# MIT Center for Energy and Environmental Policy Research
# The Drive Toward a Zero Carbon Economy

Carl Bozzuto

# Programs at MIT

- MIT Energy Initiative – MITEI, Professor Robert Armstrong, Director
- MIT Center for Energy and Environmental Policy Research – MIT CEEPR, Professor Christopher Knittel, Director
- MIT Joint Program on the Science and Policy of Global Change – Professor Ron Prin and Professor John Reilly, Co-Directors
- MIT Energy at Scale – MIT-ES, Professor Sergey Paltsev, Director
- MIT Roosevelt Project – Professor Ernie Moniz, Faculty Director
- MIT Energy, Environment, and Sustainability Network, Sarah Simon
- MIT Environmental Solutions Initiative, Professor John Fernandez
- MIT Climate and Sustainability Consortium, Professor Jeff Grossman, Dir.
- MIT Concrete Sustainability Hub, Professor Franz-Josef Ulm, Director

# Recent Paper from the CS Hub

- Concrete roadways absorb CO2 from the atmosphere.
- When they are broken up, the rubble absorbs more CO2 from the atmosphere.
- Preliminary estimates indicate that up to 5% of the annual CO2 production could be absorbed if this process were optimized.
- In a related webinar, cement buildings absorb CO2 from the atmosphere.
- When they are knocked down and reduced to rubble, they absorb more CO2 if they are left for a week.
- This could be an important aspect of decarbonizing buildings.

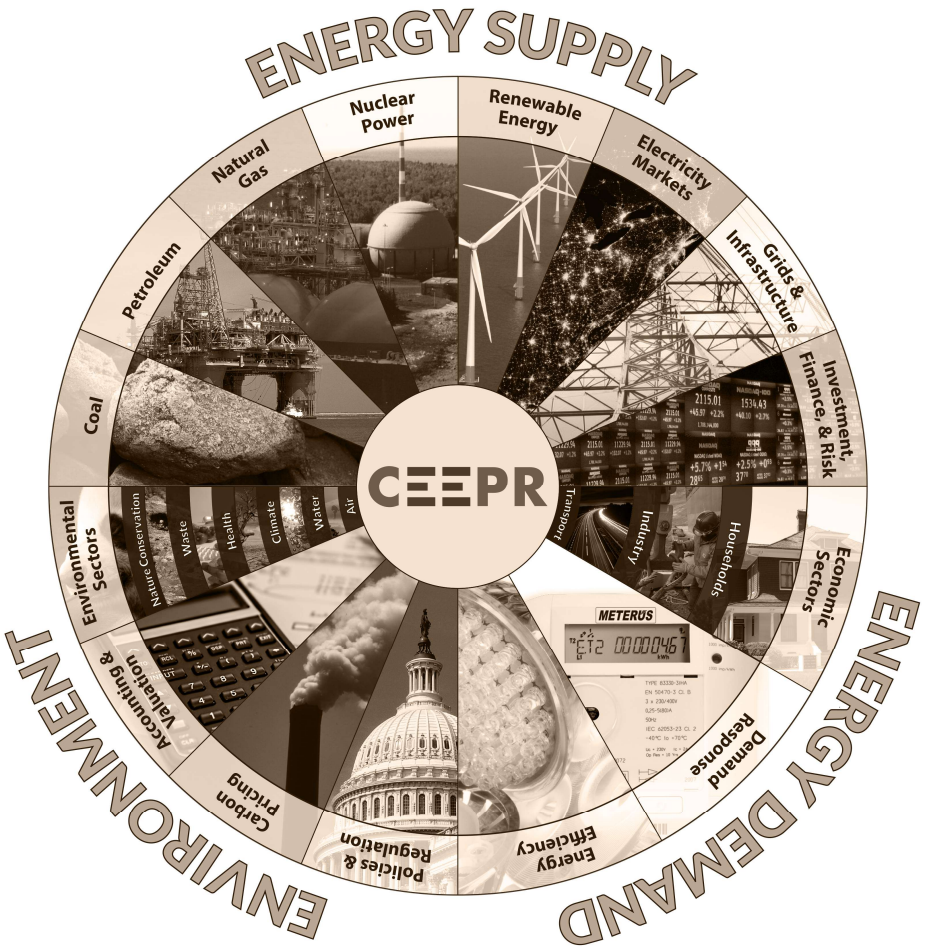
# Programs at MIT

- MITEI
- Research Areas
  - Low Carbon Energy Centers
  - Built Environment and Infrastructure
  - Conventional Energy
  - Energy Efficiency
  - Nuclear Energy
  - Power Distribution and Energy Storage
  - Transportation
  - Renewable Energy
  - Climate and Environment
  - Policy and Economics

# Programs at MIT

- MIT CEEPR
- Founded in 1977
- Promotes rigorous, objective research for improved decision making in government and the private sector, and secures the relevance of its work through close cooperation with industry partners from around the globe.
- Sponsor of the Roosevelt Project

# Programs at MIT



# Programs at MIT

- The Roosevelt Project
  - Transitioning the United States economy toward deep decarbonization will have unequally distributed effects, positive and negative, across socio-economic groups, geographies, and economic sectors. The concerns of workers and communities adversely affected by the transition must inform the discussion around decarbonization, associated policy changes, and institutional development. The goal of the Roosevelt Project is to provide an analytical basis for charting a path to a low carbon economy in a way that promotes high quality job growth, minimizes worker and community dislocation, and harnesses the benefits of energy technologies for regional economic development.
  - More nuance will follow in the next phase of the Roosevelt Project that develops implementation plans for four specific regions: the Industrial Heartland, Southwestern Pennsylvania, the Gulf Coast, and New Mexico. We will work with local partners in those communities to develop effective transition plans that are specific to those regions. That phase of the project should be complete in 2021.

# Programs at MIT

- Why do we care?
- Results from these studies point out some of the unintended consequences of popular policies.
  - CAFÉ standards cost around $600/ton of CO2 not emitted vs. CCS, which costs less than $100/ton (current estimate $60/ton, near term target $40/ton)
  - A national carbon price has a greater impact on the middle of the US than on the coastal areas, which already use more natural gas.
  - Higher electric costs disproportionately impact poorer portions of the population.
- Many of the recommendations manage to find their way into government policies (ie cap and trade, 45Q tax credit for CCS, production tax credit for new nuclear, etc.)

# Industrial Decarbonization

## Long-term: Path-dependencies and Synergies

**Structural** Changes after COVID (how we work, travel, shop, gather…)

Cheaper technology suitable for **subset** of activities **versus** more expensive technology applicable to **wider** coverage.

**Negative** emissions and **hard-to-abate** sectors.

**Spillovers** from a cheaper technology in one sector to other sectors.

**Regional** variations in low-carbon pathways.

**Geopolitics:**
Balance of power is shifting from fossil fuel owners to countries with low-carbon solutions

**New:** Prioritizing resilience over efficiency; Away from globalization -> slower growth

Geopolitics of Renewables
*Paltsev (2016) Bulletin of the Atomic Scientists, 72(6), 390-395.*

Projecting Energy and Climate
*Paltsev (2020) Economics of Energy and Environmental Policy, 9(1), 43-62.*

**Need for dynamic modeling of deeply interconnected systems**

# Industrial Decarbonization

## Decarbonization Options in Industry

Carbon Capture and Storage (CCS)

Electrification

Hydrogen (if from low-carbon or carbon-free sources)

Biofuels

Materials Substitution

*Heterogeneity of processes – focus on "marker" industry :*

Cement (lime, plaster, concrete, glass, etc.)

Iron & Steel (copper, aluminum, zinc, lead, gold, silver, etc.)

Chemicals (fertilizers, plastics, etc.)

Refineries (refined petroleum, coke, etc.)

Energy Inputs vs Feedstock Inputs

# Industrial Decarbonization

- Carbon Capture and Storage – CCS
- “We need lots of CCS and fast” – Ernie Moniz, Roosevelt Project
- Technologies
  - Amine scrubbing – demonstrated at 100 MW, Boundary Dam
  - Chilled ammonia – demonstrated at 30 MW, AEP
  - IGCC w/conventional CO2 removal – demonstrated at 200 MW
  - BECCS – gasify biomass, capture CO2, burn resulting gas, capture CO2, sequester the captured CO2…..”negative emissions”
  - Air capture – not yet demonstrated
  - Oxygen firing – demonstrated at 25 MW
- Carbon XPRIZE competition nearing completion (2 x $7.5 Million prizes)
- $100 million prize offered by Elon Musk.  XPRIZE Foundation to manage.

# Industrial Decarbonization

- Electrification – relies heavily on renewables and storage (or CCS)
  - Land use issues – good wind sites mostly taken
  - Sunlight is dilute (280 BTU/hr/ft2 at noon and 40 deg North Latitude)
  - Ancillary services (spinning reserve, ramp rates, frequency control, voltage control, etc.)
  - Cost and timing
    - Wind – 30% capacity factor
    - Solar – 11% capacity factor in New England

- Biomass – not enough land area to grow biomass for consistent power supplies
  - It takes 15 years to grow a tree at 40 deg North Latitude
  - Consider a circle 75 miles in diameter
  - Divide the circle into 15 sectors.
  - Cut down and replant one sector each year
  - This can supply 100 MW

# Industrial Decarbonization

- Hydrogen
  - “Green Hydrogen” is produced directly from renewables such is solar and wind by electrolysis of water. The resulting products are hydrogen and oxygen.
  - “Blue Hydrogen” is produced from fossil fuels with CCS.
  - Hydrogen is produced today by steam reforming methane.
    - $H_2O + CH_4 = CO + 3\,H_2$
  - The hydrogen can be separated using a semipermeable membrane.
  - Hydrogen is difficult to transport and store.
    - Small molecule leaks through piping
    - Explosive (Hindenburg disaster)
    - Never the less, hydrogen has been used for many years for cooling electric generators.
    - It is also used to make ammonia and to hydrotreat heavy oils to make lighter fractions.

# Some Recent Results

- Southwest Pennsylvania
- Second largest energy producing state
  - Thousands of gas wells
  - Coal mines
  - Oil wells
- Energy Sector has the high paying jobs across all levels of education
  - No high school diploma - Energy sector $42 K, all else $27 K
  - Technical school, but not college - Energy $69 K, all else $50 K
- Renewables and fracked gas more like “all else”

# Some Recent Results

- PA has reduced GHG emission by 18% since 2005
  - Mostly by converting from coal to gas
- CCS is anticipated
  - However, no infrastructure for storage exists
  - No current CCS projects
- Hydrogen potential?
  - No hydrogen production exists
  - No infrastructure for hydrogen exists
- Old line energy companies are well connected
  - Renewables and new gas are not

# Some Recent Results

- Organizational Learning
- Recognizing the problem, knowing why it exists, and knowing how to fix it
- Most organizations know they have a problem, but don’t know why or what to do about it (80%)
- Some organizations know they have a problem and why they have it, but don’t know what to do (15%)
- A smaller number of organizations know they have a problem and why, and, at least, have some idea of what to do about it.

# New CEEPR Webinar – Mar. 24

- Climate Policy Under the Biden Administration
  - Moderated by Prof. Emeritus John Deutch, former head of CIA and Ass't Sec'y Energy
  - George David Banks – House Select Committee on Climate Crisis (Minority)
  - Ana Unruh Cohen – Staff Director, House Select Committee on Climate Crisis
  - Dick Schmalensee – Prof. Emeritus, former head of CEEPR, and instrumental with Prof. Denny Ellerman in getting Title IV cap and trade program in the CAA revisions
- Will explore the likely paths forward for meaningful climate change policy under the Biden Administration.

# Industrial Decarbonization

- We can expect to see a lot more proposals on decarbonization.
- MIT does research to examine the impact of these proposals on the economy as a whole and on various sectors of industry.
- The big questions are, “How do we do it?”, “How fast”, and “How much will it cost?”
- Some of these proposals will eventually become policies that we will be forced to live with.
- We need to start understanding our positions now if we are to have any influence at all going forward.