CEE's as Leaders in Climate Change Mitigation and Adaptation

Kenneth Hyatt Distinguished Leadership Lecture
School of Civil and Environmental Engineering (CEE)
Georgia Institute of Technology

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Lecture Outline

- A little background information
- Our responsibilities as CEE leaders in abating the climate change crisis
- CEE contributions to climate change
  - Mitigation (reducing or capturing greenhouse gas [GHG] emissions)
  - Adaptation (reducing the adverse impacts of climate change on society and the environment)
Conclusions from 2015 Hyatt Lecture

- Climate change is occurring
- Human drivers are a significant factor
- Doing nothing is not an option
- Adaptation without mitigation is not a winning hand
- Engineers need to be part of the dialog
2022 Scientific Consensus

- Earth’s atmosphere has warmed significantly since the 1950s (about 1.0°C [1.8°F]).
- Anthropogenic GHG emissions are unequivocally the primary cause for this global warming.
- A warmer Earth is changing climate patterns with adverse impacts to society at the Georgia, U.S., and global scales.
- The world is struggling to reduce GHG emissions, notwithstanding national pledges to do so.
- Continuing high GHG emissions will cause more global warming for decades to come, resulting in more frequent and severe adverse impacts.

1The U.N. Intergovernmental Panel on Climate Change (IPCC) has stated that the evidence for human drivers is “unequivocal.” (August 2021).
Atmospheric Carbon Dioxide Levels Continue to Rise
(CO₂ increase > 2.0 ppm/year, on average)

DIRECT MEASUREMENTS: 2005-PRESENT

Data source: Monthly measurements (average seasonal cycle removed). Credit: NOAA
Increasing Atmospheric GHGs Absorb More of Earth’s Infrared Radiation, Upsetting the Earth’s Solar Energy Equilibrium and Warming the Earth

GLOBAL LAND-OCEAN TEMPERATURE INDEX

Data source: NASA’s Goddard Institute for Space Studies (GISS).
Credit: NASA/GISS

Slope ≈ 0.30°C per decade (≈ 1°C per 35 years)
Climate Change Impacts – Fourth U.S. National Climate Assessment (2017)

- Increasing temperatures
- More severe droughts and heat waves
- Increased wildfire threats
- Less mountain snowpack
- Changes in precipitation patterns
- More extreme storm systems
- Stronger and more intense hurricanes
- Groundwater aquifer depletion
- Groundwater quality degradation
- Surface-water quality degradation
- Water supply disruptions
- Arctic projected to become ice free in summer

- Antarctic losing ice mass at a rapid rate
- Glaciers continue to melt and shrink
- Increasing rate of sea level rise
- Increasing coastal flooding
- Increasing ocean acidification
- Loss of permafrost as methane sink
- Increasing coastal flooding and erosion
- Population disruptions
- Changes in agricultural patterns
- Food supply disruptions
- Ecological disruptions
- Impacts to all forms of infrastructure
- Impacts to communities and cities
Lake Mead (Hoover Dam) provides drinking and agricultural water to seven western states.

Colorado River flows feeding Lake Mead could, within 30 years, decline by 25-30% compared to flows when the dam was built.¹

¹Utah State University Colorado River Studies: Colorado River | USU

June 2021
(36% capacity, 150 feet below full pool)
Based on a 2021 meta-study, NOAA concluded\(^1\):

- Increasing ocean surface temperatures are likely to fuel more powerful (i.e., Category 4 and 5) hurricanes.
- Due to more moisture in a warmer atmosphere, hurricane rainfall amounts are likely to increase.
- The destructive power of hurricanes will be amplified by sea level rise.
- Hurricanes may move more slowly in a warmer future, further intensifying local rainfall amounts.

\(^1\)Climate change is probably increasing the intensity of tropical cyclones | NOAA Climate.gov
“Every additional 0.5°C of global warming causes clearly discernible increases in the intensity and frequency of hot extremes, including heatwaves and heavy precipitation.

“There will be an increasing occurrence of some extreme events **unprecedented in the observational record** with additional global warming, even at 1.5°C.”

Source: IPCC (2021) (Findings characterized by UN IPCC as “high confidence” or “very likely.”)
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- CEE contributions to climate change
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IPCC (2021) Modeling Predicts an Increasingly Warm Planet for All Future GHG Emission Scenarios

Your career will span the period when mankind’s actions will determine the ultimate severity of climate change impacts on our world.

What responsibilities do you have as CEE leaders to make a positive difference?

Change in global surface temperature in 2081-2100 relative to 1850-1900. Source: IPCC (2021): Global Mean Temperature in 2081-2100 Compared to 1850-1900 Baseline.
“Members of ASCE conduct themselves with integrity and professionalism, and above all else protect and advance the health, safety, and welfare of the public through the practice of Civil Engineering.”

**Question:**
Do efforts by engineers to help society mitigate climate change and adapt to its impacts serve to protect and enhance the health, safety, and welfare of the public?
Leadership Responsibilities of CEEs in Abating the Climate Change Crisis

- Communicate to the public, and build awareness of, the science that “unequivocally” demonstrates human-induced GHG emissions are driving global warming and its myriad impacts
- Advocate for government policies, actions, and regulations to
  - Reduce GHG emissions
  - Create resilient and sustainable infrastructure and communities
  - Preserve natural resources and the environment necessary for a healthy and sustainable Earth
Leadership Responsibilities of CEEs in Abating the Climate Change Crisis

- Participate in and support professional organizations who advocate to *governments, institutions, and companies* for funding of climate change adaptation and mitigation projects, for example
  - American Society of Civil Engineers (ASCE)
  - American Council of Engineering Companies (ACEC)
  - U.S. Green Building Council (USGBC)

- Encourage CEE employers to implement low-carbon and sustainable practices, such as
  - Hybrid employee working policies
  - Use of low carbon transportation modes
  - Energy and water conservation programs
  - Comprehensive recycling and waste minimization programs
Leadership Responsibilities of CEEs in Abating the Climate Change Crisis

- Advocate to project owners **generating significant GHG-emissions** (e.g., Georgia DOT, Georgia Power Company, Port of Savannah) approaches to their projects that help to:
  - mitigate GHG emissions to the atmosphere (e.g., specifying low carbon concrete and use of recycled construction materials)
  - adapt to the effects of climate change (e.g., DOTs elevating or routing roadways out of harms way)
- Develop your own CEE technical competencies in areas needed to address the effects climate change
  - see remainder of this lecture
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- Our responsibilities as CEE leaders in abating the climate change crisis
- **CEE contributions to climate change**
  - *Mitigation*
  - Adaptation
Approaches to Mitigating Climate Change and Global Warming (Reducing and/or Capturing GHG Emissions)

1. **Increasing use of renewable energy (solar, wind, hydropower, geothermal) as a replacement for fossil fuels**
2. **Improving the nation’s energy transmission and distribution grid**, developing microgrids, and improving and increasing the use of battery and compressed air energy storage
3. **Reducing carbon emissions from current emission sources** (power, industrial, construction, transportation, and buildings)
4. Developing zero-carbon and low-carbon fuels (e.g., green hydrogen, biofuels)
5. Increasing energy efficiency for all types of powered systems (reduce energy consumption and waste energy)
6. Improving land uses, forestry practices, and agricultural practices (reducing emissions and creating carbon sinks)
7. Increasing carbon capture and sequestration (CCS) and developing CO₂ mineralization technologies (carbon sinks)
Contributions of CEEs to Increasing Renewable Energy

- Siting studies, planning, and risk analyses
- Environmental impact studies and permitting
- Water resource investigations
- Hydrologic and watershed studies for hydroelectric
- Intake and receiving water studies
- Meteorological and oceanographic studies
- Wave and current forecasting and analysis for offshore wind
- Geological and geotechnical investigations
- Faulting and earthquake studies
- Foundations and earthworks design
- Structural analysis and design
- Design of site civil infrastructure
- Design of stormwater and erosion controls
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management


30-MW Block Island Wind Farm, Offshore Rhode Island (2016)
Contributions of CEEs to Improving the Energy Grid - Sunrise Powerlink Renewable Energy Transmission Line

Contributions of CEEs

- Site selection, planning, and risk analyses
- Environmental impact studies and permitting
- Corridor routing studies and planning for transmission lines
- Corridor natural hazard studies (faulting, landslides, karst, stream crossings)
- Geological and geotechnical investigations
- Site grading and earthwork design (cuts, fills, retaining walls)
- Design of transmission towers and foundations
- Design of underground transmission corridors
- Design of site civil infrastructure
- Design of stormwater and erosion control BMPs
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management
Contributions of CEEs to Climate Change Mitigation in Transportation

Light-duty vehicles are the largest contributors to GHG emissions. CEEs are not involved in mitigation measures involving increased vehicle fuel efficiency, non-carbon fuels (H\textsubscript{2}), and electric vehicles, but……

….CEE are contributing to

- Transportation ridership and route studies and planning
- Traffic congestion modeling, routing and debottlenecking studies
- Transportation project impact studies (CEQA, EIS/EIR)
- Mass transit alternatives analyses and feasibility studies
- Studies, engineering, and design for
  - Urban trolley and light rail systems
  - Bus rapid transit (BRT) systems
  - Multi-modal transportation hubs
  - Green/complete streets
  - Smart traffic control systems
- Design of alternative fuel production, distribution and delivery facilities (LNG, H:H)
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management


2019 U.S. TRANSPORTATION SECTOR GHG EMISSIONS BY SOURCE

- Light-Duty Vehicles (58%)
- Medium- and Heavy-duty Trucks (24%)
- Aircraft (10%)
- Other (5%)
- Rail (2%)
- Ships and Boats (2%)
Contributions of CEEs to Sustainable and Energy-Efficient Buildings

Contributions of CEEs

- Siting studies, permitting, and planning
- Resource and energy efficient structural engineering and building envelope design
- Resource and energy efficient building foundation design
- Low-impact site civil design
- Green roof design
- Rainwater harvesting design
- Specifying local, recycled, and/or renewable construction materials
- Requiring recycling of construction waste
- Design of grey-water and/or black-water wastewater treatment systems
- Water efficient and ecologically beneficial landscaping
- Environmental and construction monitoring
- Project and construction management
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## Partial List of Infrastructure and Environmental Sectors Requiring Climate Adaptation Measures

<table>
<thead>
<tr>
<th>Infrastructure or Environmental Sector</th>
<th>Role for CEEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal communities and low-lying areas</td>
<td>✓</td>
</tr>
<tr>
<td>Coastal cities (buildings, basements, underground structures, subways, and utilities)</td>
<td>✓</td>
</tr>
<tr>
<td>Coastal transportation systems (roads, tunnels, bridges, airports, mass transit)</td>
<td>✓</td>
</tr>
<tr>
<td>Ports and harbors; inter-coastal and inland waterways</td>
<td>✓</td>
</tr>
<tr>
<td>Rivers and riverine infrastructure</td>
<td>✓</td>
</tr>
<tr>
<td>Communities everywhere at increased risk of flooding due to extreme weather</td>
<td>✓</td>
</tr>
<tr>
<td>Surface-water and groundwater resources (both quantity and quality)</td>
<td>✓</td>
</tr>
<tr>
<td>Water supply infrastructure (reservoirs, storage tanks, canals, pipelines)</td>
<td>✓</td>
</tr>
</tbody>
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<tr>
<td>Electric power infrastructure and the electrical transmission and distribution grid</td>
<td>✓</td>
</tr>
<tr>
<td>Industrial, military, governmental infrastructure (both coastal and inland)</td>
<td>✓</td>
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<tr>
<td>Barrier islands, beaches, dunes, salt marshes, wetlands, estuaries, critical wildlife habitat (loss of and damage to)</td>
<td>✓</td>
</tr>
<tr>
<td>Terrestrial, freshwater, marine, and avian wildlife</td>
<td>✓</td>
</tr>
<tr>
<td>Contaminated land (EPA Superfund sites) in floodplains and coastal areas</td>
<td>✓</td>
</tr>
<tr>
<td>Land aridification and agriculture</td>
<td>✓</td>
</tr>
<tr>
<td>Natural hazards (wildfires, hurricanes, tornados, floods, landslides and debris flows)</td>
<td>✓</td>
</tr>
<tr>
<td>Air quality (dust and particulates, wildfire impacts)</td>
<td>✓</td>
</tr>
</tbody>
</table>
CEE's have a major role to play in engineering adaptations for city infrastructure prone to increasing storm and tide inundation:

- Storm surge and inundation modeling
- Floodplain mapping
- Recurrence, vulnerability, and risk studies
- Event forecasting and real time monitoring
- Studies, engineering, and design for:
  - Sea walls, storm-surge barriers, tide gates, and pump stations
  - Protecting or relocating roads, subways, and utilities
  - Improving power reliability and increasing backup power sources
  - Protecting or relocating critical infrastructure
  - Waterproofing buildings
  - Protecting infrastructure from saltwater corrosion
  - Improving and expanding stormwater retention systems

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1 Surging Seas: Sea level rise analysis by Climate Central
Sea Level Rise Adaptation - San Francisco International Airport Shoreline Protection Program

Project will provide an additional 5 vertical feet of barrier against sea level rise, extreme tides, and storm waves around the entire 8-mile airport waterside perimeter using a continuous system of piles, berms, and riprap. All this will be designed by CEEs.
Within this century, 2,400 miles of Gulf Coast roadways are projected to be inundated by sea level rise.¹ In the coming years, CEEs will have a lead role in protecting, elevating, and/or rerouting this at-risk transportation infrastructure.
This project, designed by CEEs, raised, strengthened, and restored 3.7 miles of dunes and associated wildlife habitat protecting Launch Complexes 39A and 39B at NASA Kennedy Space Center. The dunes had been damaged by Hurricane Matthew in 2016.
Needed projects include water conservation, water reuse, water storage and conveyance, and saltwater desalination:

- Watershed and hydrologic evaluations
- Environmental impact studies
- Regulatory and permitting
- Stormwater capture and groundwater infiltration studies and design
- Seawater desalination studies and design
- Rainwater harvesting systems
- Wastewater treatment and recycling systems (treatment plants, reservoirs, conveyance pipelines, pump stations)
- Reservoir management and operational optimization
- New reservoirs and water conveyance systems
- Water quality studies
- Water conservation programs
- Ecological and environmental restoration
- Environmental and construction monitoring
- Project and construction management
Water Supply Adaptation - Proposed Sites Reservoir, Colusa County, CA

Off-stream reservoir will be 10-miles long, 250-ft deep, with 1.5 million acre-feet of storage.

Contributions of CEEs

- Siting studies, planning, risk analyses
- Environmental impact studies
- Regulatory and permitting
- Water resource investigations
- Reservoir modeling (hydrodynamic and thermal)
- Hydrology and hydraulics studies
- Geological, geophysical, and geotechnical investigations
- Faulting, seismic hazard, site response, and soil-structure interaction studies
- Design of new dams, spillways, intakes, gates, tunnels, pipelines, and pump stations structures
- Design of site civil infrastructure
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management
Summary of CEE Contributions to Climate Change Mitigation and Mitigation and Adaptation Reviewed in This Lecture

### Renewables
- Siting studies, planning, and risk analyses
- Environmental impact studies and permitting
- Water resource investigations
- Hydrologic and watershed studies
- Intake and receiving water studies
- Meteorological and oceanographic studies
- Wave and current forecasting and analysis
- Geological and geotechnical investigations
- Faulting and earthquake studies
- Foundations and earthworks design
- Structural analysis and design
- Design of site civil infrastructure
- Design of stormwater and erosion controls
- Environmental and construction monitoring
- Project and construction management

### Energy Transmission Grid
- Site selection, planning, and risk analyses
- Environmental impact studies and permitting
- Corridor routing studies and planning for transmission lines
- Corridor natural hazard studies (faulting, landslides, karst, stream crossings)
- Geological and geotechnical investigations
- Site grading and earthwork design (cuts, fills, retaining walls)
- Design of transmission towers and foundations
- Design of underground transmission corridors
- Design of site civil infrastructure
- Design of stormwater and erosion control BMPs
- Environmental and construction monitoring
- Project and construction management

### Transportation
- Transportation ridership and route studies
- Traffic congestion modeling, routing and debottlenecking studies
- Transportation project impact studies
- Mass transit alternatives analyses and feasibility studies
- Studies, engineering, and design for: Urban trolley and light rail
  - Bus rapid transit (BRT) systems
  - Multi-modal transportation hubs
- Design of alternative fuel production, distribution and delivery facilities (LNG, H2)
- Environmental cleanup studies and design
- Environmental and construction monitoring
- Project and construction management

### Buildings
- Siting studies, permitting, and planning
- Resource and energy efficient structural engineering and building envelope design
- Resource and energy efficient building foundations
- Low-impact site civil design
- Green roof design
- Rainwater harvesting design
- Specifying local, recycled, and/or renewable construction materials
- Requiring recycling of construction waste
- Design of grey-water and/or black-water wastewater treatment systems
- Water efficient and ecologically beneficial landscaping
- Environmental and construction monitoring
- Project and construction management

### Sea Level Rise
- Storm surge and inundation modeling
- Floodplain mapping
- Recurrence, vulnerability, and risk studies
- Event forecasting and real time monitoring
- Studies, engineering, and design for:
  - Sea walls, storm-surge barriers, tide gates, and pump stations
  - Protecting or relocating roads, subways, and utilities
  - Improving power reliability and increasing backup power sources
  - Protecting or relocating critical infrastructure
  - Waterproofing buildings
  - Protecting infrastructure from saltwater corrosion
  - Improving and expanding stormwater retention systems

### Drought and Water Supply
- Watershed and hydrologic evaluations
- Environmental impact studies, regulatory and permitting
- Stormwater capture and groundwater infiltration studies and design
- Seawater desalination plant studies and design
- Rainwater harvesting systems
- Wastewater treatment and recycling systems
- Reservoir management and operational optimization
- New reservoirs and water conveyance systems
- Water conservation programs and water quality studies
- Ecological and environmental restoration
- Environmental and construction monitoring and management
Conclusions

As we have seen today, human-induced global warming and climate change are real and the disruptive impacts to infrastructure, society, and the environment are significant.

Climate change mitigation and adaptation efforts will spur countless projects that will need CEE contributions and leadership. These projects will create exciting career opportunities for many Georgia Tech CEE graduates.

With one of the best CEE educations in the world (Georgia Tech) you can make a real difference for good. As CEE leaders, you have a responsibility to do so.
I extend my thanks to Kenneth Hyatt who through his generosity made this lecture possible and to the School of Civil and Environmental Engineering for inviting me to be here today.