BUREAU OF ENERGY AND
TECHNOLOGY POLICY

Slides for the morning and afternoon sessions are in separate decks. This is the **morning** slide deck.

September 1, 2021

Introduction & Foundational Issues, Part A – End uses that are hard to decarbonize

Technical Session 1
CT 2022 Comprehensive Energy Strategy

Session is being recorded

Logistics & Housekeeping

- **This session is being recorded**
- **Please include your name and affiliation (if any) in your Zoom icon**
- **Please turn off your audio and video except when speaking**
- **To enter the queue to provide verbal comment, use Zoom's *raise hand* feature (more details will be provided later)**
- **Use the chat function to ask brief clarifying questions or procedural questions.**

Today's Agenda - Morning

Click on the agenda section headings to jump to the relevant slides

General Introduction	9:00-9:35 am
Public Comment 1	9:35-9:50 am
Introduction to End Uses that are Hard to Decarbonize	9:50-10:30 am
Industrial Thermal Processes	10:30-11:45 am
Public Comment 2	11:45-12:00 pm
------------------------------LUNCH----------------------------------	12:00-1:00 pm

Today’s Agenda – Afternoon

Slides for the afternoon session are in a separate deck.

Long-Distance Trucking	1:00-1:50 pm
Public Comment 3	1:50-2:05 pm
Aviation	2:05-2:45 pm
Public Comment 4	2:45-3:00 pm
Maritime	3:00-3:45 pm
Public Comment 5 & General Public Comments	3:45-4:30 pm
Wrap Up	4:30-4:45 pm

UPCOMING TECHNICAL SESSIONS

Session 2: Building thermal decarbonization, Parts A & B – Heat pump barriers & market strategies

Part A: Thursday Sept. 22, 2022, from 9 a.m. to 5 p.m. EST
Part B: Friday, Sept. 23, 2022, from 9 a.m. to noon EST

Session 3: Building thermal decarbonization – Support strategies

Friday, Sept. 23, 2022, from 1 p.m. to 5 p.m. EST

Session 4: Building thermal decarbonization – Economic potential & technology targets

Thursday, Oct. 6, 2022, from 9 a.m. to 5 p.m. EST

Other sessions to be announced

More information on the CES webpage: https://portal.ct.gov/DEEP/Energy/Comprehensive-Energy-Plan/Comprehensive-Energy-Strategy

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Technical Session	Meeting Date(s)	Deadline for Written Comments
1	Sept. 1, 2022 9 a.m. - 5 p.m. ET	Sept. 16, 2022, at 5:00 p.m. ET
2	Sept. 22, 2022 9 a.m. - 5 p.m. ET Sept. 23, 2022 9 a.m. - noon ET	Oct. 7, 2022, at 5:00 p.m. ET
3	Sept. 23, 2022 1 p.m. - 5 p.m. ET	Oct. 7, 2022, at 5:00 p.m. ET
4	Oct. 6, 2022 9 a.m. - 5 p.m. ET	Sept. 9, 2022, at 5:00 p.m. ET PRIOR to MTG.
		Oct. 21, 2022, at 5:00 p.m. ET

Written Comment Opportunities

- **After each technical session DEEP is accepting written comments – deadlines vary**
- **Comments are also being solicited PRIOR to technical session 4 to inform the agenda (deadline Sept. 9, 2022, at 5 p.m. EST)**
- **Please see the August 18th notice for submission instructions and specific questions for which DEEP is seeking responses**
- **More information on the CES web page: https://portal.ct.gov/DEEP/Energy/Comprehensive-Energy-Plan/Comprehensive-Energy-Strategy**

WELCOME & INTRODUCTIONS

Thanks for joining our technical session today!

Comprehensive Energy Strategy Scope & Objectives

- **Scope**: electricity, thermal energy, and fuels for transportation

- **Objectives:**
  - Examine future energy needs in the state and identify opportunities to reduce costs, ensure reliable energy availability, and mitigate public health and environmental impacts of CT's energy use
  - Provide recommendations for legislative and administrative actions to aid in achievement of interrelated environmental, economic, security, and reliability goals

BETP Mission: to manage energy, telecommunication, and broadband policy issues and program deployment with the goal of establishing a clean, economical, equitable, resilient, and reliable energy future for all residents.

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DEEP's Approach to the 2022 CES

5 Key Lenses

- **Climate** – meeting greenhouse gas reduction obligations under Global Warming Solutions Act
- **Equity** – energy decisions that produce equitable outcomes
- **Affordability** – energy decisions that produce affordable outcomes
- **Economic development** – workforce development; economic competitiveness
- **Reliability & Resilience** – energy system improvements and load balancing

Key Strategies

- Build on and/or modify findings and recommendations of 2013 and 2018 CESs
- Consider emerging issues not addressed in a prior CES
- Rely on results from recent, major quantitative studies where appropriate rather than duplicate efforts

3 Factors to Consider in all CES Technical Sessions

1. **The carbon intensity of the electric grid**
    - Impacts the speed at which electrification can support decarbonization
2. **Fuel price volatility**
    - Impacts technology affordability and access, as well as growth of the clean energy economy
3. **Need for emission-reduction solutions that facilitate climate change adaptation, resilience, and energy security**
    - Impacts solution selection strategies and requires solutions to optimize a variety of needs

Equity

Climate

Affordability

Economic Development

Reliability & Resilience

Decarbonizing the Electric Grid

1. Decarbonize the Electric Sector
2. Secure the benefits of competition and minimize ratepayer risk
3. Ensure energy affordability and equity for all ratepayers
4. Optimize siting of generation resources
5. Upgrade the grid to support and integrate variable and distributed energy resources
6. Balance decarbonization and other public policy goals

Public Act 22-5 requires the state to achieve a 100% zero carbon electric sector by 2040

2020 Integrated Resources Plan found there are multiple pathways to achieve this goal

Procurement Plan Update

- Procurement for solar
- Procurement for transmission- and distribution- connected front of the meter storage
- Coordinate with New England states on cost-effective transmission strategies
- Procurement for anaerobic digestors

Supporting Electric Grid Decarbonization

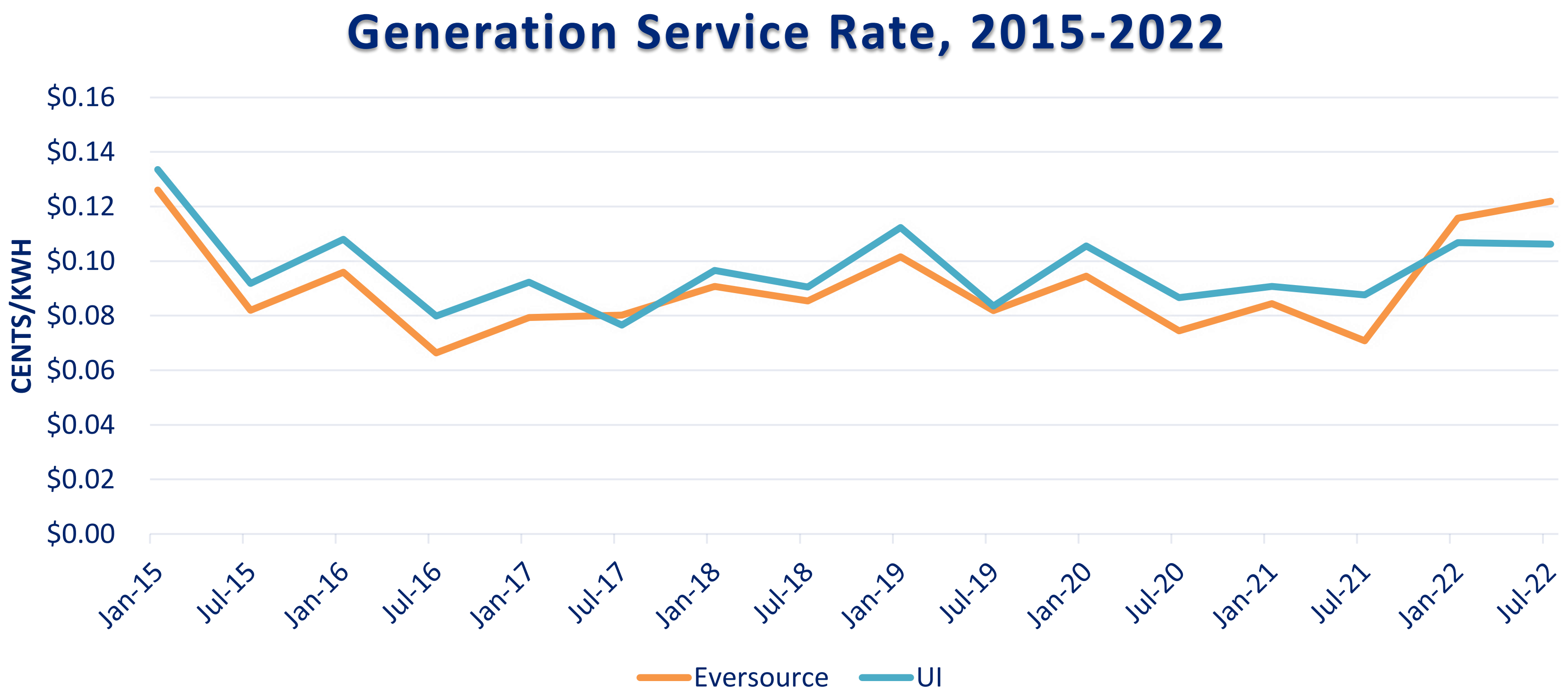
Load Management via 2022-2024 Conservation & Load Management Programs (C&LM)

- Promoting co-delivery of energy efficiency and demand management programs, including
  - smart thermostats
  - electric vehicle chargers
  - battery storage

- Promote sustainable building practices and energy-saving retrofits in the commercial and residential sectors

- Aiming to significantly reduce peak demand and greenhouse gas emissions

Fuel Price Volatility



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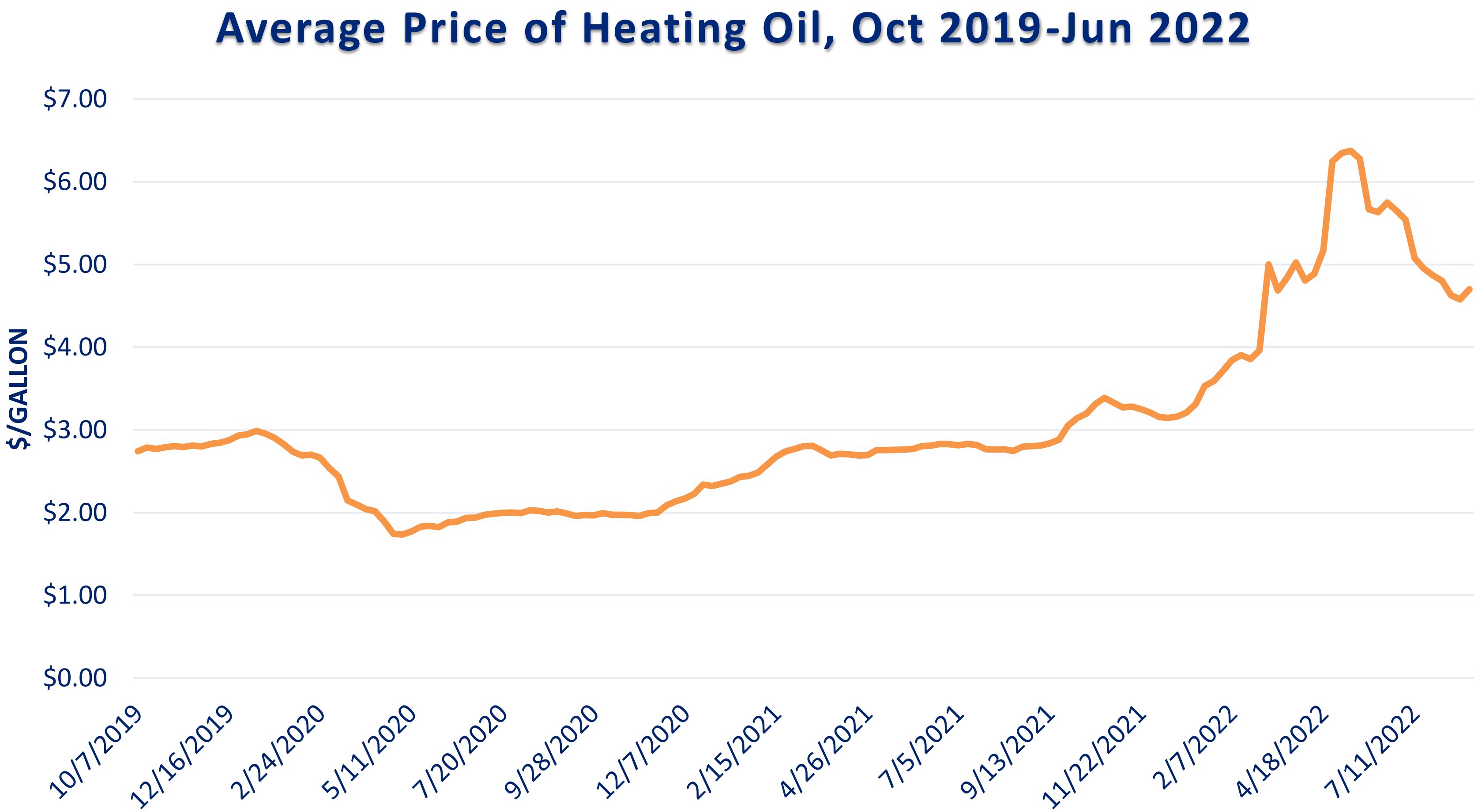
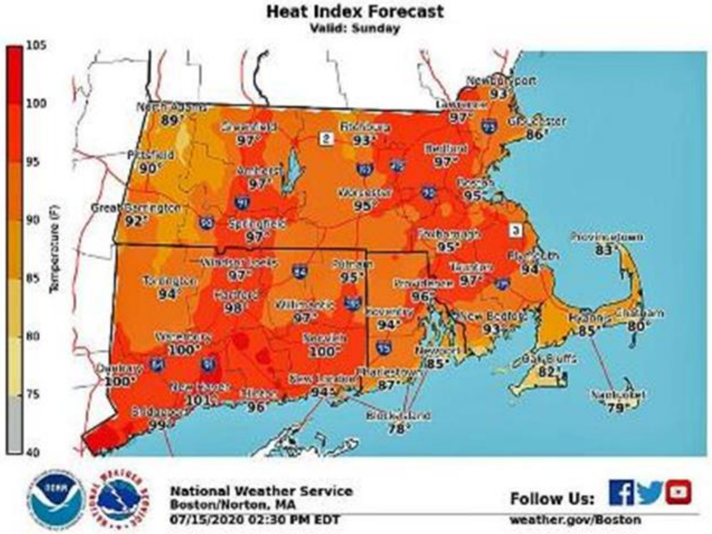
Fuel Price Volatility



Impacts of Climate Change in Connecticut by 2050

- Stronger **storms** with **more wind and** rain, more frequent and longer **droughts**
- Up to **20 inches of sea level rise** along CT coast **by 2050**
- Increased frequency of **flooding** with levels like those seen in Superstorm Sandy every 5-10 years
- Indices of **extreme rainfall** to increase
- Increased frequency of **90°F days**, from average of 5 per year from 1970-1999, to 25 per year from 2040-2069



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Emission-reduction and climate resilience nexus

Assessing impacts of climate change on electric grid

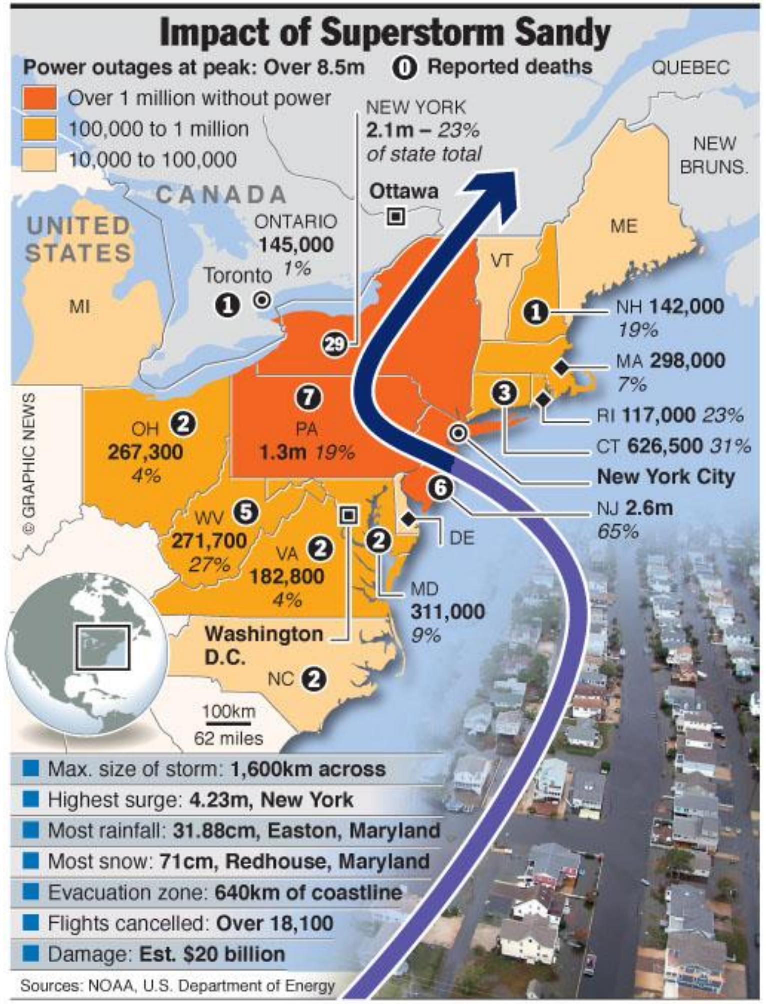
- PURA Resilience and Reliability Standards and Programs ([17-12-03RE08](17-12-03RE08))
    - Climate Change Vulnerability Assessment

Climate-impacts driving energy use

- Increased days over 90 degrees driving need for cooling
- Need for energy efficient heating and cooling and community-scale resilience measures, e.g. urban forest canopy

DEEP Climate Resilience Fund

- Funding for resilience planning and project development



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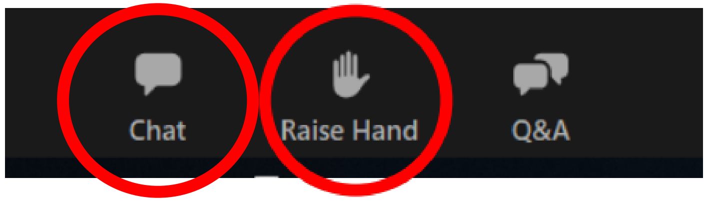
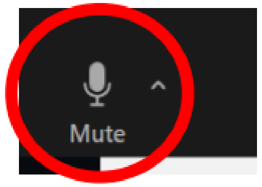
Questions and Comments





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At the conclusion of each panel DEEP will hold a brief question and comment period.

If you have a clarifying question, please drop it into the chat to either Jeff Howard or Becca Trietch. DEEP will pose as many questions as time allows to the speakers.

If you would like to make a comment:

- Please use the “Raise Hand” feature if you would like to speak
- After any interested elected officials have provided their comments, you will be invited to provide your comment in the order the hands were raised
- Please unmute yourself, state your name and affiliation
- Given time limitations, please limit your comment to 2 minutes.
- After your comments, please remember to click the “Mute” button

General Public Comment

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September 1, 2022

Introduction – End Uses That Are Hard to Decarbonize

Jeff Howard, Environmental Analyst

Foundational Issues, Part A
Energy end uses that are hard to decarbonize

- Foundational issues
- Why begin with 'hard to decarbonize'?
- 4 key hard-to-decarbonize end uses
- CES lenses
- What DEEP is doing
- Agenda

Energy end uses for which, at a given time:

- few decarbonization pathways are available OR
- available pathways are expensive, technically limited, or difficult to scale up

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Foundational Issues

Part A

Energy end uses that are hard to decarbonize
TODAY

Part B

Carbon pricing and low-carbon incentives
Date to be announced

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Why kick off the CES technical meetings with a session on end uses that are hard to decarbonize?

The four hard-to-decarbonize end uses examined today are not major sources of emissions in Connecticut, but:

- Paying attention to contexts where decarbonization is challenging can help Connecticut think more clearly about contexts where multiple decarbonization options are available
- Connecticut companies are leading players in decarbonizing some of these end uses
- Hard-to-decarbonize end uses disproportionately affect Environmental Justice communities
- Policies in Connecticut may have ramifications regionally, nationally, and globally

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4 key hard-to-decarbonize end uses

Industrial thermal processes

Long-distance trucking

Aviation

Maritime

4 key hard-to-decarbonize end uses

Industrial thermal processes

Long-distance trucking

Maritime

Aviation

How does this relate to the key CES lenses?
- Climate
- Equity
- Affordability
- Economic development
- Reliability & Resilience

Again, CT companies are major players

These end uses affect air quality and public health in CT and more broadly, esp. in Environmental Justice communities

Decarbonization of these end uses – both in CT and more broadly -- can enhance resilience and reduce energy price volatility

Context: Connecticut initiatives on industry and transportation

- **Combined heat & power and waste heat recovery** – Supported by Renewable Portfolio Standard and other programs
- **Conservation & Load Management** programs for commercial and industrial facilities
- **DEEP engagement with:**
  - U.S. Climate Alliance initiatives on industry and transportation
  - Other regional and national organizations addressing industrial and transportation emissions

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Agenda

Introduction	9:50-10:30
Industrial thermal processes	10:30-12:00
Lunch	12:00-1:00
Long-distance trucking	1:00-2:05
Aviation	2:05-3:00
Maritime	3:00-4:00
Public comment	4:00-4:30
Wrap up	4:30-4:45

Click on the presenters to jump to their slides

Introduction (continued)

Ling Tao – National Renewable Energy Laboratory

Steve Howell & Veronica Bradley – Clean Fuels Alliance America

Kevin Boughan – Eversource

(speaker order may vary)

National Renewable Energy Laboratory

How Can We Decarbonize using Biofuel, RNG and Green Hydrogen?

Ling Tao, PhD, Bioenergy Analysis Platform Lead
On behalf of Zia Abdullah, NREL Laboratory Program Manager, and NREL Analysis team

Presentation to CT DEEP, September 1st, 2022

- Biofuel Potentials
- Bioethanol
- Hydrogen
- RNG
- Key Takeaways

Biofuel Potentials

Bioethanol

Hydrogen

RNG

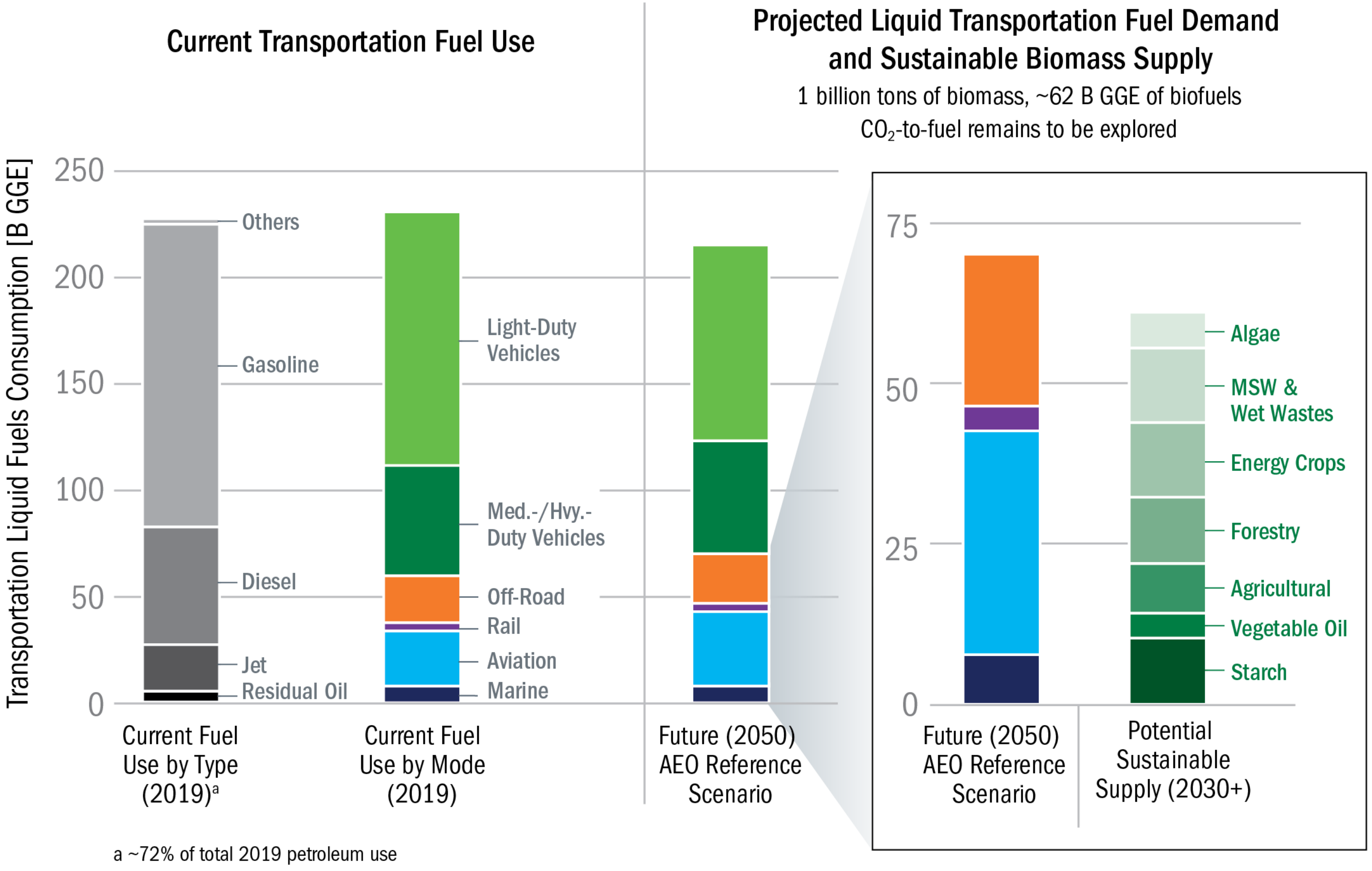
Key Takeaways

The Role of Biomass in Sustainable Transportation

- **Transportation accounts for 34% of U.S. greenhouse gas (GHG) emissions.**
- **Biofuels are part of a sustainable transportation fuel strategy to decarbonize all modes.**
- **U.S. biomass can meet the needs of "hard to electrify" modes, such as aviation, marine and rail.**

Focus areas for biofuels:

- Ethanol for passenger cars
- "Drop-in" fuels that can use existing infrastructure such as renewable diesel/sustainable aviation fuels



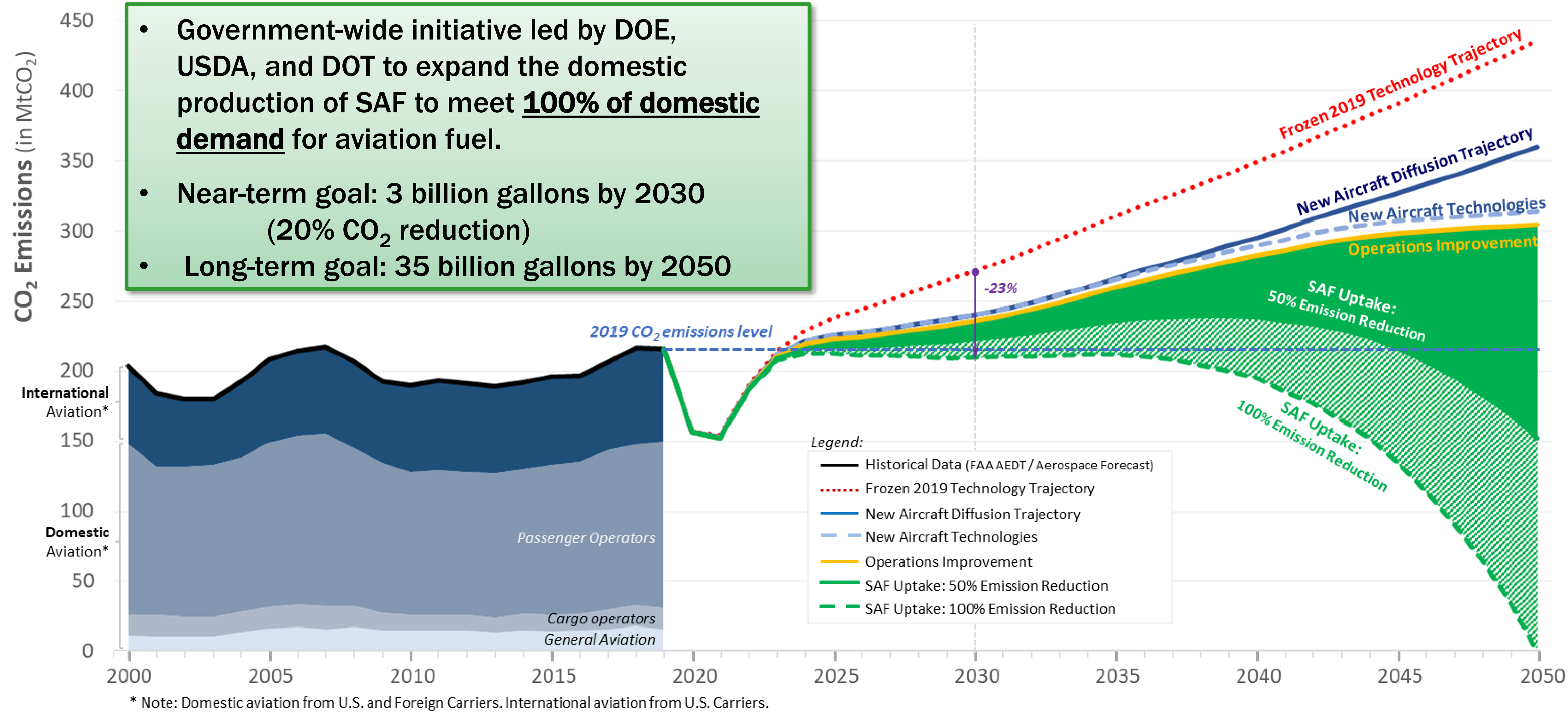
[a] ~72% of total 2019 petroleum use

AEO = annual energy outlook | GGE = gasoline gallon equivalent | MSW = municipal solid waste

Courtesy of Valerie Reed and Zia Haq DOE BETO

Sustainable Aviation Fuel (SAF) Grand Challenge

- Government-wide initiative led by DOE, USDA, and DOT to expand the domestic production of SAF to meet **<u>100% of domestic demand</u>** for aviation fuel.
- Near-term goal: 3 billion gallons by 2030 (20% CO_2 reduction)
- Long-term goal: 35 billion gallons by 2050



* Note: Domestic aviation from U.S. and Foreign Carriers. International aviation from U.S. Carriers.

Courtesy of Valerie Reed and Zia Haq DOE BETO

New SAF Capacity Coming Online Within Next 3 Years With Several Pathways That Expand Feedstocks Beyond HEFA

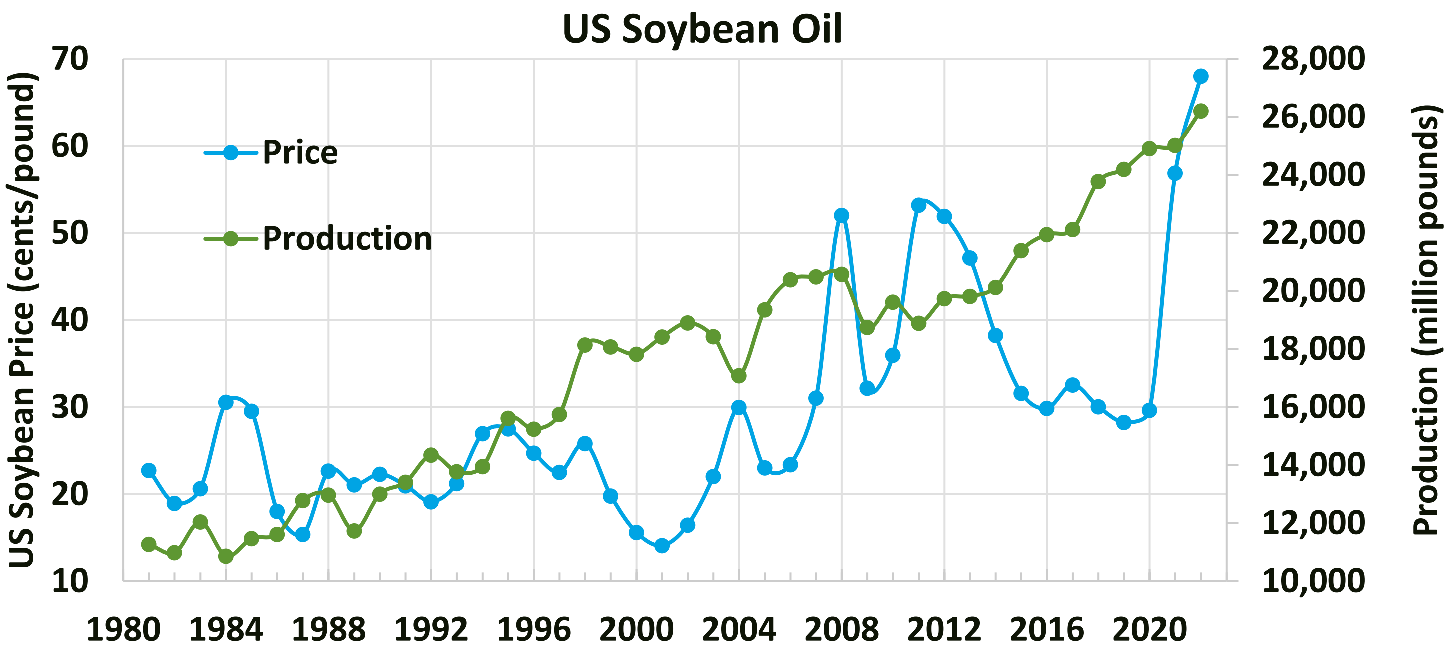
- New feedstocks includes lignocellulosic biomass, alcohol from industrial waste gas, and gasification of municipal waste and forestry residues

2020	2021	2022	2023
world energy 25 MPGY	Fulcrum BIOENERGY 7 MPGY	NESTE 25 MPGY	gevo 10 MPGY
NESTE 34 MPGY	RED ROCK BIOFUELS 6 MPGY	SkyNRG 34 MPGY	Go Sunshine drive clean, save green 29 MPGY
gevo DEMO		LanzaJet 10 MGPY	Fulcrum BIOENERGY 21 MGPY
TOTAL TBD		world energy 150 MGPY	ReadiFuels 24 MPGY

CAAFI COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

Source: Commercial Aviation Alternative Fuels Initiative CAAFI.org

Lipids to Hydrocarbon Fuels



Source: https://www.ers.usda.gov/data-products/oil-crops-yearbook/oil-crops-yearbook/

	HEFA
FOGs (Dry million tons/yr)	5.9
FOG HC yield (GGE/dry ton)	238
FOG HC (billion GGE/yr)	**1.4**
Soybean (Dry million tons/yr)	12.7
Soybean HC yield (GGE/dry ton)	249
Soybean HC (billion GGE/yr)	**1.5**
Corn oil (Dry million tons/yr)	2.0
Corn oil HC yield (GGE/dry ton)	238
Corn oil HC (billion GGE/yr)	**0.5**
FOGs + Soybean + Corn oil HC (billion GGE/yr)	**3.4**

- Estimated about 6 million tons of inedible FOG are produced annually in the US (7 million tons including edible fats). The rendering industry processes about 4 million tons of these materials annually. About 1 million tons of FOG is used in biodiesel (Source: EIA)
- The USDA currently predicts 6 billion tons of soybean oil will go to biofuel production for 2023-'22, 5 billion tons of soybean oil will go to biofuel in 2021-'22 (Source: USDA)
- The annual corn distillers oil production in 2021 was about 2 million tons (Source: USDA)

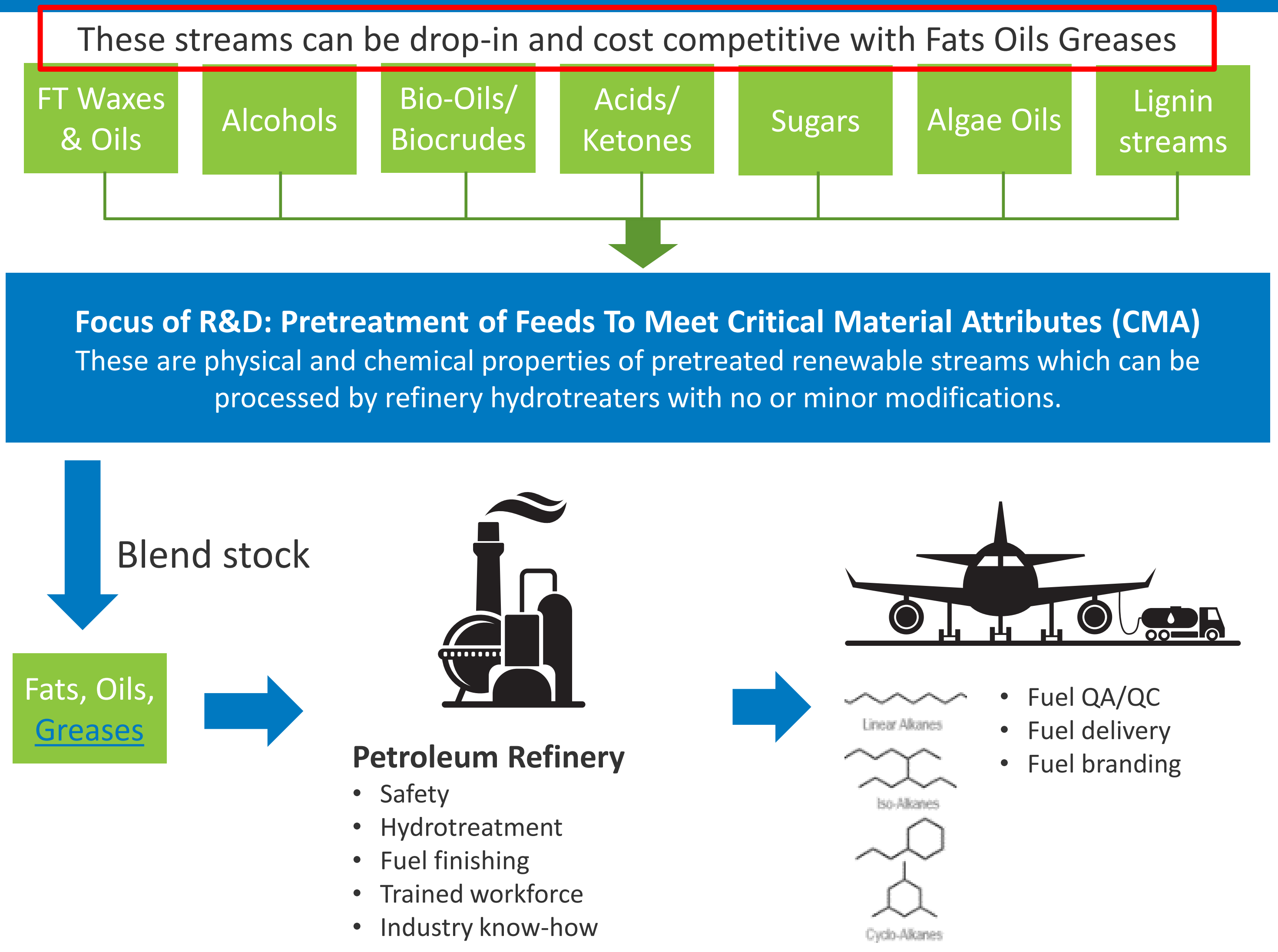
Refineries Can Be Customers For Biofuels Intermediate Stream Producers

Opportunities

- ~6.6M BBPD (97 BGPY) distillate HT capacity available in the United States
- Leveraging this capacity may save significant capital costs
- May allow incremental transition to renewables by blending renewable and fossil streams
- Opportunities where re-permitting may not be required

Challenges

- Large variability of streams
- Match equipment to streams
- Hydrotreater scale too large
- ASTM approval of pathways
- Incompatibility of materials of construction with bio-streams
- Managing exothermic reactions



These streams can be drop-in and cost competitive with Fats Oils Greases

FT Waxes & Oils

Alcohols

Bio-Oils/ Biocrudes

Acids/ Ketones

Sugars

Algae Oils

Lignin streams

Focus of R&D: Pretreatment of Feeds To Meet Critical Material Attributes (CMA)

These are physical and chemical properties of pretreated renewable streams which can be processed by refinery hydrotreaters with no or minor modifications.

Blend stock

Fats, Oils, Greases

Petroleum Refinery

- Safety
- Hydrotreatment
- Fuel finishing
- Trained workforce
- Industry know-how

- Fuel QA/QC
- Fuel delivery
- Fuel branding

https://www.eia.gov/dnav/pet/PET_PNP_CAP1_A_(NA)_8CDHD0_BPSD_A.htm

Strategy To Achieve 35 BGPY by 2050

- Use lowest cost feedstock first, and minimize CAPEX/OPEX/Permit Requirements
- Be mindful of tradeoff between carbon intensity and cost
- Co-develop conversion processes with feedstock
- Target “drop-in” fuel though ASTM D4054 “fast track” to get to market quickly
- Then apply for conventional ASTM D4054 approval for higher blending ratio
- Partner with feedstock suppliers and refiners who know how to process at scale
- Be mindful of bottleneck owners and process guarantors and partner
- Focus on risk reduction to survive scaleup difficulties
- Focus on intermediate streams to make them compatible with existing refineries

Biofuel Potentials

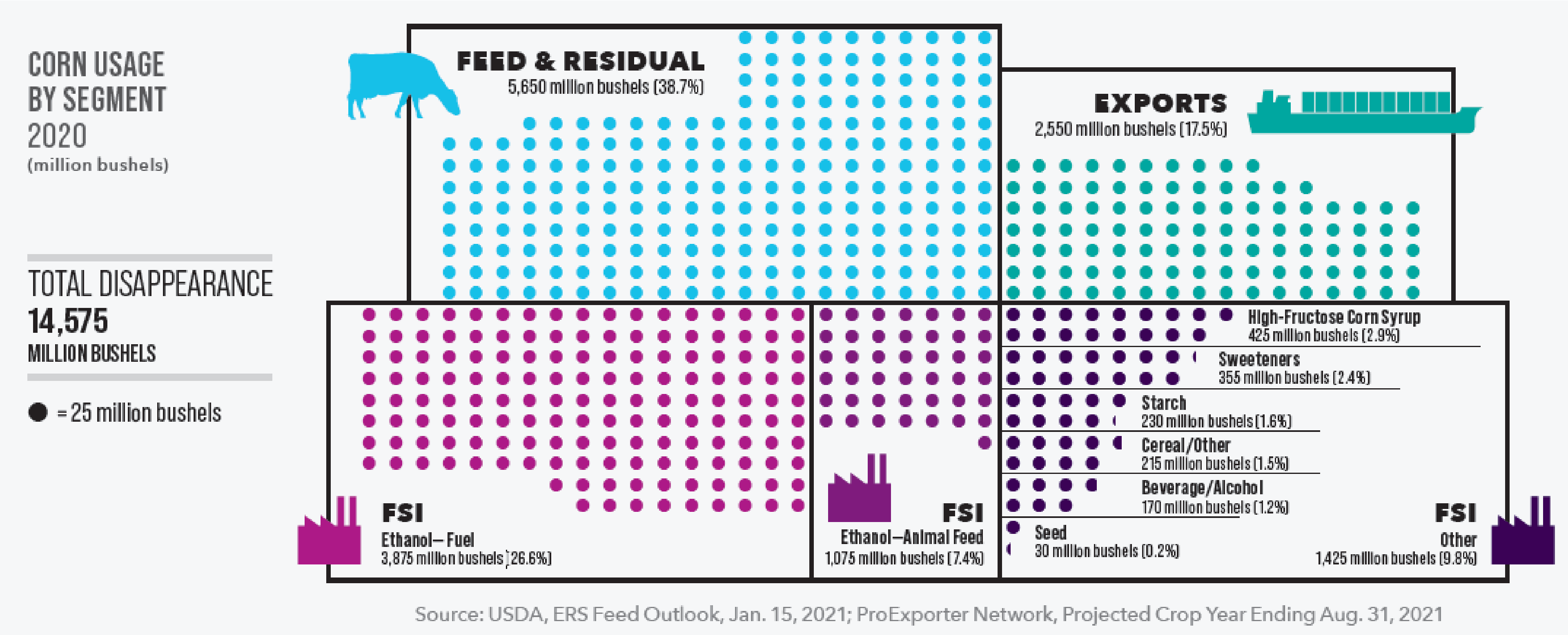
Bioethanol

Hydrogen

RNG

Key Takeaways

Corn Use by Segment in 2020

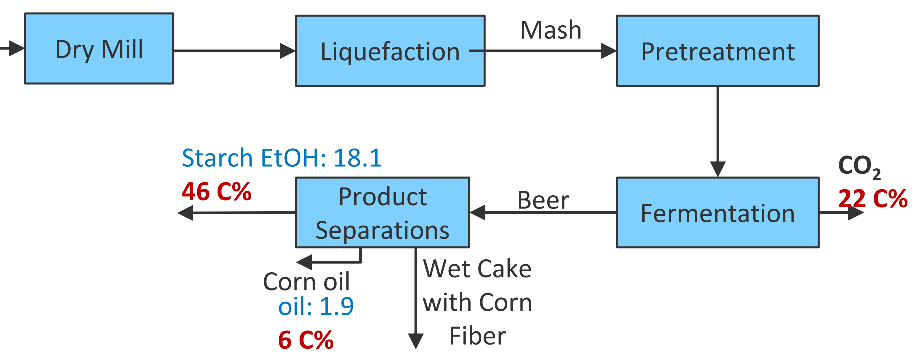


Source: USDA, ERS Feed Outlook, Jan. 15, 2021; ProExporter Network, Projected Crop Year Ending Aug. 31, 2021

- For 2021, total corn use is virtually unchanged at 14.8 billion bushels.
- An estimated 5.0 million bushels of corn went to ethanol production in 2020-’21, up from 4.9 million bushels in 2019-’20.
- 5.0 billion bushels are equivalent to 128 million MT corn per year (141 million US tons) or 16.6 billion gallons of ethanol

Source: https://www.worldofcorn.com/#

Corn Grain



Starch: 33.3
Oil: 1.9
Cellulosic: 3.9
Other DDGS: 8.5

100 C%

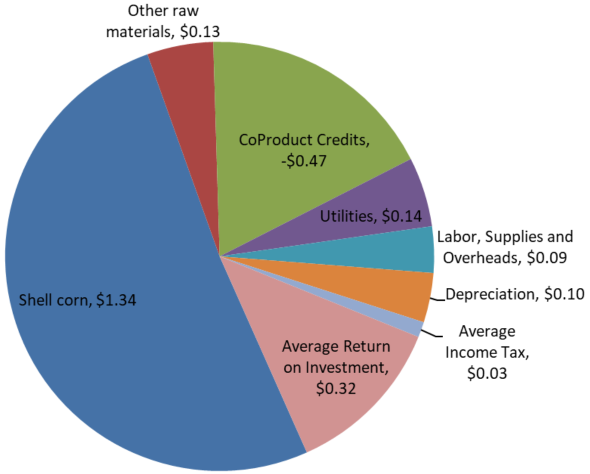
Unit: lb/bushel
Unit: C%

CO_2
22 C%

Starch EtOH: 18.1
46 C%

Corn oil
oil: 1.9
6 C%

Wet Cake with Corn Fiber
Cellulosic: 3.9
Other DDGS: 8.5



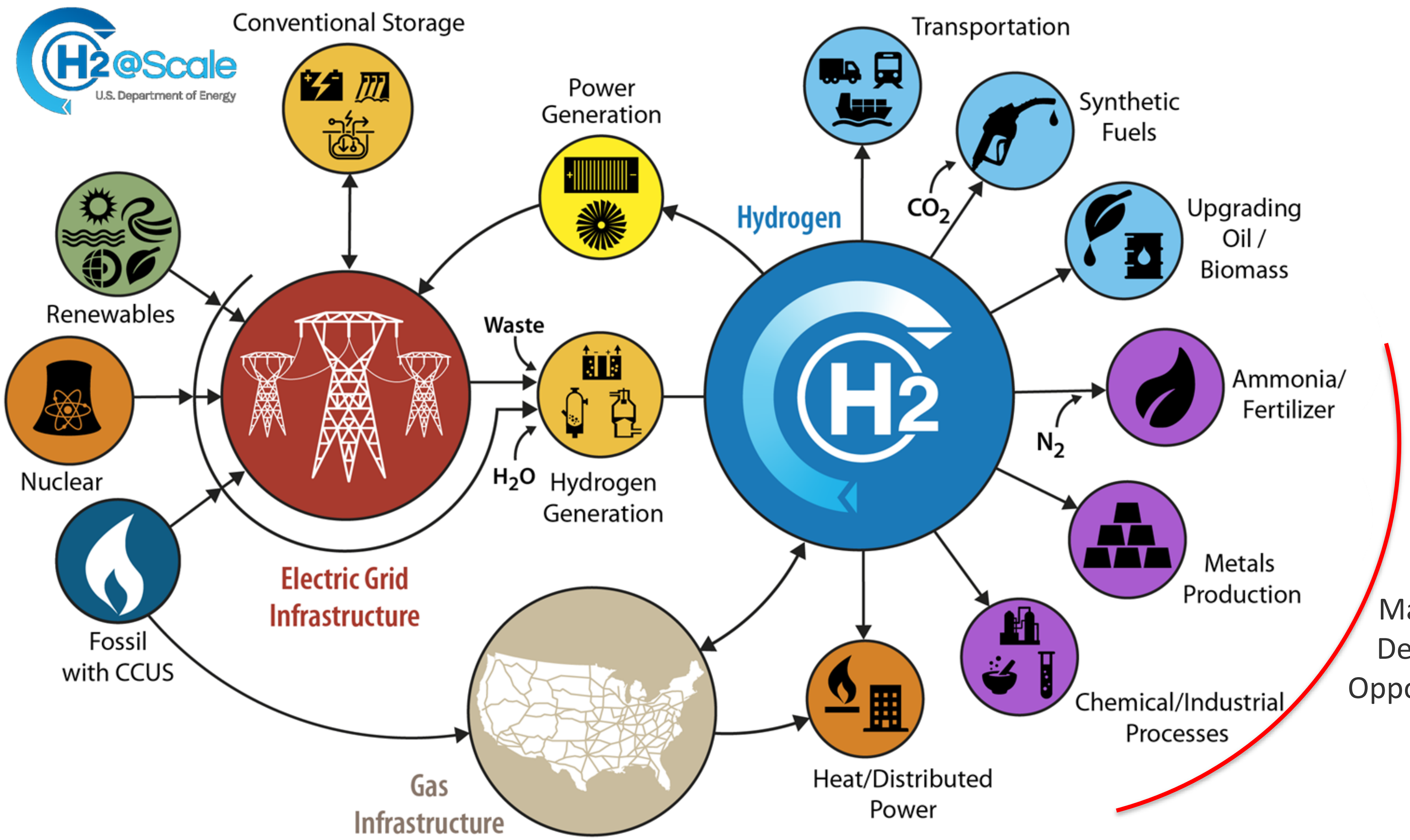
	Based on Capacity	Based on RFA Data
Dry million tons/yr	148	132
Ethanol yield (gal/dry ton)	118	118
Ethanol yield (GGE/dry ton)	67	67
Total Ethanol (billion gal/yr)	17.5	15.6
Total Ethanol (billion GGE/yr)	**9.9**	**8.8**

198 Corn ethanol facilities exist, averaged 79-million-gallon ethanol annual production

Source: https://ethanolrfa.org/markets-and-statistics/annual-ethanol-production

- Biofuel Potentials
- Bioethanol
- **Hydrogen**
- RNG
- Key Takeaways

H2@Scale Opportunities for Industrial Decarbonization

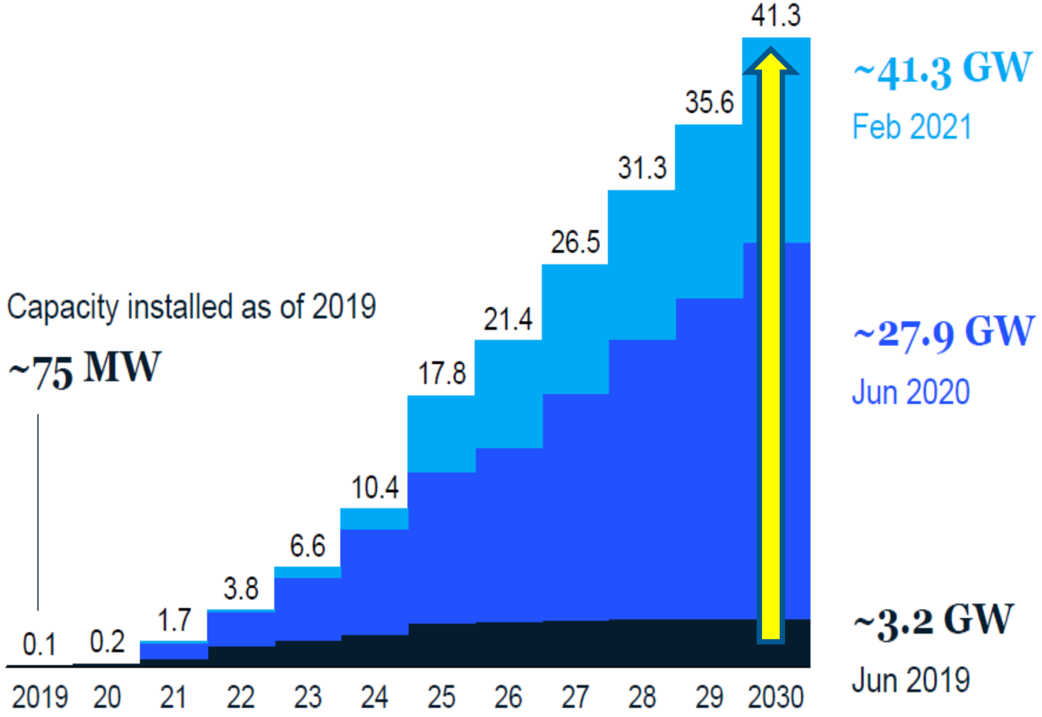


Major Industrial Decarbonization Opportunity with H2

Recent Increased Interest in Hydrogen: Global Drivers

- ✓ **Low-cost renewables** are now available
- ✓ **Countries see clean H_2 can help meet climate goals**
  - Hard to decarbonize sectors
  - Energy storage
  - Import/export opportunities

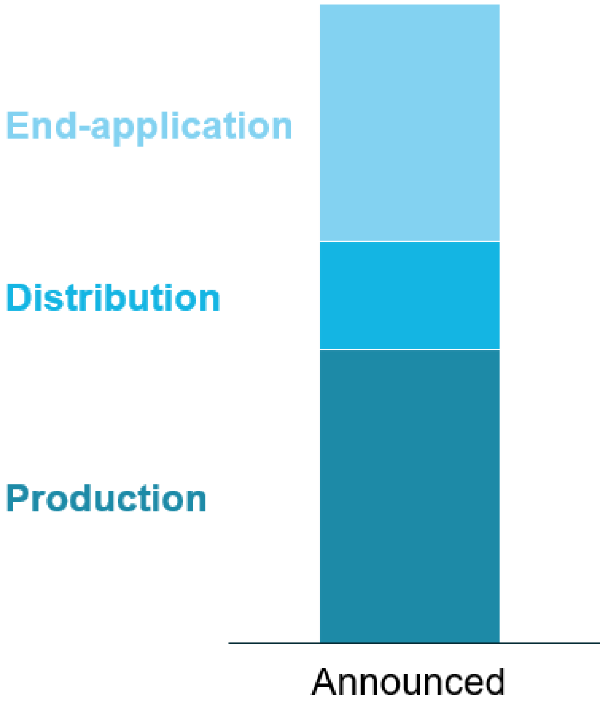
200-fold electrolyzer growth by 2030
Over 40 GW planned



1. For projects without known deployment timeline capacity additions were interpolated between known milestones

Source: McKinsey Hydrogen Project database

$80B Global Government Funding. 6X More with Private Sector through 2025



Source: McKinsey, H2 Council, Spring 2021
(From Sunita Satyapal, HFTO)

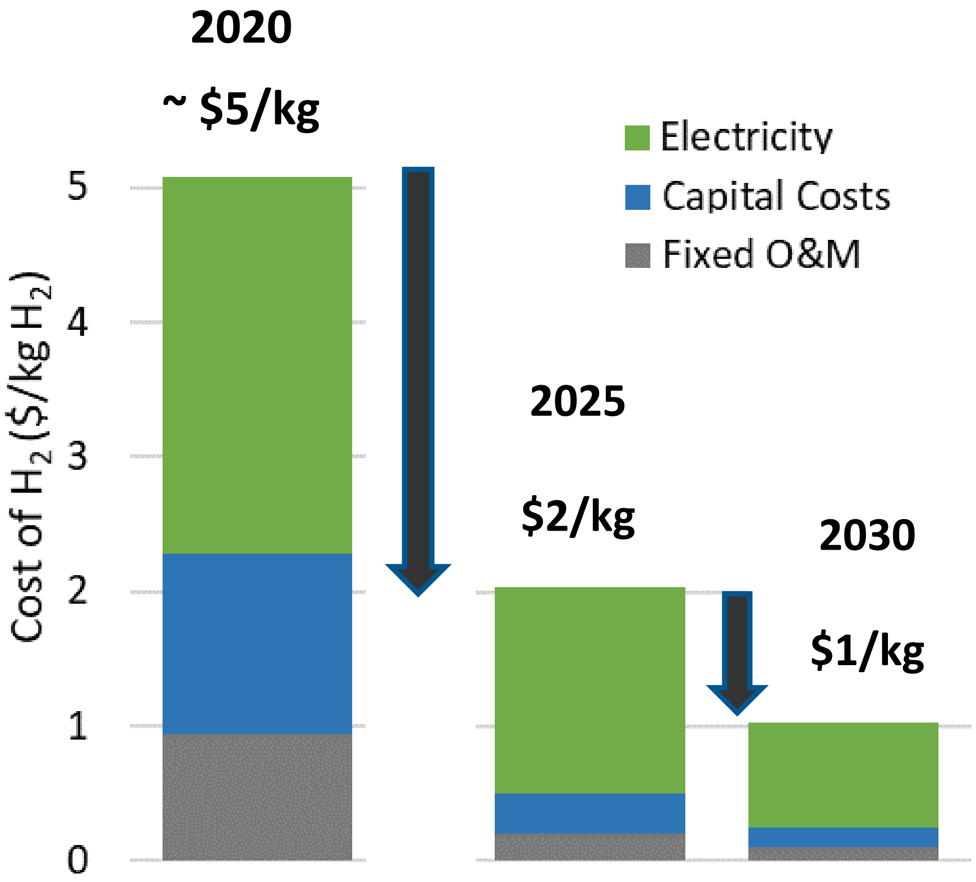
Studies show potential for 10 to 25% global GHG reduction using clean hydrogen. $2.5T Revenue. 30M Jobs.

Hydrogen Shot: “1 1 1”
$1 for 1 kg in 1 decade for clean hydrogen

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Launched June 7, 2021
Summit Aug 31-Sept 1, 2021

Example: Cost of Clean H_2 from Electrolysis



Bipartisan Infrastructure Law – $9.5B H2 Highlights

- $8B for at least 4 regional clean H2 Hubs
- $1B for electrolysis (and related H2) RD&D
- $0.5B for clean H2 technology mfg. & recycling R&D
- Aligns with H2 Shot priorities by directing work to reduce cost of clean H2 to $2/kg by 2026
- Requires developing a National H2 Strategy & Roadmap

All pathways for clean hydrogen included: Thermal conversion w/ CCS, advanced water splitting, biological approaches, etc.

- Reduce electricity cost from >$50/MWh to
  - $30/MWh (2025)
  - $20/MWh (2030)
- Reduce capital cost >80%
- Reduce operating & maintenance cost >90%

2020 Baseline: PEM low volume capital cost ~$1,500/kW, electricity at $50/MWh. Need less than $300/kW by 2025, less than $150/kW by 2030 (at scale)

(Adapted from multiple briefing slides from Sunita Satyapal, DOE’s HFTO)

- Biofuel Potentials
- Bioethanol
- Hydrogen
- **RNG**
- Key Takeaways

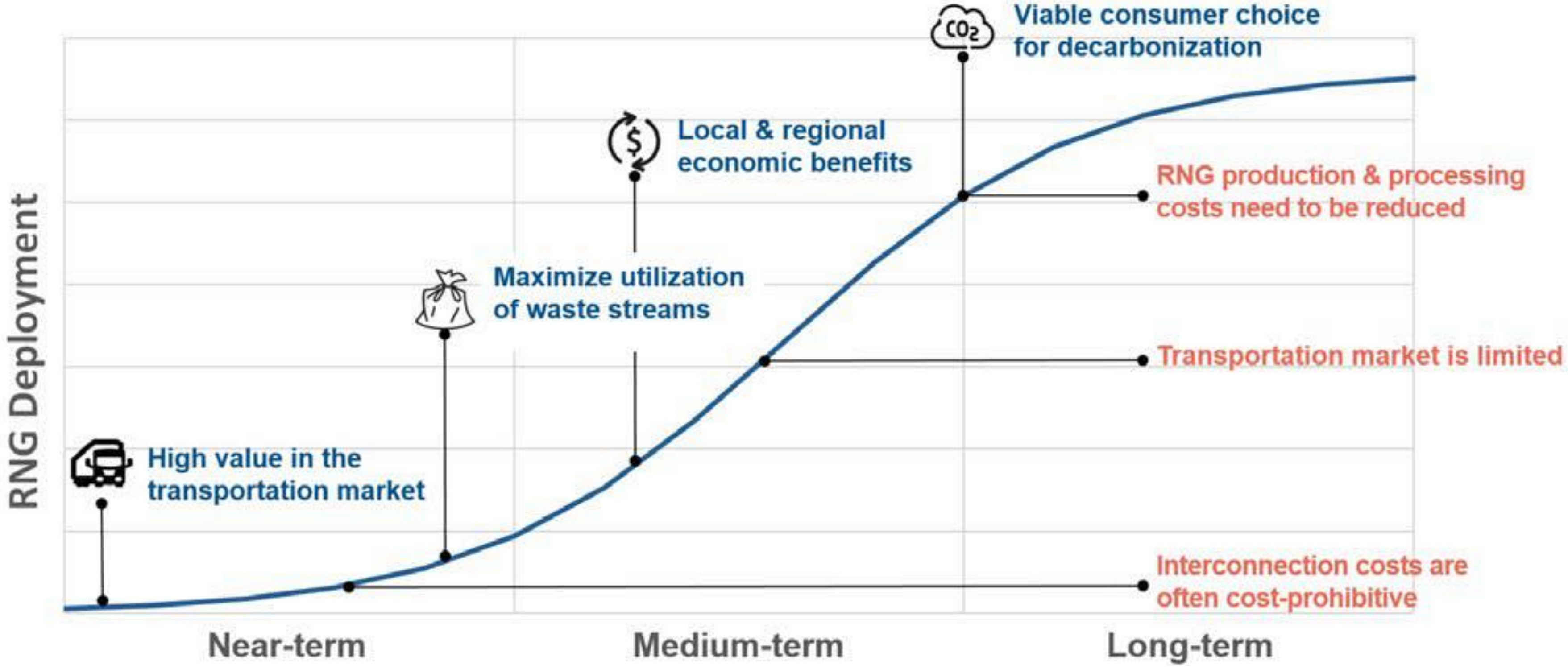
RNG Opportunities and Challenges

	Feedstock	Cost Range ($/MMBtu)
Anaerobic Digestion	Landfill Gas	$7.10 – $19.00
	Animal Manure	$18.40 – $32.60
	Water Resource Recovery Facilities	$7.40 – $26.10
	Food Waste	$19.40 – $28.30

- 2016: 17.5 trillion Btu (tBtu) of RNG produced for pipeline injection
- 2020: 50 tBtu per year of RNG from landfills, dairy digesters, and water resource recovery facilities (WRRFs) is injected into pipelines, growth rate about 30%
- ICF estimates 1,890-7,160 tBtu/y of RNG production by 2040.

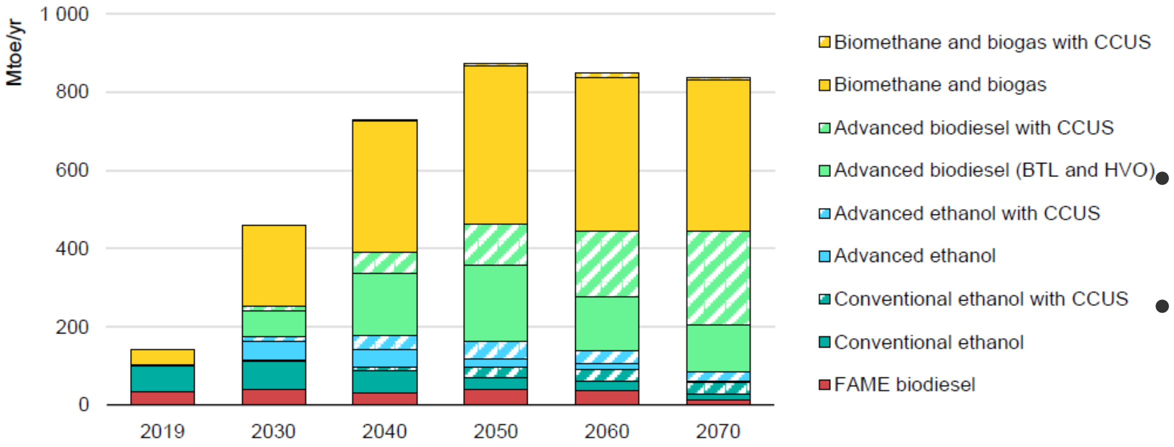
For comparison, the United States consumed approximately 17,500 tBtu of NG in 2018 in the residential, commercial, transportation, and industrial sectors.

Source: STUDY ON THE USE OF BIOFUELS (RENEWABLE NATURAL GAS) IN THE GREATER WASHINGTON, D.C. METROPOLITAN AREA (ICF - MARCH 2020)



Anaerobic Digestion Remains the Dominate Route

Figure 3.7 Global biofuels production by technology in the Sustainable Development Scenario, 2019-70

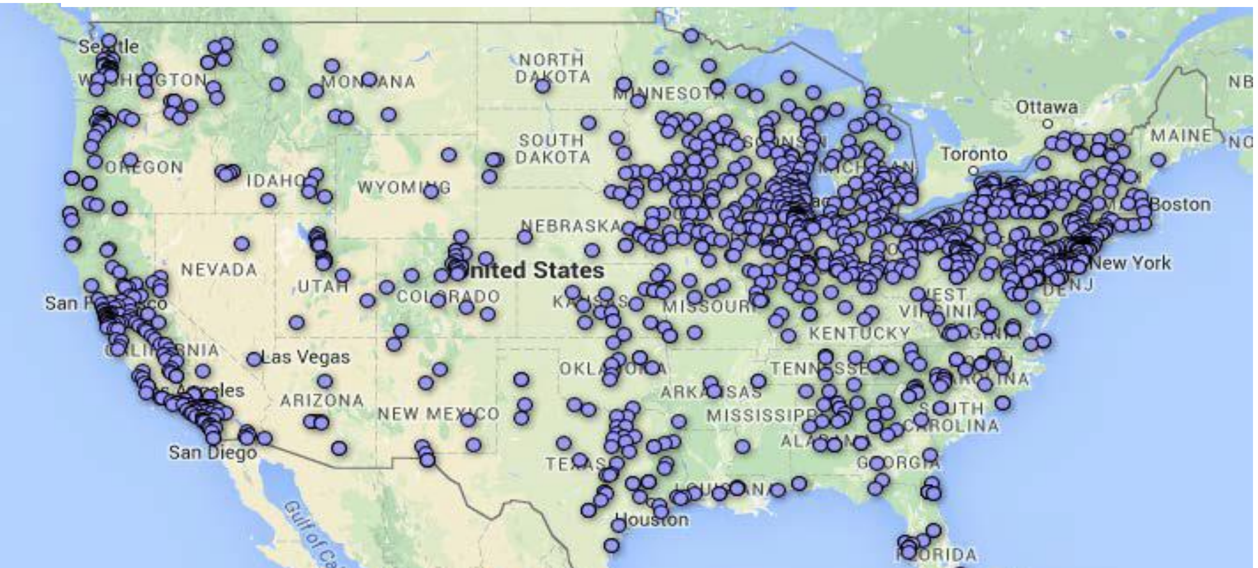


IEA 2020. All rights reserved.

Notes: Advanced biodiesel here includes biojet fuel production. Biomethane and biogas numbers shown here include power generation, gas grid injection and transport use. The vast majority of liquid biofuels are consumed in transport, while a small portion is consumed in industry.

IEA Energy Technology Perspective 2020 (Sept. 10, 2020)

- Total biogas and biomethane production worldwide grows from 30 million tonnes of oil equivalent (Mtoe) today to 335 Mtoe in 2040 and 390 Mtoe in 2070.
- Global average blending shares for biomethane into natural gas networks reach 8% in 2040 and 16% in 2070.
- Biogas-fired internal combustion engines, a modular technology with relatively high part-load efficiencies, are a flexible generation operation in the Sustainable Development Scenario, supporting the integration of variable renewables.



Operational Biogas Systems in the US – data from biogasdata.org

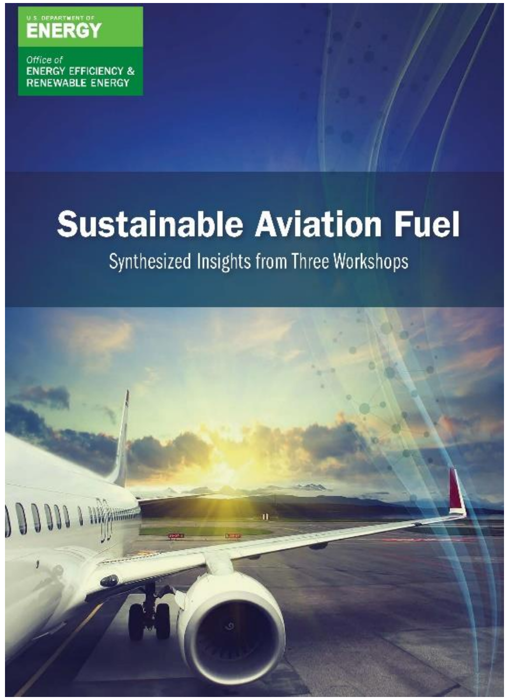
Of the 16,000 water resource recovery facilities (WRRFs) in the US, approximately 1,500 use anaerobic digestion to stabilize solids and generate biogas

Key Takeaways

- Biofuel can play a significant role in decarbonizing several sectors of the economy. Near-term deployment is driven by strong market pull and strong sustained policies to accelerate investments.

- Two main drivers driving for low-cost clean hydrogen are economics and climate goals, especially in the hard to decarbonize sectors of their economy.

- RNG is available today and is a valuable renewable resource with carbon-neutral, and in some cases carbon-negative characteristics.



U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Sustainable Aviation Fuel

Synthesized Insights from Three Workshops

Thank you

Ling.Tao@nrel.gov

www.nrel.gov

Sources: https://www.energy.gov/sites/prod/files/2020/09/f78/beto-sust-aviation-fuel-sep-2020.pdf

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Clean Fuels Alliance America

Clean Fuels
ALLIANCE AMERICA

Biogenic Low Carbon Liquid Diesel Fuels for the Future

Connecticut DEEP: Sept 1, 2022

Steve Howell, Partner, M4 Consulting, Inc.
ASTM Biodiesel Task Force Chair
Senior Technical Advisor to Clean Fuels Alliance America

Clean Fuels Industry Vision 2020

Biodiesel, renewable diesel, and sustainable aviation fuel will be recognized as mainstream low-carbon fuel options with superior performance and emission characteristics. In on road, off road, air transportation, electricity generation, and home heating applications, use will exceed **six billion gallons by 2030**, eliminating over 35 million metric tons of CO2 equivalent greenhouse gas emissions annually. With advancements in feedstock, use will reach **15 billion gallons by 2050**.

Biodiesel And Renewable Diesel Future Target Markets

- On- and off-Road
- Heating Oil/Industrial Boilers
- Marine
- Locomotive
- Power Generation

- Traditionally, most U.S. biodiesel and renewable diesel is in on-/off-road diesel, with increasing amounts in home heating oil and large boilers.
- B20 use is common in regions with strong policy support (Midwest, West)
- R80/B20, R95/B5, R100 is common in California due to strong LCFS values

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New Opportunities Driving Markets

- Carbon reduction is now driving the market
  - Federal, State, and voluntary private industry (ESG, etc.)
- B20 is simply not enough for many policy goals
  - B50 and B100 are needed to hit carbon targets
- Focus is shifting to higher blends….and the markets that are demanding them
- Fuel quality is at an all time high
- The high fuel quality is providing confidence higher blends will work

HEATING OIL: THE PROVIDENCE RESOLUTION

Industry leaders from the New England States and New York gathered for the 1st Northeast Industry Summit 2019

Out of this meeting the Providence Resolution was developed which said;

The industry resolved that it would reduce greenhouse gas emissions, based on 1990 levels, as follows:

- 15% by 2023 (B20)
- 40% by 2030 (B50)
- Net zero by 2050 (B100)

➡ This will make B20, B50 and B100 available at terminals in the NE for other applications

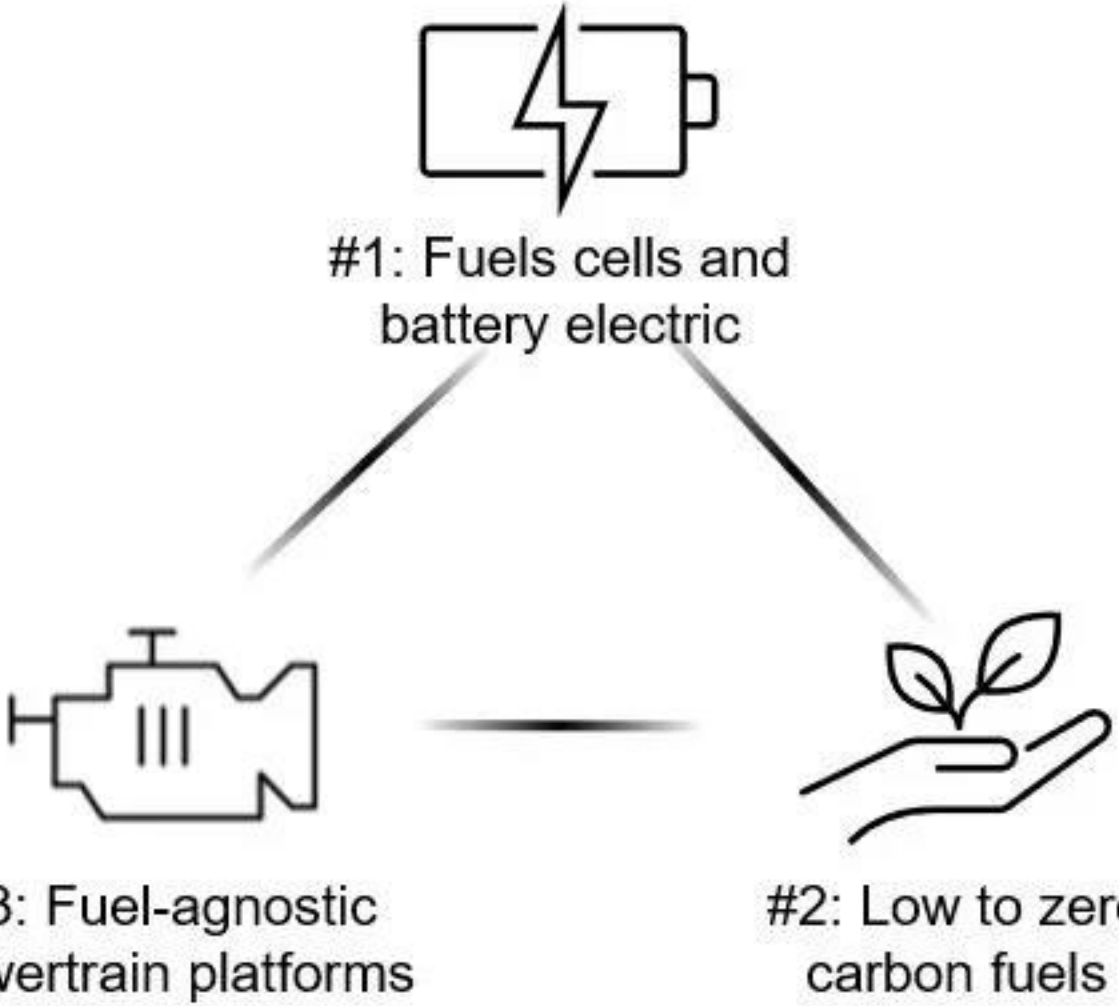
NATIONAL BIODIESEL BOARD

Destination Zero for Clean Fuels Market Panel

Traci Kraus

6/15/22

Three components of the technology roadmap to a zero emissions future


#1: Fuels cells and battery electric

#3: Fuel-agnostic powertrain platforms

#2: Low to zero carbon fuels

Cummins Destination Zero Vision

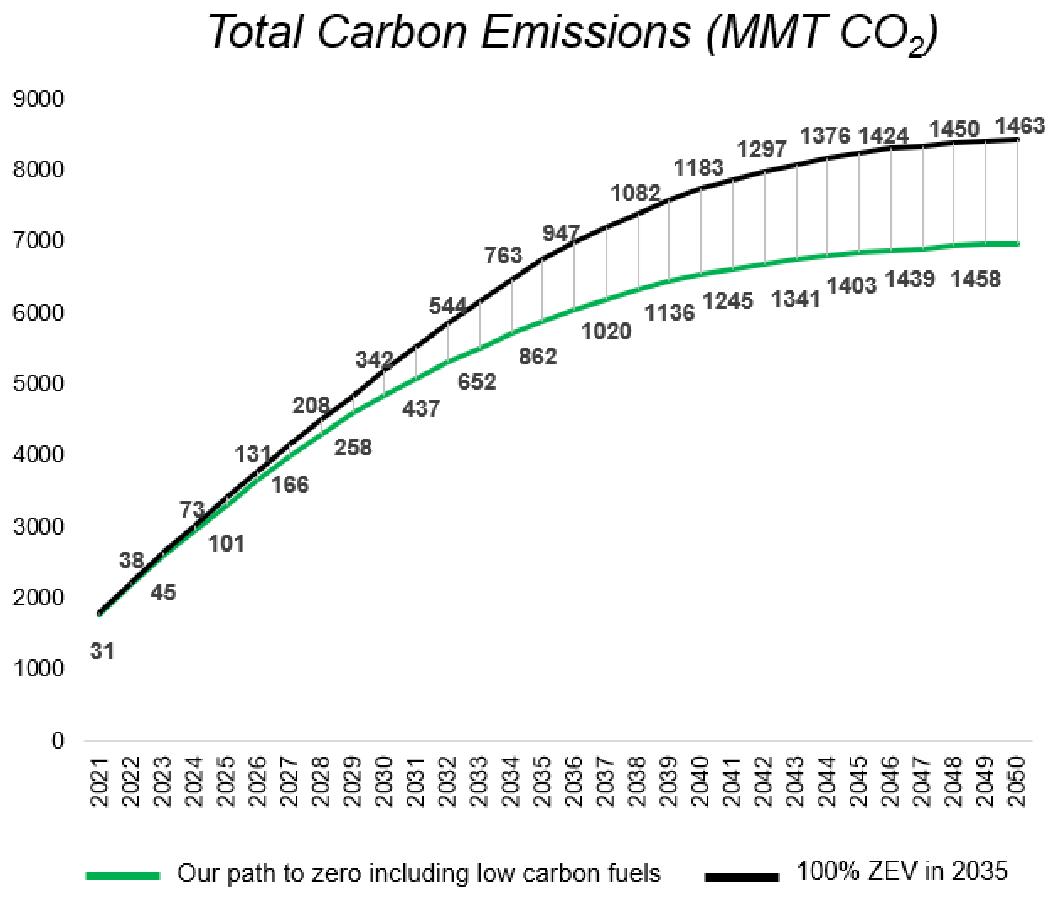
2: Low to zero carbon fuels lower and eliminate carbon emissions on a well-to-wheel basis:

- Hydrogen (combustion or fuel cell), natural gas, biodiesel, synthetic or e-fuels

“B20 is already in our lives today with many engines capable of running on it; the next step towards lowering emissions will be to have engines that can run on B40 and then on B100, pure biodiesel.”

Cummins has asked to partner with Clean Fuels Alliance America on specifications, EPA emissions approvals, and policies to provide incentives for OEMs to support higher biodiesel blends

More cumulative carbon reduction



This analysis is representative of the North America heavy-duty truck application from a wells-to-wheels perspective.

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Ultra Low Emissions Diesel Engines are coming in 2027-2030

- New Technology Diesel Engines (NTDEs, 2010) reduced NOx emissions >90%
- Ultra Low Emissions Diesel Engines (ULEDE), 2027-2030 timeframe
  - EPA and CARB regulations will lower tailpipe NOx emissions by another 90%
  - Implemented for new on-road diesel engines
  - This will make future new ULEDEs near zero tailpipe emissions
- Biogenic low carbon liquid fuels like biodiesel or renewable diesel (or their blends) used in these new ULEDEs can provide significant carbon reductions:
  - 100% Scope 1 carbon reductions
  - 70-80% Scope 3 carbon reductions (full life cycle)

➢As fuels and power decarbonize, Scope 3 carbon reductions will approach 100% i.e., net-zero carbon

Locomotive Fleet Facts

- Class I railroads had 24,597 locomotives in 2019, a 5.7% decrease over 2018
- 7,500 locomotives in storage
- 31.2% of locomotives built before 1995
- Avg. of 197 new locomotives added to N. American railroad fleet over last three years
- Class I railroads interchange locomotives

ASSOCIATION OF
AMERICAN RAILROADS

Clean Fuels
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Railroads and Higher Blends

American Association of Railroads, June 2022 CFAA Board Meeting:

- **Biodiesel and renewable diesel will play an important role in Class I railroads meeting their carbon reduction goals**

- **Biodiesel & Renewable Diesel Use in Existing Locomotives**
  - Progress Rail recently announced its approval of B-20 and 100% renewable diesel in its locomotives; May reduce carbon emissions by 20-25%
  - AAR's members are partnering with Progress Rail and Wabtec to test different blends of biodiesel and renewable diesel in various engines to ensure no negative effects on locomotives

Biodiesel in Marine Applications

WHY?

Paris Climat Agreement:

- Limit Global Warming to well below 2 and preferred max 1,5 °C compared to pre Industrial level.
- This is progressive and is evaluated on a 5 yearly basis.
- Main lever is CO2 reduction.

EU legislation:

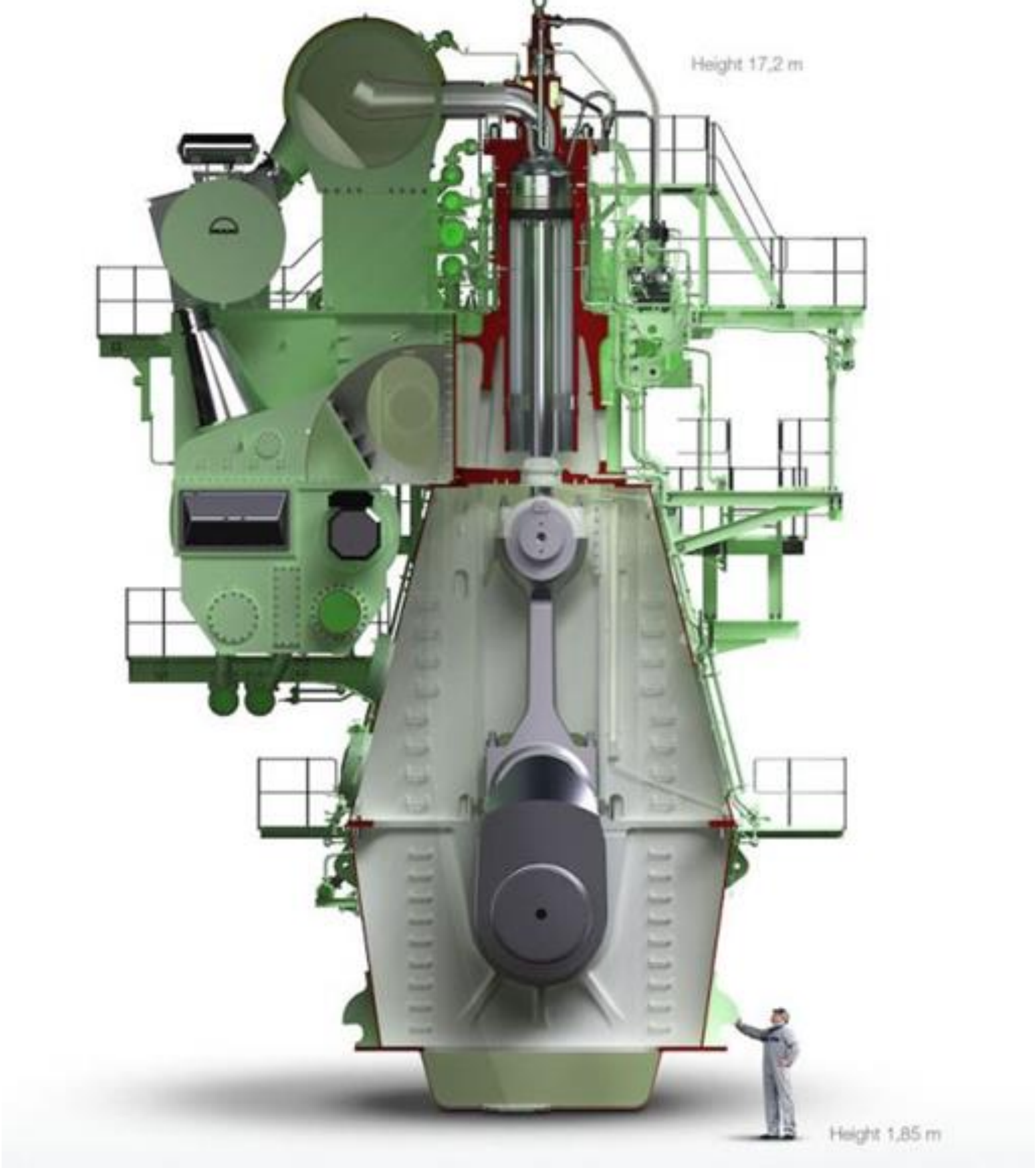
- Recently launched the ‘FIT for 55’ -> Which means 55% less CO2 emissions in 2030 compared to 1990.

IMO:

- 40% GHG reduction by 2030 compared to 2008
- ‘Pursuing Efforts’ towards 70% by 2050.

MAERSK:

- 60% GHG reduction by 2030 compared to 2008
- Nett Zero CO2 Emissions from our ocean operations by 2050



MAERSK

Marine Status and Needs

- Large opportunity for low-cost biodiesel across the globe
- Private companies are conducting trials now, primarily in Europe:
  - Maersk: Over 50 voyages B30-B45, looking at higher blends
  - Cargill: B30, B100
- Specifications (ISO 8217) are being updated for B50, up to B100

Low Carbon Liquid Fuels: 2030, 2050 and Beyond

- As a low capital and low infrastructure way to decarbonize, we anticipate Biodiesel and Renewable Diesel volumes will increase substantially:
    - **6 billion gallons in 2030**
    - **15 billion gallons in 2050**
    - The volumes could be higher depending on feedstock breakthroughs
- These fuels will be used where state policies and industry demands are the strongest, logistics for higher blends are the easiest, and cost to the customer is low
    - On-/Off-Road, Heating Oil/Industrial Boilers, Marine, Locomotive, Electricity Generation
- Clean Fuels Alliance America, industry, and OEM partners are committed to addressing technical needs for these new markets and opportunities

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Thank you!

Charles Darwin purported that, “It is not the strongest of the species that survive, nor the most intelligent, but rather the one most adaptable to change.”

Clean Fuels
ALLIANCE AMERICA

END USES THAT ARE HARD TO DECARBONIZE: AVIATION

Veronica Bradley, Director of Environmental Science

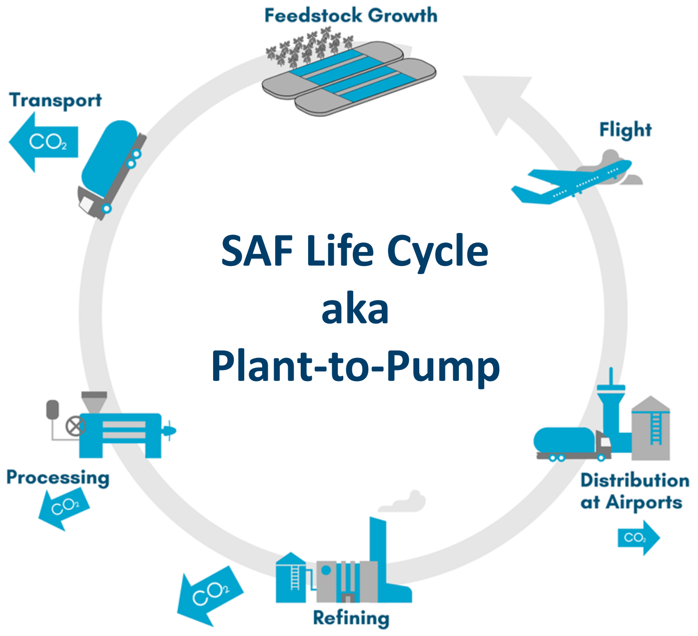
SAF: THE FUEL

Sustainable Aviation Fuel:

- Structurally similar to petroleum-based jet fuel, currently blended up to 50%
- Made from alternative feedstocks like vegetable oils, animal fats, used cooking oil
- Reduces GHG emissions on a life cycle basis relative to petroleum jet fuel.

SAF in Context

	2020
U.S. SAF Production	110,000 Barrels
Connecticut Total Jet Fuel Consumption	1.1 Million Barrels
U.S. Total Jet Fuel Consumption	394.0 Million Barrels



SAF: CURRENT POLICY

U.S. Airline Commitments

All major U.S. Airlines have committed to **Net-Zero Carbon Emissions by 2050**

International Policy

UN ICAO Carbon Offsetting & Reduction Scheme for International Aviation (**CORSIA**): Carbon neutral growth from 2020

Domestic Policy

SAF Grand Challenge (USDA/DOT/DOE): Reduce the cost, enhance the sustainability, and expand the production and use of SAF

- Near-term goal: RD&D to scale up production to **3B gallons/year by 2030 (>71.4M Barrels)**

Inflation Reduction Act tax credits

SAF: CONNECTICUT'S ROLE

What can the State do to promote SAF production & uptake?

Considerations:

- What have other states done to promote SAF?
- Are there legal hurdles like federal preemption to overcome?
- Are there new and different ways to promote SAF production through its supply chain (e.g., transportation infrastructure, airport-specific opportunities)?

Clean Fuels ALLIANCE AMERICA

Eversource

Hard to Decarbonize Sectors: Transportation

Long-Haul Trucking, Aviation and Marine *share common inherent challenges towards decarbonized market development – longer term regional coordination necessary for planning*

Inherent Challenges to Market Development

- Regional Markets require multi-jurisdictional coordination
- Standards Development
- Available Models / Vehicles
- Dwell Time impact on Logistics
- In/flexibility of demand
- Resilience / Redundancy Needs

Utility Challenges

- Large Battery Capacity Requirements = Large Electrical Demand Requirements
- Distribution System and Transmission Planning
- Regional Electrical Capacity Planning
- Resilience / Redundancy Needs
- Optimization of the resulting load
- Extent to which clean H2 plays role

Click on the presenters to jump to their slides

Industrial Thermal

Kareem Hammoud – U.S. Climate Alliance

Blaine Collison – Renewable Thermal Collaborative

Amanda De Vito Trinsey – CT Industrial Energy Consumers

Rob Kirts – Stanley Black & Decker

(speaker order may vary)

U.S. Climate Alliance

Decarbonizing Industrial Thermal Processes

CT DEEP Technical Session for the 2022 Comprehensive Energy Strategy

September 1, 2022

UNITED STATES
CLIMATE ALLIANCE

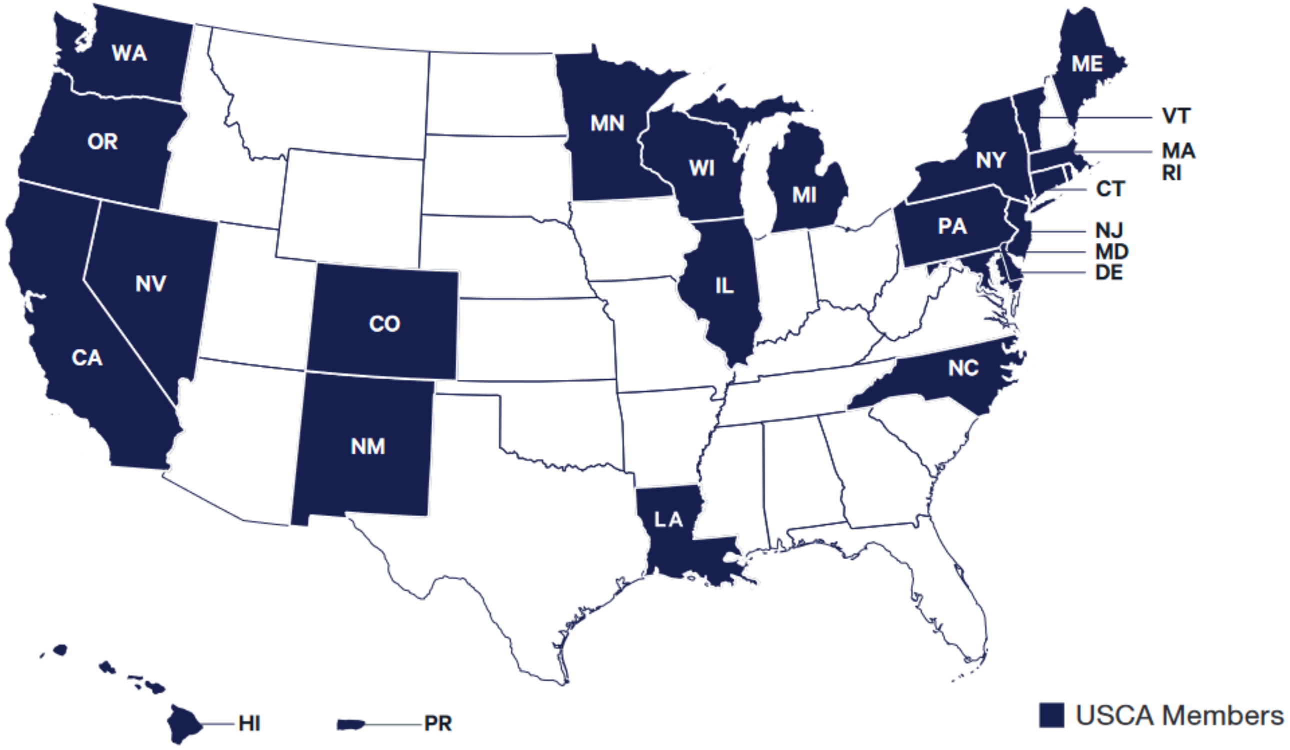
Agenda

1. USCA overview and work on industrial decarbonization
2. Challenges of industrial thermal decarbonization
3. Primary opportunities

US Climate Alliance Overview

U.S. Climate Alliance

Bipartisan coalition of 24 governors cooperating to tackle climate challenge.



59% of the U.S. economy.

54% of the U.S. population.

42% of U.S. emissions.

http://www.usclimatealliance.org/

U.S. Climate Alliance

OUR COLLECTIVE GOALS

- Reducing collective net GHG emissions at least **26-28 percent by 2025** and **50-52 percent by 2030**, both below 2005 levels, and collectively achieving **overall net-zero GHG emissions** as soon as practicable, and no later than 2050.

- Accelerating new and existing **policies to reduce GHG pollution**, **building resilience** to the impacts of climate change, and promoting **clean energy deployment** at the state and federal level.

- Centering **equity, environmental justice, and a just economic transition** in their efforts to achieve their climate goals and create high-quality jobs.

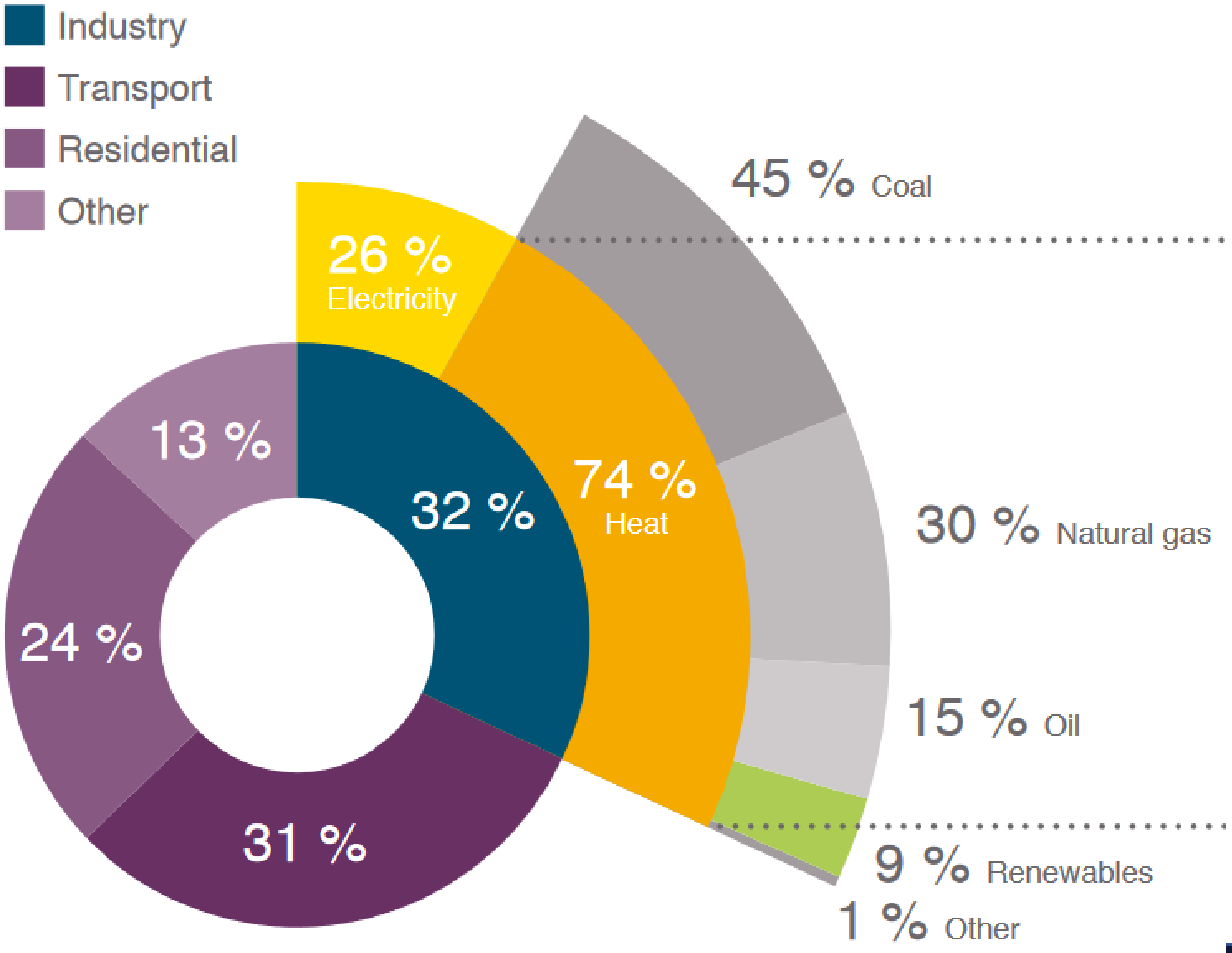
- **Tracking** and **reporting progress** to the global community in appropriate settings, including when the world convenes to take stock of the Paris Agreement.

Priority Policy Areas

1. Power
2. Buildings
3. **Industry**
4. Transportation
5. Just Transition and Equity
6. Resilience
7. Natural and Working Lands
8. Social Cost of Greenhouse Gases

Industrial Thermal Challenges

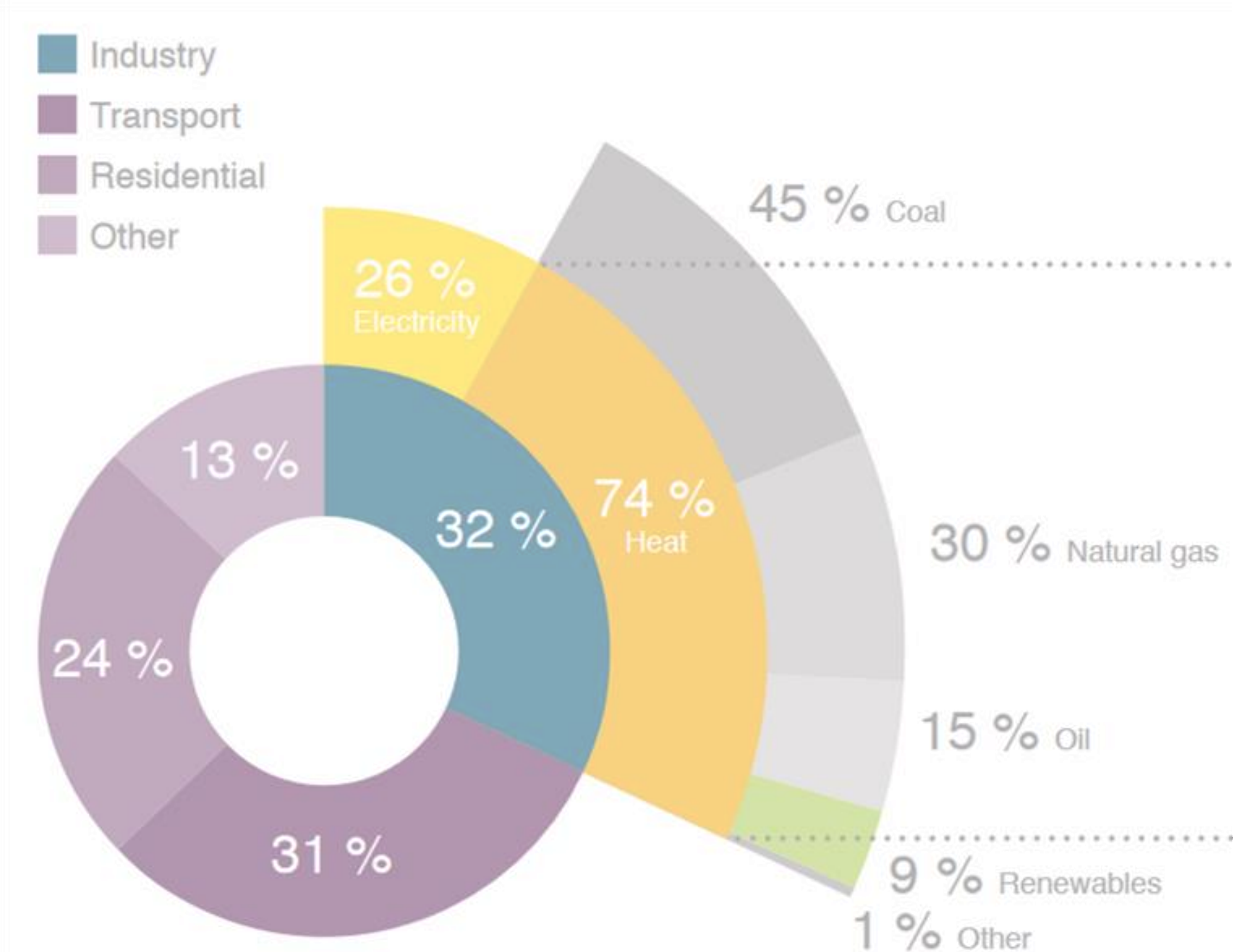
Most industrial energy consumption (global) is for heat, mostly generated from fossil fuels…



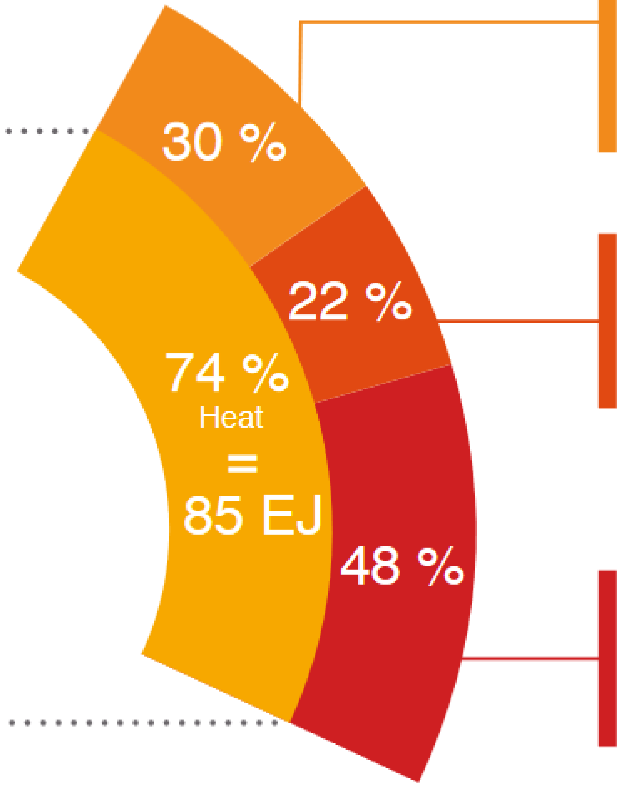
TOTAL FINAL ENERGY CONSUMPTION 2014: 360 EJ (EXAJOULE, see Glossary

Source: Solar Payback

…and heating needs vary



TOTAL FINAL ENERGY CONSUMPTION 2014: 360 EJ (EXAJOULE, see Glossary page 17); IEA [1]



Low-temp heat
(below 150 °C)
Boiling, pasteurising, sterilising, cleaning, drying, washing, bleaching, steaming, pickling, cooking.

Medium-temp heat
(150 to 400 °C)
Distilling, nitrate melting, dyeing, compression.

High-temp heat
(above 400 °C)
Material transformation processes.

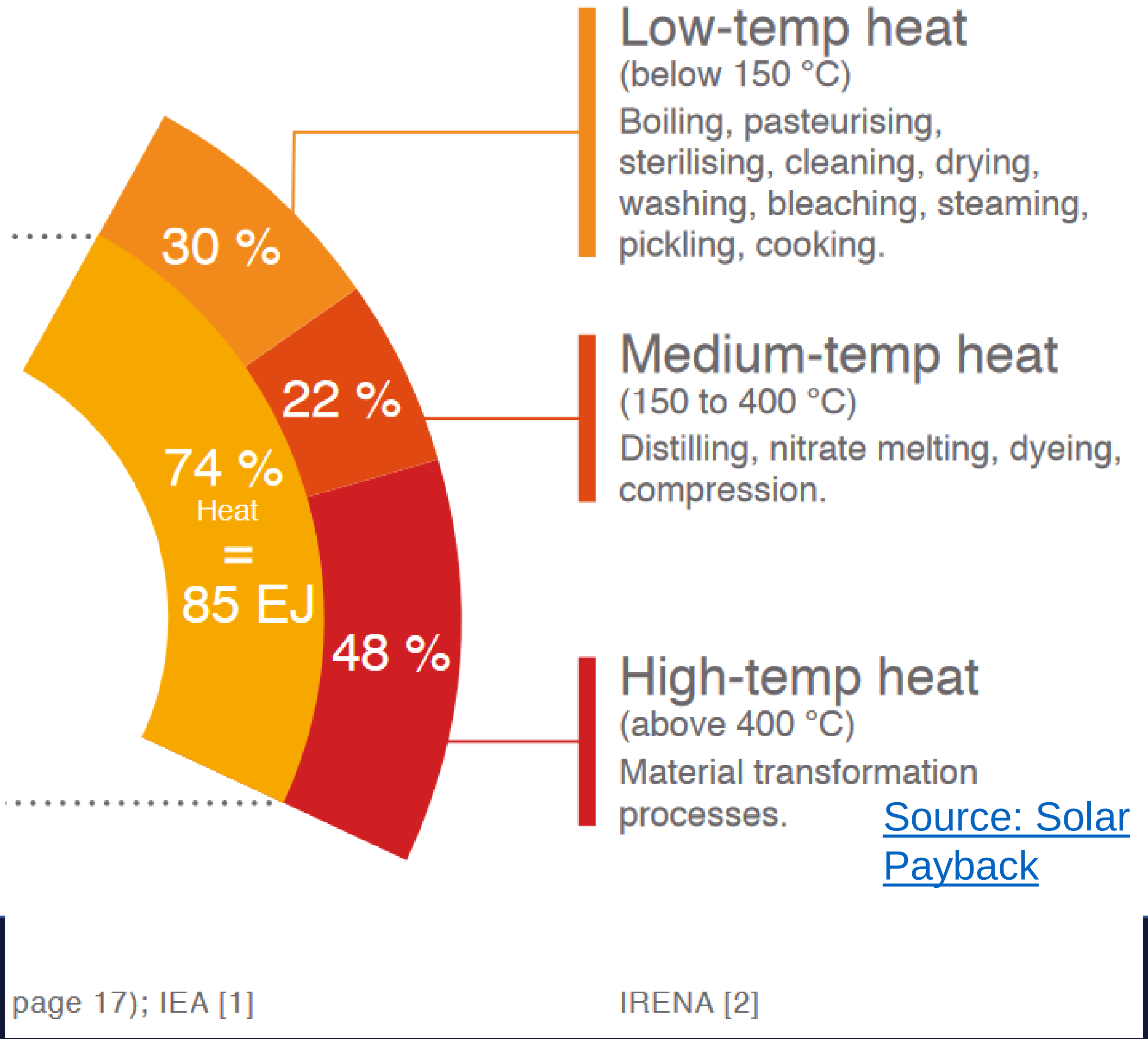
IRENA [2]

Source: Solar Payback

…and readily provided by fossil fuels

Fuel	Max Temp (C)
Coal	2175
Oil	2100
Natural Gas	1960

Source: Thiel and Stark



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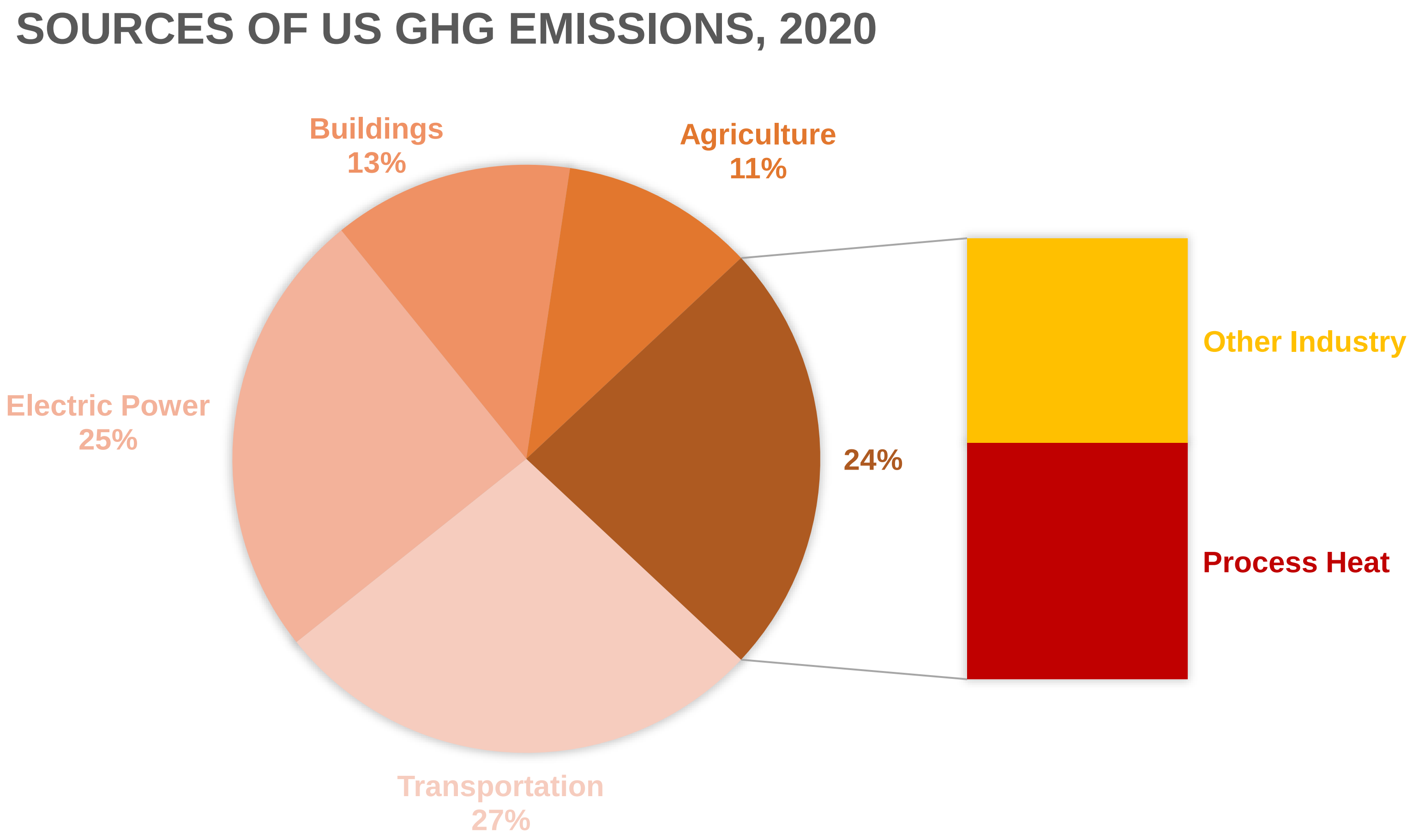
High-temp heat
(above 400 °C)
Material transformation processes.

Source: Solar Payback

page 17); IEA [1]

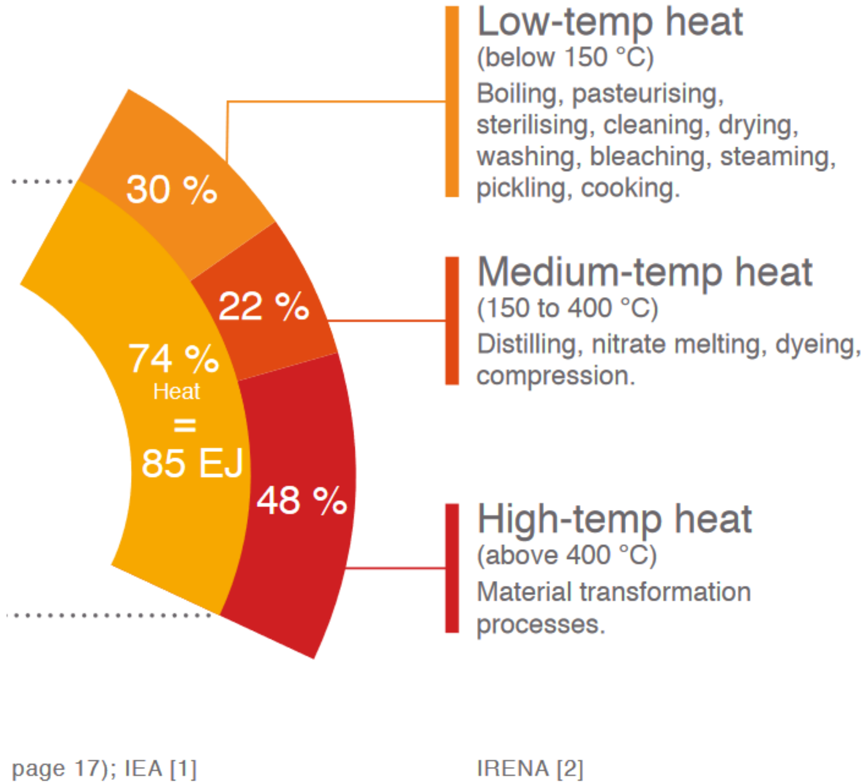
IRENA [2]

Industry is 24% of US GHG emissions, **process heat is 54%** of industrial emissions



Source: EPA, 2021

Common industrial process heating operations, including typical applications and required temperature ranges



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page 17); IEA [1]

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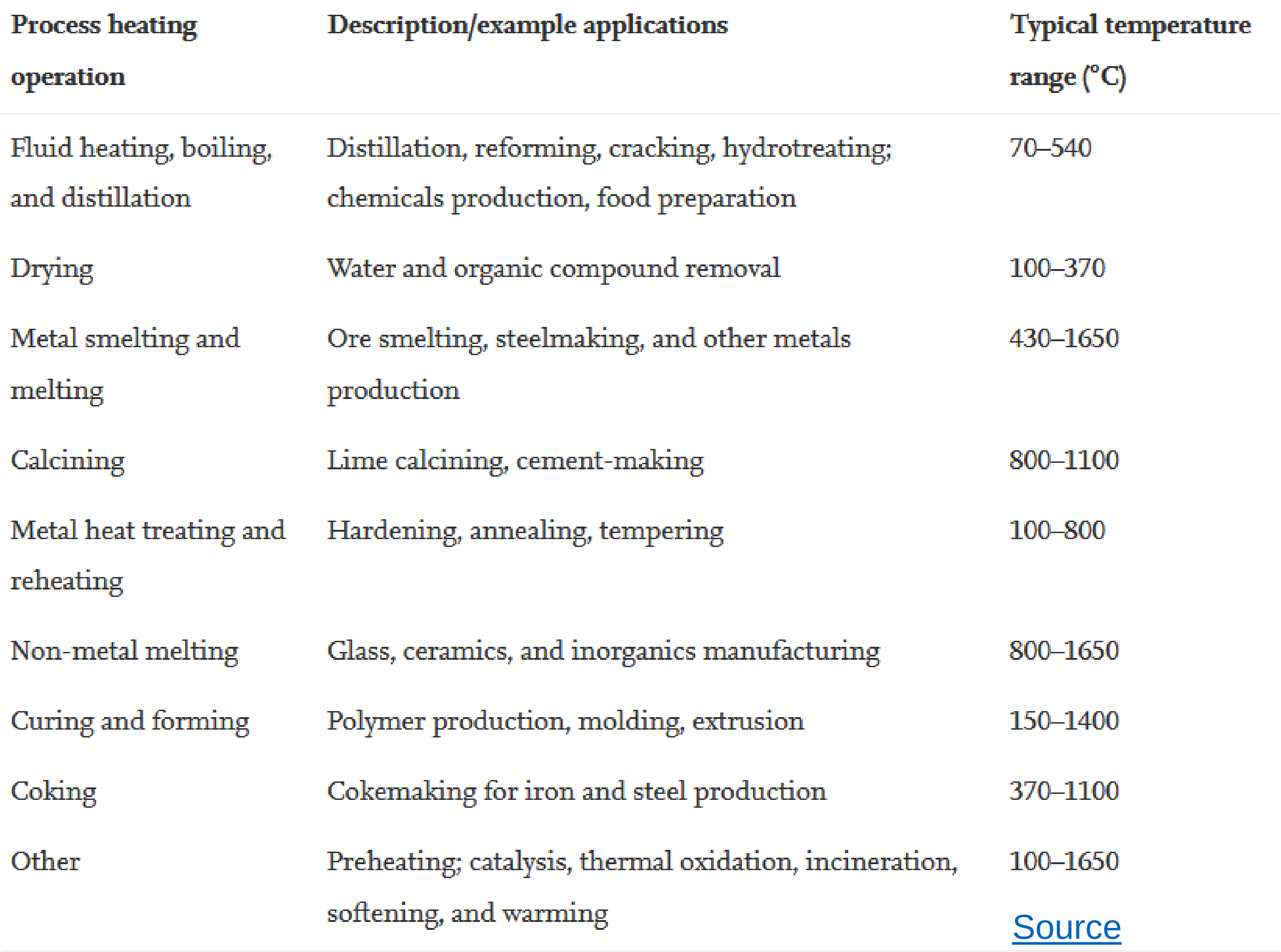
[Source: Solar Payback]



Process heating operation	Description/example applications	Typical temperature range (°C)
Fluid heating, boiling, and distillation	Distillation, reforming, cracking, hydrotreating; chemicals production, food preparation	70–540
Drying	Water and organic compound removal	100–370
Metal smelting and melting	Ore smelting, steelmaking, and other metals production	430–1650
Calcining	Lime calcining, cement-making	800–1100
Metal heat treating and reheating	Hardening, annealing, tempering	100–800
Non-metal melting	Glass, ceramics, and inorganics manufacturing	800–1650
Curing and forming	Polymer production, molding, extrusion	150–1400
Coking	Cokemaking for iron and steel production	370–1100
Other	Preheating; catalysis, thermal oxidation, incineration, softening, and warming	100–1650

[Source]

Challenges by industry subsector

Subsector	Heat Temp Needs (C)
Cement	1200-1500
Iron & Steel	1100-2200
Chemicals	875-900 (petrochems, basic chems) 850 (fertilizer) 230-450 (ethanol) 290 (plastics) 175 (chlorine)
Petroleum Refining	600
Pulp & Paper	150-180 (paper) 150-800 (pulp)
Food Processing	50-175 (corn milling)

Source: C2ES, NREL

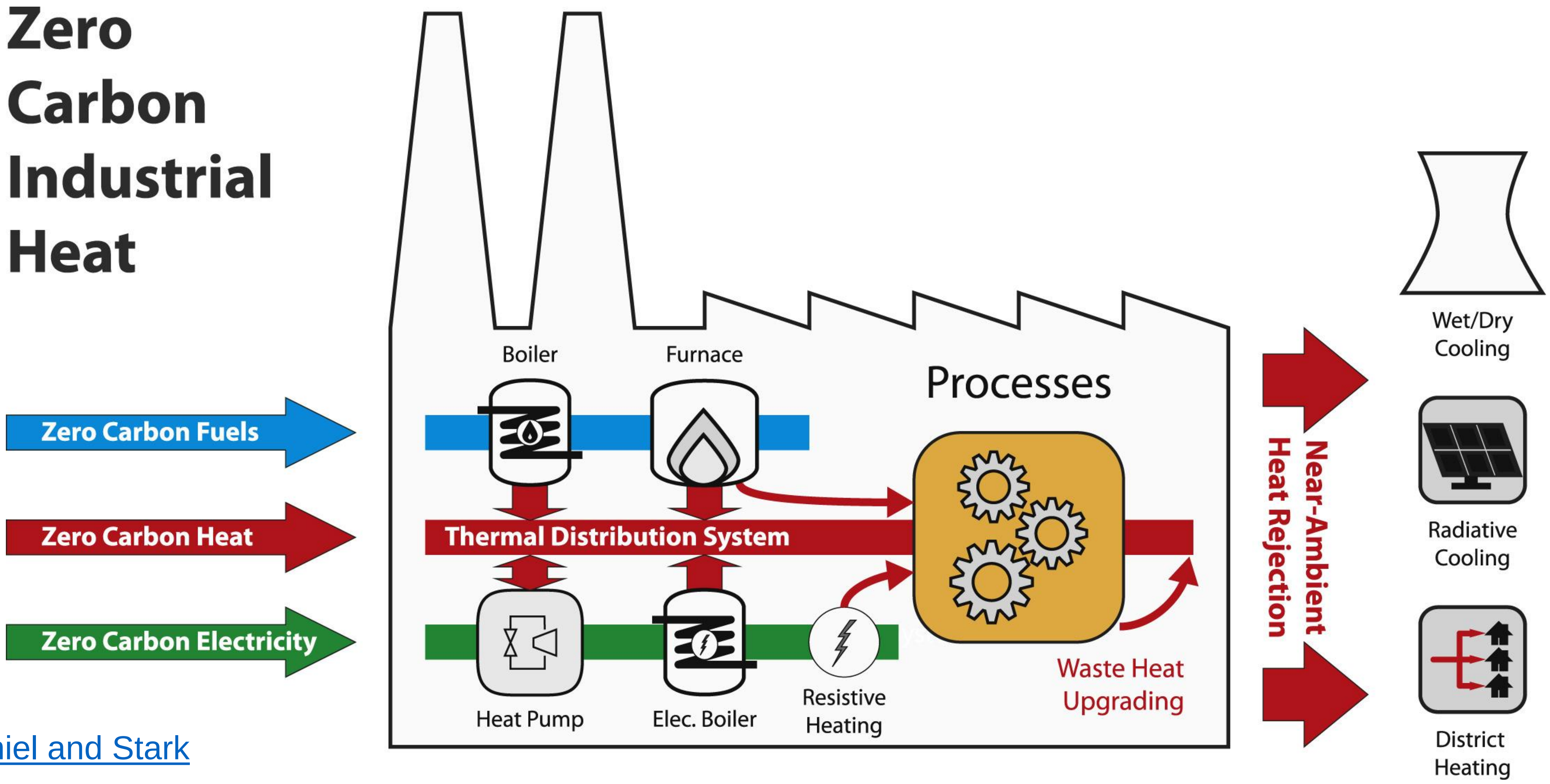
General heat decarbonization challenges

1. Industrial heat is often generated on-site, making it more difficult to regulate than a more centralized sector such as large thermal power generation
2. Heating needs for residential/commercial buildings are fairly standard, but industrial heat encompasses a wide variety of temperature levels for diverse processes and end-uses
3. Different technology and fuel options are available depending on the required temperature level, but these are often not interchangeable
    - For example, low-temperature heat from a heat pump cannot be substituted for high-temperature heat from a gas boiler

source: IEA

Industrial Thermal Opportunities

4 pathways to decarbonizing industrial heat



Source: Thiel and Stark

Heat decarbonization opportunities

Zero Carbon Electricity

- Induction furnaces
  - 3000C
- Microwave, radio heating
  - 2000-2200C
- Resistance heating
  - 1800C
- Heat pumps
  - <100-180C
- Boilers
  - 100-150C

Zero Carbon Heat

- Solar thermal
  - 260-1200C, typically operates at <565C
- Geothermal
  - 150-370C
- Nuclear
  - 300C (new tech up to 850C)

Zero Carbon Fuels

- Hydrogen
  - 2250C
- Ammonia
  - 1800C
- Biofuels
  - 2200C
- Biomass
  - 1100C (wood chips)

Opportunities Summary

- **Electrification** can be a low-cost and sustainable option – heat pumps can be economical solutions for low- and medium-temperature needs, esp. in light industries like food/beverage
    - 2/3rds of process heat used in US industry is for applications below 300C, making electrification and solar thermal strong candidates Source: NREL
- Direct renewable heat sources such as **solar thermal** and **geothermal** can be economical for applications below 400 C, which accounts for approximately half of today's industrial heat demand, but they are not easy to integrate in all industrial facilities
- Low-carbon fuels like **hydrogen** and some forms of **biomass** can be used for high-temperature applications above 500 C, with some studies finding that using biomass for high-temperature heat applications will be the most cost-effective way to meet industrial emissions reduction targets. However, bioenergy is resource-constrained and only economical and sustainable under certain operating conditions and in certain regions, and zero-carbon hydrogen requires more R&D to produce, deploy, and scale in a clean manner

source: IEA

New federal opportunities in the Inflation Reduction Act

$5.8B: Advanced Industrial Facilities Deployment Program (Sec. 50161)

- Financial assistance for energy-intensive manufacturing facilities (incl iron, steel, aluminum, cement, concrete, glass, pulp, paper, ceramics, chemicals) to purchase, install, or conduct studies for technologies that reduce GHG emissions
- Prioritized on GHGs, greatest benefit to people locally, partnerships with purchasers of the output
- “Technologies” incl:
  - industrial energy efficiency;
  - equipment to electrify industrial processes;
  - equipment to utilize low or zero carbon fuels, feedstocks and energy sources;
  - **low or zero carbon process heat systems**;
  - CCUS

New federal opportunities in the Inflation Reduction Act

- Expansion of 45Q tax credits for Carbon Capture and Storage (Sec. 13104)
- Clean Hydrogen Production tax credit (Sec. 13204)
- Revives and expands 48C Advanced Manufacturing Tax Credit (Sec. 13501)
  - adds eligibility to projects that retrofit facilities with technologies (including **low-carbon process heat**, CCUS, energy and material efficiency) that reduce GHG emissions by at least 20%
  - adds eligibility to projects that produce or install energy storage systems, low carbon fuels, energy efficient equipment, EV and fuel cell vehicles and their related components and charging infrastructure, and process, refine, or recycle critical materials

Questions?

Resources for further reading

- Clean Industrial Heat: A Technology Inclusive Framework (C2ES, 2021)
- To decarbonize industry, we must decarbonize heat (Thiel & Stark, 2021)
- Low-Carbon Heat Solutions for Heavy Industry: Sources, Options, and Costs Today (CGEP, 2019)

Contact

Kareem Hammoud, Senior Policy Analyst, US Climate Alliance

khammoud@usclimatealliance.org

Renewable Thermal Collaborative

Decarbonizing Industrial Thermal Processes

Renewable Thermal Collaborative
September 1, 2022

The Challenge of Decarbonizing Thermal

Renewable Thermal: Beyond Electricity

50% OF GLOBAL
final energy is comprised of energy used for heating and cooling

$270 BILLION
amount heating and cooling cost in the United States annually.

39% OF GHG
emissions from energy-related sources can be attributed to heating and cooling.

> The world already has great renewable electricity solutions but if we are to keep the warming of the planet below 2 degrees then we also need great renewable thermal solutions.
>
> Barry Parkin, Chief Sustainability and Health & Wellbeing Officer, Mars

Facilitated by:

C2ES
CENTER FOR CLIMATE AND ENERGY SOLUTIONS

D|G/A
David Gardiner and Associates

WWF

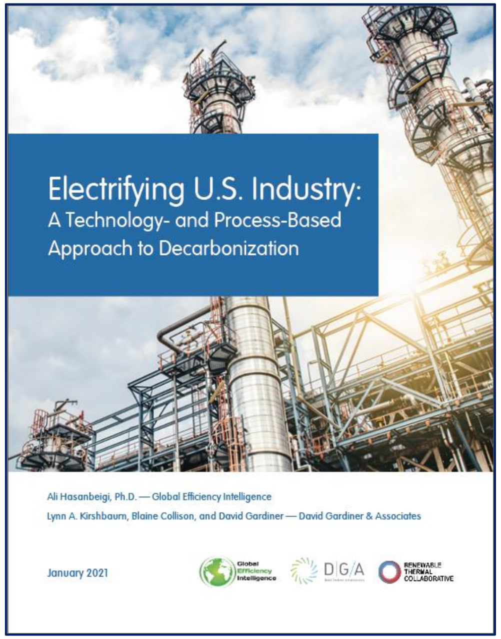
The Renewable Thermal Collaborative

The RTC is the only global, buyer-led coalition focused on decarbonizing thermal energy with renewables.

We focus our work across the intersecting issues of **technology**, **market development**, and **policy**.

RTC Members (buy-side) and Sponsors (solutions-side) are invited to participate in multiple RTC workstreams to:

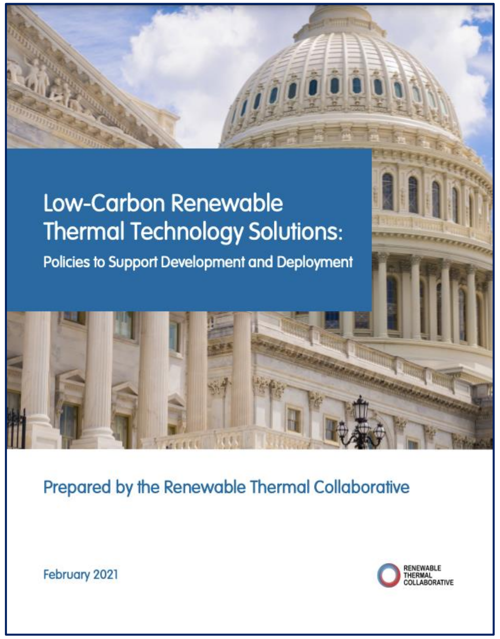
- Identify and address barriers;
- Accelerate solutions;
- Implement projects and policies.



Electrifying U.S. Industry:
A Technology- and Process-Based Approach to Decarbonization

Ali Hasanbeigi, Ph.D. — Global Efficiency Intelligence
Lynn A. Kirshbaum, Blaine Collison, and David Gardiner — David Gardiner & Associates

January 2021



Low-Carbon Renewable Thermal Technology Solutions:
Policies to Support Development and Deployment

Prepared by the Renewable Thermal Collaborative

February 2021

RTC Members

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AstraZeneca

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WE WISEWOOD ENERGY

What We Do

Technology Action Plans and Partnerships (TAPPs)

- Working Groups of members, sponsors, and select experts convened to identify barriers and execute solutions for these renewable thermal technologies:
  - Beneficial Electrification
  - Solar Thermal
  - Renewable Natural Gas (RNG)
  - Green Hydrogen
  - Sustainable Biomass
  - Thermal Storage (2022-23)

Policy

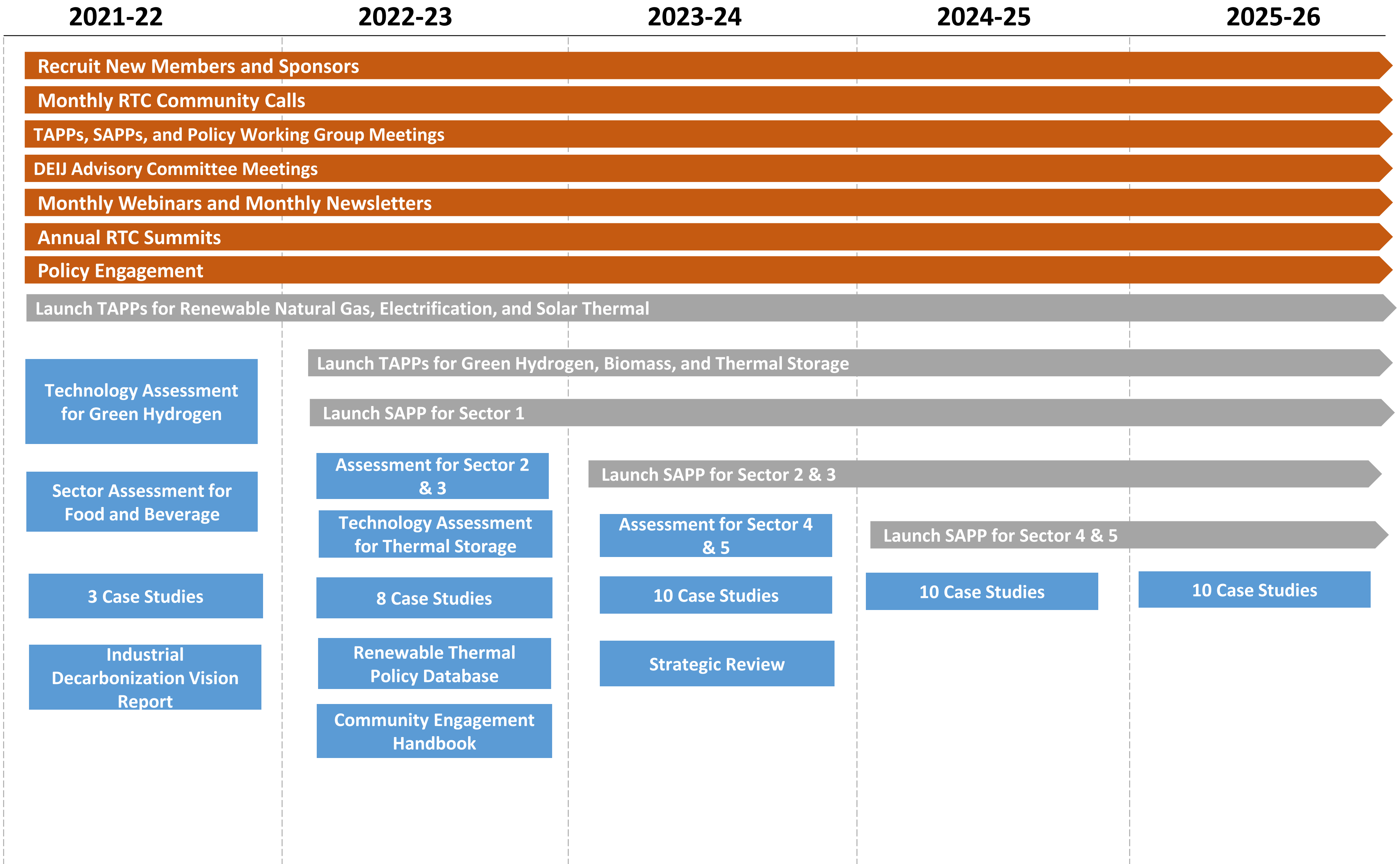
- Working Group of members and sponsors; currently focused on U.S. federal policy;
- Will expand to targeted states.

Market Development

- Monthly Community Calls
  - Members, sponsors, and select guests only
- Annual Summit – October 20-21, Washington, DC
- Greenhouse Gas Accounting and Claims Working Group
- Sector Action Plans and Partnerships (SAPPs)
  - Working Groups of members, sponsors, and select experts convened to identify barriers and execute solutions for specific sectors;
  - Five SAPPs 2022-26;
  - Food & Beverage will be first; others TBD.
- Collaborative Projects Working Group

RENEWABLE
THERMAL
COLLABORATIVE

RTC's Five Year Plan



2021-22
2022-23
2023-24
2024-25
2025-26

Recruit New Members and Sponsors

Monthly RTC Community Calls

TAPPs, SAPPs, and Policy Working Group Meetings

DEIJ Advisory Committee Meetings

Monthly Webinars and Monthly Newsletters

Annual RTC Summits

Policy Engagement

Launch TAPPs for Renewable Natural Gas, Electrification, and Solar Thermal

Launch TAPPs for Green Hydrogen, Biomass, and Thermal Storage

Launch SAPP for Sector 1

Launch SAPP for Sector 2 & 3

Launch SAPP for Sector 4 & 5

Technology Assessment for Green Hydrogen

Sector Assessment for Food and Beverage

3 Case Studies

Industrial Decarbonization Vision Report

Assessment for Sector 2 & 3

Technology Assessment for Thermal Storage

8 Case Studies

Renewable Thermal Policy Database

Community Engagement Handbook

Assessment for Sector 4 & 5

10 Case Studies

Strategic Review

10 Case Studies

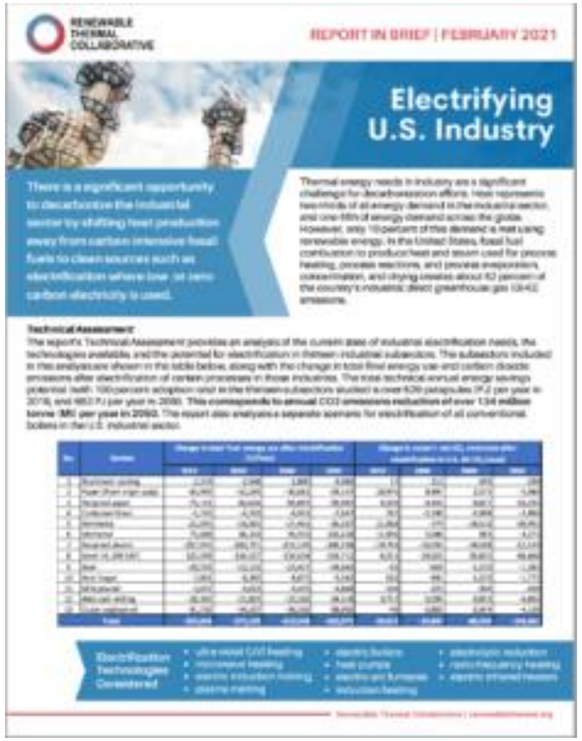
10 Case Studies

Ongoing Engagement & Communication

Ongoing Activities

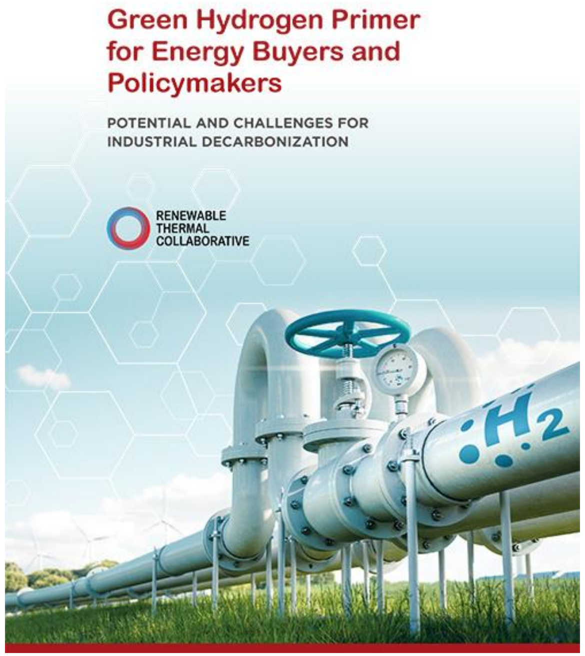
Deliverables

Example RTC Resources



REPORT IN BRIEF | FEBRUARY 2021

Electrifying U.S. Industry



Green Hydrogen Primer for Energy Buyers and Policymakers

POTENTIAL AND CHALLENGES FOR INDUSTRIAL DECARBONIZATION

RENEWABLE THERMAL COLLABORATIVE

DIAGEO

CASE STUDY

Project Overview

Project Description

www.renewablethermal.org

Questions?

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Sign up for our newsletter at renewablethermal.org

Follow us on Twitter and LinkedIn @Rethermal

Connecticut Industrial Energy Consumers

CIEC Connecticut Industrial Energy Consumers

DEEP 2022 Comprehensive Energy Strategy

CIEC Presents on Session 1: Introduction and foundational issues, Part A – End uses that are hard to decarbonize

September 1, 2022

Decarbonizing Industrial Processes that Rely on Thermal Energy

- Need for high temperatures (>1500 deg F): there are products that require manufacturing and testing with rapid temperature changes and large volumes of air.
  - Not achievable with electric at this time.
- Need for significant build out of electrical infrastructure located at manufacturing facilities and electric grids to accommodate the added load.
  - Cost prohibitive.
- Acceptance of manufacturing techniques and testing procedures by third party groups.
  - Changes either to the manufacturing process or testing procedures to transition from gas to electric requires rewriting, resubmission and approval from the third parties with years of testing and process rewrites to validate the changes. Customers and regulators need confirmation that modified process is equivalent or superior to previous process.

Maintaining the Reliability of the Electric Grid

- Potential alternatives to thermal energy?
  - Electric
  - Hydrogen
- Highly efficient Onsite Combined Heat & Power facilities, fueled by cleaner, reliable natural gas, provide reliable sources of electricity and steam for manufacturing processes.
- IMPERATIVE that businesses in the State continue to receive safe and reliable electric service.
  - The reliability of New England's electric grid continues to be threatened by the retirements of baseload generation.
  - The prospect of load shedding due to an unreliable grid not only threatens public safety but could irreparably harm Connecticut's economy by forcing companies who can move their operations to do so.

A Path Forward

- Industrial organizations agree there are social and financial benefits to reducing energy consumption and ensuing GHG emissions.
- Reduction opportunities must be implemented in a reliable, cost effective manner that does not adversely affect production.
- Generally, there should be a focus on the potential unintended consequences of decarbonizing too quickly.
  - Delicate balance of timing and resources
  - Strategic
- Electrical outage during testing and manufacturing incurs $M in scrapped parts and inaccurate test results (Tests can be >24hrs)
- Maintaining the competitiveness of doing business in Connecticut is important, as the affordability of energy is directly intertwined with the economy of the region.

Questions?

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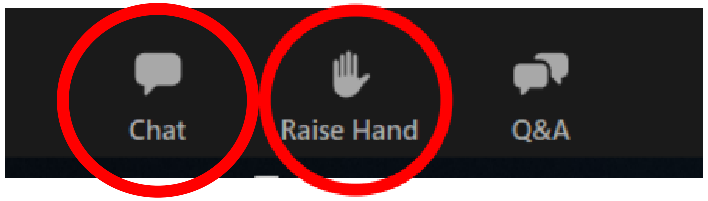
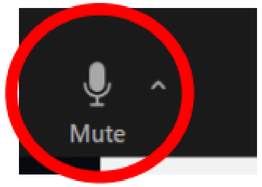
Stanley Black & Decker

Questions and Comments





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At the conclusion of each panel DEEP will hold a brief question and comment period.

If you have a clarifying question, please drop it into the chat to either Jeff Howard or Becca Trietch. DEEP will pose as many questions as time allows to the speakers.

If you would like to make a comment:

- Please use the “Raise Hand” feature if you would like to speak
- After any interested elected officials have provided their comments, you will be invited to provide your comment in the order the hands were raised
- Please unmute yourself, state your name and affiliation
- Given time limitations, please limit your comment to 2 minutes.
- After your comments, please remember to click the “Mute” button

Public Comment – Industrial Thermal

BUREAU OF ENERGY AND
TECHNOLOGY POLICY

Lunch Break

(we'll restart at 1:00 p.m. EST)

BUREAU OF ENERGY AND
TECHNOLOGY POLICY