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Building a Cleaner Energy Bridge to the Future

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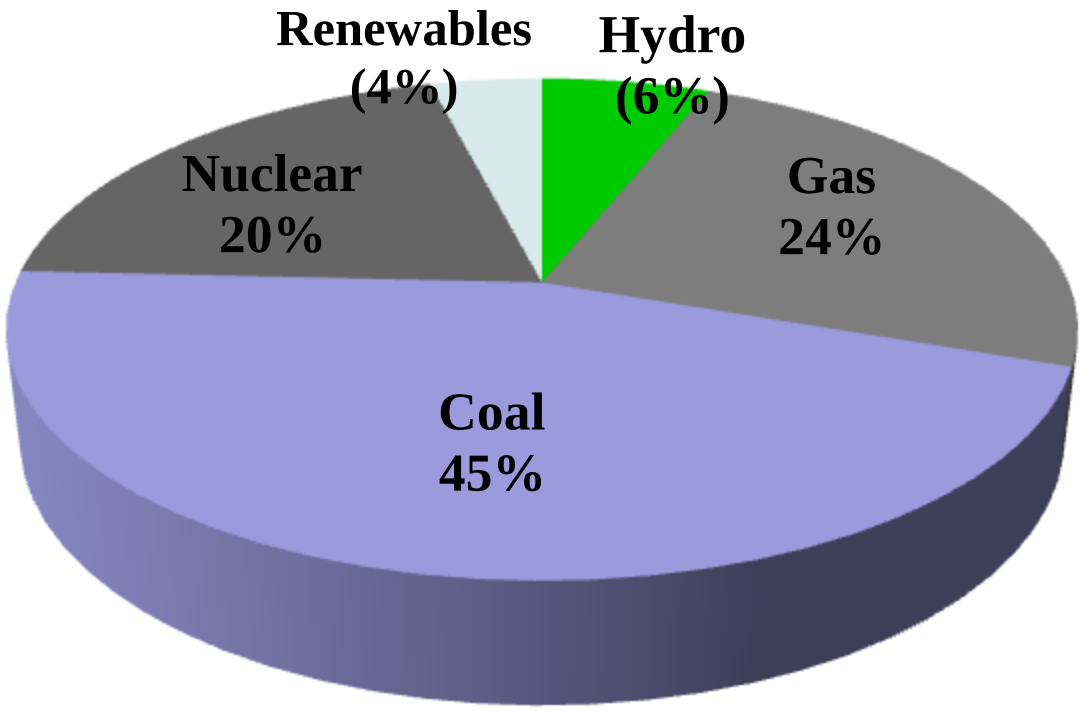
USA
Power Generation



Source: DOE Energy Information Agency (2010)

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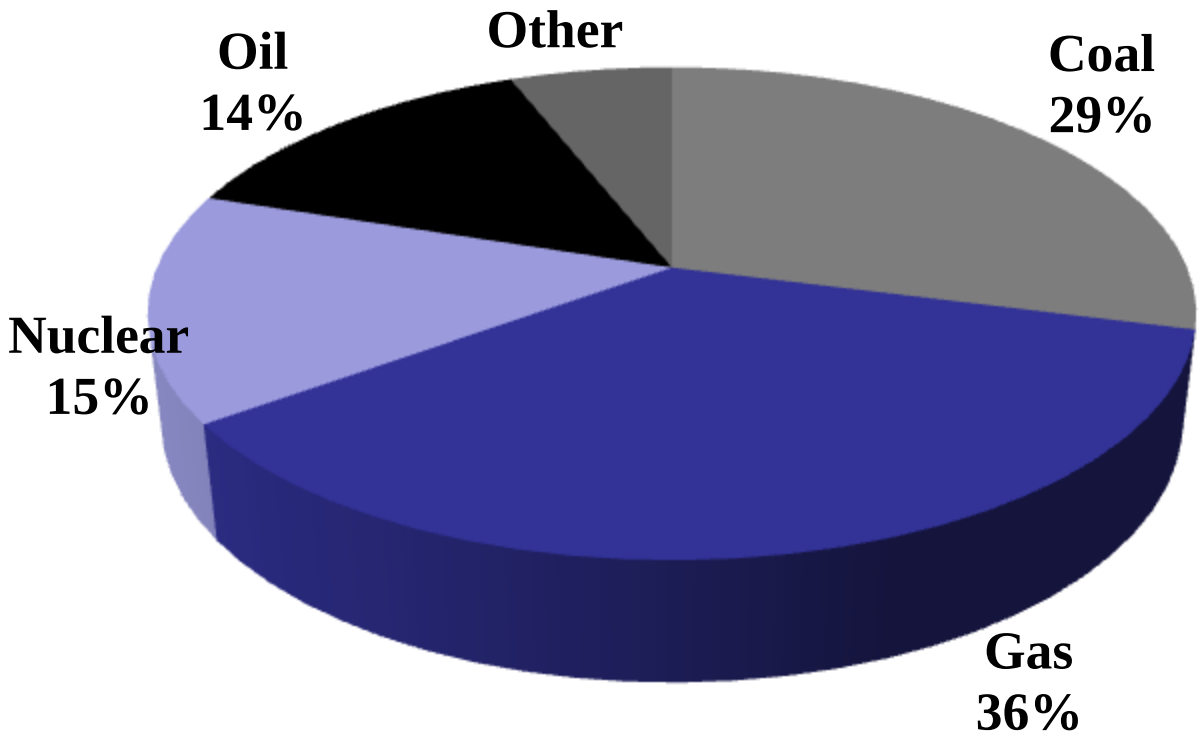
Florida Power Generation



Source: DOE Energy Information Agency (2010)

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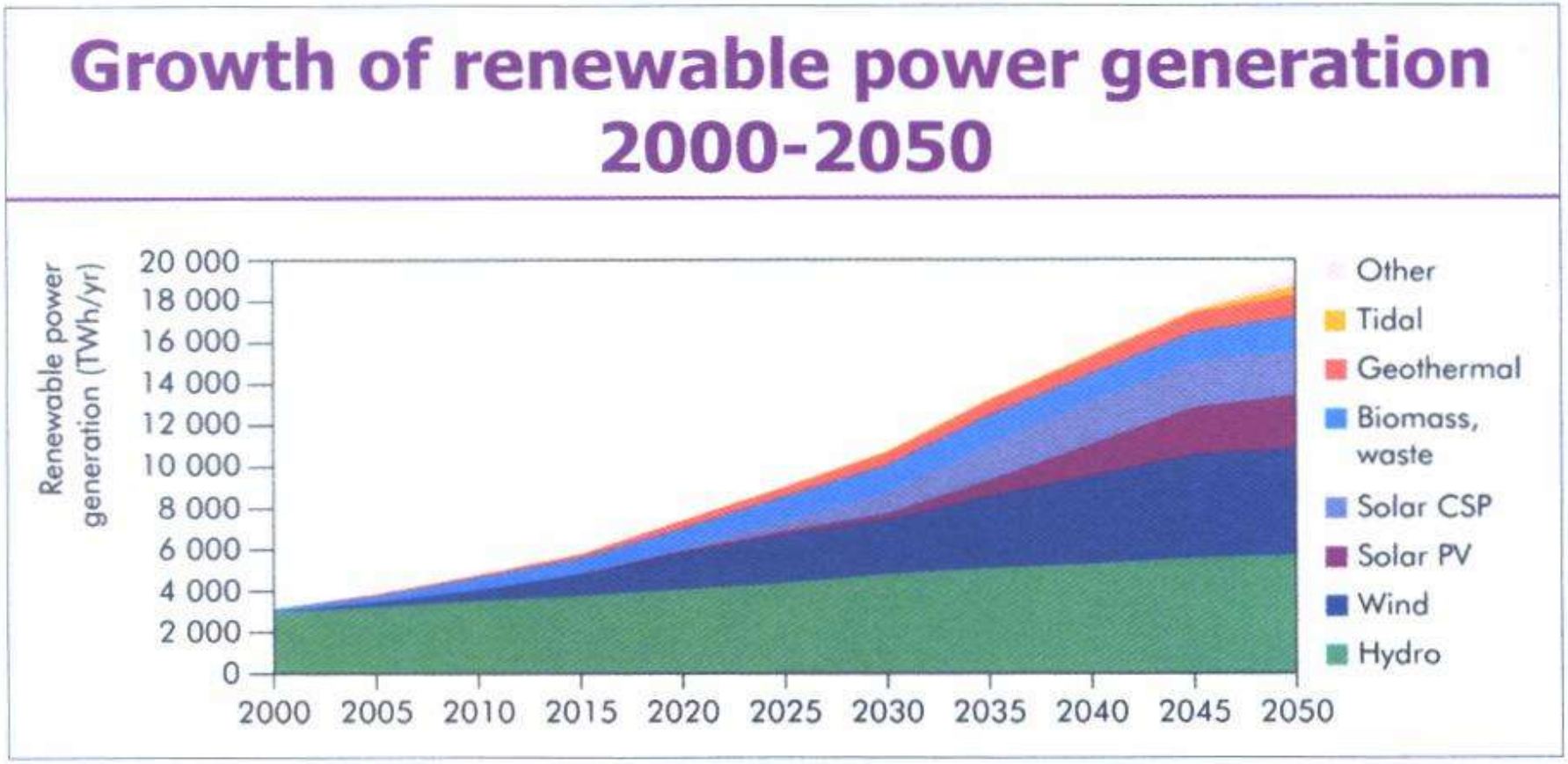
Future Energy Trends



Source: Cleantech Group (2008)

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Cleaner Energy Future

- **NATIONAL SECURITY**
  - Less dependence on imported oil
  - No dependence on single fuel
- **ENVIRONMENT**
  - Lower greenhouse gas (GHG) emissions
  - Better air quality
- **CONSUMER**
  - Fuel choices
  - Price competition at the pump
- **ECONOMY**
  - Employment
  - Increased trade
  - Private investment

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US Market Drivers for Alternative Fuels

Climate Change

- International efforts to reduce greenhouse gas emissions
- US climate change legislation
  - Renewable portfolio standards in 35 States, feed-in tariffs, tax incentives; billions of government funds committed

Sustainable Economic Growth

- Improved economics of renewable energy
- Global clean energy spending expected to increase 15% annually through 2020*

Energy Security

- Improved national security through domestic power and fuel production

* Source: New Energy Finance (2009)

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Alternative Fuels: Current Status

- **TODAY**
  - Ethanol from corn
  - Biodiesel from vegetable oils
  - Sustainability? "*Food vs. Fuel*" competition for land use

- **TOMORROW**
  - Natural gas
  - Ethanol, other biofuels, and green diesel from biomass
  - Biodiesel, aviation, and military fuels from algae
  - Multi-fuel vehicles (as in Brazil)

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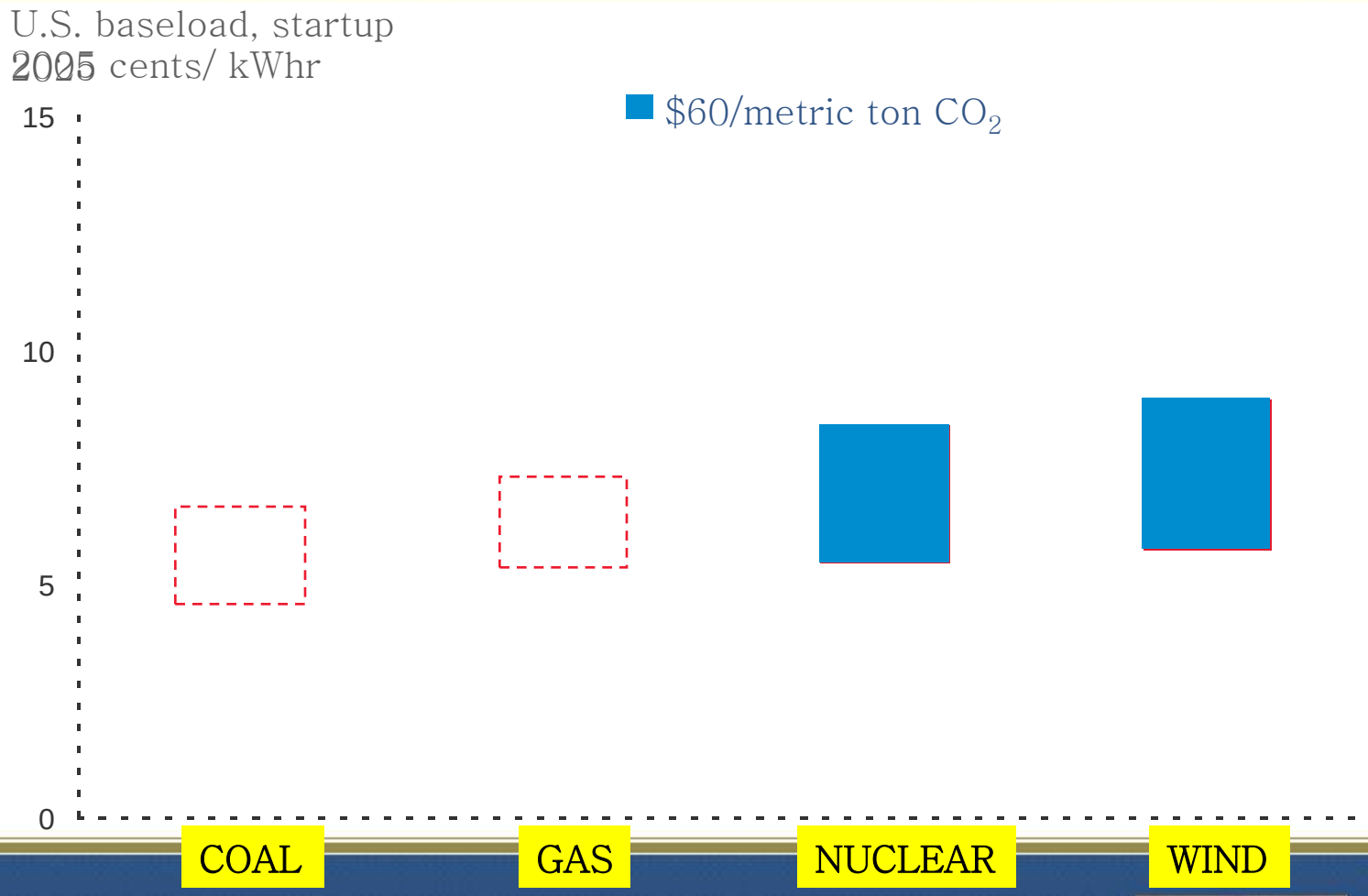
Power Generation Cost



Source: ExxonMobil (2009)

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Biofuels in Florida

- Ethanol market size: ~ 1 billion gal/yr (E10)
  - Gasoline: 9.0 billion gal/yr
- Biodiesel market size: 500 million gal/yr (B20)
  - Diesel: 2.5 billion gal/yr
- Policy: FL Law 7135 mandates E10 effective 12/31/10
- Production: None
- Transport options
  - Rail, truck, pipeline
- Imports/Exports
  - Strategic location in the US and the Americas

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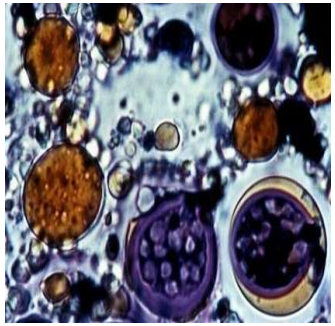
Advanced Biofuels from Biomass

- Cellulosic Biomass*
  - Sugarcane bagasse, corn stover, wheat straw
  - Wood, energy crops
  - Inedible and abundant

- Aquatic Biomass**
  - Warm weather and sunlight
  - Marginal land
  - Brackish water and CO_2



* Florida is #1 in cellulosic biomass availability (7% of US)

** Florida is ideal for outdoor cultivation of algae

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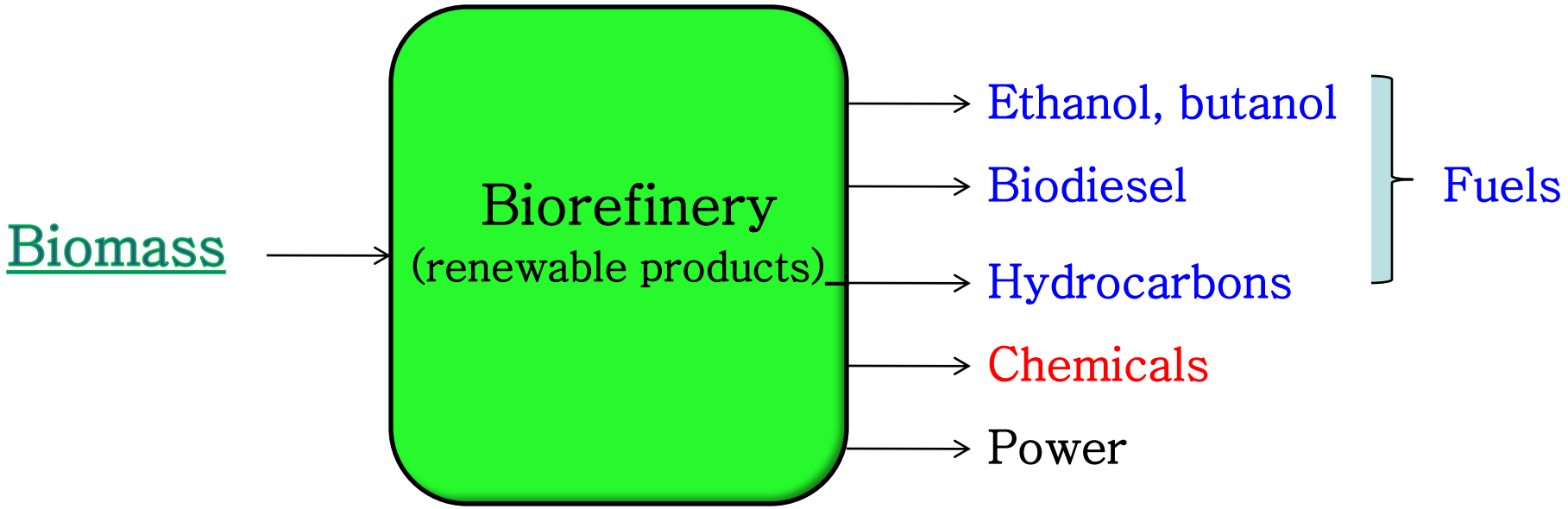
Biorefinery: Biomass Refinery



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Advanced Biofuels Technologies

1. Cellulosic Biomass —*Enzymes / Chemicals*→ Sugars —*Fermentation / Reforming*→ Alcohols, Hydrocarbons
2. Cellulosic Biomass —*Gasification / Pyrolysis*→ Syngas, Oil —*Catalysis*→ Hydrocarbons
3. Cellulosic Biomass —*Gasification*→ Syngas —*Fermentation*→ Alcohols
4. Algae —*Cultivation*→ Lipids —*Esterification / Reforming*→ Biodiesel, Hydrocarbons

Cellulosic Biofuels

- Biofuels from sugarcane bagasse and other local feedstocks
- Public-private joint venture (FIU-Florida Crystals Corp)
- Funded by the State of Florida and FCC
- Potential: 80-100 million gal/yr biofuels

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New Sources of Biodiesel

Oil-Seed Plants

- ***Jatropha***
  - Marginal land, warm climate
- ***Salicornia***
  - Salty water, warm climate
- ***Camelina***
  - Colder climate

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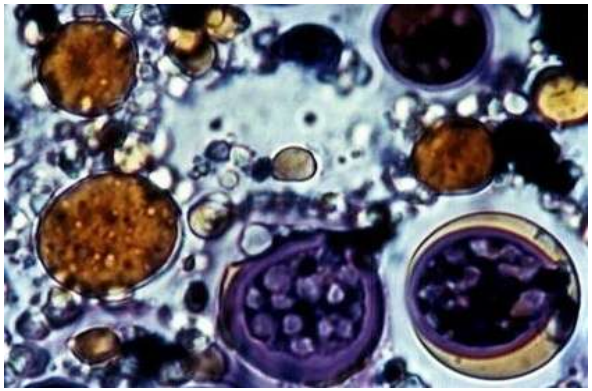
Algal Fuels

- Sunlight + CO_2 + brackish water
- Green diesel, aviation and military fuels
- High oil-yield promise (>5,000 gal/ha)
  - Corn ethanol 1,000
  - Palm oil biodiesel 1,500
  - Sugarcane ethanol 2,000
  - Cellulosic ethanol 2,500



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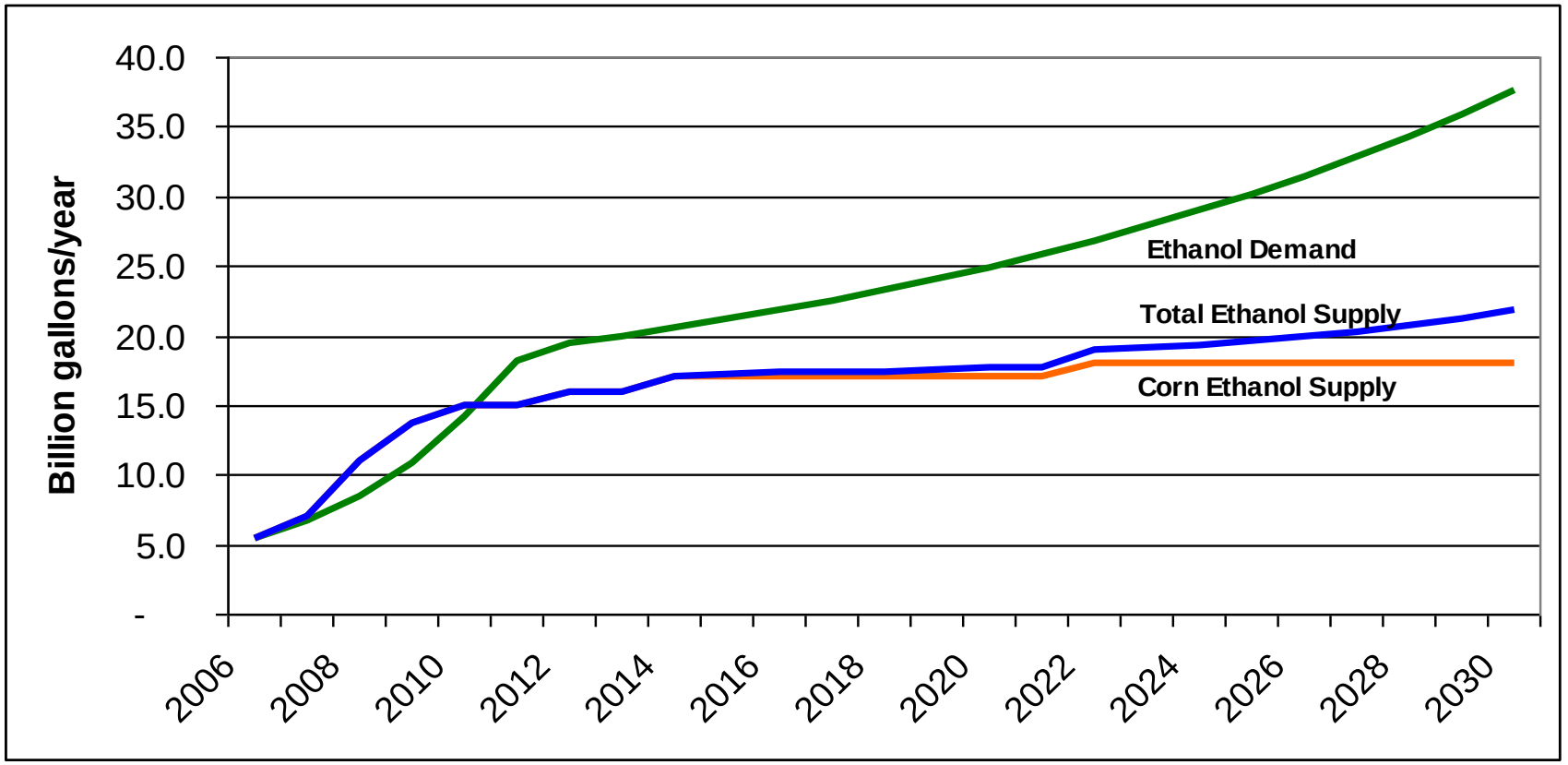
Advanced Biofuels: Natural gas can buy us time



Source: Philippidis, G. "Energy Security Achievable with Biofuels Made in the Americas", *Ethanol Producer Magazine*, pp. 232-235, Aug. 2008.

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Path Forward

- No silver bullet, but natural gas and biofuels can synergistically enhance energy diversification
- Long-term energy policy required
- Investment will follow policy
- Need public-private partnerships
- “Manhattan project” mentality needed for breakthroughs

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