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Congressional Climate Camp #2: Federal Policies for High Emitting Sectors

Briefing Series: Congressional Climate Camps

Friday, February 26, 2021

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EESI
Environmental and Energy Study Institute

NON-PROFIT

Founded in 1984 by a bipartisan Congressional caucus as an independent (i.e., not federally-funded) non-profit organization

NON-PARTISAN

Source of non-partisan information on environmental, energy, and climate policies

DIRECT ASSISTANCE

In addition to a full portfolio of federal policy work, EESI provides direct assistance to utilities to develop “on-bill financing” programs

SUSTAINABLE SOCIETIES

Focused on win-win solutions to make our energy, buildings, and transportation sectors sustainable, resilient, and more equitable

...About EESI

EESI
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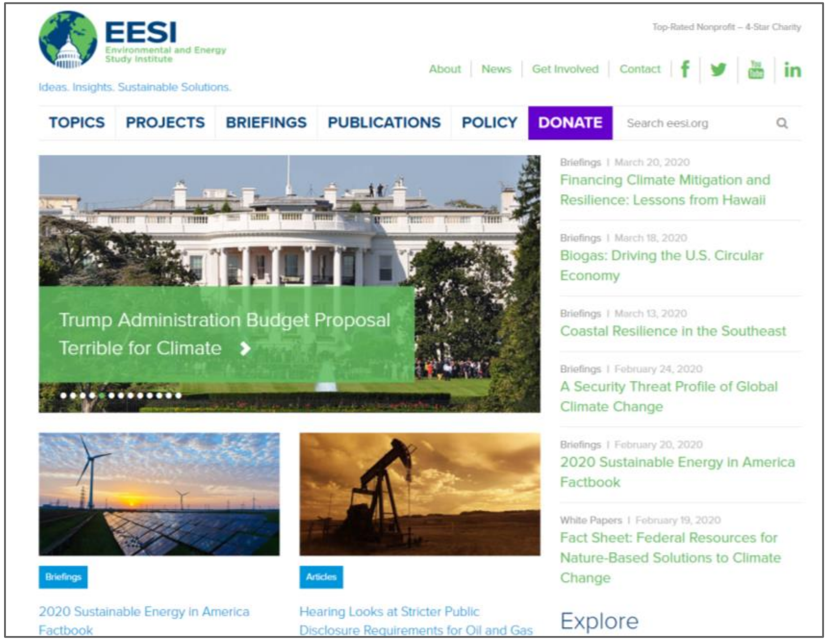

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CONGRESSIONAL
CLIMATE CAMP II

FRIDAY, FEBRUARY 26 | 2 PM EST

FEDERAL POLICIES FOR HIGH EMITTING SECTORS

@EESIONLINE

Regenerative Agriculture and Greenhouse Gas Mitigation

Dr. Christina Tonitto, Dr. Peter Woodbury, Dr. Dominic Woolf

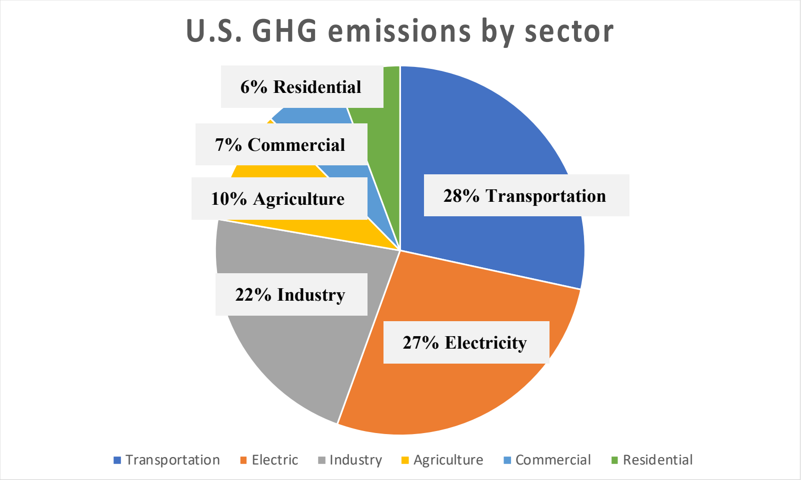
Cornell University

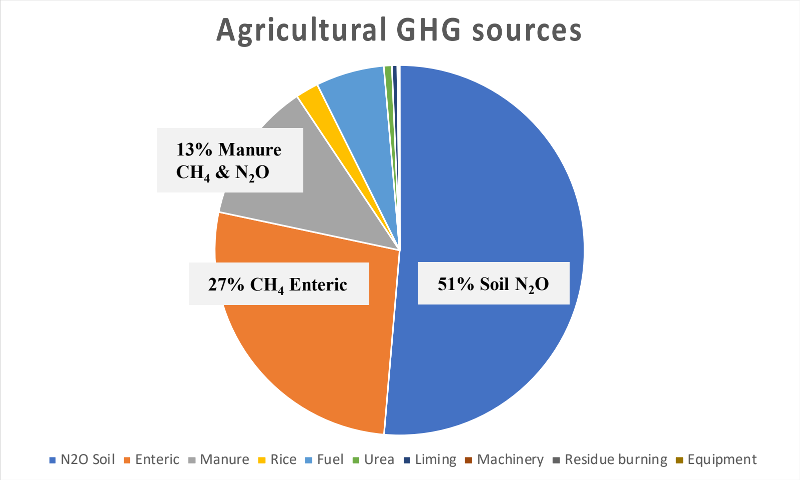
February 26, 2021

Overview

- Greenhouse Gas (GHG) Emissions from Agriculture
- Conventional vs. Regenerative Agriculture
- Agriculture and GHG Mitigation
- Policy Considerations
- Questions?

Greenhouse Gas Emissions from Agriculture





- **Agriculture** causes 10% of total U.S. GHG emissions.
- **Nitrous oxide** (N_2O) is largest component of agricultural GHG emissions. Agriculture contributes most of U.S. N_2O emissions.
- **Reducing Nitrous oxide** is a key potential benefit of improved agricultural management.
- **Methane** (CH_4) is second largest agricultural GHG. Animal agriculture is a dominant source of CH_4 emissions in the U.S.

Data: 2018 U.S. EPA inventory

Conventional vs. Regenerative Agriculture

Historic Midwest U.S. Ecosystems

Restored Wetland
Dixon Waterfowl Refuge, Illinois

Restored Prairie
Dixon Refuge, Illinois

Images: The Wetlands Institute

Conventional Agricultural Practices

Bare fallow and tillage

Tile drainage

Images: Mark David

Conventional Agriculture and Nutrient Pollution

Eutrophication and toxic algal blooms

Hypoxia: Gulf Coast Dead Zone
Average size: 5,408 square miles

Images: NASA

Conventional Agriculture and Soil Erosion

Natural Soil Erosion

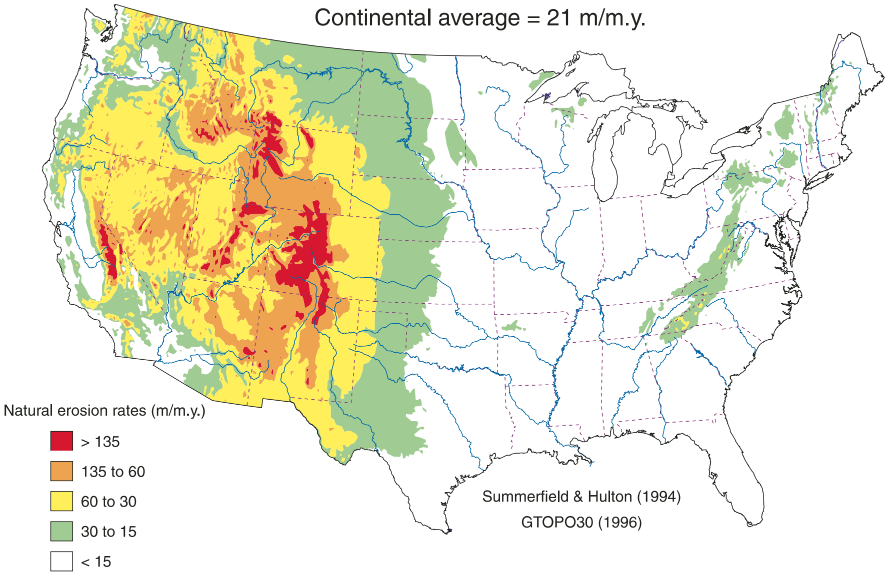


Figure 6. Estimates of average natural erosion (denudation) rates inferred from GTOPO30 area-elevation data and global fluvial erosion-elevations relations from Summerfield and Hulton (1994). Mean rate of denudation for the entire area of the contiguous United States is ~21 m/m.y.

Cropland soil erosion

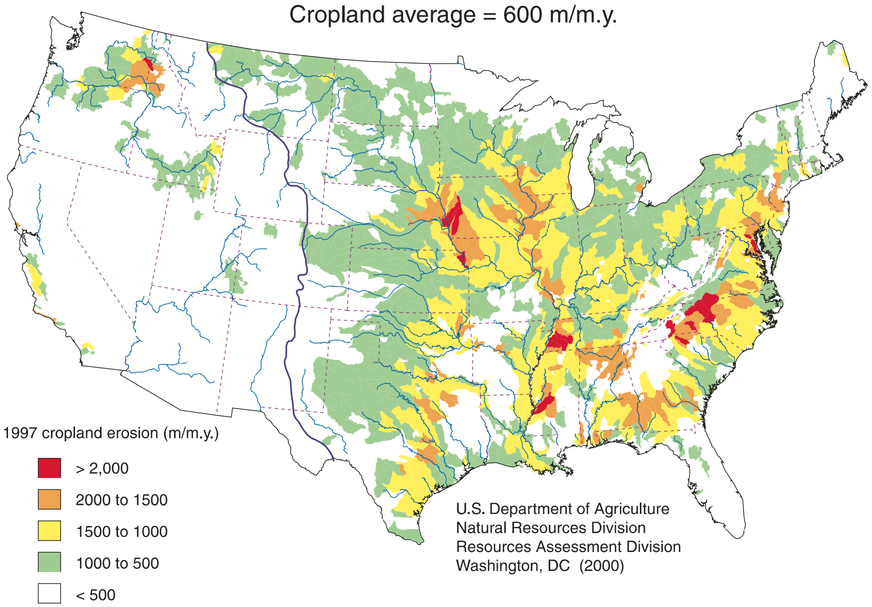


Figure 8. Rates of cropland erosion derived from estimates by the Natural Resources Conservation Service using the Universal Soil Loss Equation, and scaled to a farmland average of 600 m/m.y. The solid blue line is the western edge of the North American craton, here defined as the margin of the Great Plains physiographic province. Areas of arable land are largely confined to cratonic regions under 1 km in elevation.

Wilkinson and McElroy. 2007.
Geol. Soc. Am. Bull.. 119(1/2):140-156

Implementing Regenerative Practices

Cover bare soils with plants

- Increase system productivity
- Increase soil organic matter (SOM) from increased plant residues
- Active root zone retains nutrients, increases infiltration, reduces erosion and improves soil physical structure

Diversified rotations to cover bare soils

- Cover crops (retain nutrients)
- Legume crops (nitrogen fixation)
- Perennial rotations (deeper, denser roots)

No-till to reduce runoff and erosion

Images: Laurie Drinkwater

Regenerative Agriculture: No-Till and Soil Health

Reduce soil erosion; improve soil structure, water infiltration and water retention

No-till planting

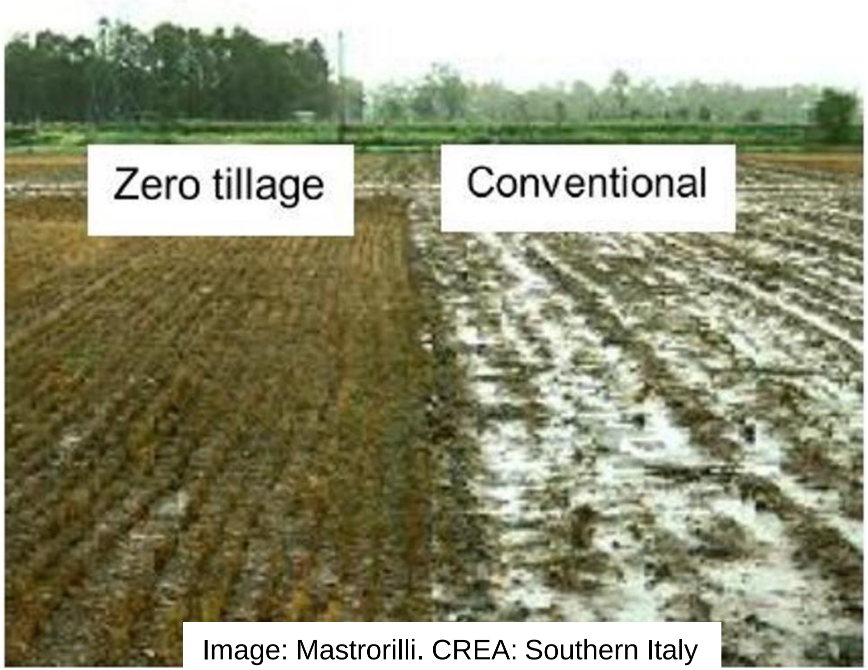
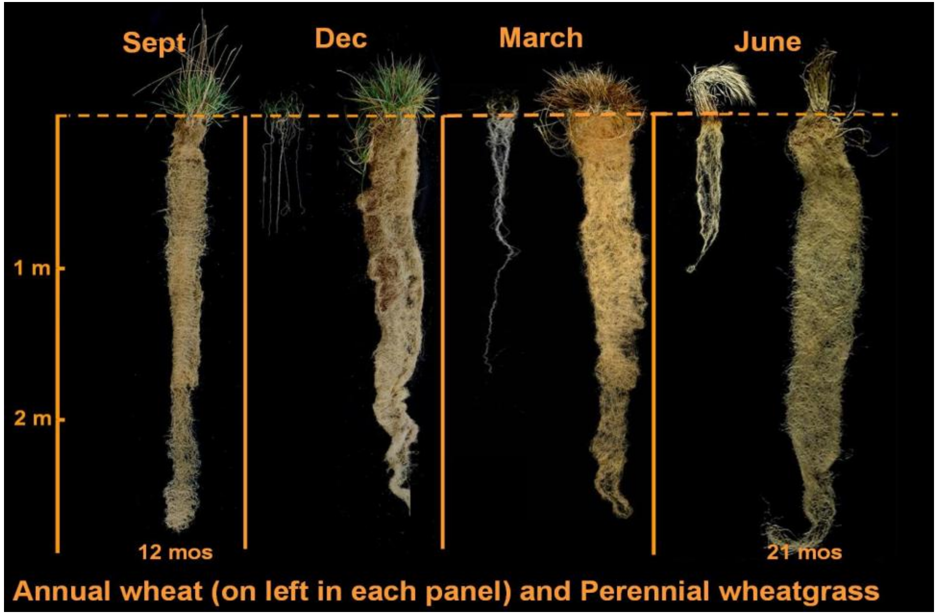


Image: Mastrorilli. CREA: Southern Italy

Regenerative Agriculture: Perennial Systems

Continuous plant cover; reduce soil erosion; improve soil structure, water infiltration, soil moisture, and nutrient use efficiency

Perennial grasses
Image: Jennifer Blesh



Perennial grains
Image: Jerry Glover

Agriculture and GHG Mitigation: Scale of Offsets

FAST-GHG: Greenhouse Gas Accounting Tool

U.S. commodity crops:

- corn, soybean, wheat

Management practices:

- Cover crops
- No-till, reduced tillage
- Nitrogen management

Time scale:

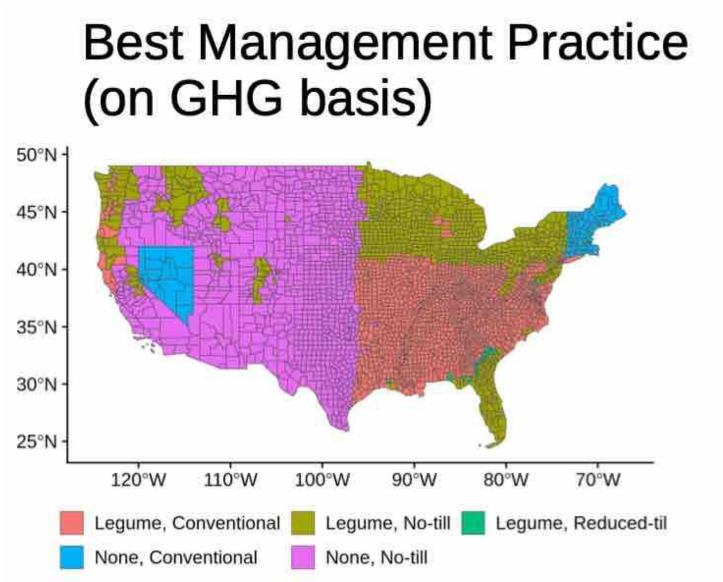
- 100-year accounting framework

Accounts for:

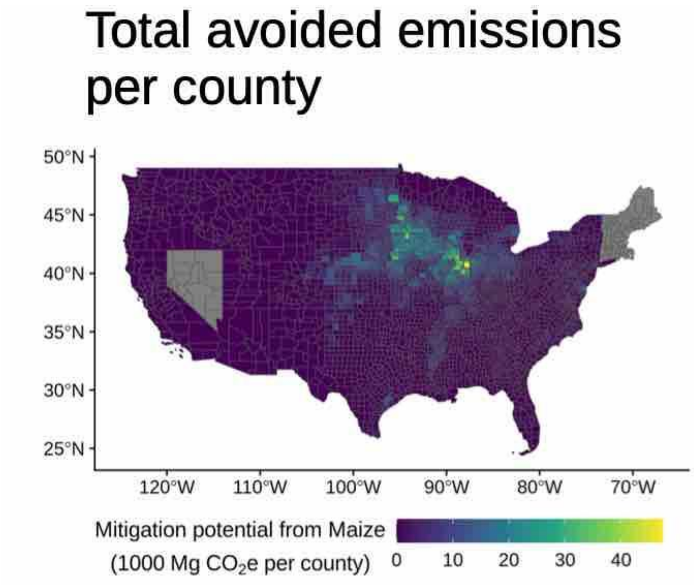
- Change in nitrous oxide (N_2O) emissions, carbon dioxide (CO_2) emissions, and soil organic carbon (SOC) sequestration
- Leakage
- Permanence

GHG Mitigation Potential for Corn

Corn soil health BMPs



Total avoided net GHG per county



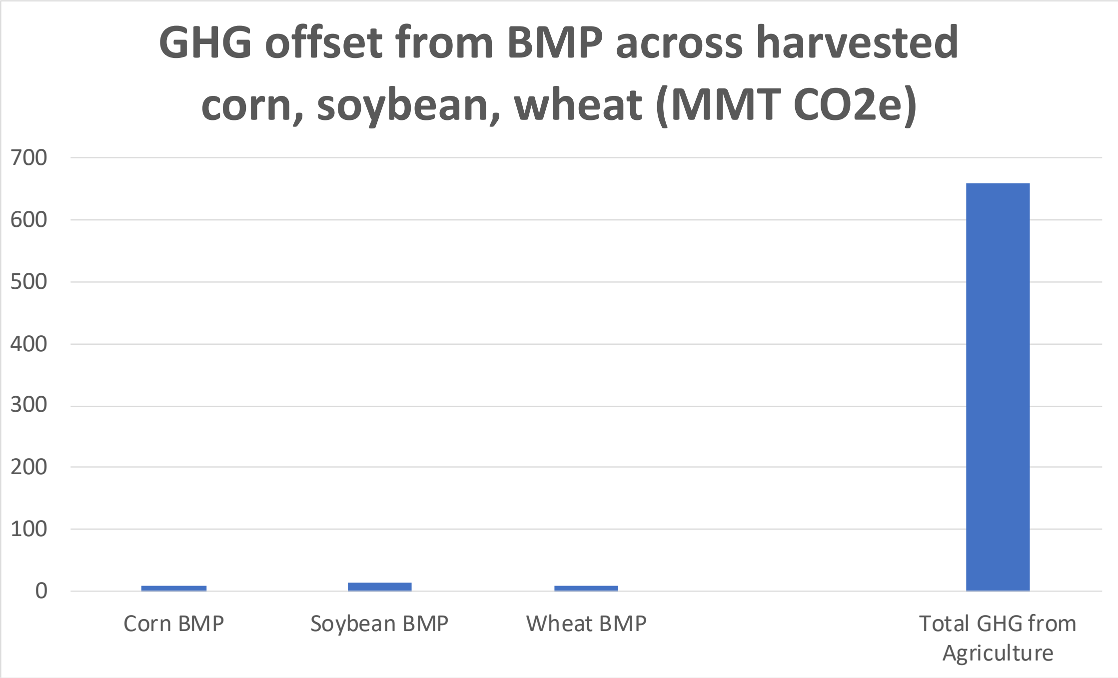
FAST-GHG tool estimates corn best management practices (BMPs) avoid a total of 8.3 Million Metric Tons (MMT) CO_2e

FAST-GHG (Woolf, Woodbury, Tonitto 2020)

Regenerative Agriculture and GHG Mitigation

Annual reduction of net GHG from improved management of commodity crops in 2018:

- 5-10% reduction of national agricultural emissions.
- <1% of total national emissions.
- Reduction results from regenerative agricultural practices and improved nitrogen management.



Policy Considerations

Regenerative Agriculture and GHG Mitigation

The main benefit is to maintain the soil resource and improve water quality:

- Add soil organic carbon.
- Retain nutrients.
- Reduce soil erosion.
- Improve soil structure and water management.

A smaller co-benefit is to mitigate GHG emissions:

Non-reversible GHG benefits from reducing excess nitrogen inputs.

- Reduced nitrous oxide (N_2O) emissions.
- Reduced carbon dioxide (CO_2) and N_2O emissions from nitrogen fertilizer production.

Reversible GHG benefit from **increased soil organic carbon** accumulation.

Regenerative Agriculture and GHG Mitigation Accounting

Permanence: We must account for the reversibility of soil organic carbon.

- Soil organic carbon accumulation saturates after 20-30 years of regenerative management.
- Regenerative agricultural practices must be continued indefinitely to retain this accumulated soil carbon, otherwise it can be lost.
- Cost of long-term commitment to improved practice.

Regenerative Agriculture and GHG Mitigation Accounting

Risk of reversal in practice to quantify soil organic carbon benefits

- Policy should factor in reversibility.
- Reversible benefits (increased soil organic carbon) are riskier than non-reversible benefits (reduced nitrous oxide or carbon dioxide emissions).
- Long time scales, such as 100-years, are important because climate change is a long term process.

Regenerative Agriculture and GHG Mitigation Accounting

Leakage: Net GHG emissions resulting from a change in yield must be accounted for.

- Yield change has large impact on net GHG emissions.
- Leakage quantification:
  - Yield change due to management
  - Extensification vs. Intensification
  - Carbon cost of converting natural lands to agricultural production
  - Carbon benefit if land removed from production
- Policy assessment must account for leakage.

Managing Landscapes to Increase Carbon Storage

Reduced demand for current commodity crops

Perennial systems

- Improved perennial forage and managed grazing
- In the future, possibly perennial grains
- 2nd generation biofuels and bioenergy

Dietary changes

- Reduced animal product consumption
- ‘Manufactured proteins’

Increased demand for non-crop ecosystem services from landscapes

- Water quality
- Flood mitigation
- Wildlife habitat and recreation

Motivating Improved Agricultural Management

Payments for Ecosystem Services (PES):

Payment for practice – *Challenging to quantify benefits*

- Estimate benefits based on long-term research studies
- Estimate benefit averaged over many farms
- Proven feasible for implementation

Payment for outcomes – *Challenging to verify benefits*

- On-farm monitoring can cost more than the payment amount.
- Modeling requires trained experts and sufficient on-farm data.

Reversibility and leakage affect both practice or outcomes based PES.

Summary

Net GHG emissions reduction

- Focus on reducing fossil fuel use across all sectors.

Regenerative agricultural practices

- Maintaining the soil resource and improving water quality are the main benefits.
- GHG mitigation is a co-benefit.

Agricultural GHG emissions assessment

- Include leakage and permanence.
- Nitrous oxide and methane are the main GHGs.
- Focus on permanent rather than reversible reductions in GHG emissions.

Carbon-rich landscapes

- Farmer access to improved practice
- Shift in crop demand
- Accounting for ecosystem benefits (regulatory & market approaches)

www.nas.edu/gridmod

Georgia Tech Center for Distributed Energy

Reducing Emissions from the Electricity Grid

EESI Congressional Camp #2

Prof Deepak Divan, Center for Distributed Energy, Georgia Tech

Feb 26, 2021

GT Center for Distributed Energy

cde.gatech.edu

Georgia Tech | Center for Distributed Energy

Creating holistic solutions in electrical energy that can be rapidly adopted and scaled

WORLD ECONOMIC FORUM
TOP 3 TRANSMISSION GRID INNOVATIONS 2010-2020
"Accelerating the Energy Transition"

Platform Initiatives

7.2 kV 50 kVA Hybrid Transformer | 13 kV 1 MVA Modular Transformer | Smart Wires

Grid Asset Augmentation

13 kV/50 kVA FUT
13 kV 1 MW Power Router
67 MVA Modular LPT
Improving Grid Resiliency
Smart Wires
Meshed Grid VVC

Energy Access in Emerging Markets

'Exponential' Tech
Self Organizing Nano Grid
Pay-Go Smart Meter
Low Cost DA for Grids
Ad-Hoc Bottom-Up Grids
Empower a Billion Lives

Emerging Technology: D-Light | Top 10 Emerging Markets *Source: Global Intelligence Alliance*

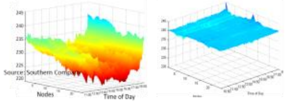
4 kV MVSI for Large PV Farms | 7.2 kV 50 kVA SST

Next Generation Grid Power Electronics

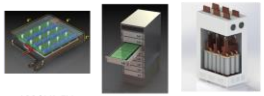
5 kV DC Grid Building Block
7.2 kV 50 kVA Grid Connected SST
4 kV MVSI for Large PV Farms
Triports for PV/Storage/Grid
MVSI with Integrated Storage
Microgrid-Grid Interface Device

Decentralized Grid Control Techniques & Markets

Grid Edge Volt VAR Control
Collaborative Control
High PV Integration
DER Micro grid Impact
Self-Pricing Island Grids
Virtual Power Plants



Feeder Voltage w/o and with GE Control | Feeder Voltage w/ Grid Edge Control



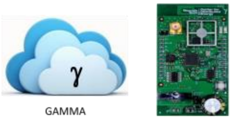
100 kVA EV Drive System | 200 kVA Isolated Drives | 2 MVA Industrial SIVOM

Next Generation Industrial Power Electronics

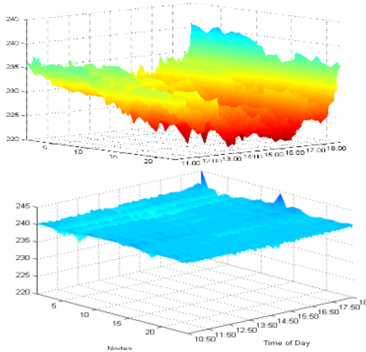
Industrial CVR Energy Efficiency
100 kVA EV Drive System
25-500 kVA Isolated Drives
Energy Hub – DC Fast Charging
Programmable Load/Source
Data Center Power Sources

Global Asset Monitoring Management & Analytics (GAMMA)

Low-Cost Communications
Cyber-Security
Data Management
AMI Data Analytics
Global Sensor Networks
Cloud Based GAMMA System

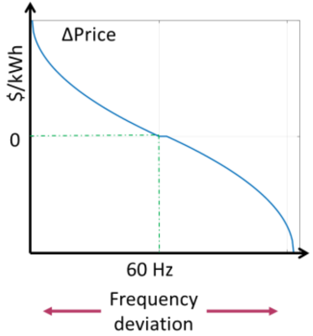


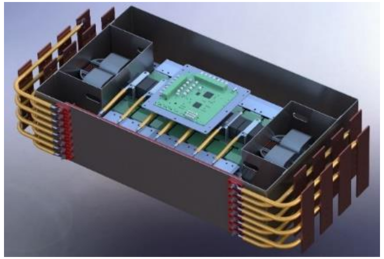
GAMMA Platform | Gamma kernel



COLLABORATIVE CONTROL
Varentec

TRANSMISSION POWER FLOW CONTROL
Smart Wires





SELF-PRICING MICROGRIDS
Transactive/Physical Grid

SOLID STATE TRANSFORMER (S4T)

<u>Exponential Technologies</u> (outside utility influence)

Computation, PV solar, wind, EV, power semis, storage, microcontrollers, prosumers, sensors, IoT, comms, online services, social media, mobile pay, block-chain, cloud, autonomous control, AI, ML, deep learning

<u>Primary Drivers</u>

Digitalization
Decentralization
Decarbonization

Reducing Grid Related Emissions

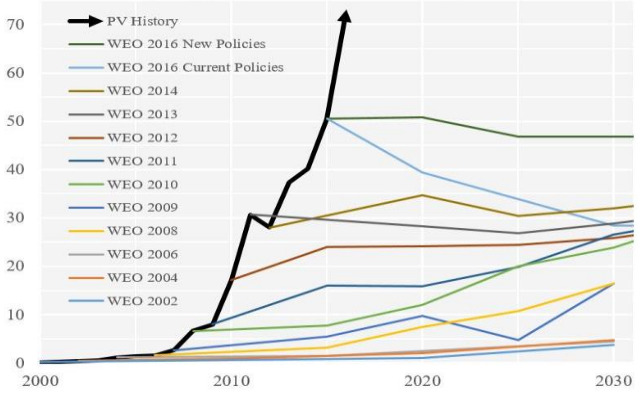
- **Opportunity:** Electricity generation (coal, gas) accounts for 26.9% of US emissions, transportation 55.1% , buildings and industry 35% - key drivers for new solutions are lower cost and emissions
- **Zero Carbon Resources:** Hydro, nuclear, wind and PV – future technologies include clean fuels (e.g. hydrogen) and SMR
- **Resource Adequacy:** YES (100 mi x 100 mi PV farm in Arizona could, in principle, meet US annual energy needs)
- **Challenge:** coordinating time and location of generation and consumption (over milliseconds to seasons all over the grid)
- **Attributes:** dispatchability, fast-ramping, spinning reserve
- **Enablers:** long/medium duration energy storage; AC & DC transmission; power electronics; ICT and cyber; ultra-automation; microgrids; carbon capture & sequestration
- **Approach:** Centralized generation AND distributed generation (microgrids) together meet reliability, resiliency and cost goals
- **New Paradigm (?):** reliability & resiliency from the grid edge; affordability & sustainability from bulk PV/wind/hydro/other

Centralized, Passive & Rigid → Grid Transformation → **Decentralized, Dynamic & Resilient**

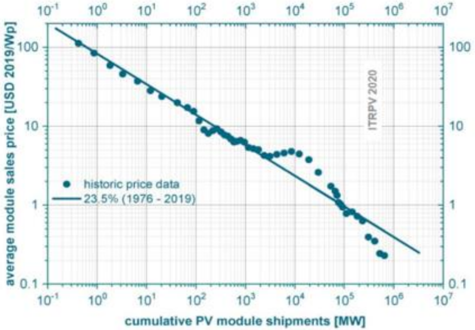
In 2000, IEA forecast for 2030 → RE 4.4% of total
In 2014, RE was 27.7% of total, 58.5% of new build

It is difficult to make forecasts, especially about the future – old Danish proverb

In GW of added capacity per year - sources World Energy Outlook and PVMA



Learning curve for module price as a function of cumulative shipments



2019: PV + 4 hours storage: $32/MWHr

Fast Growing Sectors are Transforming the Grid

Georgia Tech | Center for Distributed Energy

PV and Wind Farms

- PV and wind represent fast global growth – **(120+160) GW/yr**
- With storage, shows much lower LCOE and better dispatchability
- Needs transmission to connect load centers with generation


Energy Storage

- Fast growth for modular battery energy storage – **1100 GW by 2030**
- Hydro to pumped hydro conversion and CAES offer central storage
- Clean fuels – hydrogen, ammonia offer long duration energy storage


DC Fast Charging (DCFC)

- 125 million EVs by 2040,buses, trucks, semis – all going electric
- DCFC at 100 kW to 1 MW will stress the grid (peak load 1000 GW)
- Significant coordination with grid edge resources will be needed

Community Resiliency Microgrids

- Hurricanes, wildfires & ice-storms show need for grid edge resiliency
- High cost, complex integration with grid operations, poor scaling
- Will reshape the design of the future grid, technology/cost challenges

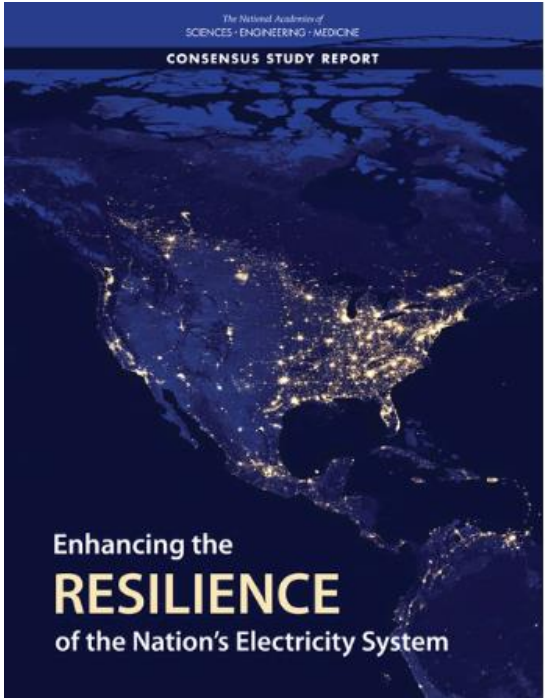

Intersection of forward-leaning incentives and 'exponential' technologies hold the key to this transformation

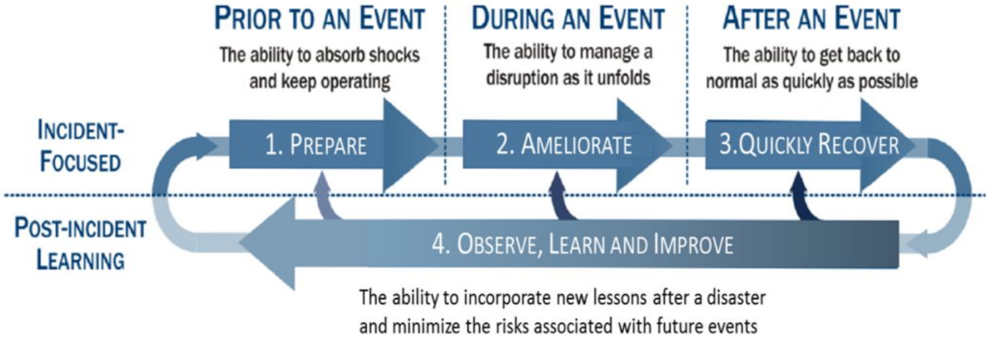
Recent NASEM Reports - Resilience

Georgia Tech | Center for Distributed Energy

Recent Events in Texas Again Emphasize Need for Resilience

2019





Recommendation: The Department of Energy and Department of Homeland Security <u>should jointly establish and support a "visioning" process</u> with the objective of systematically imagining and assessing plausible large-area, long-duration grid disruptions [...]

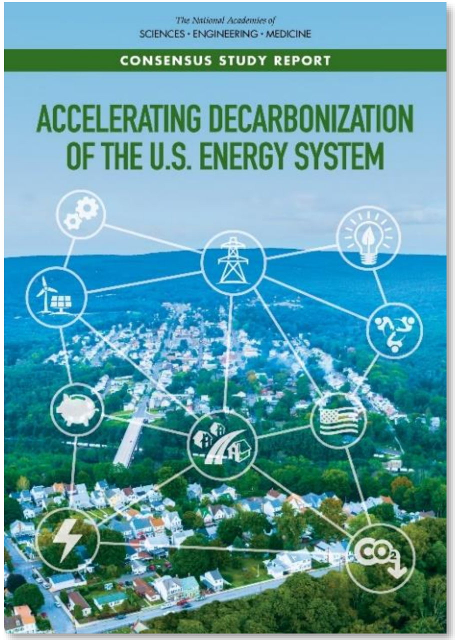
Recommendation to the electric power sector and DOE: The owners and operators of electricity infrastructure should work closely with DOE in <u>systematically reviewing previous outages and demonstrating technologies, operational arrangements, and exercises that increase the resilience of the grid</u>

Recent NASEM Reports - Decarbonization

Georgia Tech | Center for Distributed Energy

Committee asked to produce two reports that evaluate the status of technologies, policies, and societal factors needed for decarbonization and recommend research and policy needs.

This first report focuses on federal actions over the **next ten years** to put the U.S. on a **fair and equitable path to net-zero in 2050**.



nap.edu/decarbonization
2021

- Set **energy standard for electricity generation** to reach 75% clean electricity by 2030 and net-zero emissions by 2050.
- Enact congressional actions to **advance clean electricity markets**, and to improve their regulation, design, and functioning.
- Set national **zero-emissions vehicle standards** and **manufacturing standards** for zero-emissions appliances.
- Facilitate **new transmission infrastructure** by amending Federal Power Act and Energy Policy Act.
- Triple federal **investment in clean energy RD&D,** including funds for social science research.

Plan, permit, and build critical infrastructure

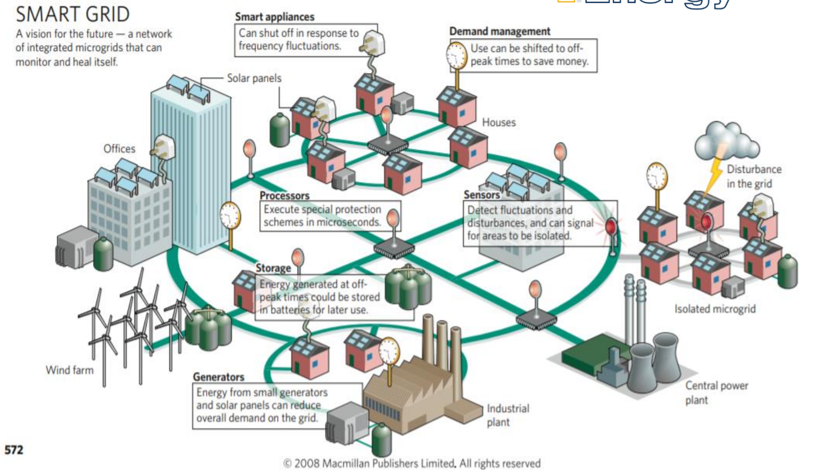
Produce carbon-free electricity

Electrify energy services in transportation, buildings, and industry

The Future of Electric Power in the US*...new NASEM report*

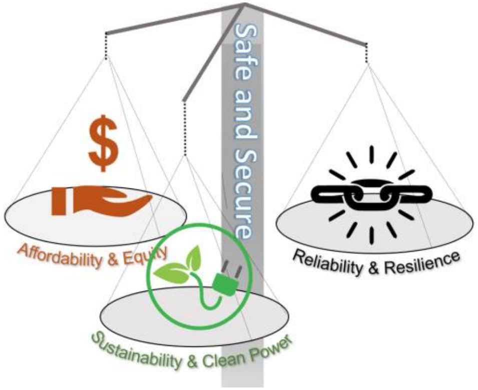
nas.edu/gridmod
2021

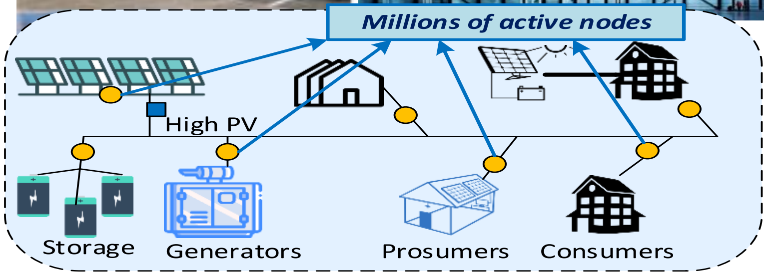
Increasing automation and decentralization



The system is on the cusp of fundamental transformation, many elements of which are not under industry control.

We can identify drivers of future change, but how they will manifest is uncertain – and it will be different in different parts of the country





Grid of the future

The Future of Electric Power in the US – *NASEM Report*

Georgia Tech | Center for Distributed Energy

Paraphrased Recommendation 5.1: To meet the challenge of dramatically lowering U.S. CO_2 emissions, there is a need to develop: generation technologies with zero direct CO_2 emissions; low-carbon technologies with high dispatchability and fast ramping capabilities; storage systems for multi-hour, multiday and seasonal time-shifting; power electronics to enable real-time control of the grid.

Paraphrased Recommendation 5.2: Developments in rapidly growing technologies, such as PV, wind, EV, and energy storage, suggest a new paradigm may be rapidly emerging which is more modular, distributed and edge-intelligent, and which may be able to compete with and outperform the existing grid paradigm in terms of sustainability, reliability, resilience, and affordability. …….

Additional findings and recommendations:

- Decarbonize the U.S. economy, <u>both</u> by transitioning power generation to low or zero-emission sources and by making greater use of decarbonized electricity as a substitute for fossil fuels in transportation, buildings and industry.
- <u>Grid stability challenges</u> arising from high penetration of non-dispatchable sources of generation, such as wind and solar, need to be addressed.
- Addressing nearly all of the fundamental challenges for the grid of the future—from the integration of renewables to deep decarbonization—<u>requires innovation</u>
- The country's investment in innovation is far below what is needed to match the scale of the challenge and what's feasible - <u>At least double public expenditure on innovation, from states and mainly federal government</u>

NASEM Grid Report – Key Technology Recommendations

Clean Generation and Commercialization

- Develop generation, storage, and distributed energy technologies with no emissions.
- Government and Industry collaborate to develop, fund and de-risk new and critical technologies essential to the future grid.
- Report also recommends tripling federal investment in RD&D

Communication, Automation, and Simulation

- Develop *secure and reliable* ICT technologies to support millions of grid connected devices.
- Develop technologies to enable a high-level of automation in a flexible & resilient system.
- Develop advanced *inter-compatible* simulation tools to analyze evolving grid architectures.
- Explore the use of large field experiments for new grid architectures

Develop Workforce of the Future

- Fund training and retraining of the current and future workforce.

Conclusions

Georgia Tech Center for Distributed Energy

- Achieving low-emissions has always been seen as a trade-off, with higher cost and poor reliability – resulting in the disruption of the electricity system that has been at the heart of human progress
- The last 20 years has seen unprecedented and rapid change in the energy industry – at a time when climate change (and related grid resiliency) has also become a pressing concern
- 'Exponential' technologies with rapidly decreasing prices, driven by forward-leaning incentives and policies, have transformed the energy landscape – with renewables at grid parity in many places
- There is an opportunity to transform the system to a low-carbon system, that is also reliable, resilient and affordable – requires fundamental rethinking, innovation, policies & investments

Thanks to NASEM staff and the committee that authored 'The Future of Electric Power in the US' NASEM report


U.S. GREEN BUILDING COUNCIL
USGBC
WORLD
THE CLIMATE IS CHANGING, WHY AREN'T WE?
EARTH
MATH

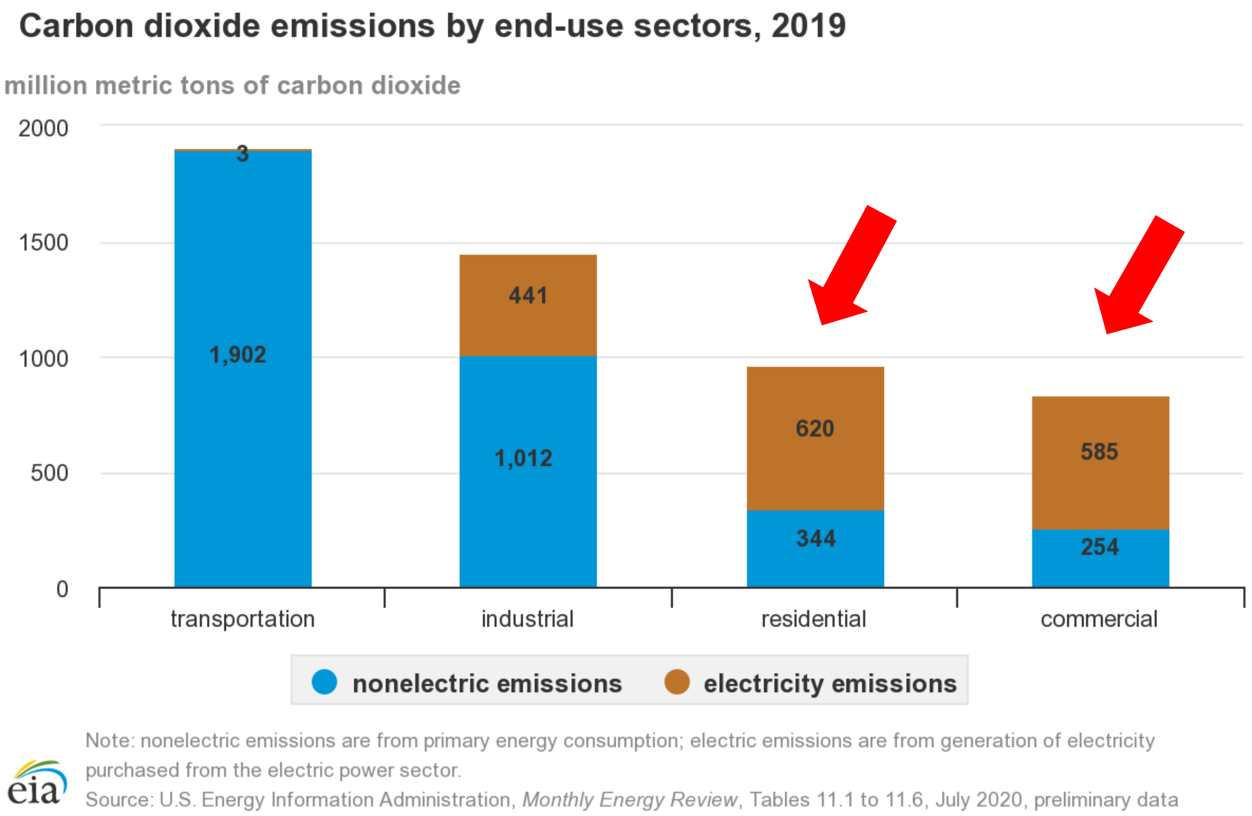
Buildings Sector

EESI February 26, 2021

Buildings Contribution to GHG Emissions

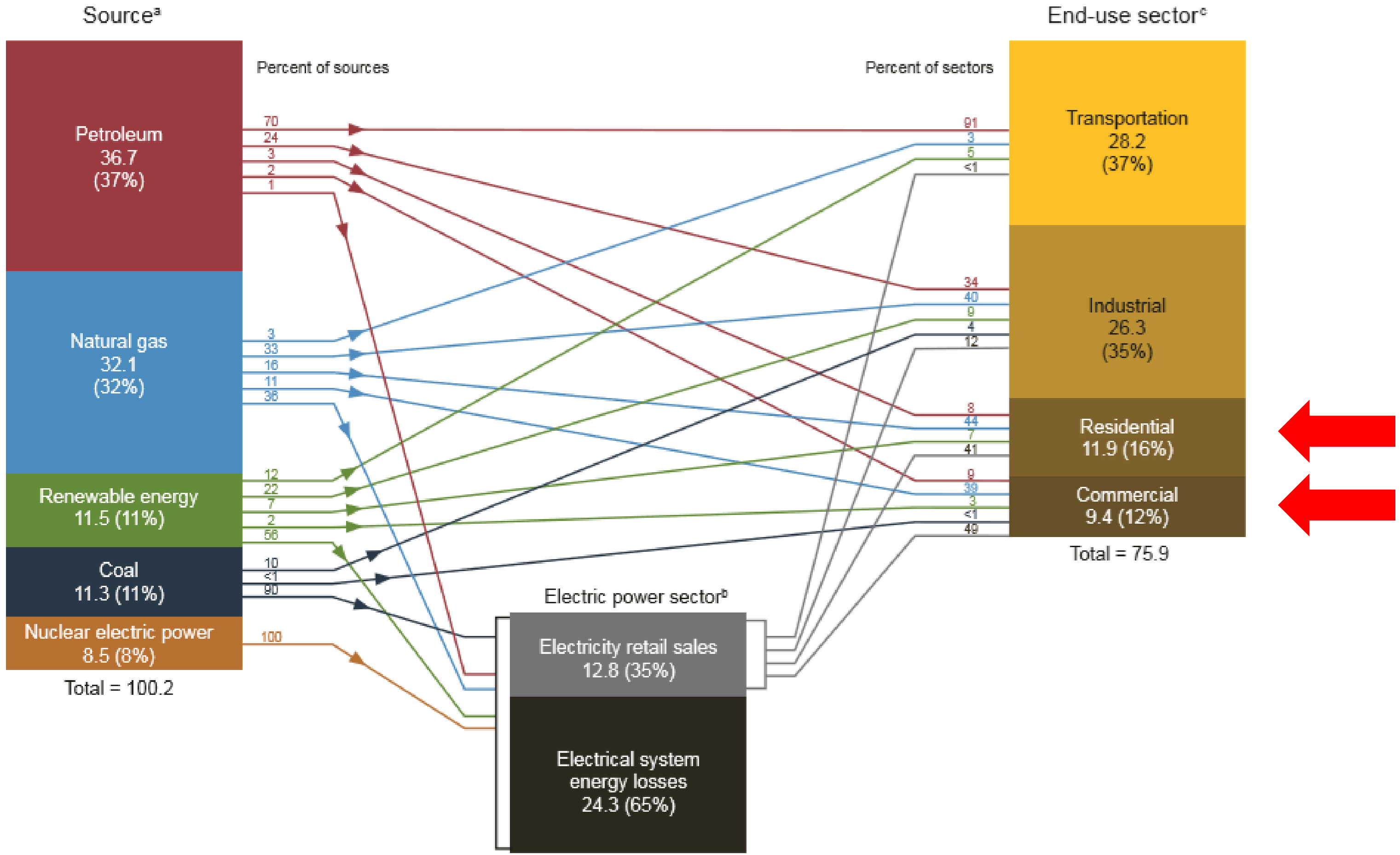
- Significant: 12% direct combustion, 38% including power use
- Drivers include building age, code/efficiency, size
- Buildings have carbon impact beyond energy: waste, water, transportation, materials
- Both Construction phase + Operations phase matter

Buildings as End Use Sector



U.S. energy consumption by source and sector, 2019

(Quadrillion Btu)



Where is the energy demand?

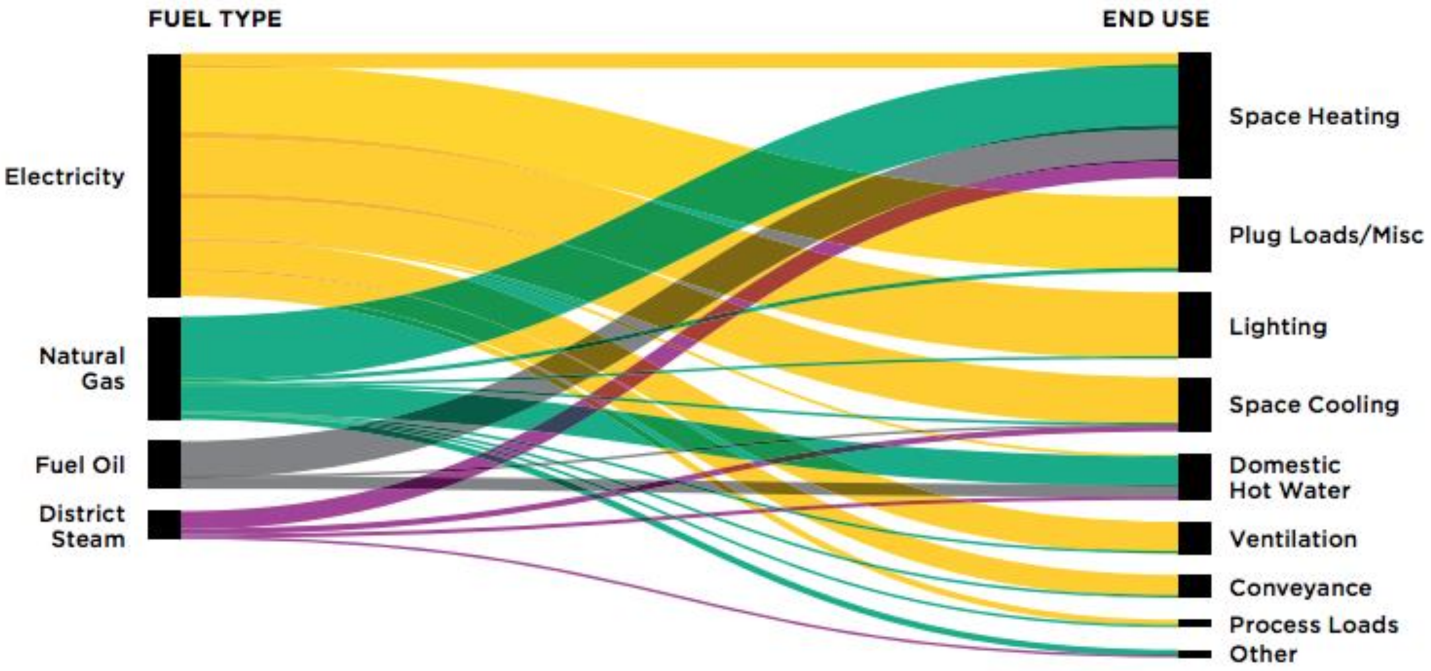
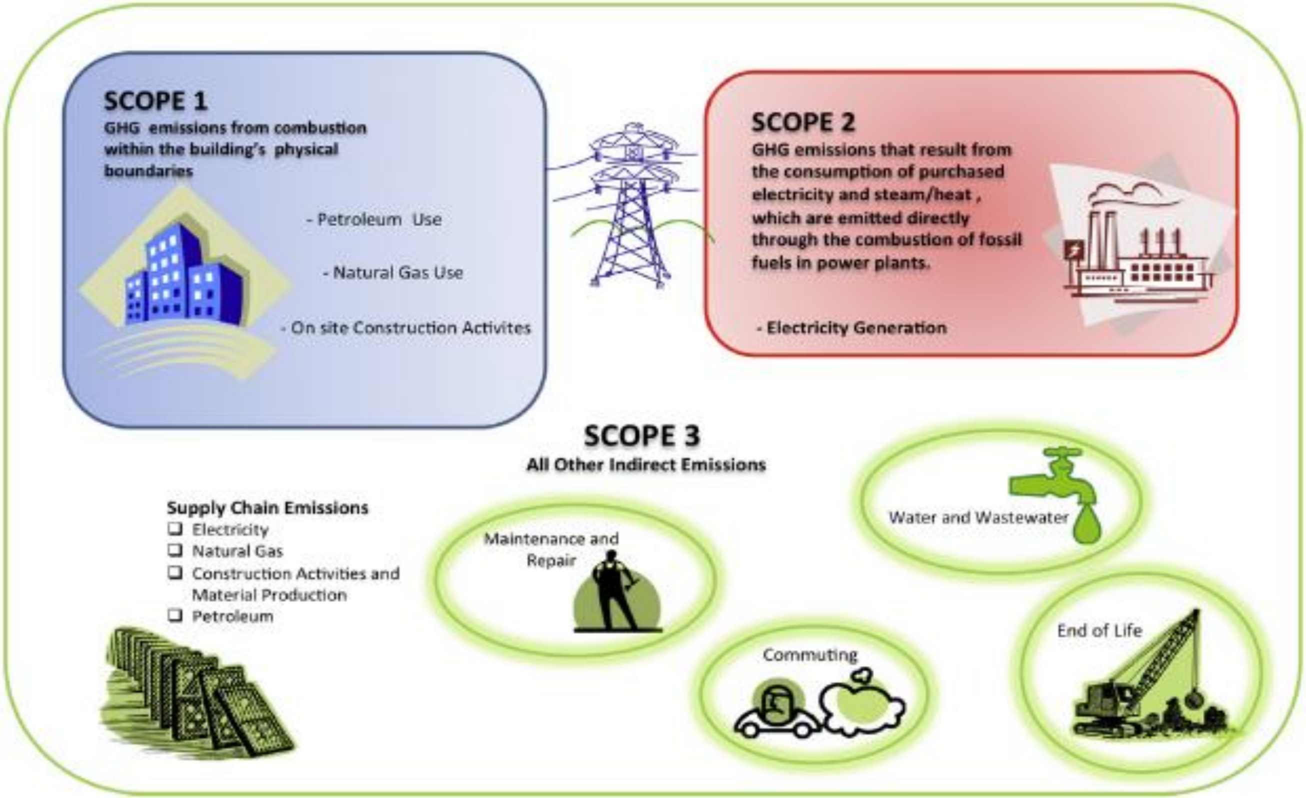


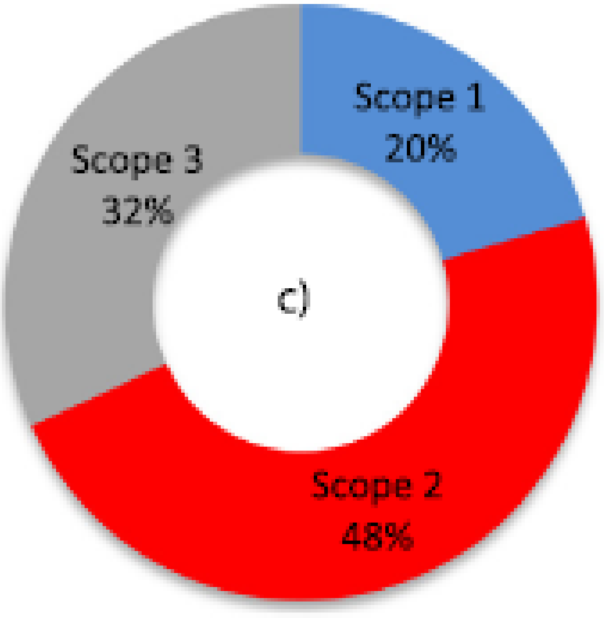
Figure 4: Flow of Fuel Types to End Use (LL84 and LL87 data) [14]

Electricity represents more than half of the audited source energy, while space heating, fueled mainly by natural gas, represents the largest end use. (Urban Green Council)

As grids get cleaner, scope 3 emissions become more significant



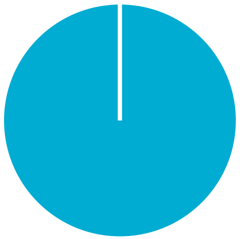
Building Life Cycle Carbon Footprint



Source: Onat et al, Scope-based carbon footprint analysis of U.S. residential and commercial buildings (2013).

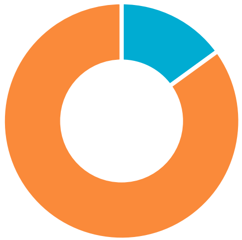
Building Carbon footprint from construction to end of life

Day 1



Year 100

10-15%*



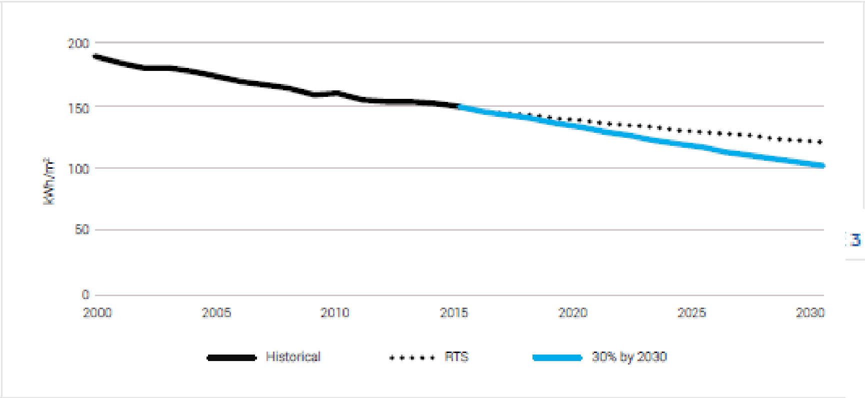
More Efficient Building

■ Materials...

* B. Lippke et al "Life-Cycle Environmental Performance of Renewable Building Materials" June 2004 Journal of Forest Products

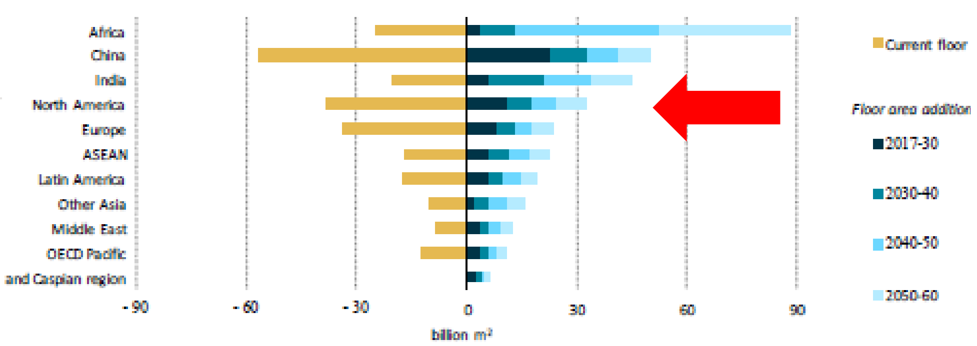
Buildings are more efficient, but footprint is growing

FIGURE 1 Global final energy use per square meter



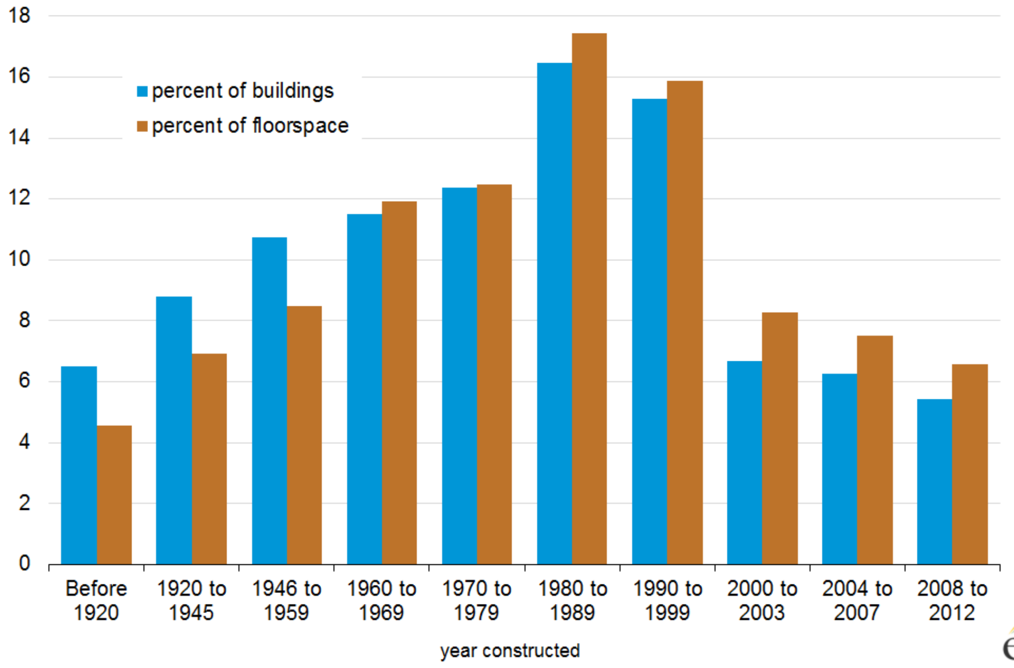
Notes: EJ = exajoules; kWh/m2 = kilowatt-hours per square metre; RTS = Reference Technology Scenario.
Source: IEA (2017), Energy Technology Perspectives 2017, IEA/OECD, Paris www.iea.org/etp/.

3 Floor area additions to 2060 by key regions



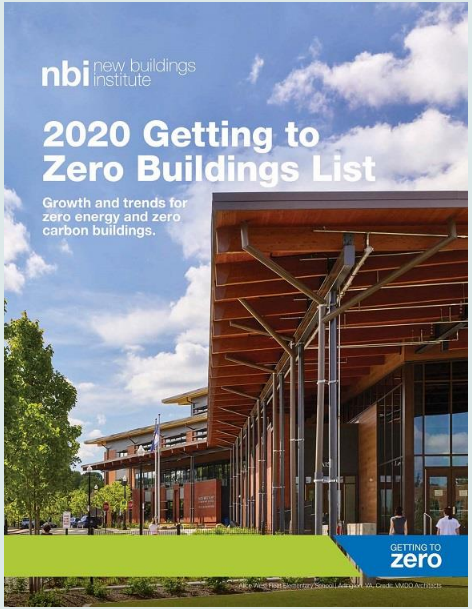
) Pacific includes Australia, New Zealand, Japan and Korea; ASEAN = Association of Southeast Asian Nations.
(2017), Energy Technology Perspectives 2017, IEA/OECD, Paris, www.iea.org/etp

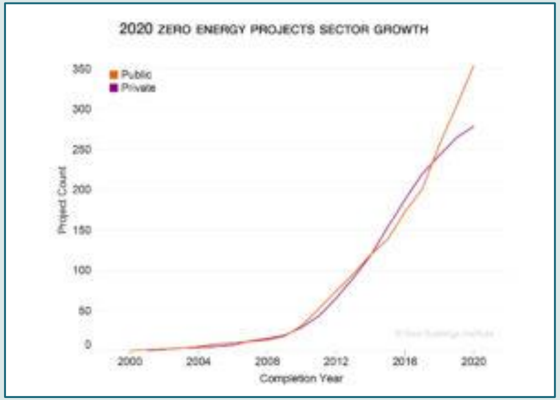
Buildings aren’t getting younger

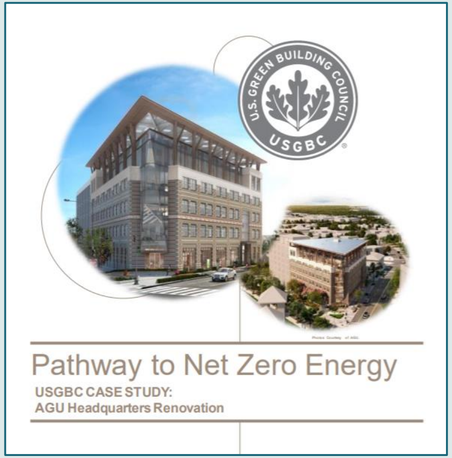


- About half of buildings in 2012 were built before 1980
- Pre-1980/1990 buildings less impacted by energy codes
- Poor insulation, envelopes, inefficient systems

The good news: We can do better







Existing buildings achieving LEED O+M contributed:

- 50% less GHGs from water use
- 48% less GHGs from solid waste
- 5% less GHGs from transportation

Source: UC Berkeley-California Air Resources Board

Policy Approaches to Decarbonizing Buildings

- New construction
- Retrofits
- Workforce
- RD&D, technology

Administration goal: retrofit 6 million buildings

Federal Buildings: Opportunity to Lead by Example

- Invest in cost-effective energy improvements, boost resilience & health
- Appropriations & funding including supplemental, stimulus
- Establish buildings goals and direction – e.g. *GREEN Building Jobs Act (116-S.5001)*
  - Energy and water efficiency, GHG intensity
  - Net Zero, deep retrofits, incorporate ZEV charging
- Leverage private sector finance – e.g., *Open Back Better (116-H.R. 7303/S. 4060)* using AFFECT program

Commercial Buildings (including public)

- Appropriations & funding including supplemental, stimulus
- Use DOE programs to advance on all fronts:
  - workforce, RD&D, deployment, energy codes, Better Buildings
- Tax incentives – e.g., *GREEN Act (H.R. 848)*
- Leverage private sector finance – e.g., *Open Back Better (H.R. 7303/S. 4060)* through State Energy Program
- Invest in public buildings improvement – e.g., *Energy Efficiency Conservation Block Grants* program
- State Energy Program – numerous activities, proposals

Schools

- Boost U.S. Dept. Education ability to support healthy, green, low-carbon schools
- Appropriations & funding including supplemental, stimulus – e.g., *Reopen & Rebuild America's Schools Act (H.R. 604/S. 96)*
- Energy Efficiency grants – e.g., *116-H.R. 2-Sec. 33222*
- Leverage private finance – e.g., *Open Back Better*
- Technical assistance on school facilities improvements through DOE, EPA, State Energy Offices, State Departments of Education

Residential Buildings

- Appropriations & funding including supplemental, stimulus – e.g., Housing is Infrastructure Act (in 116-H.R. 2)
- Use DOE programs to advance on all fronts:
  - workforce, RD&D, deployment, energy codes, Better Buildings
- Use HUD, USDA programs impacting housing – e.g., Energy Efficient Neighborhoods Act
  - Establish minimum code
  - Above-code incentive or requirement
- Weatherization Assistance Program (WAP)
- Workforce training – e.g., HOPE for HOMES
- Tax incentives – e.g., GREEN Act
- Rebates – e.g., HOMES Act

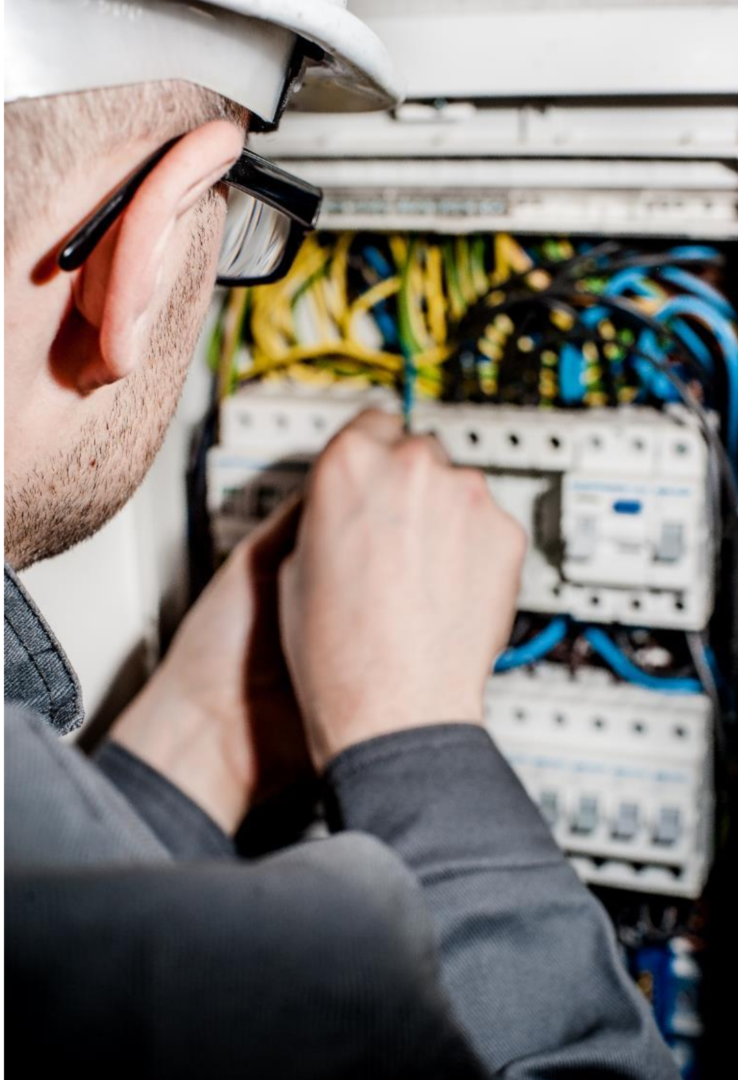
Specific technologies, approaches

- Beneficial electrification
- Heat pumps
- Solar water heating
- Thermal storage
- Battery storage with renewable energy generation
- LED lighting
- Integrating ZEV needs
- Reducing construction phase GHG impacts
- Reducing embodied carbon in materials
- Many more

RD&D

Example: Grid-Interactive Efficient Buildings

- Buildings that work with the grid
- Smart, connected technology
- Flexible demand, reduced peak
- Integration
- GridOptimal emerging standard



Buildings ARE Infrastructure

- Part of the system – with huge opportunities to improve resilience, health, and quality of life while reducing GHGs

Buildings Sector

Liz Beardsley

ebeardsley@usgbc.org

EESI February 26, 2021

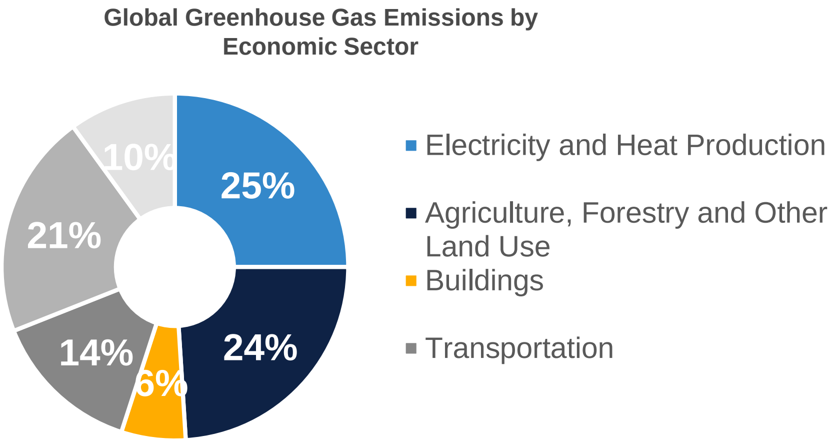
COLUMBIA | SIPA
Center on Global Energy Policy

Clean Industry for America: Options, Costs, and Policy Considerations

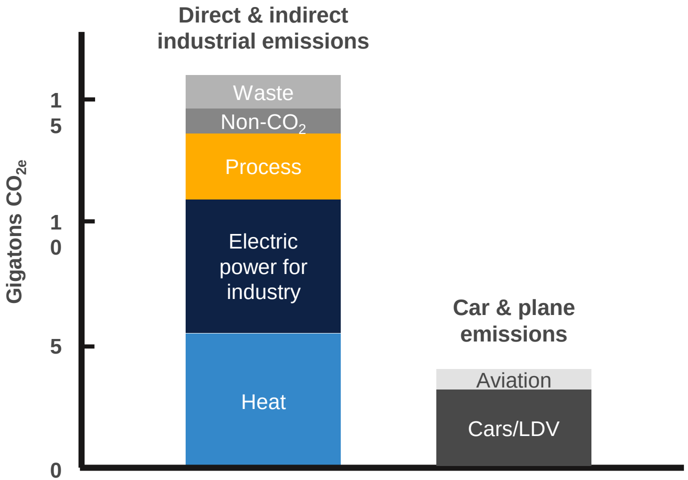
Dr. S. Julio Friedmann, Center on Global Energy Policy at Columbia Univ.
EESI “Climate Camp” Feb 27th, 2021

Industrial heat emissions: ~10% global emissions

Can't make key climate goals without solutions



EPA 2016



IPCC (2014); IEA (2017, 2019)

Industry emits more than transportation

Heat for industry emits more than cars & planes combined

The core arithmetic of net-zero is clarifying:

All sectors
All approaches

Only one way to stabilize climate: net-zero everywhere

- Any emissions anywhere add to atmospheric CO_2 concentration
- Every year of delay makes problem worse
- We haven't yet fielded solutions for about 50% of the portfolio

For net zero: CO_2emissions - CO_2removals = 0

- Any residual emissions must be balanced by removal
- Likely need 10 Gt/y CO_2 removal by 2050
- Any delay or failure requires more CO_2 removal

Carbon from the earth must be returned to the earth

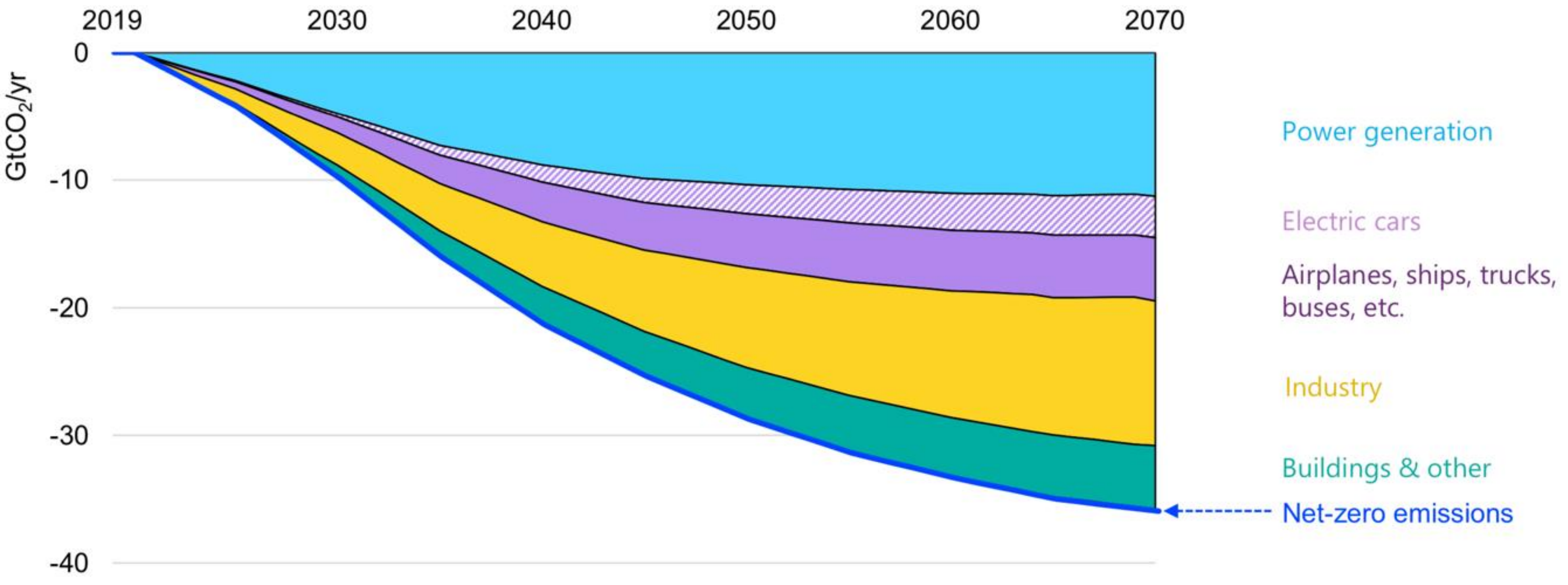
- Natural systems must return to balance
- Biosphere has limited capacity
- Risk of return is getting worse

CO_2 return to the geosphere anchors the net-zero global economy

Industry is huge and hard

Trade exposed, few technology options, expensive

Global CO_2 emissions reductions in the IEA Sustainable Development Scenario (2 °C) relative to baseline

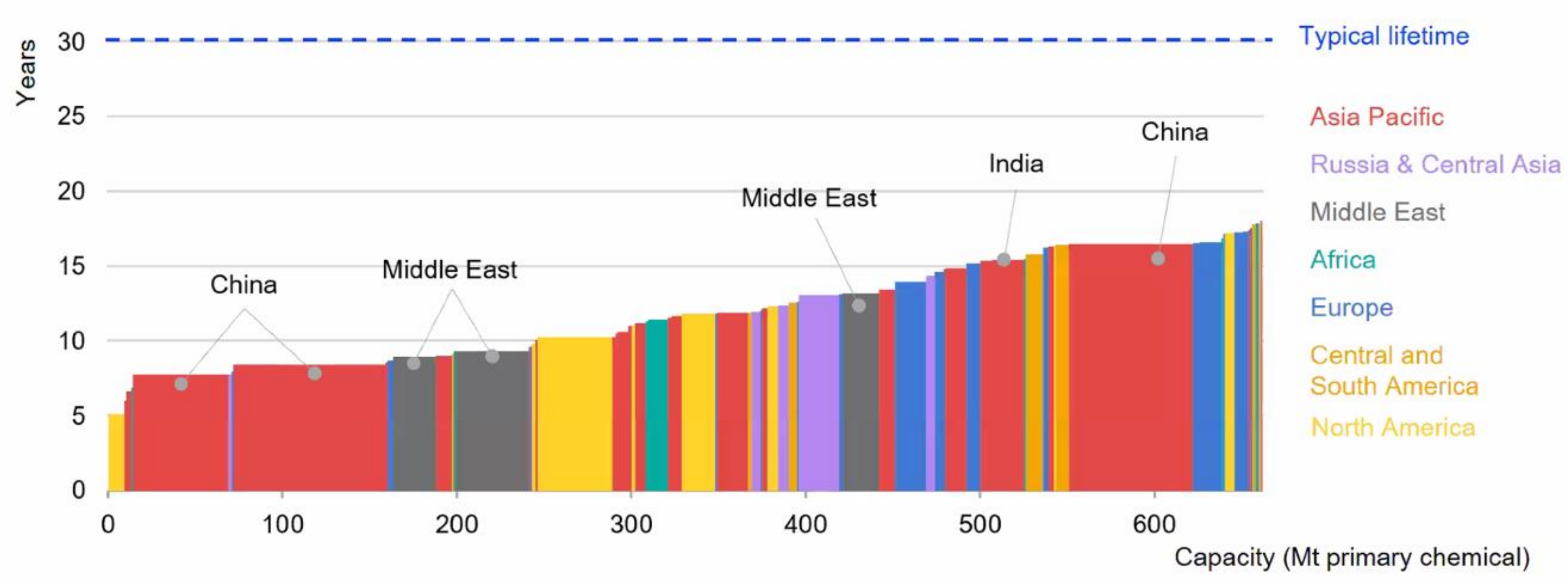


Source: IEA 2020

CCUS key benefits: saves time, saves money, reduces risk

Can decarbonize existing assets without waiting for retirement

Age profile of primary chemical production facilties

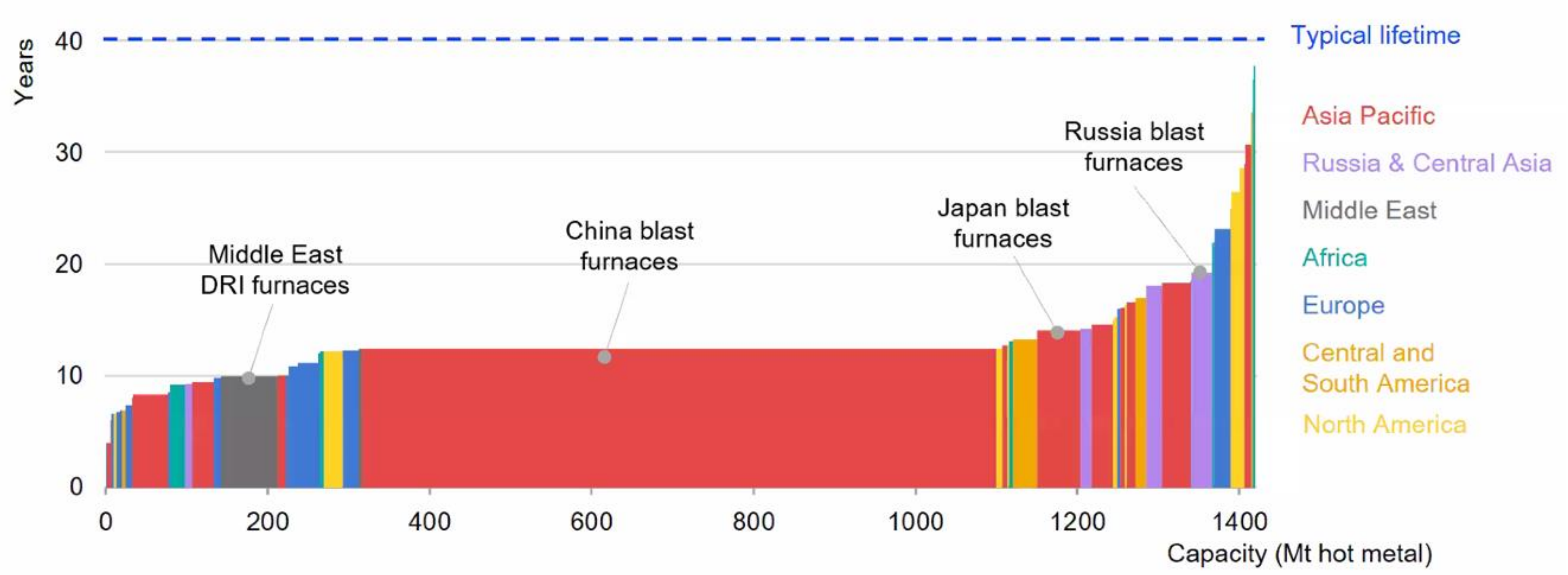


Source: IEA 2020

CCUS key benefits: saves time, saves money, reduces risk

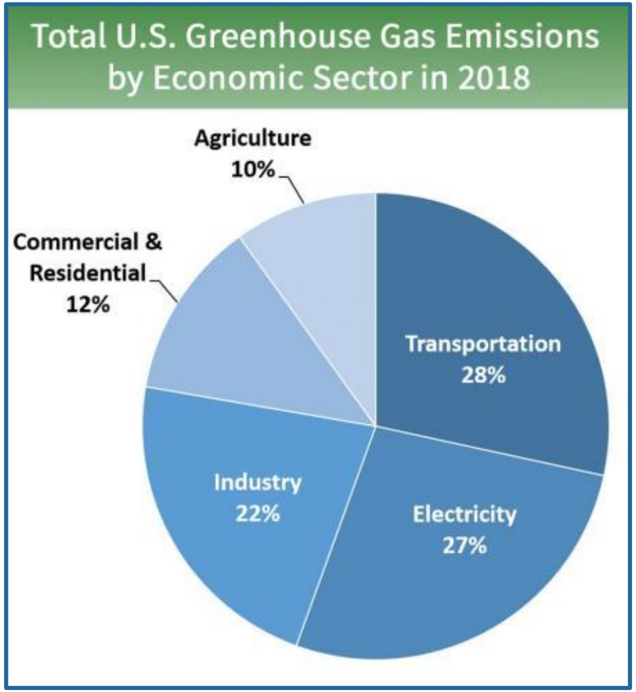
Can decarbonize existing assets without waiting for retirement

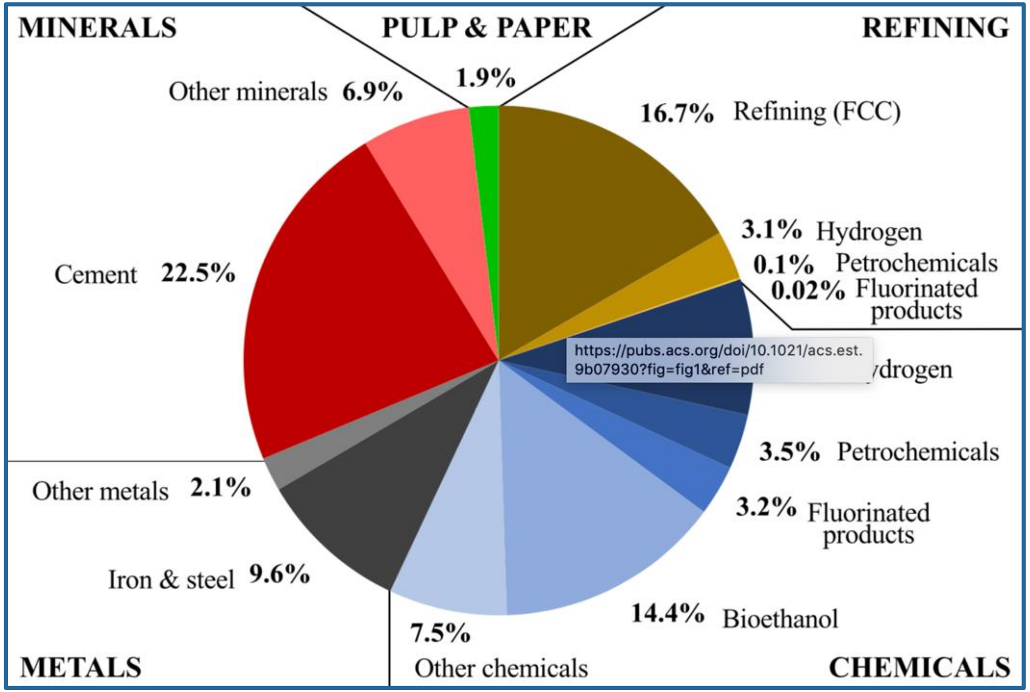
Age profile of primary steelmaking from iron ore (mostly blast



Source: IEA 2020

US industrial emissions by sector

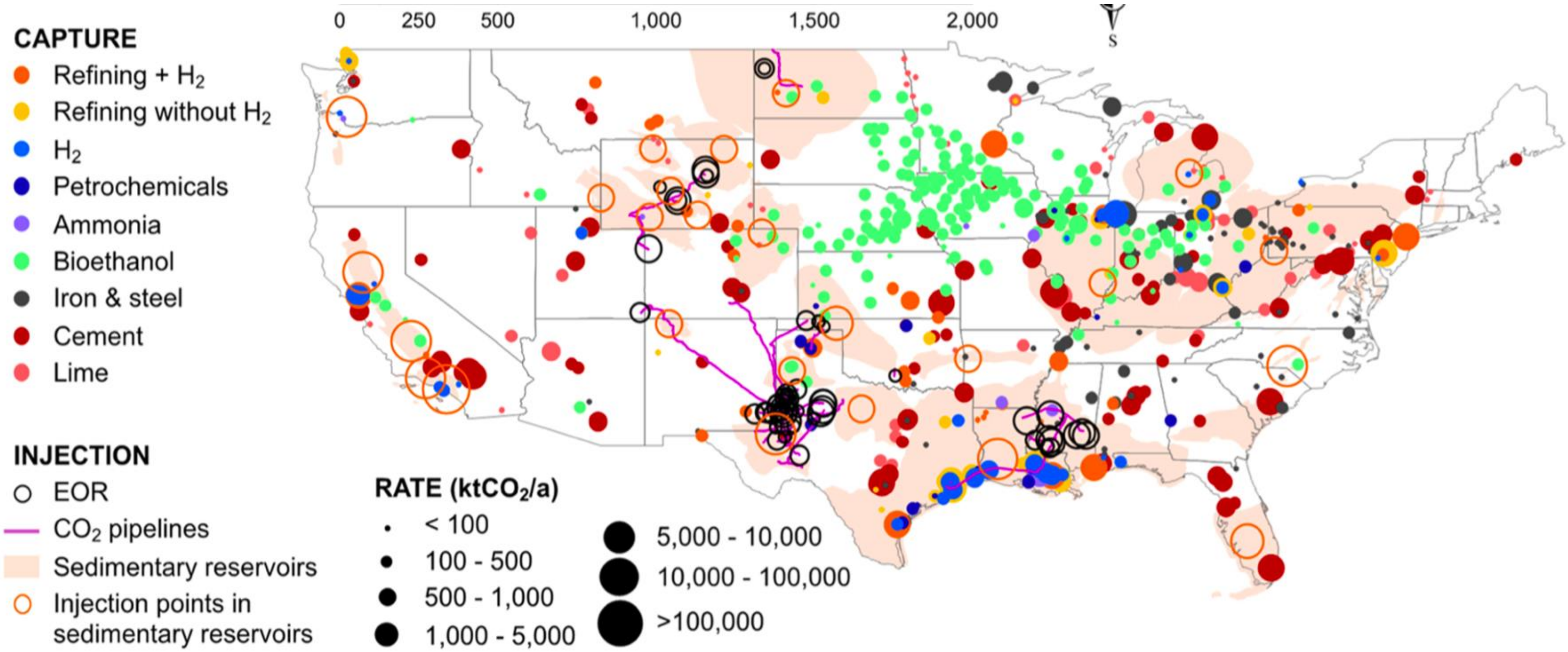




Sources: EPA (2018) & Pilorgé et al., 2020

US industrial source locations by sector

Many are near viable CO_2 storage resources



Source: Pilorgé et al., 2020

Low C Heat: Applications & Sources

Not that many options for high-quality, large volume heat

Hydrogen

- Green: electrolysis of water from zero-C power
- Blue: From natural gas, with CCS (90%)
- Gray: From natural gas, but not low-C

Electricity

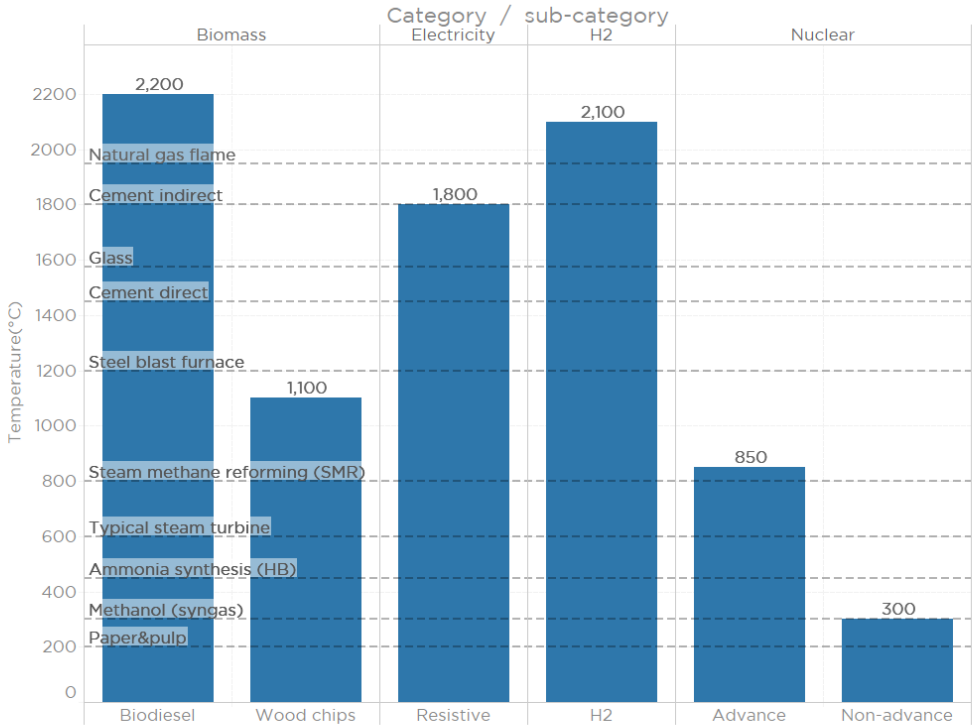
- Must be zero-C supply & 90% capacity
- Radiant & resistive heating most mature

Biomass

- Must be low-C on a life-cycle basis
- Wood chips & biofuels most mature
- Biogas supplies are problematic

Carbon Capture

- Captures both heat and process emissions
- Lower cost than many options
- Requires CO2 storage sites & infrastructure



Hydrogen: Essential for speed, cost, and versatility

The Swiss Army knife of deep decarbonization

Heavy Industry

- Replacing/decarbonizing current hydrogen production (70 Mt/y + 477 Mt/y CO_2)
- Industrial heat (cement, iron & steel, chemicals, refining, glass, ceramics, paper)

Transportation Sector

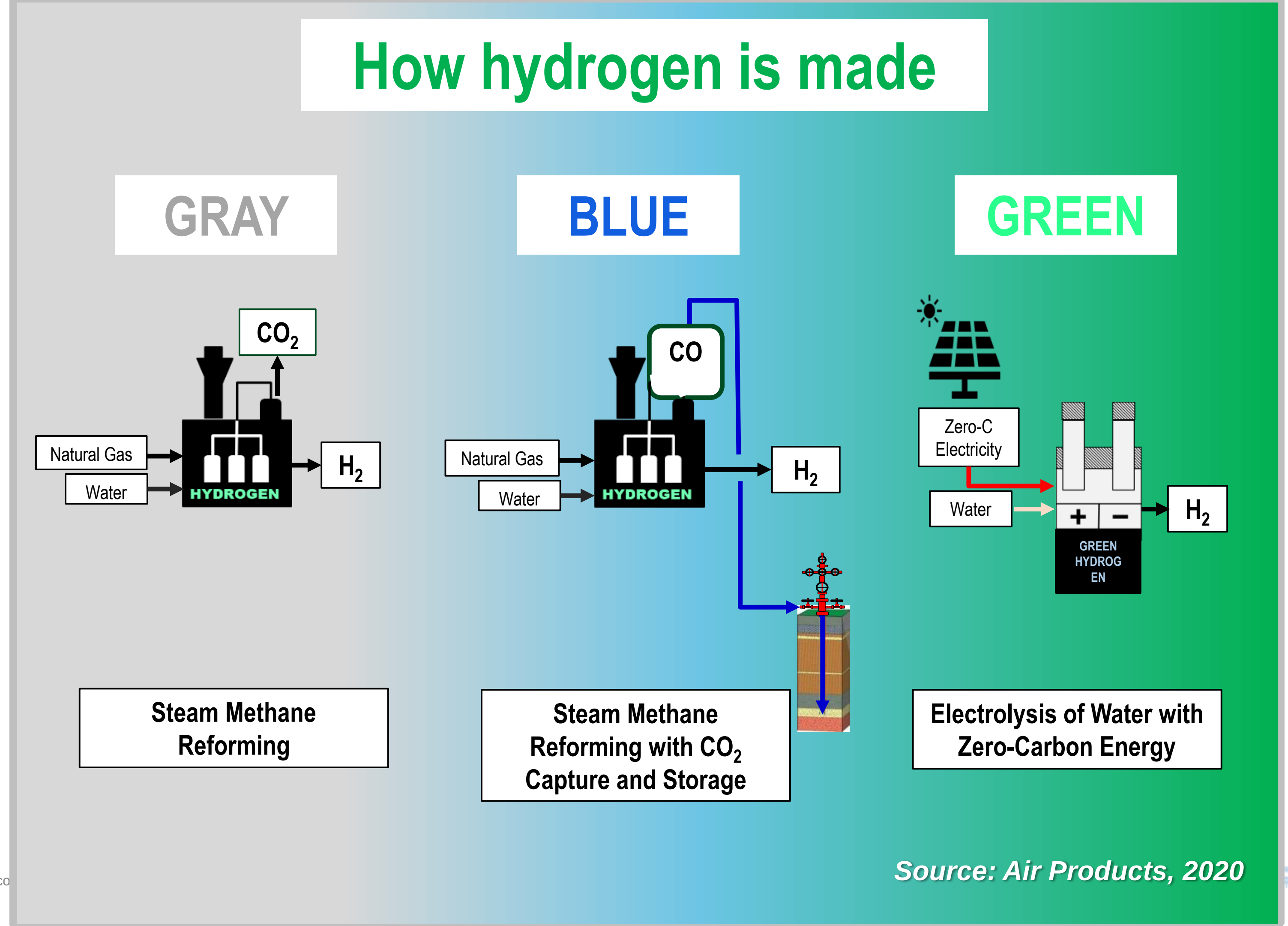
- Direct use as a fuel (heavy duty trucking; port operation)
- Feedstock to synthetic fuels (ammonia, synthetic jet fuel & methanol)

Power Sector

- Alternative power storage (like a long-duration battery) with stationary fuel cells
- Get value from power congestion & curtailment

Multi-sectoral Applications

- Near-term and long-term replacement for natural gas (heat and power)
- Feedstock to a circular carbon economy (fuels, plastics, chemicals)
- CO_2 removal (biomass+CCS to hydrogen; energy for CO2 removal systems)


How hydrogen is made
GRAY
BLUE
GREEN
CO_2
Natural Gas
Water
HYDROGEN
H_2
CO
Natural Gas
Water
HYDROGEN
H_2
Zero-C Electricity
Water
+ −
GREEN HYDROG EN
H_2
Steam Methane Reforming
Steam Methane Reforming with CO_2 Capture and Storage
Electrolysis of Water with Zero-Carbon Energy
Source: Air Products, 2020

Key challenges

Cost

- **Green**: $3-8/kg (55% electricity, 30% electrolyzer, 15% BOP)
- **Blue**: $1.2-1.8/kg (for D, price of gas & decarb fraction)

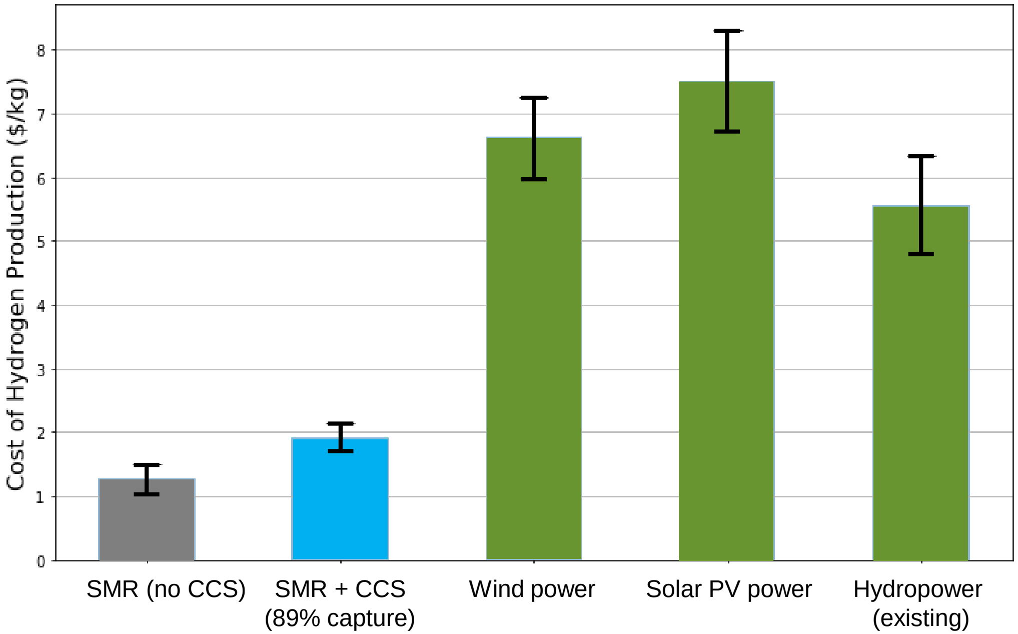
Manufacturing limits

- No mass manufacturing: bespoke production
- China, Germany, Korea, Norway, Japan trying to change

Infrastructure limits

- Massive build of transmission & zero-C electricity (26,000 TWh = 530 Mtpa)

Costs of U.S. hydrogen production ($/kg)



Cost of electricity	Capacity Factor	Cost of H_2 ($/kg)*
$30/MWh	90%	$2
$. 5/MWh	20%	$2

* For $1000/kW electrolyzers

Source: Friedmann et al., 2019

Facility	H_2 Production (tonnes/day)	H_2 Production Process	Operational Commencement
Blue hydrogen			
Enid Fertiliser	200 (in syngas)	Methane reformation	1982
Great Plains Synfuel	1,300 (in syngas)	Coal gasification	2000
Air Products	500	Methane reformation	2013
Coffeyville	200	Petroleum coke gasification	2013
Quest	900	Methane reformation	2015
Alberta Carbon Trunk Line - Sturgeon	240	Asphaltene residue gasification	2020
Alberta Carbon Trunk Line - Agrium	800	Methane reformation	2020
Sinopec Qilu	100 (estimated)	Coal/Coke gasification	2021 (planned)
Green hydrogen			
Trondheim	0.3	Solar (!)	2017
Fukushima	2.4 (10 MW)	Solar	2020
NEOM	650	Wind + Solar	2025 (planned)

Chemicals: 3% of global CO_2 emissions

Heat for chemicals: ~1.5% of global CO_2 emissions

Wide range of processes, uses, footprints, options

Best options (cost & footprint)

- **Hydrogen (first blue H_2 then green)**
- **Biogas, biomethane**
- **Partial electrification (e.g., steam)**

Other decarbonization options:

- **Efficiency (large opportunity)**
- **Novel processes (e.g., electrolytic chemical production; CO_2 upcycling)**

Grangemouth ethylene plant, Scotland

Iron & Steel: 5% of global CO_2 emissions

Heat for Iron and Steel: ~2.5% of global CO_2 emissions

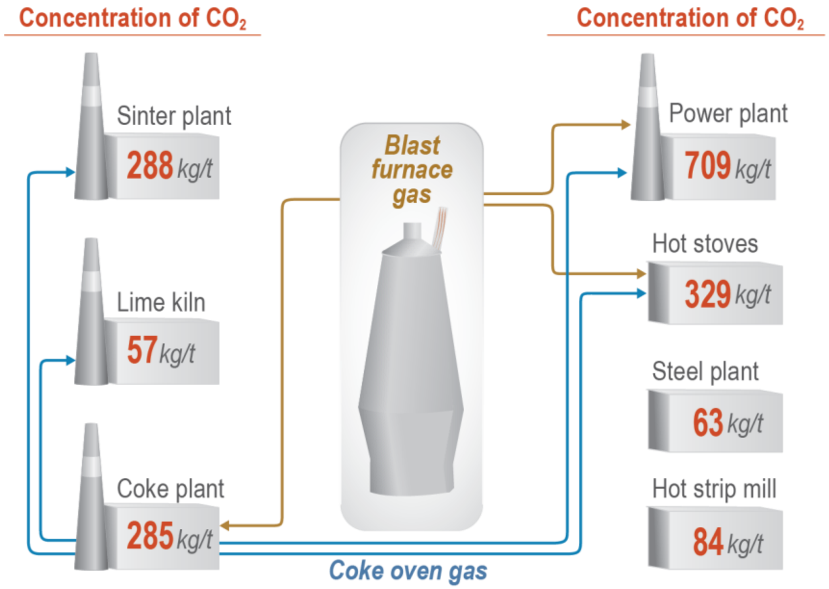
Requires 1200° C and continuous operation

Best options (cost & footprint)

- CCS on whole system
- ”Biocoke”
- Some hydrogen (Nippon Steel)

Other decarbonization options:

- Efficiency
- Modified coking
- Adopting EAF (w/ DRI & zero-C H_2)
- Novel processes (e.g., upgraded smelting, electrical reduction of ore)



Cement industry: 6% of global CO_2 emissions

Heat for cement : ~2% of global CO_2 emissions

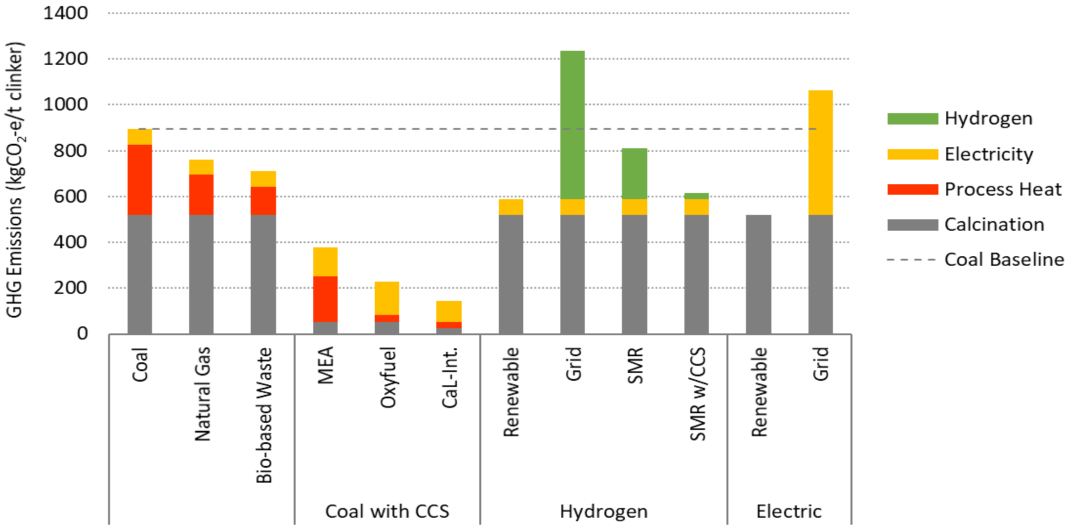
Requires 1450° C and continuous operations

Best options (cost & footprint)

- **CCS on whole system**
- **Biomass mix**

Other decarbonization options:

- **Clinker substitution**
- **Efficiency**
- **Alternative binders**
- **Novel processes (e.g., Ca-L, electrical decomposition)**



Policy options for US low-C industrial development

Incentives
- Buy-clean procurement: cement & steel & fuels
- Tax credits: PTC/ITC for low-C hydrogen, expanded 45Q, etc.
- DOE grants: Demonstration & pilot testing
- Asset replacement assistance

Infrastructure
- CO_2 pipelines & storage facilities, hydrogen pipelines
- High-voltage transmission lines
- Port upgrades

Regulations etc.
- Emissions standards & caps (+/- trading)
- Border tariffs vs. output-based rebates

Innovation is essential and underserved

Wage, equity & labor considerations are essential

MORE ANALYSIS IS GOOD

Levelized Cost of Carbon Abatement (LCCA) is an improved tool for net-zero decisions

It allows one to assess the most cost-effective way to reduce emissions

Key findings for decision-makers

- **Net-zero framework** requires improved methodologies focused on **carbon reduction & removal**.
- LCCA is keyed to **specific displacements of emissions**, which varies greatly by geography, market, technology, policy specifics, and what is displaced.
- LCCA can serve to make rigorous "**apples-to-apples**" comparisons of policies or potential investments.
- LCCA is **powerful** but is only one metric and concern.

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