



NextSTEPS Sustainable Transportation Energy Pathways

# Three paths forward for biofuels

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# Outline

- Models and projections:  Need for low carbon liquid fuels for long-term climate goals
- Expectations for biofuels:  shifting volume projections to 2030
- Snapshot:  current innovations in biofuels (‘three routes’)
  - Leapfrog investments
  - Incremental improvements
  - Transitional technologies
- Three Routes Forward:  supply-side scenario analysis
- Policy landscape
- Final thoughts:  Key questions moving forward

# Key takeaways

- **Incremental**: Small, incremental improvements in existing biorefineries can rapidly achieve near-term reductions in CO2e emissions.

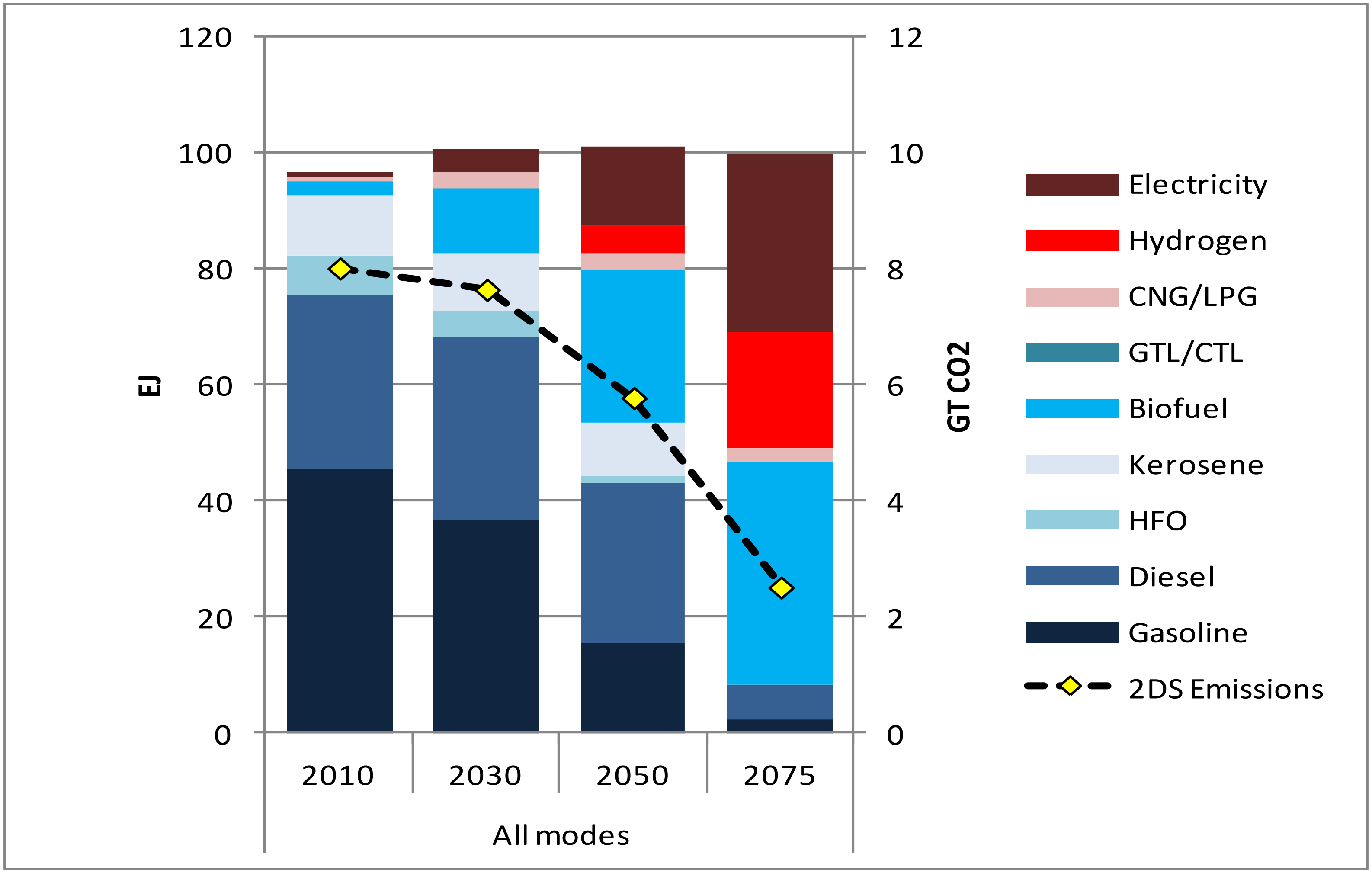
- **Leapfrog**: Large stand alone cellulosic biorefineries that require new technologies and large investments have the largest long-term potential but won't surpass *incremental* achievements until production hits at least 2 BGY.

- **Transitional**: Bolt-on/Gen 1.5 technologies that use corn stover and corn fiber have lower investment risk than stand-alone cellulosic facilities and might enable learning that provides a better business model for transitioning to cellulosics.

*Current policy landscape favors incremental improvements

# ETP-2012 extensions (Fulton et al draft paper)

## Summary picture: 27 EJ of biofuels in 2050, 40 in 2075

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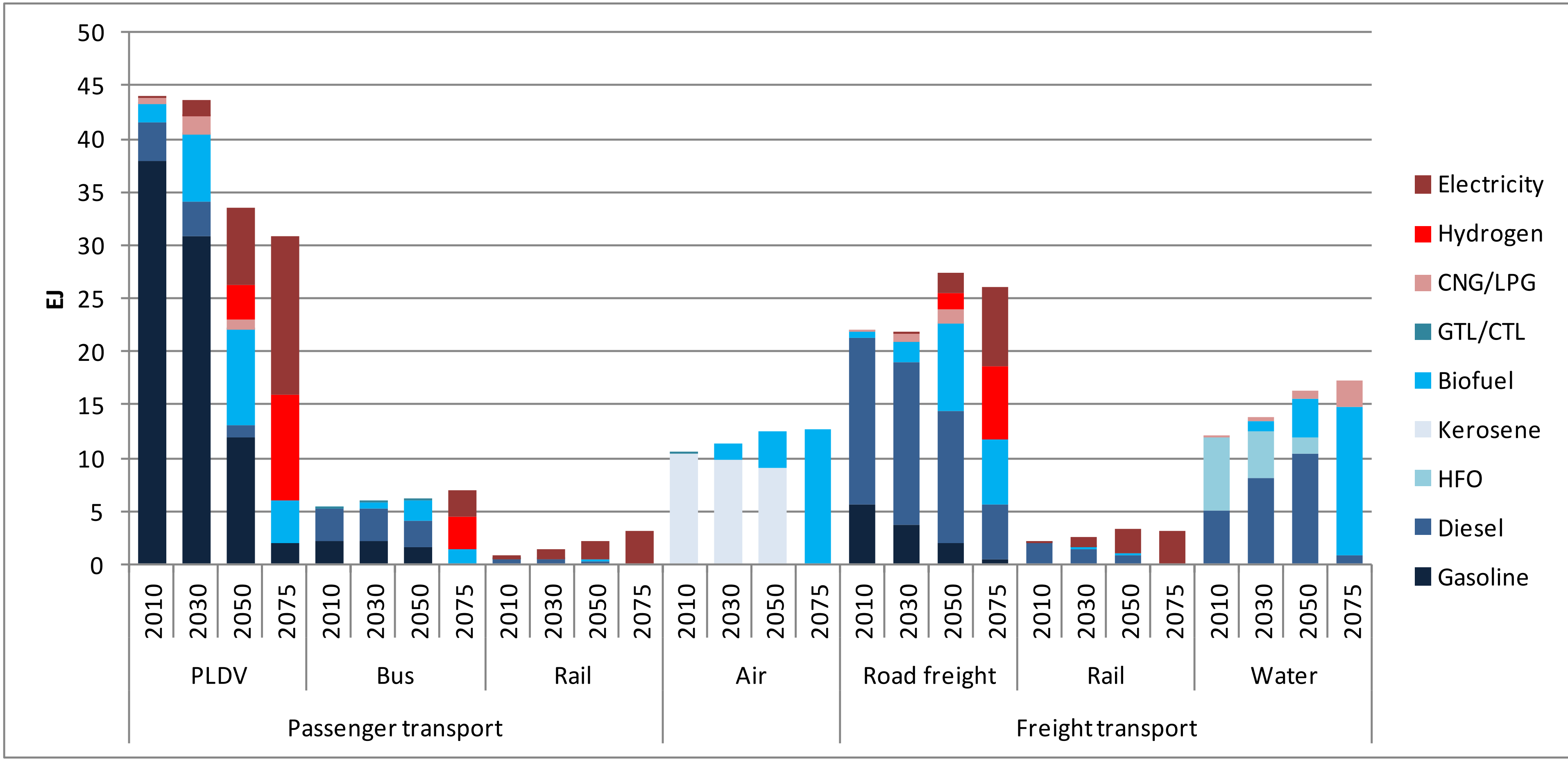
# Lots of electricity and hydrogen by 2050 in some modes, but still a huge liquid fuels need



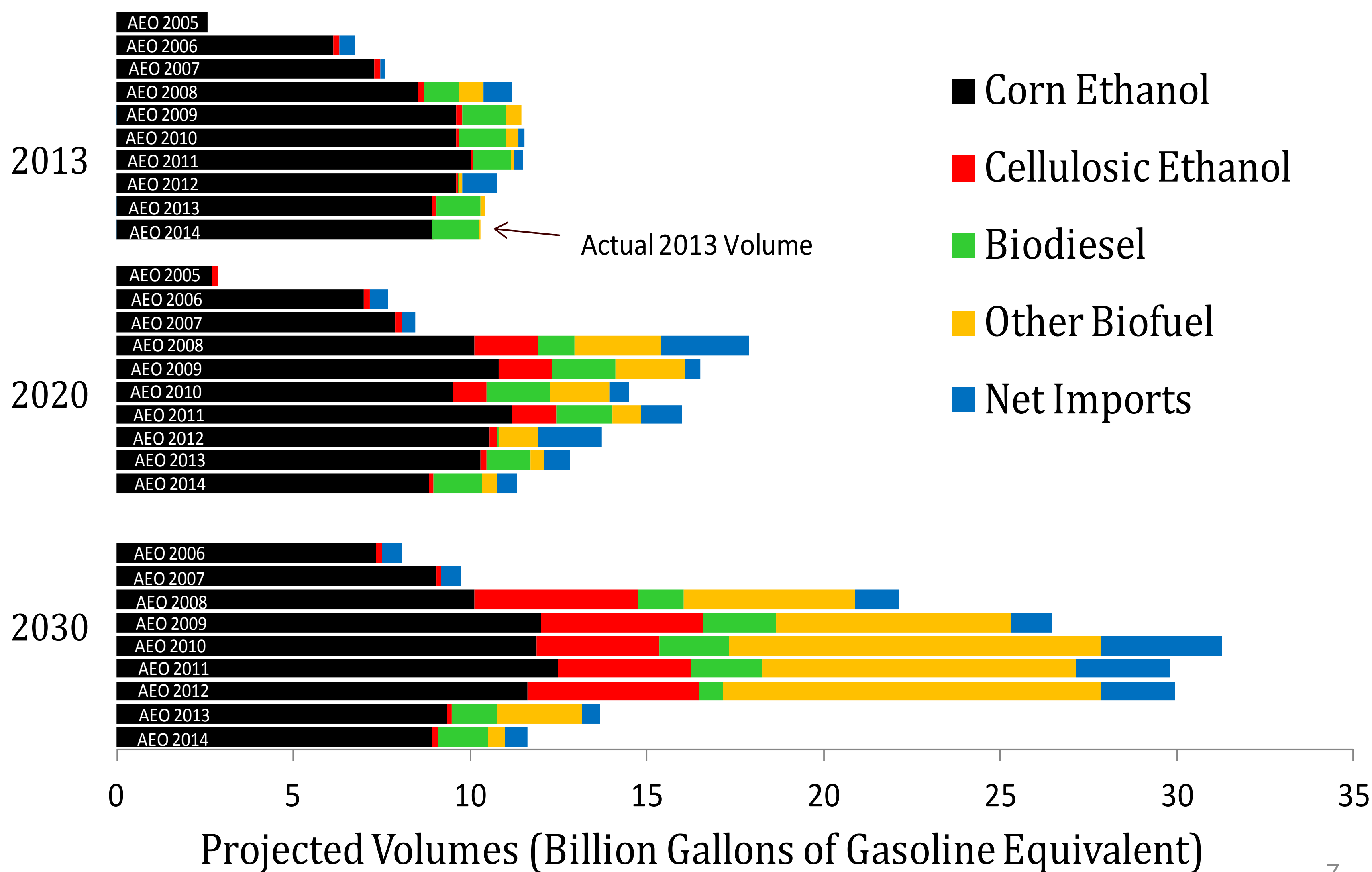
# Our aim: inform debate on biofuels, focusing on *technological development*

- Biofuel growth faces many constraints…
  - demand side (e.g., ethanol blendwall)
  - supply side (low carbon technologies)

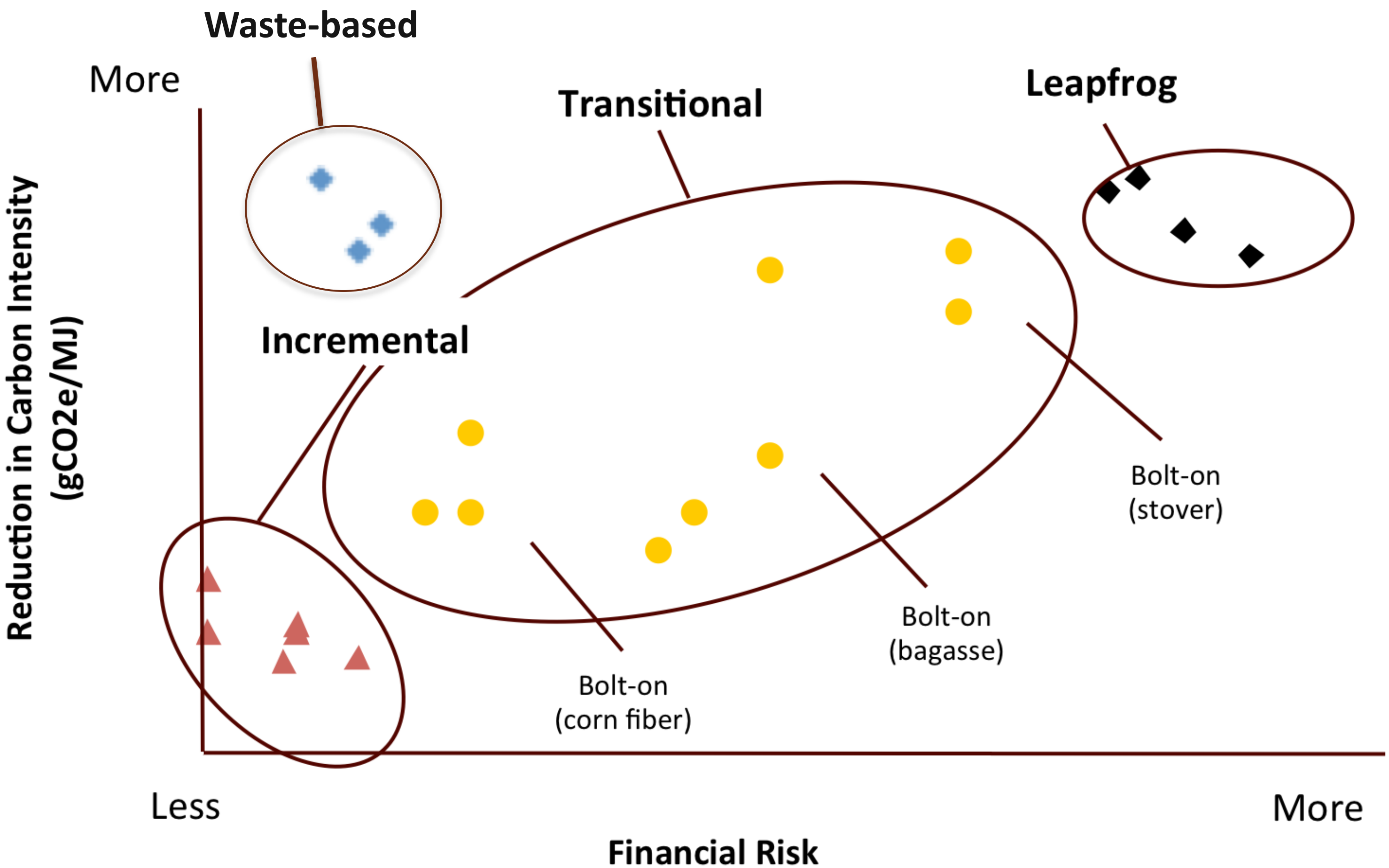
- …and many unresolved issues
  - full environmental impact (on climate and other factors)
  - appropriate policy (how to scale sustainably?)

- We focus on the near term *supply side* picture in the US
  - factors affecting technology development to date
  - using GHG emission profiles of the technologies *as currently assessed in policy* (not a comprehensive assessment of climate effects from policy)

# DOE Projections: Highly variable over time



# Improvements in biofuels operate on spectrum of carbon intensity and financial risk



# A new approach: Leapfrog vs. Incrementalism

| Dimension | Incremental | Transitional | Leapfrog |
|---|---|---|---|
| **Capital Requirement** | Small | Moderate | Large |
| **Risk to Capital** | Small risk of failure | Small to high risk of failure | High risk of failure |
| **Payback on Investment** | <2 years | ~2-10 years | >10 years |
| **Carbon Intensity Reduction from Petroleum Baseline** | Small reductions | 50% or greater but limited scalability. | Expected to be 50% or greater |
| **Actors** | Established producers (e.g. corn ethanol, soy biodiesel, etc.) | Established biofuel producers (e.g. corn ethanol, soy biodiesel, etc.), biochemical firms, petroleum refiners | Start-ups, established producers, Fortune 500 companies |
| **Primary Conversion Technologies** | Fermentation+distillation (FD), Transesterification (TE) | Enzymatic hydrolysis + fermentation (EHF), Pyrolysis to bio-oil | Enzymatic hydrolysis + fermentation (EHF), Pyrolysis + hydrotreating, Hydrotreating of algae oil, Gasification |
| **Examples of Firms** | Pacific Ethanol, Little Sioux Corn Processors (corn ethanol), Minnesota Soybean Processors (biodiesel) | Quad County Processors (corn fiber), Poet-DSM (corn stover), Abengoa Bioenergy, DuPont | KiOR, Mascoma, Ineos, BP Biofuels, Cool Planet, ZeaChem |

# Leapfrog firms having challenges or poised for commercialization?

**Cellulosic hydrocarbons:**

- e.g. KiOR, Columbus, MS
- Start-up difficulties

**Cellulosic ethanol:**

- e.g. Beta Renewables, Crescentino, Italy
- Slow start-up

**Stand-alone cellulosic plants in development:**

| Company | Location | Capacity |
|---|---|---|
| KiOR | Columbus, MS | 13 MGY |
| Beta Renewables | Crescentino, Italy | 20 MGY |
| Cool Planet | Alexandria, LA | 10 MGY |
| INEOS | Vero Beach, FL | 8 MGY |

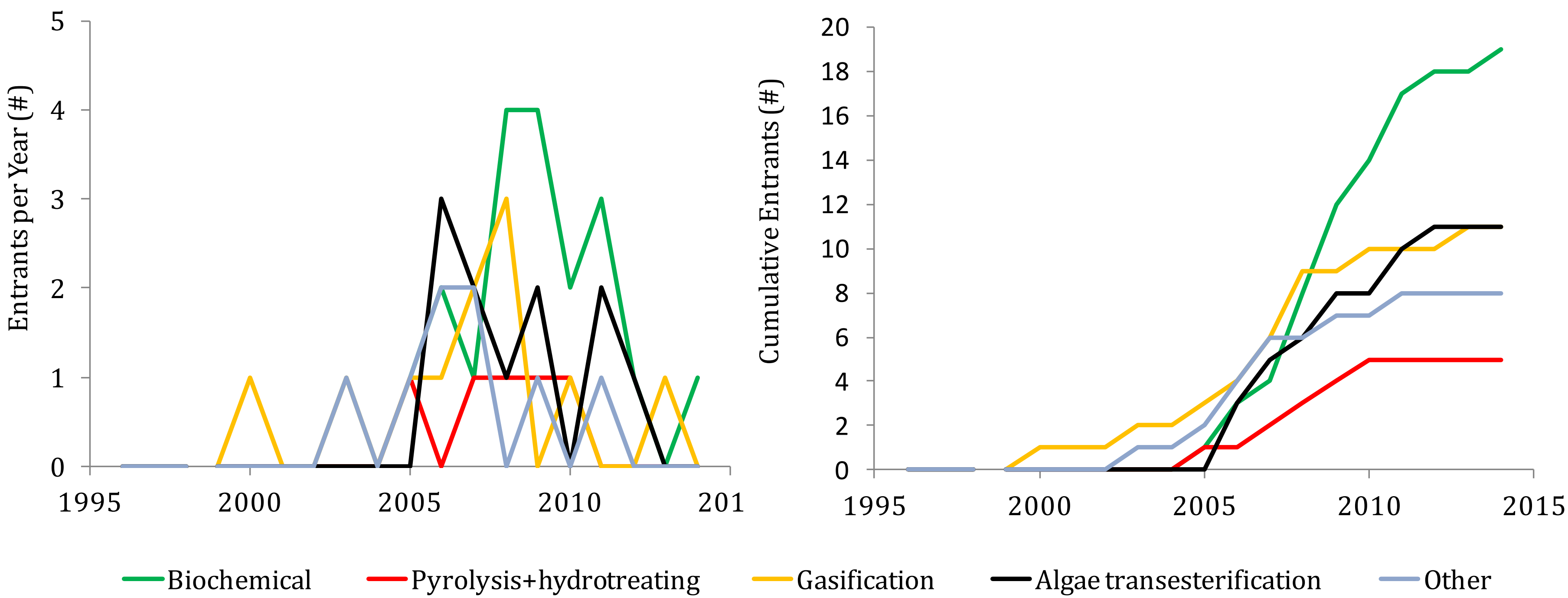
# Over $8 billion in Leapfrog biofuels funding since 2009

Seed Funding for Leapfrog facilities, split between Gov't, VC and energy company investments

| Leapfrog 2009-2012 | Total | Per year | Source |
|---|---|---|---|
| Federal | $3,335 million | $833 million | http://energyinnovation.us/ |
| Venture Capital | $2,325 million | $581 million | www.privco.com |
| Energy Companies | ~$2,000 million | $500 million | Company websites |

# Slow growth for most conversion technologies, enzymatic hydrolysis most common Leapfrog conversion technology

## New entrants (annual) | Cumulative

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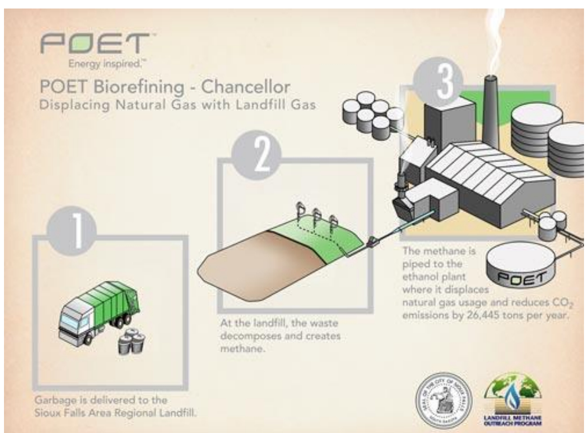
# Examples of Incremental Biorefineries

**Louis Dreyfus corn ethanol plant, Grand Junction, IA**

- NG-fired, DDGS, with corn oil extraction
- More efficient plant than reference
- Drops CI from 98.35 $gCO_2e/MJ$ to 89.56 $gCO_2e/MJ$
- Payback <2 years.
- 1.0 Gen

**Enogen corn**

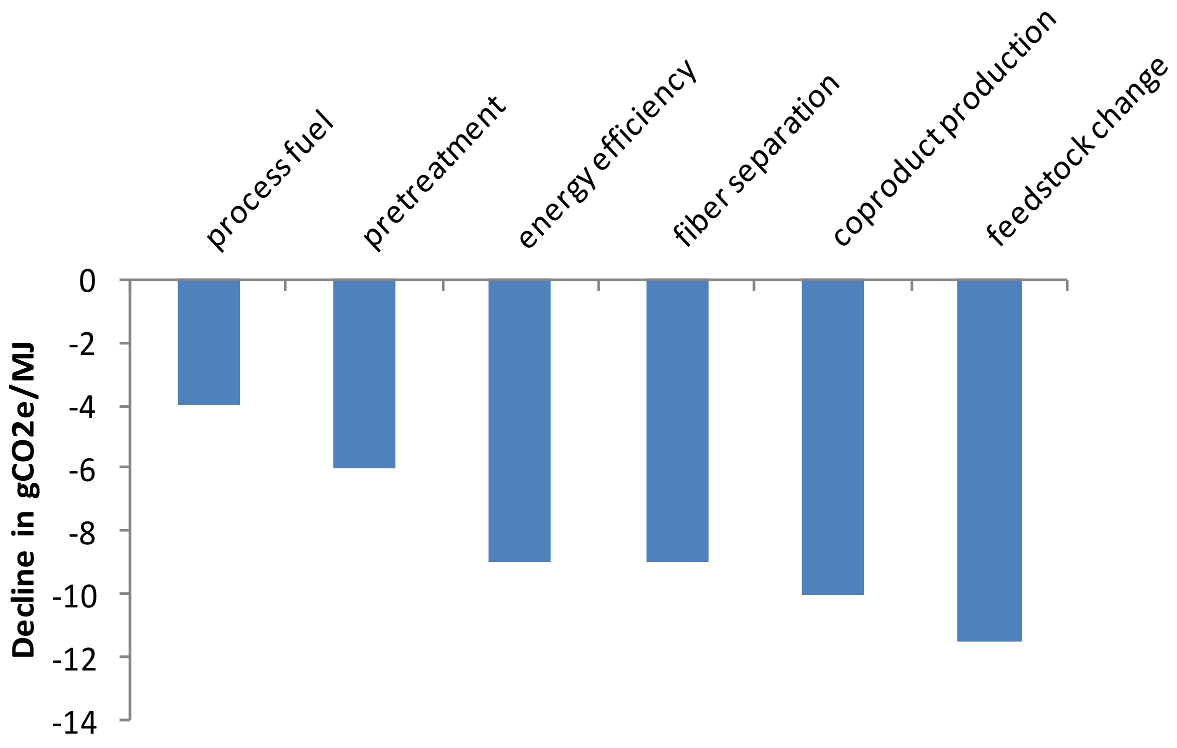
- GMO corn includes enzymes in kernel
- Enables process efficiencies




**POET corn ethanol plant, Chancellor, SD**

- Corn fractionation (1% lower CI)
- Landfill gas (no CI value given)
- Raw Starch Hydrolysis (6% lower CI)
- CHP vs. grid electricity (2% lower CI)

# Incrementalism is bringing down carbon intensities (self-reports)




- Compared to corn ethanol reference fuel at 98 $gCO_2e/MJ$
- Incremental changes to corn ethanol production result in modest carbon intensity reductions (~13% reduction at POET in SD)
- Source: Self-reported ratings for available pathways in California's Low Carbon Fuel Standard

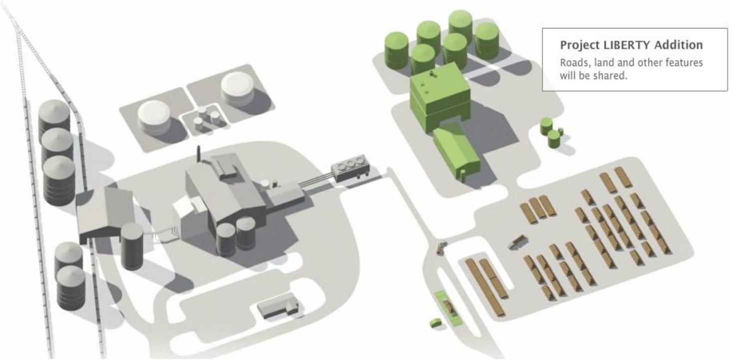
# Examples of transitional technologies

**Corn fiber cellulosic:**

- e.g. Pacific Ethanol, Stockton CA
- Payback 12-18 months
- 2-3% yield improvement

**Bagasse cellulosic:**

- e.g. Usina Vale, Brazil
- Increases plant capacity from 40 MGY to 51 MGY at capital cost of $3.50/gal of capacity




**Corn Stover cellulosic:**

- e.g. POET-DSM, Emmetsburg, IA
- Shared road, rail spur, grid connections
- Separate facilities

**Other transitional plants in development:**

| Company | Location | Production |
|---|---|---|
| Abengoa | Hugoton, KS | 25 |
| DuPont | Nevada, IA | 30 |
| GranBio | Alagoas, Brazil | 21 |
| Quad County Processors | Galva, IA | 2 |

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# Can the Transitional route be stepping stone to Leapfrog?

Transitional
(Bolt-ons) → ? → Full Leapfrog

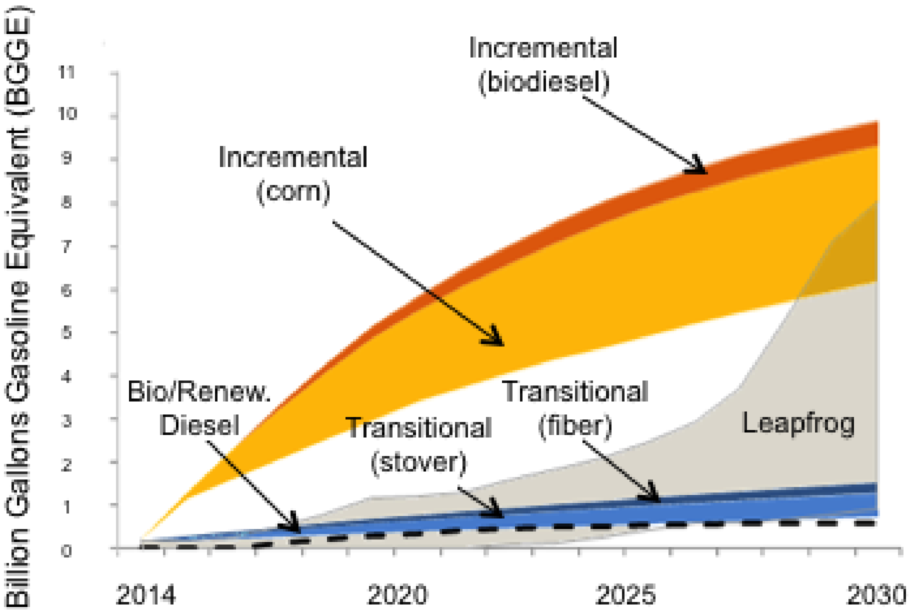
Current bolt-ons:

1. Corn fiber → cellulosic ethanol
2. Corn stover → cellulosic ethanol
3. Sugarcane bagasse → cellulosic ethanol

*No thermochemical pathways
**Only residue feedstocks

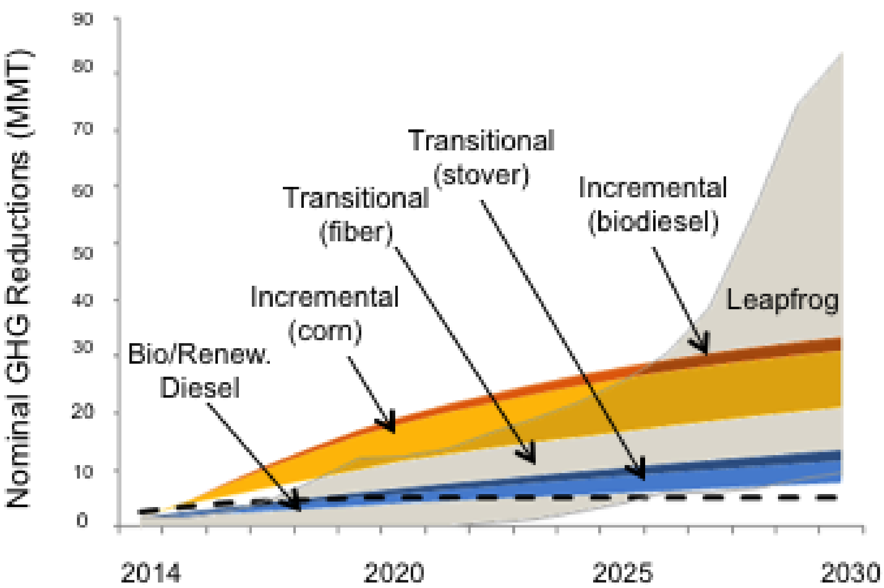
# Incremental route is most important for near term developments

## Biofuel production potential




Base biofuel use in 2013 = 10.5 BGGE

## Nominal GHG Impacts




US Transport GHG in 2012 = 1,735 MMT

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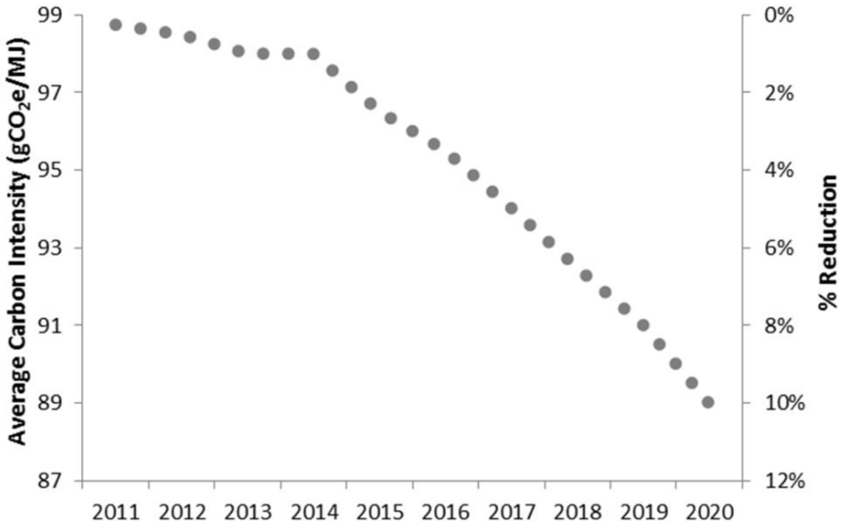
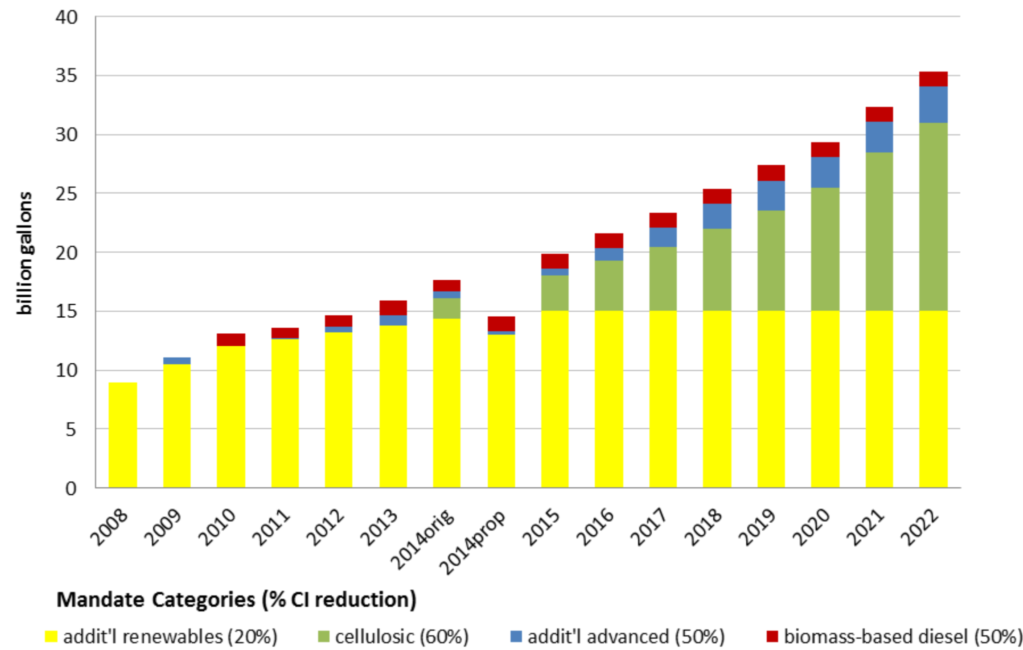
# US policy landscape for low carbon fuels includes two different policy designs




**California's Low Carbon Fuel Standard (LCFS)**

Annual Carbon Intensity Targets

rated as 10% reduction by 2020 (from 2010)

**US Renewable Fuel Standard (RFS)**

Annual Volume Mandates (nested)

15 bg corn eth limit (2015)

16 bg cellulosic fuels (2022)

Carbon intensity reduction thresholds

(rated as 20%, 50%, 60% from gasoline reference)

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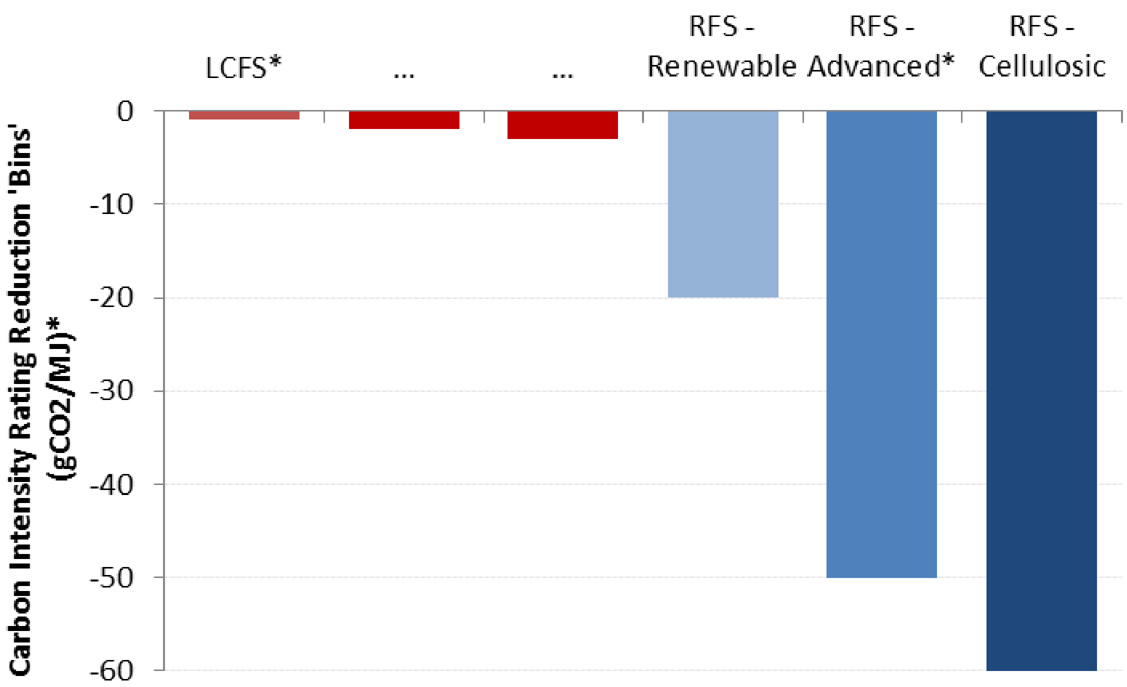
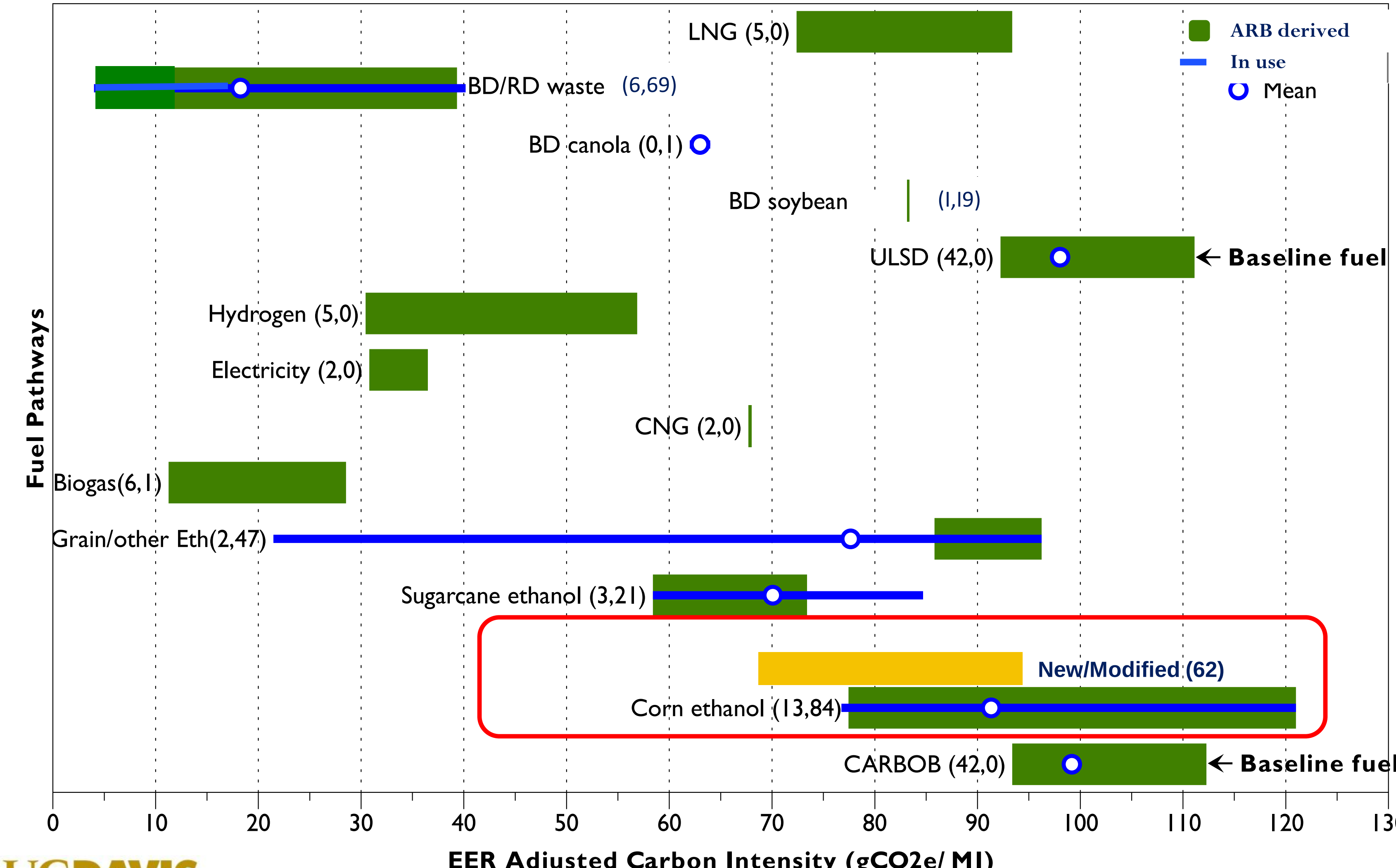
# Policy landscape currently favors incrementalism




- **Incremental.** California's Low Carbon Fuel Standard especially
  - $1gCO_2e/MJ$ carbon reduction bin width; wider under US Renewable Fuel Standard
- **Transitional.** Limited support
  - modest credit prices, RFS cellulosic 'price premium' from waiver
- **Leapfrog.** Either program *could*
  - 'high enough' credit price + 'low enough' capital gap
- *Volatile, uncertain credit prices (in both policies) → favors incrementalism*

*** Bins are rewarded reductions from CI of target (LCFS) or reference fuel (RFS); LCFS has 5gCO2e/MJ min to modify existing pathways; RFS-Advanced includes Biomass-Based Diesel**

# California LCFS tracks carbon intensity ratings for existing and new pathways

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California Low Carbon Fuel Standard (LCFS) pathways, Nov 2013 (# default, # in use)

Source: CA Air Resources Board (ARB)

# Final thoughts (5 questions for the future)

- How far should (can) we go down an ethanol pathway over the medium-long term?
- **Leapfrog.** What is required (and when will it happen) to spur investments in large-scale Leapfrog facilities?
  - Key lessons from existing leapfrog efforts for next steps?
  - How to ensure scale-up occurs with proper environmental safeguards?
    - conditions for sustainable use – how to identify, enforce, monitor?
- **Transitional.** Are there ways to encourage 'transitional' investments so that they open up opportunities for higher volume, low carbon liquid fuels?
- **Incremental.** Is more needed to realize incremental improvements in the near term?
- Slower ramp-up – perhaps provides 'breathing space' for society to debate biofuel pros and cons, find answers to questions above, refine policies.

# Questions?

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