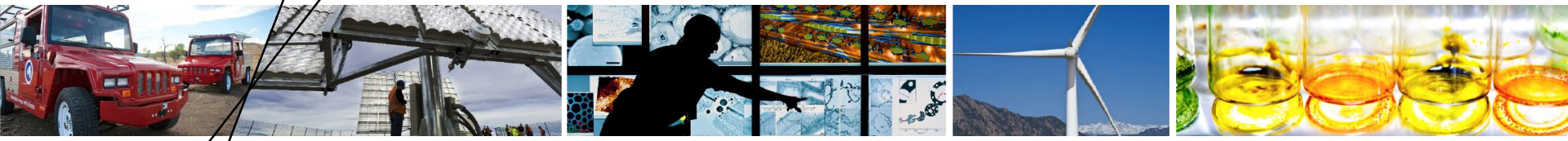
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

United States of America Country Update



IEA Bioenergy Task 39 business meeting

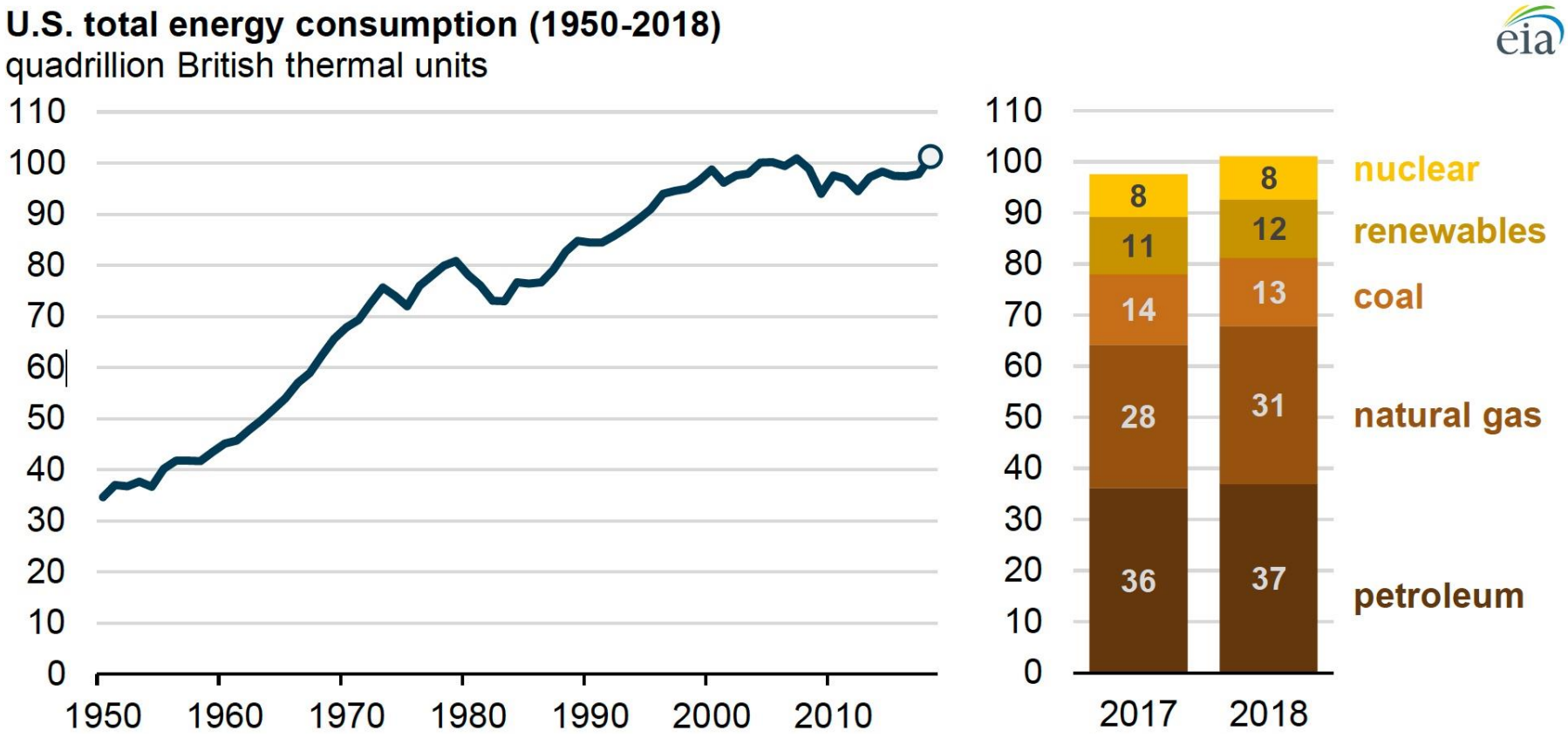
James D. "Jim" McMillan; jim.mcmillan@nrel.gov

Ispra, Italy

May 15, 2019

Energy Production & Use by Source 1950-2018

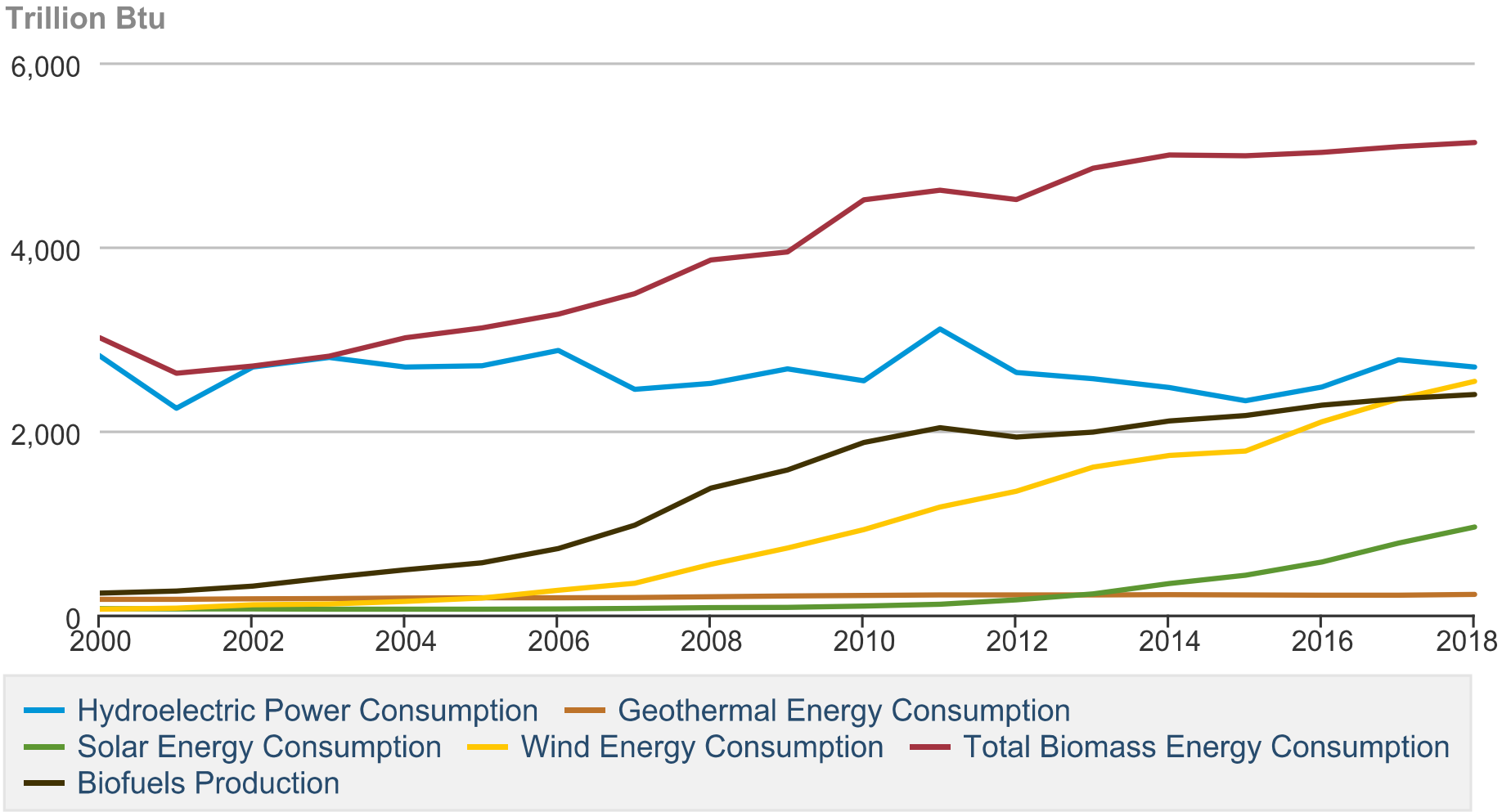
In 2018, energy consumption in the United States increased slightly (to its highest level ever). Fossil fuels use grew by 4% (natural gas by 10% over 2017 but coal use down by 4%), with small increases in the use of petroleum fuels, renewable energy, and nuclear electric power.



Source: US Energy Information Administration (EIA). 2019. https://www.eia.gov/todayinenergy/detail.php?id=39092#

RE Production & Use by Source 2000-2018

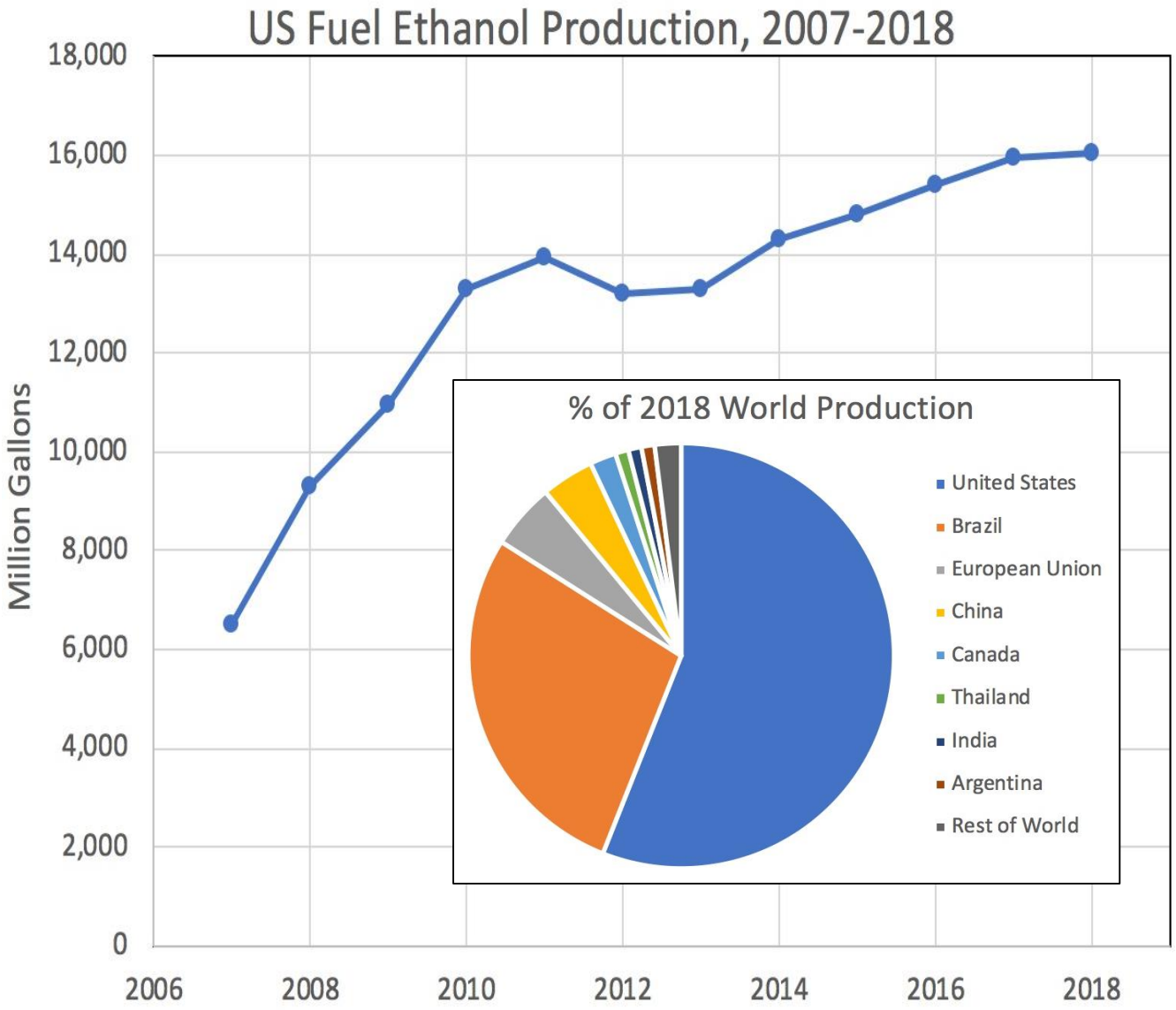
Renewable energy production and consumption in the United States continues to increase. Bioenergy remains largest contributor to RE but seeing far less growth than solar and wind.



Source: US EIA. 2019. https://www.eia.gov/totalenergy/data/browser/?tbl=T10.01#/?f=A&start=2000&end=2018&charted=6-7-8-9-14-2

Historical US Ethanol Production

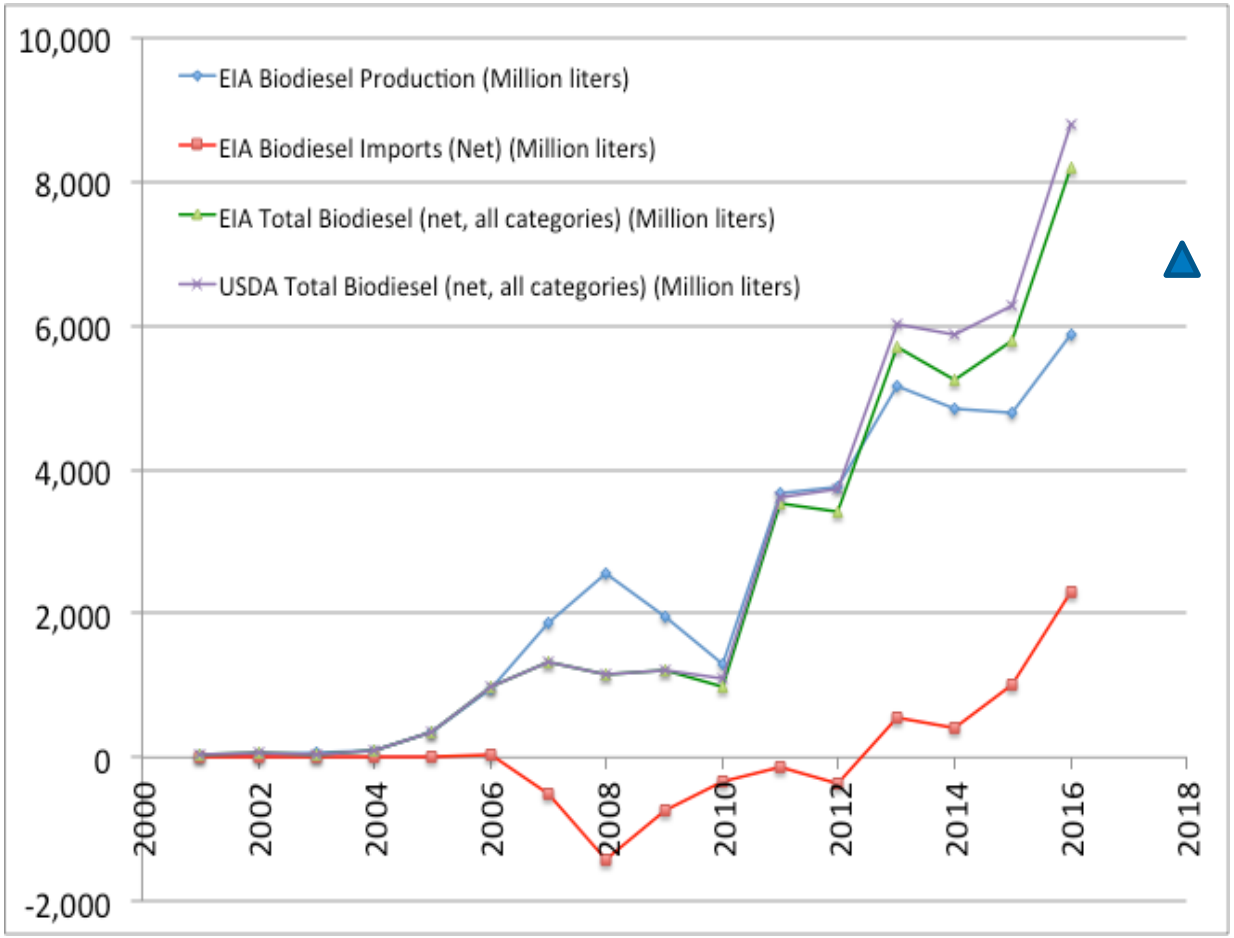
- 16.1 billion gallons (60.9 billion liters) produced in 2018, from ~200 plants, mostly from corn (starch); 2019 trending similarly
- 10% v/v blend wall slightly exceeded; E15 starting to be pushed but mostly E10 now
- Cellulosic production ~ 0.68 MM gal/month, about 50% above 2017 levels (based on RIN data); projected to reach 2 MM gal/month in 2019
- Anticipate on-going modest production increases in future; depends on ability to export and how fast cellulosic ramps up



Sources: Renewable Fuels Association (RFA). 2019. http://ethanolrfa.afflectommbeta.com/statistics/annual-ethanol-production/

USA Diesel Biofuels Production, 2001-2018

- From 2010–2011 and 2017–2018, biodiesel production grew from 0.7 billion gallons to 1.8 billion gallons (6.8 billion liters)
- Production volumes remain limited by available oleaginous feedstocks – soybean oil remains largest single feedstock used; use of waste feedstocks growing
- Increasing share of HVO/HEFA fuels (Renewable Diesel) relative to traditional FAME biodiesel

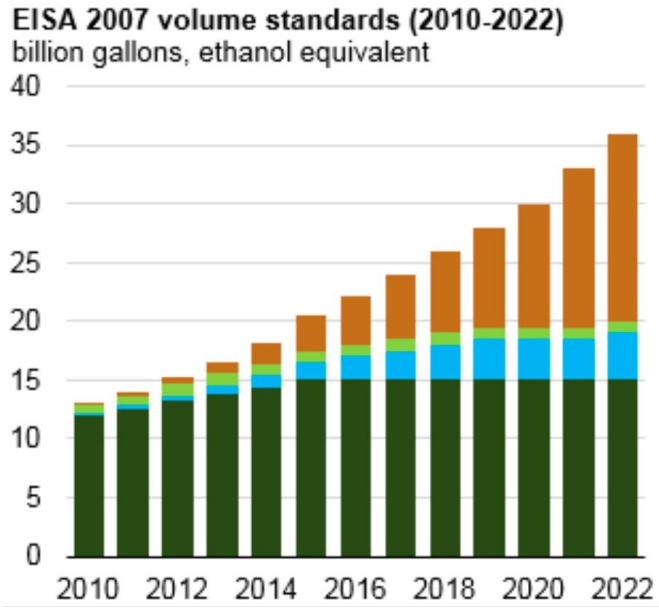


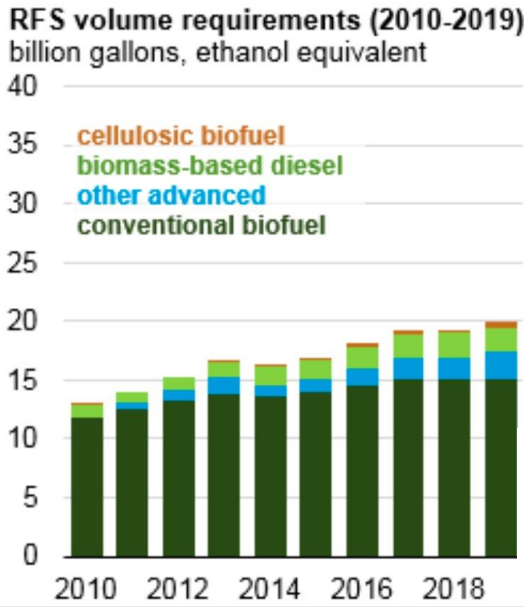
Sources: EIA 2017; 2019; RFA (http://www.ethanolrfa.org/resources/industry/statistics/)

Other Developments

EPA has finalized the Renewable Fuel Standard volume obligations for 2019. Lowered targets reflect shortfalls ramping up production of advanced and cellulosic biofuels

Source: https://www.eia.gov/todayinenergy/detail.php?id=37712





eia

- Farm Bill renewed in 2018, retains most energy programs through FY23; particularly important for USDA-funded (versus DOE-funded) programs, including feedstock development projects and loan guarantees for first of a kind commercial production plants
- DOE continuing to fund a lot of RD&D however emphasis shifted from demonstration & deployment to lower technology readiness level (TRL) research and development projects
  - Most recently announced a new $79 million Funding Opportunity Announcement (FOA) for bioenergy R&D (multi-topic spanning drop-in fuels, biopower and bioproducts from algae and lignocellulose feedstocks as well as (”negative cost”) urban and suburban “waste” feedstocks
- Changes to Marine Fuel Sulfur Limits coming in 2020; large emerging opportunity for lower specification biofuels

2018-2019 US Biofuels Summary

Federal RFS2 continues w/ uncertainty; CA's LCFS has become largest driver for advanced biofuels development

Positive

- Federal-level RFS2 and state of CA's LCFS remain in force, together providing strong driver for further biofuels development
- Many cities/states re-committing to Paris agreement goals after US administration stated its intention to withdraw from it
- US remains world's largest producer; 2018 production was ~ 60 B L ethanol, mostly from corn grain, and ~ 7 B L diesel biofuels, both FAME biodiesel and HVO/HEFA renewable diesel (RD), from oleaginous feedstocks.
- Biofuels production efficiencies for many routes keep improving
- Commercialization of dedicated cellulosic and CO/syngas to fuels progressing (e.g., Lanzatech for ethanol, Fulcrum for FT fuels), as is corn fiber cellulosic ethanol (e.g., Edeniq, QCCP, ICM and ADM)

* RFS2 = Renewable Fuel Standard

* LCFS = Low Carbon Fuel Standard

Negative

- Petroleum production booming, prices too low for advanced biofuels to be economically competitive. Policy uncertainty and political polarization also remain high.
  - Many companies have redirected RD&D & business strategy towards renewable chemicals (e.g., Amyris)
  - Other producers also going slow, e.g., POET-DSM cellulosic ethanol plant production still below design (inferred from RIN generation data); progress on routes also slowed, e.g., Ensyn co-processing
- US administration continues to deemphasize R&D funding for sustainable biofuels/reducing GHGs as impacts of climate disruption increase
- Urban e-mobility advancing, has public's attention, shifting focus away from biofuels
- Bioenergy still being held to a higher standard than other technologies, e.g, concerns about:
  - Food vs. fuel; carbon neutrality
  - Adv. biofuel production lags RFS2 targets; obligated volumes revised down to reflect actual production; RFS2 being attacked; further policy changes remain likely but uncertain about what they will be

Acknowledgment

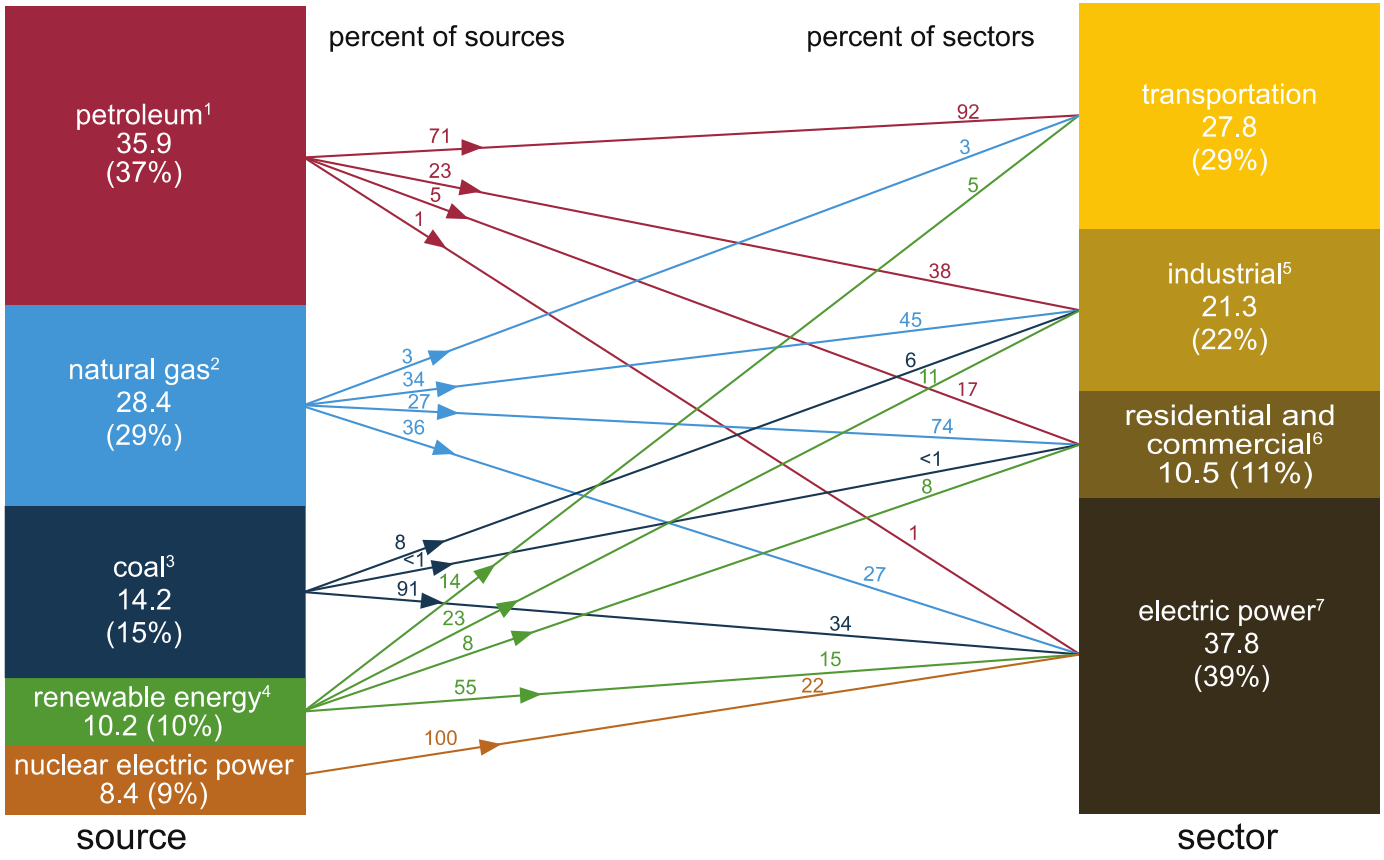
Funding from USDOE EERE Bioenergy Technologies Office (BETO) and IEA Bioenergy Task 39.

Thanks for Your Attention!
Questions?

Additional Slides
(EIA ethanol data)

USA Primary Energy Use in 2016

Total = 97.4 quadrillion British thermal units (Btu)



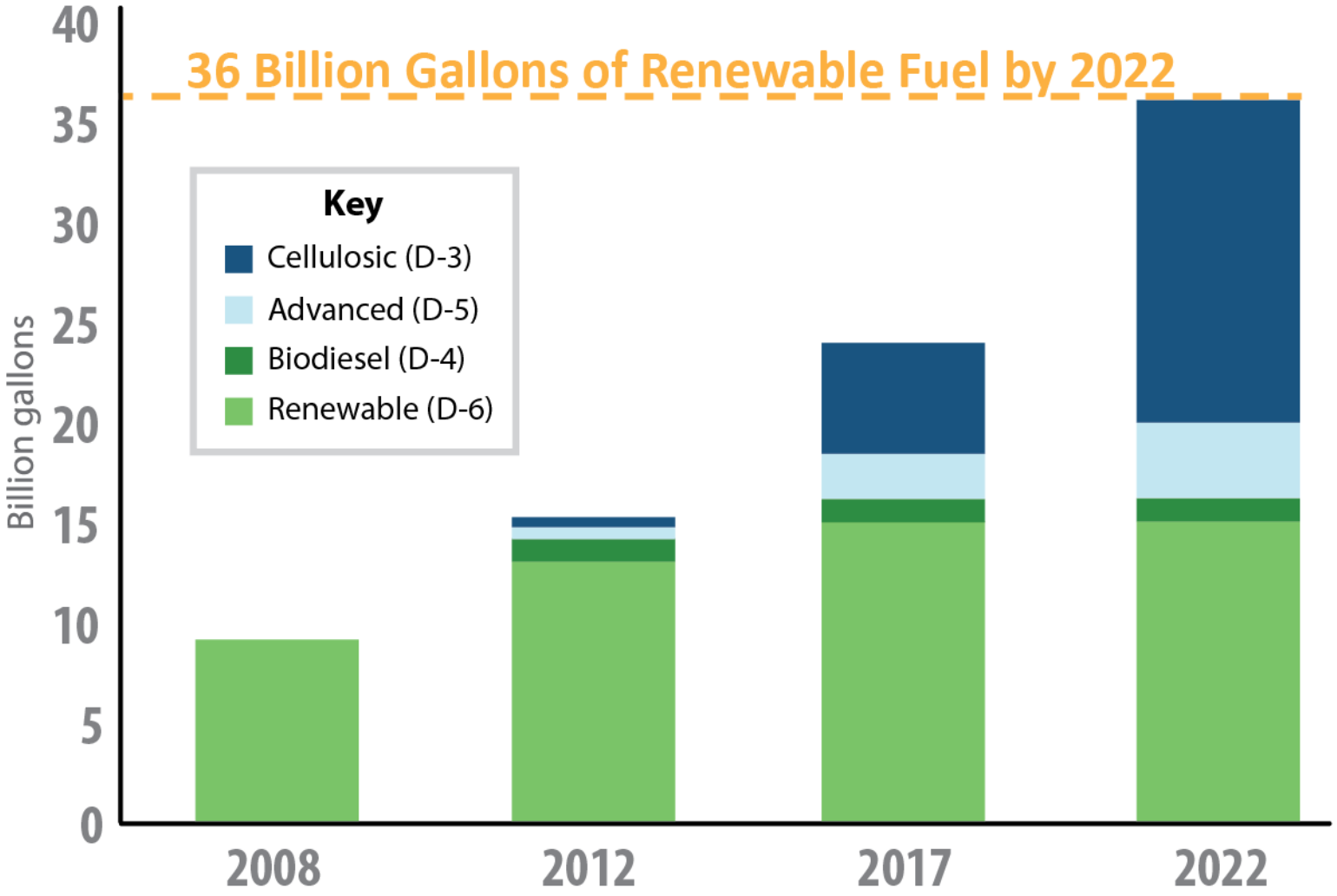
[1] Does not include biofuels that have been blended with petroleum—biofuels are included in "Renewable Energy."
[2] Excludes supplemental gaseous fuels.
[3] Includes -0.02 quadrillion Btu of coal coke net imports.
[4] Conventional hydroelectric power, geothermal, solar, wind, and biomass.
[5] Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[6] Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[7] Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes 0.24 quadrillion Btu of electricity net imports not shown under "Source."

Notes: • Primary energy is energy in the form that it is accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy occurs (for example, coal before it is used to generate electricity). • The source total may not equal the sector total because of differences in the heat contents of total, end-use, and electric power sector consumption of natural gas. • Data are preliminary. • Values are derived from source data prior to rounding. • Sum of components may not equal total due to independent rounding.

Sources: U.S. Energy Information Administration, *Monthly Energy Review* (April 2017), Tables 1.3, 1.4a, 1.4b, and 2.1–2.6.

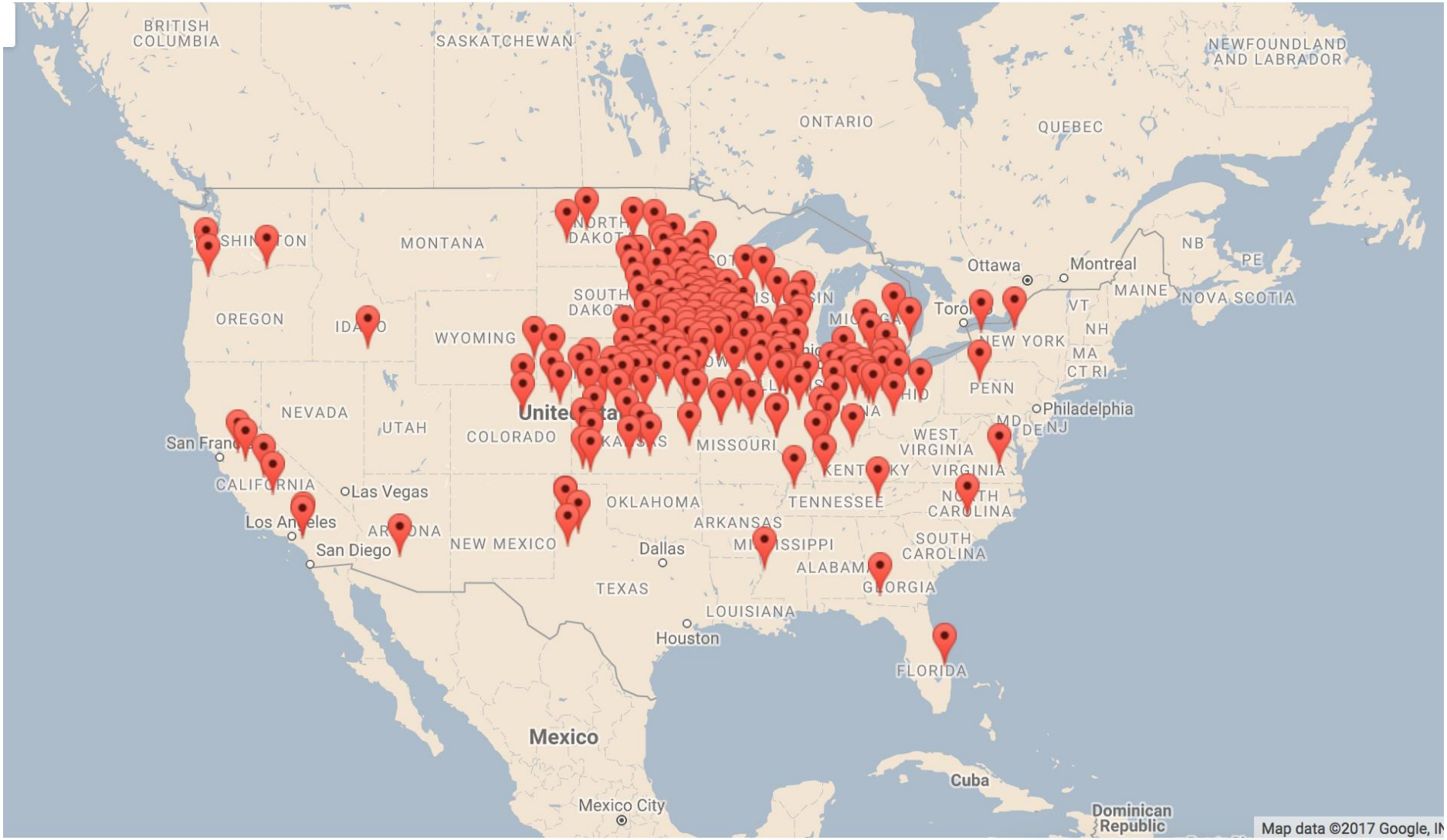
Source: US EIA. https://www.eia.gov/petroleum/ethanolcapacity/index.cfm

Renewable Fuel Standard 2 (RFS2) Targets



Source: USEPA, https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard

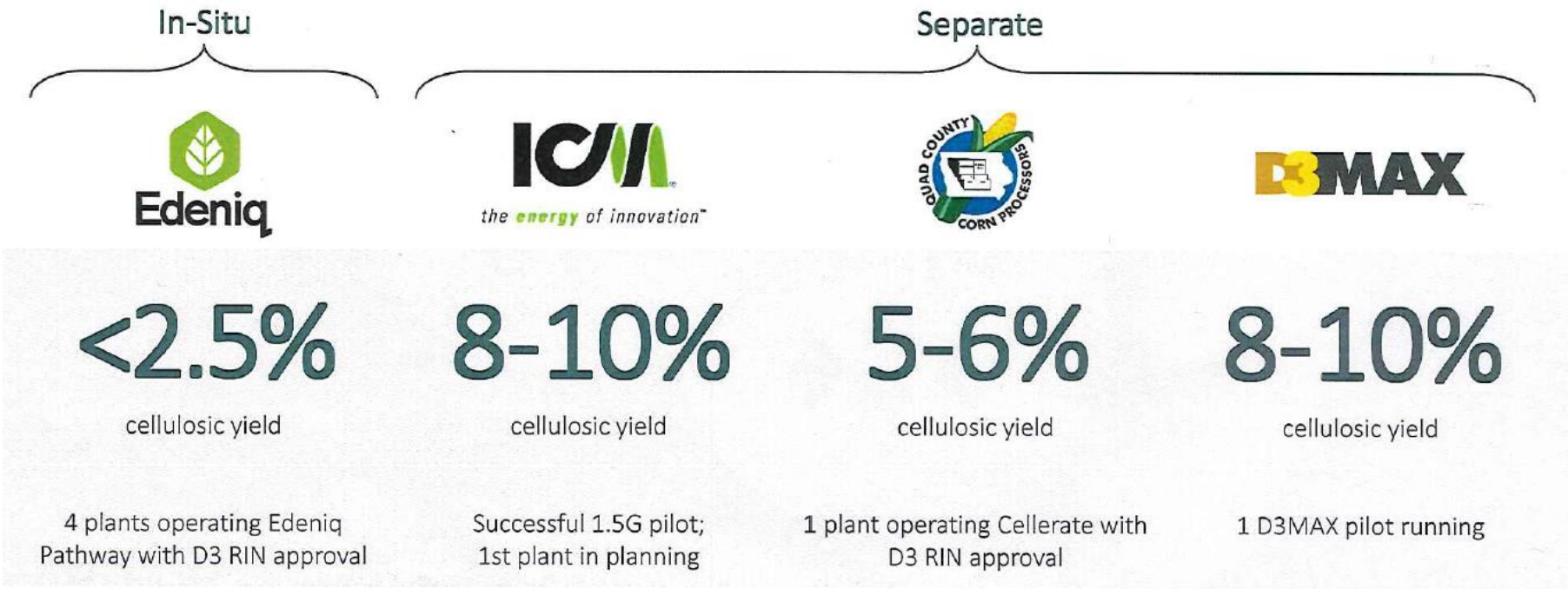
US Commercial Ethanol Production Plants 2017



Source: Renewable Fuels Association (RFA), 2017: http://www.ethanolrfa.org/resources/biorefinery-locations/

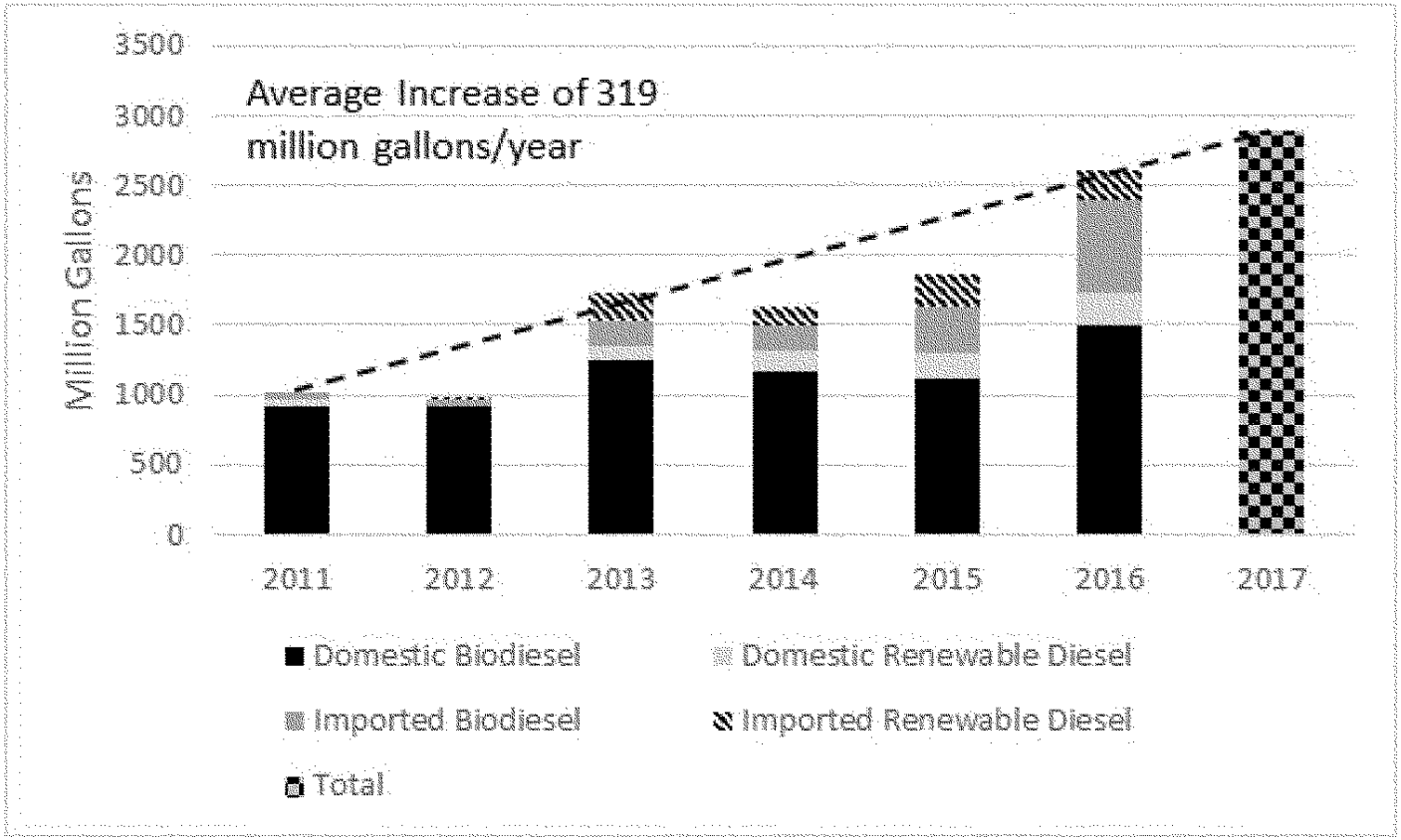
Ethanol Production from Corn Fiber Growing

- Multiple routes being commercialized to convert some or most of the corn kernel fiber present in dry mill ethanol facilities to cellulosic ethanol (CE).
- D3 RIN data indicates 2016 CE production averaged ~ 1 million l/month
- D3 RIN data show 2017 CE production levels (through July) about double this



Source: K. Cagle (Novozmes). Bioeconomy 2017 conference, session 1E: Drawing a Roadmap to Cellulosic Biofuel Deployment, July 11, 2017 .

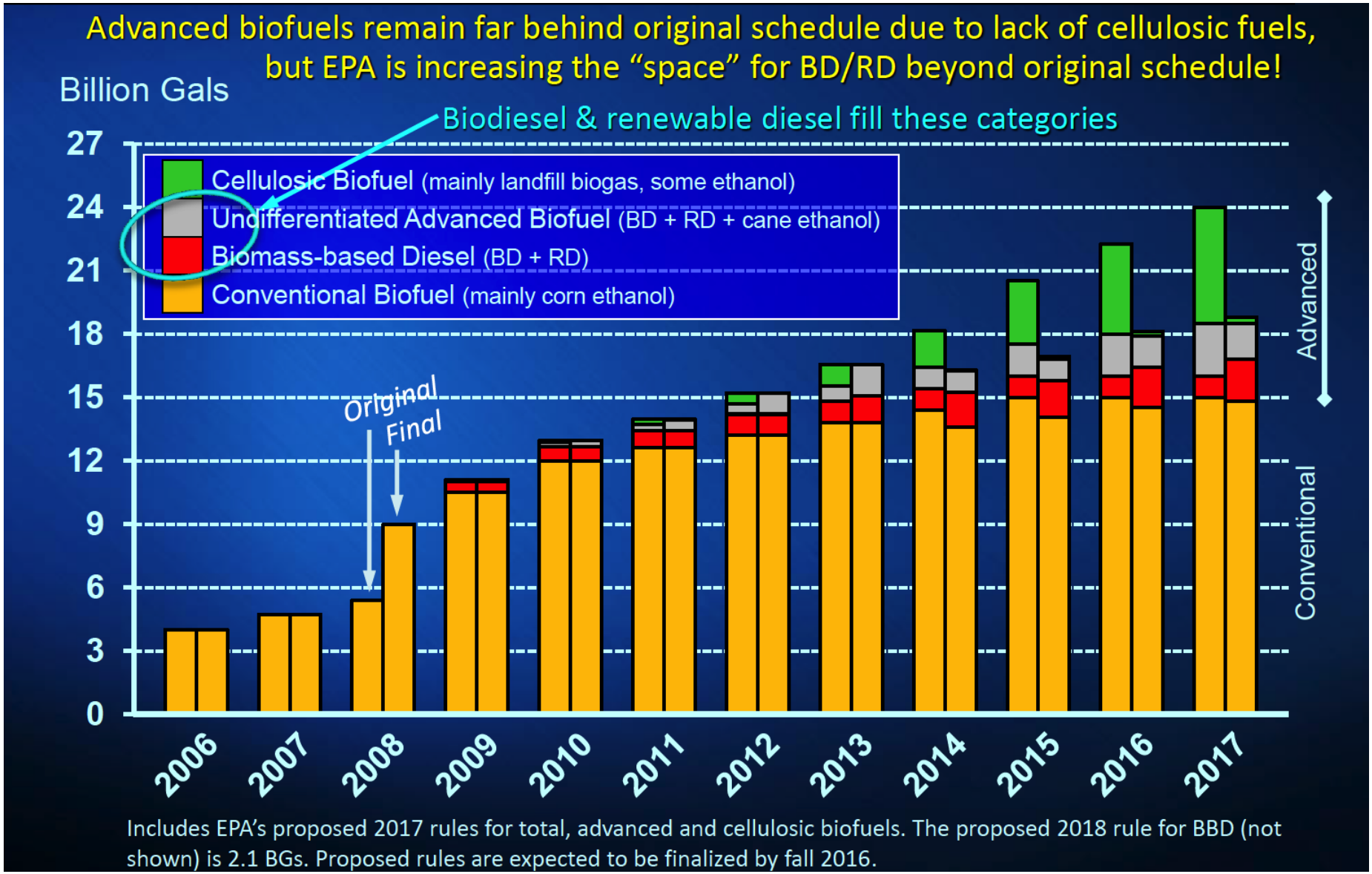
Biodiesel and RD Supply, 2011-2017[a]



[a] Values represent current estimates of the net supply of biodiesel and renewable diesel (including conventional, advanced, and BBD biodiesel and renewable diesel) from EMTS, accounting for the production, import, and export of biodiesel and renewable diesel. 2017 supply is based on the projections for 2017 in the 2017 final rule

Source: US EPA 2017 RFS2, https://www.gpo.gov/fdsys/pkg/FR-2017-07-21/pdf/2017-14632.pdf

RFS2 Biofuels Production History, 2006-2017



Source: Carter, 2016 (USDA). https://www.usda.gov/oce/energy/files/US_Biodiesel_RD_MarketJul2016.pdf

Co-Optimization of Fuels and Engines ("Co-optima")

Co-Optimization of Fuels and Engines

Draws on collaborative expertise of two DOE research offices, nine national laboratories, and numerous industry and academic partners.

Crosscutting initiative tackling **fuel and engine innovation** to **co-optimize performance,** maximize transport efficiency. Will contribute to Adv. Fuels in Adv. Engines Task 39-AMF study.

Advancing R&D to:

- Bring **affordable, scalable advanced** biofuels and advanced engine solutions **to market more quickly**
- Improve fuel economy **15%–20% beyond targets** of BAU R&D efforts
- Reduce petroleum use, achieve **massive** cost savings annually via improved fuel economy
- **Dramatically decrease** transport sector pollutants and GHG emissions

Early finding: attractive combo is higher ethanol (octane) blends in high compression engines.

http://energy.gov/eere/bioenergy/co-optimization-fuels-engines