Climate change in Indiana: Engineering for a new future

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DISCOVERY PARK

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PCCRC Director
We live in times of rapid change.

- Climate
- Technology
- Energy
- Communications
- COVID-19
Our context: Rapid changes
Important trends in atmosphere and climate
Global temperature anomalies averaged and adjusted to early industrial baseline (1881-1910)
Source: NASA GISS, NOAA NCEI, ESRL
Our context: Rapid changes
Important trends in health: COVID-19
Societal lockdowns reduced global daily CO₂ emissions by up to 15%

Source: Le Quéré et al. Nature Climate Change (2020), Global Carbon Project

Figure 3. Global daily fossil CO₂ emissions for six sectors of the economy. Updated from Le Quéré et al. (2020).
The reduction in CO$_2$ emissions briefly brought us back to 2006 levels.
During societal lockdowns, energy *efficiency* also dropped, for many reasons:

- Commercial buildings unused, but still running
- Public transit running, but less used
- Airline flights at lower capacity
- More energy use at home
- Many building retrofits stalled
- Incentive to heat the outdoors in winter
- Single-use plastic more common
How do we learn from COVID?

• Can we build back more efficiently to deal with COVID? E.g., HVAC retrofits that filter air better and also increase energy efficiency?

• Can we take advantage of remote conferencing and working to reduce our travel impacts?

• Can economic recovery plans encourage more climate-friendly infrastructure?
Our context: Rapid changes
Important trends in technology and energy
Renewable Energy Costs are Falling

Analysts at Lazard compared the changing costs over time for generating a megawatt-hour of electricity from different energy sources, including coal, solar, wind, nuclear and natural gas.

**HISTORIC AVERAGE LEVELIZED COST OF ENERGY**

*Per megawatt-hour, unsubsidized values, 2009-2019*

![Graph showing the historic average levelized cost of energy from 2009 to 2019 for different energy sources: Utility-scale solar PV, nuclear, coal, wind, and gas. The costs are presented in dollars per megawatt-hour. The graph indicates a downward trend for all sources except nuclear and coal, which show slight increases. Notable costs include:

- **Nuclear**: $155 in 2019.
- **Coal**: $109 in 2019.
- **Wind**: $83 in 2019.
- **Gas**: $41 in 2019.

**NOTE:** Reflects average of unsubsidized high and low levelized cost of energy range.

*SOURCE: Lazard*
Falling Battery Prices

The global average price of lithium-ion batteries has plummeted, making electric cars much more affordable.

LITHIUM-ION BATTERY PRICES
U.S. dollars per kilowatt-hour, 2010-2019

SOURCE: BloombergNEF
Enough context. Let’s talk about climate change.
How is the climate changing in Indiana?
IN CCIA Reports
Putting global change into local perspective

Climate
Health
Forest Ecosystems
Urban Green Infrastructure
Agriculture
Aquatic Ecosystems
Tourism & Recreation
Energy
Water Resources
Infrastructure

www.IndianaClimate.org

Coming Soon!
Indiana is getting warmer

Annual Average Temperature
Indiana

+1.3°F
Indiana is getting warmer

Annual temperature has increased 1.3°F over the last century.

- Longer frost-free season
- Fewer cold days
- Significantly warmer overnight temperatures
Indiana is getting wetter

Annual Total Precipitation
Indiana

+6.5”
Indiana is getting wetter

Annual Total Precipitation
Indiana

Change in annual average precipitation based on linear trend between 1895 to 2019

+6.5"
+7.1"
+7.2"
+6.2"
+5.3"
+4.2"
+8.1"
+8.1"
+6.6"
Heavy rainfall is more intense & happening more often.

42%

In the amount of rain falling in heavy downpours

More frequent extreme precipitation

Days per year that exceed the 1900-2016 period’s 99th percentile for Indiana (statewide average).
Stream flows have increased
Should we expect these changes to continue?
Indiana will get warmer

Annual temperature has already increased 1.3°F over the last century.

Warming expected to continue and intensify

Indiana scientists used 10 climate models to look at future warming.

Range of outcomes based on medium- and high-emissions scenarios
Indiana’s **warming** will continue and accelerate.

- Fewer “mild” days
- More hot days
- Longer warm season
- Milder cold season

5°F to 6°F of warming expected by mid-century

Future projection for medium & high emissions scenario

Mid-century represents average from 2041-2070, with change relative to the average from 1915-2013
Days Above 90 °F

PAST

2041-2070

MEDIUM EMISSIONS
Urban Heat Islands & Ozone
Urban Heat Islands & Ozone

- Ozone gas is a strong lung irritant
- Combustion, other pollutants react in air to form ozone
- High temperatures accelerate ozone formation
- Effect greater in downtown areas
  - Emission sources
  - Urban heat island effect
Freeze Thaw Cycles

Average Number of Cycles in February

2-6 Events (PAST) 4-7 Events (2041-2070)

Increased variability in winter temperature resulting in more freeze/thaw cycles
Annual precipitation has increased 6.5” over the last century.

6% to 8% increase in annual rainfall is projected by mid-century.
Some seasons will be wetter

- WINTER: 16 to 20% increase by mid-century
- SPRING: 13 to 16% increase by mid-century

- More falling as rain, not snow
- Increased early-season soil saturation
Some seasons will be drier

Summer & fall show slight declines by mid-century, with less certainty in the projections

- Increased water demand from added heat
- Drier soils
Seasonal Analogs
Based on seasonal average temperature and precipitation

Statewide Average
2050s represents average from 2041 to 2070
2080s represents average from 2071 to 2100

Base map shows 1981 to 2010 average seasonal temperature from PRISM archive
Changes in temperature & precipitation will alter all aspects of the hydrologic cycle:

- Amount & timing
  - Snow cover
  - Runoff
  - Soil moisture
  - Evaporation
  - Streamflow
  - Flooding
  - Drought
Snow Days

Annual number of days with over 2” snowfall

St. Joseph County, Indiana

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Vanderburgh County, Indiana

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Marion County, Indiana

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"Historical" is an average for the period 1915 to 2013. "2020s" represents the average 30-year future period 2011 to 2040. "2050s" represents the average 30-year period 2041 to 2070. "2080s" represents the 30-year period 2071 to 2100.
Increasing Spring Drainage

Amount of water flowing from subsurface tile drains from March to May

- 2.8-3.4 in. Future +40-70% by Mid-Century
- 2 in. Future +29-47% by Mid-Century
- 3.4 in. Future +26-28% by Mid-Century

Historical period is from 1981 to 2010. Mid-century represents the period from 2041 to 2070. Range of results based on medium and high emissions scenarios.
**Higher Highs, Lower Lows**

**White River near Indianapolis, IN**

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**Annual Average Monthly Streamflows**

**Medium Emissions Scenario**

All values are simulated discharge for comparison purposes. Past is an average for the period 1984 to 2013. For the future projections, “2050s” represents the 30-year period from 2041 to 2070, and “2080s” represents the 30-year period from 2071 to 2100. Percent change on right panel is relative to the 1984 to 2013 average.
No change in heat-trapping gas emissions

CIRA analysis identified bridges that may be vulnerable to increased peak river flows.
Adaptation:
Are we ready for these changes?
Adaptation strategy: rethinking location of structures

“One of the most effective strategies for reducing the risks of climate change is to avoid placing people and infrastructure in vulnerable locations.”

-- Transportation and Climate Change: An Assessment by the National Research Council (2008)

- Need to consider CC impacts on infrastructure investments
- There needs to be integration between land use planning and transportation planning.
Critical infrastructure in the floodplain?

New analysis suggests flood risk is underestimated in many communities.

The First National Flood Risk Assessment
Defining America’s Growing Risk
Adaptation strategy: update design standards

Are past experiences with extreme events still a reliable indicator for future risk?

Climate and hydrological projections show the frequency and magnitude of extreme rainfall events and streamflows/flooding will shift in Indiana.

Several Indiana communities are already building stormwater systems to accommodate changing rainfall and runoff patterns. What about adjustments in bridge design? Pavement specs?
Adaptation strategy: integrated planning

“Cities can enhance their adaptive capacity to climate change through their urban land management, which includes the legal and political systems, planning departments, zoning regulations, infrastructure and urban services, land markets, and fiscal arrangement.”

NCA 2014 Technical Input Paper
“Climate Change and Infrastructure, Urban Systems, and Vulnerabilities”

We must take a systems approach to achieve climate resilience.
Coping with excess rainfall - watershed impacts

- Slow down the runoff
- Rain gardens, bioswales
- Increase pervious pavement
- Nutrient stewardship (4-R’s)
- Insurance options
- Relocating infrastructure vs. buffering systems against impacts
Impacts to green drainage systems include floodwater stress, degrading structure & function of riparian buffers and reducing rain garden benefits.
Mitigation:
Minimizing the changes
Transportation contributes to climate change

![Pie chart showing Indiana Carbon Dioxide Emissions by Sector (2017)]

- Residential Sector: 46%
- Commercial Sector: 24%
- Industrial Sector: 23%
- Transportation Sector: 4%
- Electric Power Sector: 3%

Source: EIA
Mitigation matters!

Reducing emissions will result in less extreme impacts, less risk to built and natural systems.

Some strategies that can help transportation systems reduce emissions also have other social benefits (co-benefits)

- Roundabouts - reduce fuel use AND can improve air quality (less idling, better traffic flow), reduce traffic accidents

- Electric vehicles - reduce GHG emissions AND saves on fuel costs, improves air quality
Electric Vehicles

EV adoption is rapidly increasing

Charging infrastructure and policies need to evolve as demand shifts

- Different needs in rural vs urban charging sites

Co-benefits of EVs

- Improve air quality
- Lower fuel costs
- Reduced GHG emissions
Integrating renewable energy into the landscape

Are there opportunities to incorporate wind and solar generation into transportation systems?

Example: Evansville, IN regional airport is currently building the country’s largest parking canopy solar installation.

Policies and ordinances to support or restrict renewables in the landscape are evolving and vary by location. Watch this space!
Resources
New Resources from Purdue Extension

A new series from Purdue Extension aims to help community and regional planners understand and prepare for climate change.

Topics include

- Communication strategies
- Past & future climate summary
- Sustainable land use (forthcoming)
- Managing stormwater (forthcoming)

Access resources from the Purdue University Extension Education Store (keyword: climate change).
Tipping Point Planner - Purdue Extension

Facilitated web-based program that allows planners to work with their community to develop watershed action plans.

Innovative visualization tools help communities understand links between land use and water quality & prioritize natural resource assets.

https://tippingpointplanner.org
We live in times of rapid CHANGE.

Are we nimble?
Are we looking ahead?
Are we part of the solution?
Stay informed, stay connected

http://IndianaClimate.org

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Advancing sustainable, electrified transportation

A new research center, co-led by Purdue University, is developing new infrastructure that facilitates widespread adoption of electric vehicles. The center is named **ASPIRE** – Advancing Sustainability through Powered Infrastructure for Roadway Electrification.

**The goal:**
Eliminate vehicle range and charging as obstacles for all types of vehicles
Rain vs Snow

Percent of precipitation falling as snow (Nov - Mar)

- **St. Joseph County, Indiana**
  - Historical: 39
  - 2020s: 32
  - 2050s: 31
  - 2080s: 25

- **Vanderburgh County, Indiana**
  - Historical: 15
  - 2020s: 10
  - 2050s: 8
  - 2080s: 7

- **Marion County, Indiana**
  - Historical: 22
  - 2020s: 15
  - 2050s: 15
  - 2080s: 11

"Historical" is an average for the period 1915 to 2013. "2020s" represents the average 30-year future period 2011 to 2040. "2050s" represents the average 30-year period 2041 to 2070. "2080s" represents the 30-year period 2071 to 2100.