# **EPA Biofuels Workshop**

Overview of modeling frameworks of cropbased biofuels

ADAGE Global CGE Model

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# ADAGE Model: Overview

- Recursive-dynamic computable general equilibrium (CGE) model
  - Characterize the entire economy; account for linkages between sectors, balances labor & financial markets

## • History

- > Developed/maintained by RTI International since 2010
- Main data source GTAP 7, complemented by many sources (e.g. IEO, FAO, EIA)
- Written in GAMS/MPSGE and solved for 40 years (2010-2050 in 5-year time steps) in around 3 hours
- Initially designed for ag & biofuel related analysis and expanded for transportation, energy related

## • Geography: Global

> 8 regions (including US, China, Brazil)

## • Emissions:

- > Greenhouse gases (CO2, CH4, N2O, HFCs, PFCs, SF6)
- > Air pollutants (black carbon, CO, NH3, NMVOC, NOx, OC, PM10, PM2.5, SO2)



## **ADAGE Model: Sectoral Detail**

• Sectors: all sectors included with most detail in energy, transportation, and agriculture

#### > Energy

- ✤ Fossil fuel energy: coal, oil, natural gas
- Electricity generation: coal & gas (CC, CT; +/- CCS), hydro, solar, wind, nuclear, biomass
- ✤ Biofuels: eight 1st gen, five advanced

#### > Transportation

- ✤ Modes: LDV, trucks, buses; non-road modes
- ✤ Technologies: ICE, HEV, BEV, FCEV, and natural gas

#### > Agriculture, livestock, & forestry

Crop types: corn, wheat, cereal grains other than corn and wheat, soybean, oilseeds other than soybean, sugarcane, sugarbeet, other crops

#### > Land use and land use change:

- Cropland (exclusively used for crops); pasture and natural grassland (used for livestock); forestland and natural forest (used for forest)
- Can convert from one type to another, conversion cost is the difference of land rent between two types
- ✤ Net emission from land use change is accounted in CO2

## ADAGE Model: 1<sup>st</sup> Generation Biofuels Supply

- $\circ$  **Ethanol**  $\leftarrow$  corn, wheat, sugarcane, sugar beet
- Biodiesel ← soybean, rapeseed mustard, and palm-kernel and corn oil
- $\circ$  Coproducts:
  - > Corn ethanol  $\rightarrow$  distiller's grains (ddgs)
    - $\rightarrow$  corn oil bio-diesel
  - Soybean biodiesel → oil meal
- Production: yield & conversion rate improve over time
- Feedstock Supply: Intensification, extensification, switch from other crops or land uses



**Production Structure** 

# ADAGE Model: Advanced Biofuels Supply

#### **Production Structure**

- **Crop land**  $\rightarrow$  Switchgrass, miscanthus
- Forest land → Forest wood (e.g., pulp logs and roundwood)
- Residues (no land) → Agricultural (e.g., corn stover), forest (e.g., milling and harvest)
- Production: yields & cost improve over time and become competitive after 2030



## **ADAGE Model: Biofuels Demand**

#### Biofuel demand

- > Reference blending ratio (see right figure)
  - Differ by modes and biofuels
  - Substitution among biofuels and oil is governed by elasticity of substitution
- > Blended fuel is used in on-road transportation modes and their technologies (ICE, HEV) in the current model
- Blended fuel will be expanded to other non-road transportation modes and their technologies (ICE, HEV) (in progress)

#### • GHG emissions

- > Accounted if fossil fuel is directly used during production
- > Accounted if associated with land use change

#### Share of Biofuels in Blended fuel



## ADAGE Model: CGE Benefits

- **Economy-wide linkages:** all economic activity is linked
  - Input-output accounting: link activity across sectors
  - Bi-lateral trade: link activity across regions
- **Substitution:** price-responsive producers and consumers drive market dynamics
- **Capital Accounting:** investment activity and stock vintaging constrain production
- Households: income balance constrains consumption and helps determine welfare
- Price determination: reflects economy-wide resource scarcity, production technology, consumer preferences, and policy
- **Dynamic structure:** improvement on sectorial and land productivity, energy efficiency, cost reduction of advanced technology, resource depreciation, capital vintaging

# **ADAGE Model: Key Features**

## • Monetary and Physical Quantities:

> Energy, transportation, agriculture, land activities linked economy-wide

## • **Demand calibration:**

- VMT demand for light-duty aligns to income, population, urbanization, preference
- Agriculture demand aligns to income, population

## • Technological Detail:

- Electricity, transportation, biofuels
- Represent technological improvement over time
- Vintage structure: vehicle VMT schedule, survival during its lifetime in transportation

## • Emissions:

Tracked from all sectors and sources, including land conversion

## Potential Biofuels Research: Energy, Food, Land, & Emissions

#### • Biofuels compete for land and water with:

- Crops for food and fibers
- Livestock pasture demands
- Forests for products and carbon sequestration
- Electricity from wind and solar generation

## • These interactions will be complicated by several factors:

- $\blacktriangleright$  Economic growth  $\rightarrow$  higher aggregate demand, shifts in diet
- $\blacktriangleright$  Climate policy  $\rightarrow$  biofuels, wind, and solar demand, forest sequestration
- $\blacktriangleright$  Climate impacts  $\rightarrow$  changes in land productivity, energy demand, water supply and demands

## Potential Biofuels Research: Improving Model Resolution

#### • Linkage with bottom-up models – improve sectorial and spatial resolution

- Electricity models (e.g. ReEDs)
- Agriculture and forest models (e.g., FASOM)
- Systems Optimization Models (e.g., GCAM, NEMS)

#### • Spatial downscaling model results

- Use historical time series of land cover at Landsat pixel scale (30x30 m resolution) to estimate relative likelihood of land conversion using machine learning
- Can be used to downscale land cover projections from ADAGE/FASOM models (e.g., increased cropland expansion due to biofuel policy)

# Thank you

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