | |
| | ☑ Space heating | ☑ Space cooling |

| | | |
|---|---|---|
| **Residential and commercial** | ☐ Cooking<br>☐ Refrigeration<br>☐ Washing | ☐ Lighting<br>☑ **Other electrical uses** |

# Land-use

| | | |
|---|---|---|
| **Land cover** | ☑ **Cropland**<br>☑ **Cropland irrigated**<br>☑ **Cropland food crops**<br>☑ **Cropland feed crops**<br>☑ **Cropland energy crops**<br>☑ **Forest** | ☑ **Managed forest**<br>☑ **Natural forest**<br>☑ **Pasture**<br>☑ **Shrubland**<br>☑ **Built-up area** |
| **Agriculture and forestry demands** | ☑ **Agriculture food**<br>☑ **Agriculture food crops**<br>☑ **Agriculture food livestock**<br>☑ **Agriculture feed**<br>☑ **Agriculture feed crops**<br>☑ **Agriculture feed livestock**<br>☑ **Agriculture non-food** | ☑ **Agriculture non-food crops**<br>☑ **Agriculture non-food livestock**<br>☑ **Agriculture bioenergy**<br>☑ **Agriculture residues**<br>☑ **Forest industrial roundwood**<br>☑ **Forest fuelwood**<br>☑ **Forest residues** |
| **Agricultural commodities** | ☑ **Wheat**<br>☑ **Rice**<br>☑ **Other coarse grains**<br>☑ **Oilseeds** | ☑ **Sugar crops**<br>☑ **Ruminant meat**<br>☑ **Non-ruminant meat and eggs**<br>☑ **Dairy products** |

# Emission, climate and impacts

| | | |
|---|---|---|
| **Greenhouse gases** | ☑ **CO2 fossil fuels**<br>☑ **CO2 cement**<br>☑ **CO2 land use**<br>☑ **CH4 energy**<br>☑ **CH4 land use**<br>☑ **CH4 other**<br>☑ **N2O energy** | ☑ **N2O land use**<br>☑ **N2O other**<br>☑ **CFCs**<br>☑ **HFCs**<br>☑ **SF6**<br>☑ **PFCs** |
| **Pollutants** | ☑ **CO energy**<br>☑ **CO land use**<br>☑ **CO other** | ☑ **NOx energy**<br>☑ **NOx land use**<br>☑ **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<br>☑ Concentration: CH4<br>☑ Concentration: N2O<br>☑ Concentration: Kyoto gases<br>☑ Radiative forcing: CO2<br>☑ Radiative forcing: CH4<br>☑ Radiative forcing: N2O<br>☑ Radiative forcing: F-gases<br>☑ Radiative forcing: Kyoto gases | ☑ Radiative forcing: aerosols<br>☑ Radiative forcing: land albedo<br>☑ Radiative forcing: AN3A<br>☑ Radiative forcing: total<br>☑ Temperature change<br>☑ Sea level rise<br>☑ Ocean acidification<br>☑ Radiative Forcing (Land Albedo) - Yes (exogenous) |
| **Carbon dioxide removal** | ☑ Bioenergy with CCS<br>☑ Reforestation<br>☑ Afforestation | ☐ Soil carbon enhancement<br>☑ Direct air capture<br>☐ Enhanced weathering |
| **Climate change impacts** | ☑ Agriculture<br>☐ Energy supply<br>☐ Energy demand | ☐ Economic output<br>☐ Built capital<br>☐ Inequality |
| **Co-Linkages** | ☑ Energy security: Fossil fuel imports & exports (region)<br>☑ Energy access: Household energy consumption<br>☐ Air pollution & health: Source-based aerosol emissions | ☑ Air pollution & health: Health impacts of air Pollution<br>☑ Food access<br>☑ Water availability<br>☐ Biodiversity |

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