GHG Emissions Comparison Between EV and Biofuels

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UIC

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May 2020

Challenge in Understanding GHG Emissions

- EVs have zero direct emissions
- Ethanol is a biogenic fuel using short-cycle carbon
- Emission comparisons need to be made on a life cycle basis
- Wide range of resource mixes and vehicle efficiency parameters affects comparison

GHG Emissions Metric

- The unit to quantify the GHG emissions of a liquid fuel is generally stated as the mass of carbon dioxide equivalent (including carbon dioxide, nitrous oxide, and methane) emitted per energy unit of fuel.
- The common unit of this carbon intensity (CI) is gCO_2e/MJ. The diagram below details the life cycle emissions modeling boundaries for corn ethanol.
- For EV vehicles we calculate the life cycle emissions in gCO_2e/MJ by using EER (Energy Economy Ratio) which allows to represent the electricity on a gasoline mileage equivalent basis. This is the methodology employed in the California LCFS market.

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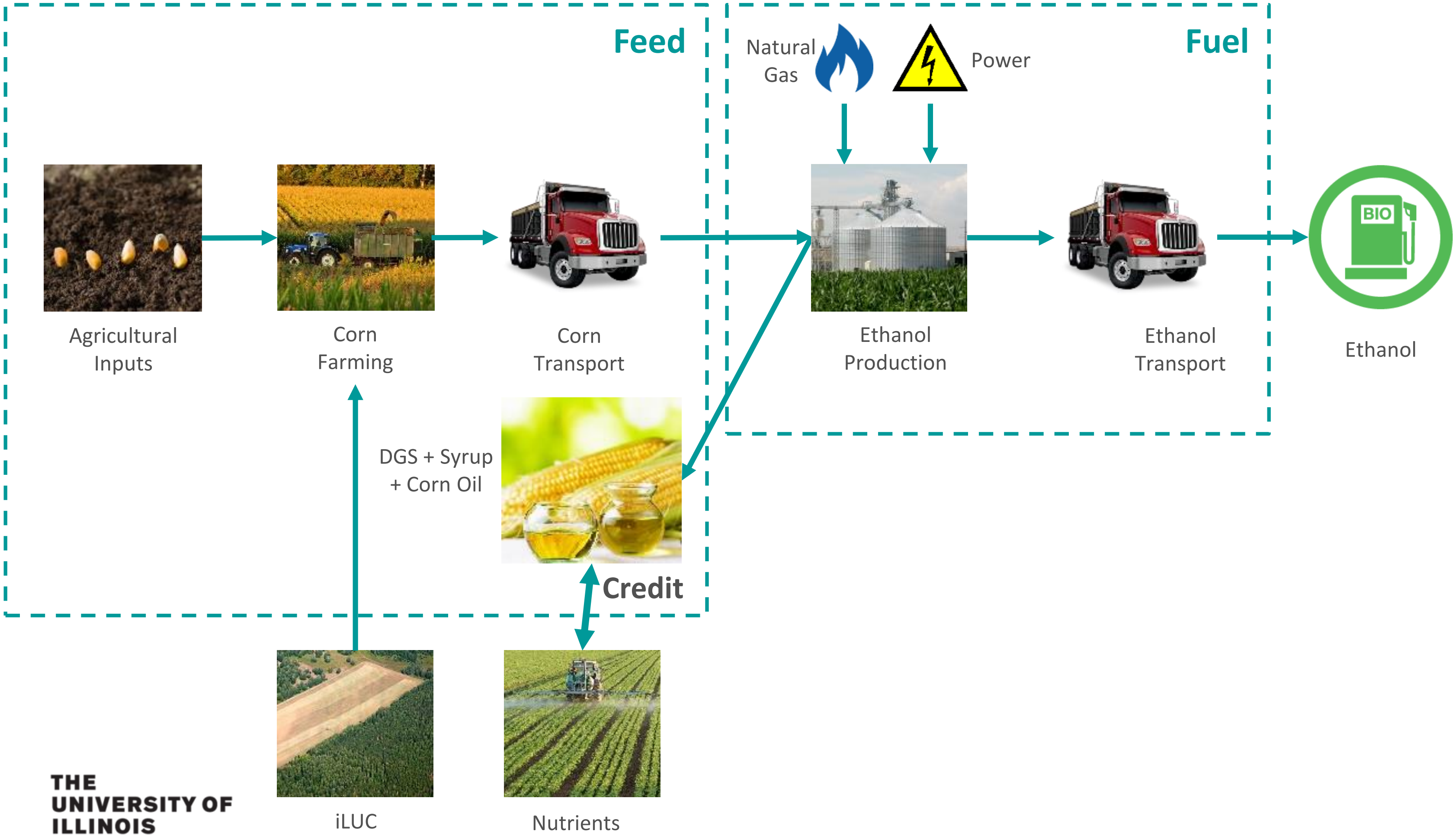
Life Cycle Boundaries of Corn Ethanol Production



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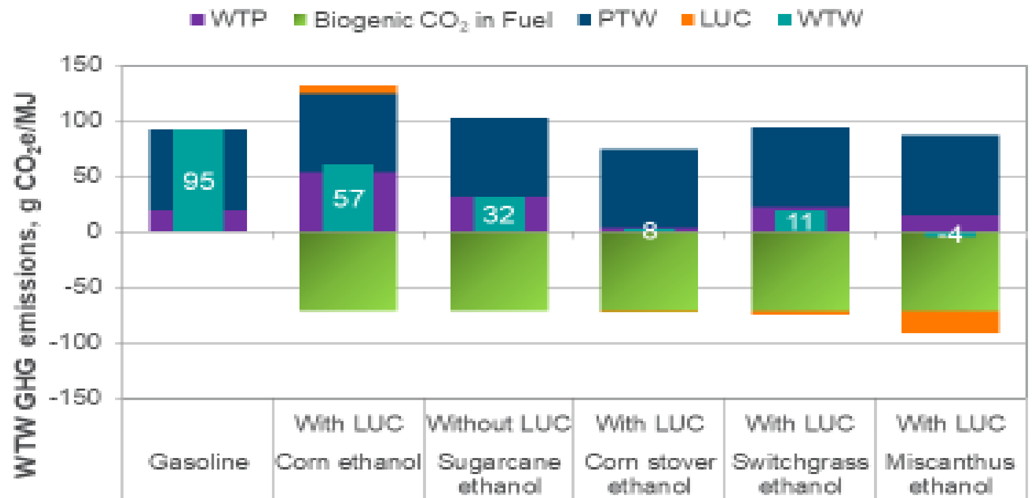
Comparison of Life Cycle GHG Emissions for Ethanol from Different Feedstocks <u>Compared to Gasoline</u>

Well to Wheel Emissions WTW	Gasoline	Corn Ethanol	Stover Ethanol
	95 gCO_2/MJ	57 gCO_2/MJ	8 gCO_2/MJ

GREET life-cycle GHG emissions of ethanol: feedstock is a main driver



Source: Michael Wang 2019; Argonne National Laboratory Transportation Group; Developer of the GREET Life Cycle Model

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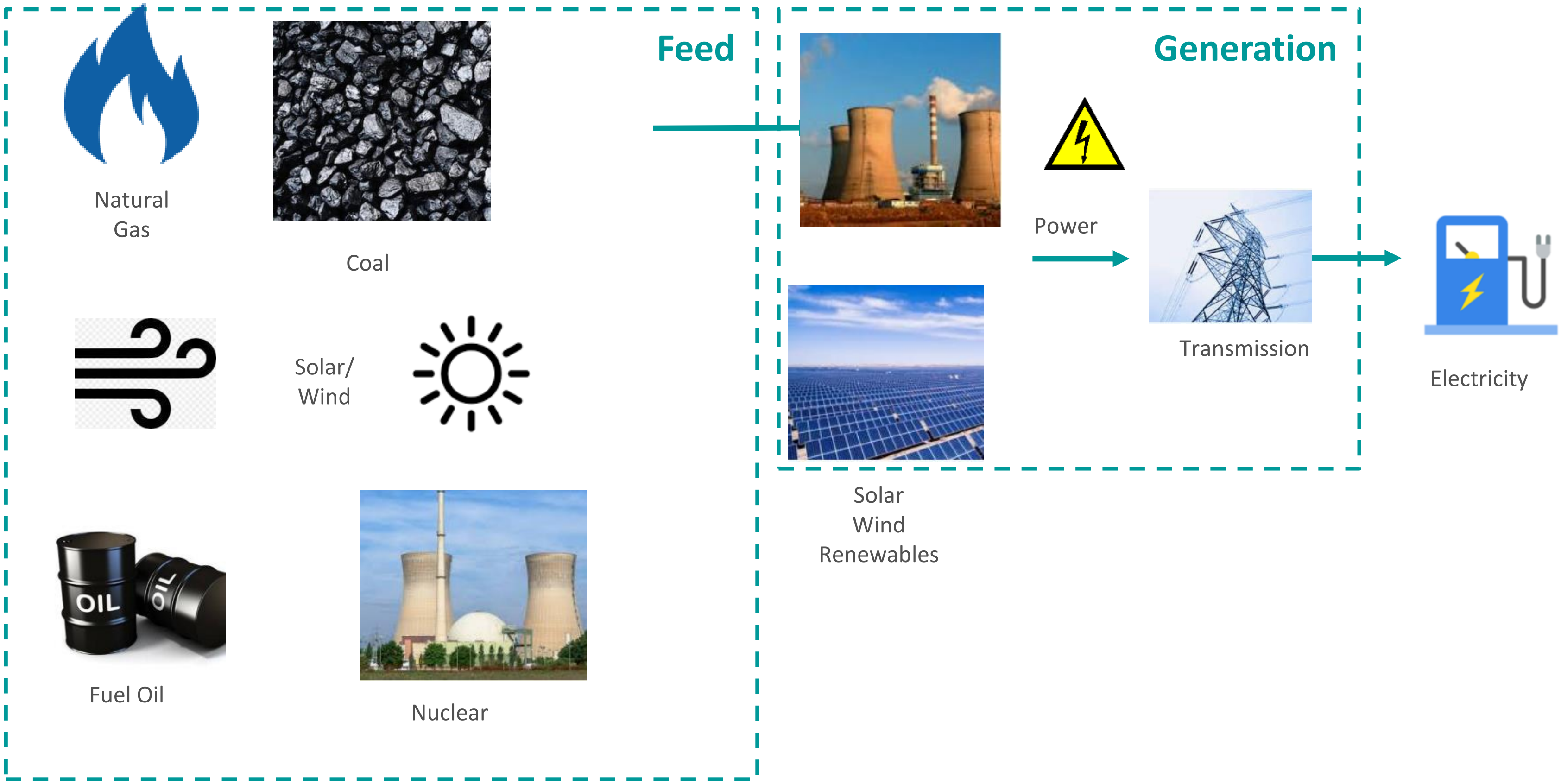
Life Cycle Boundaries of Electric Power to EVs



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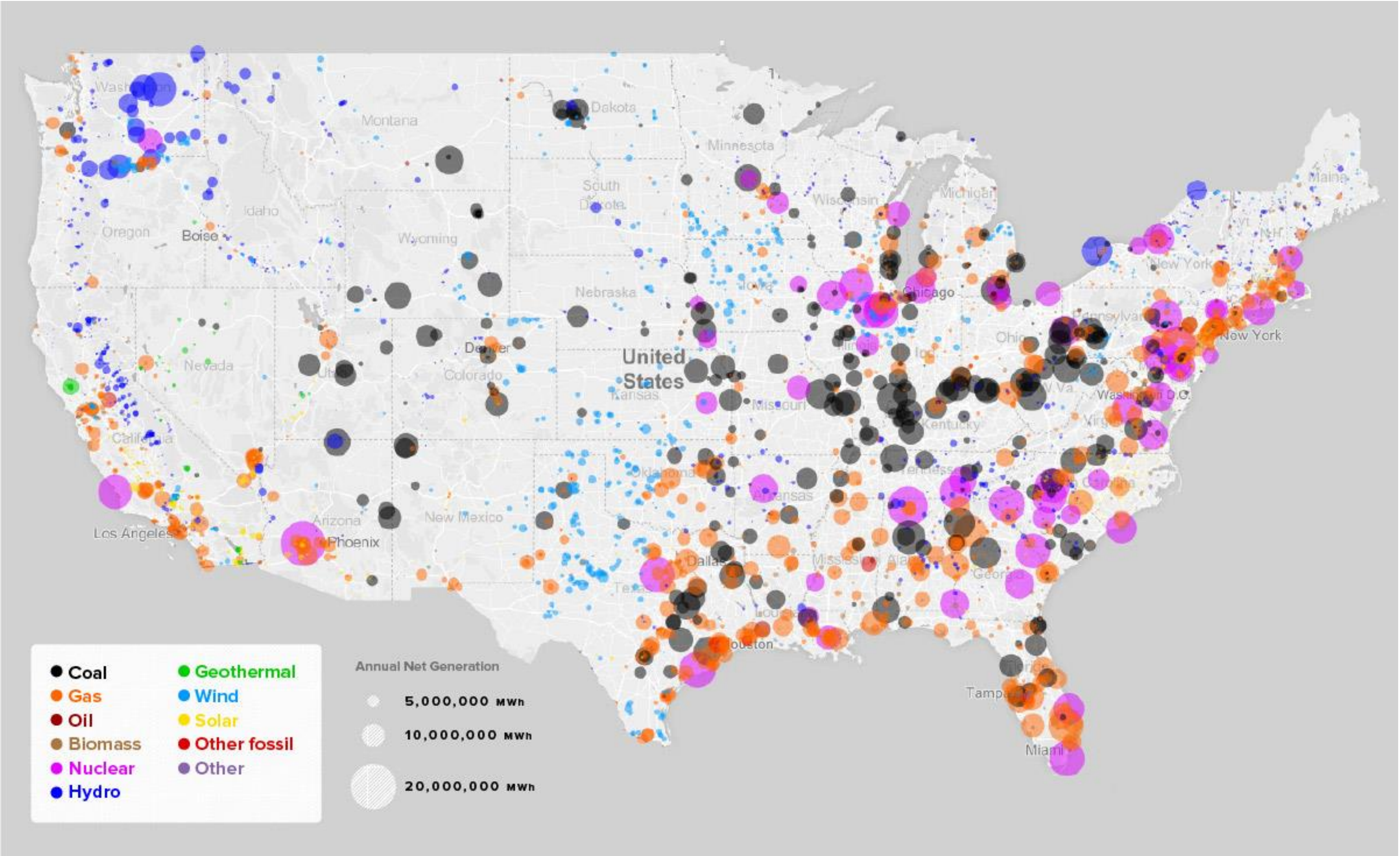
Electric Generation Mix

- Midwest is dominated by nuclear, coal, gas



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Renewable Utility Scale Resources: Solar

- Midwest is not ideal for solar

Source: "Utility Scale Solar Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States – 2018 Edition"; Authors: Mark Bolinger, Joachim Seel; Lawrence Berkeley National Laboratory

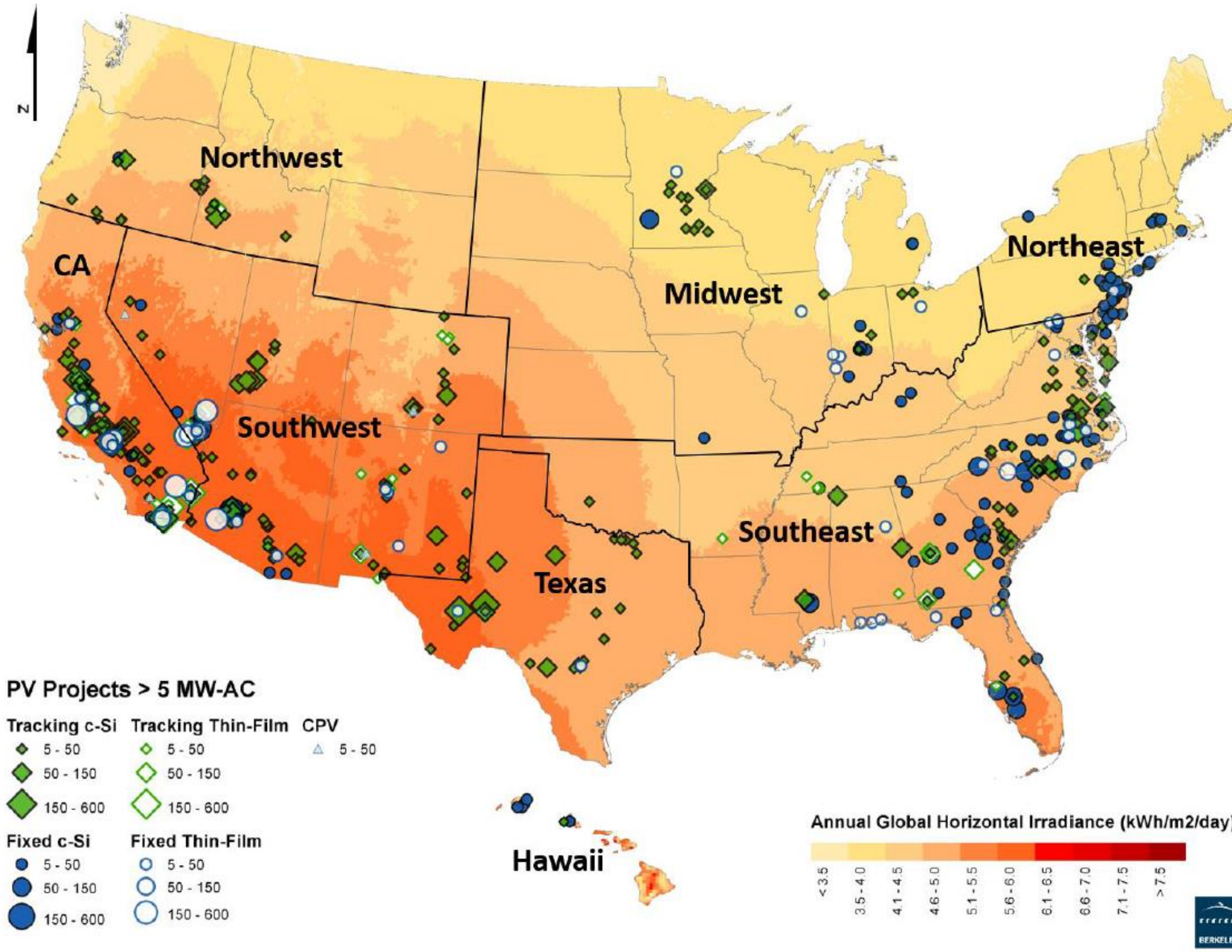

Figure 3. Map of Global Horizontal Irradiance (GHI) and Utility-Scale PV Projects

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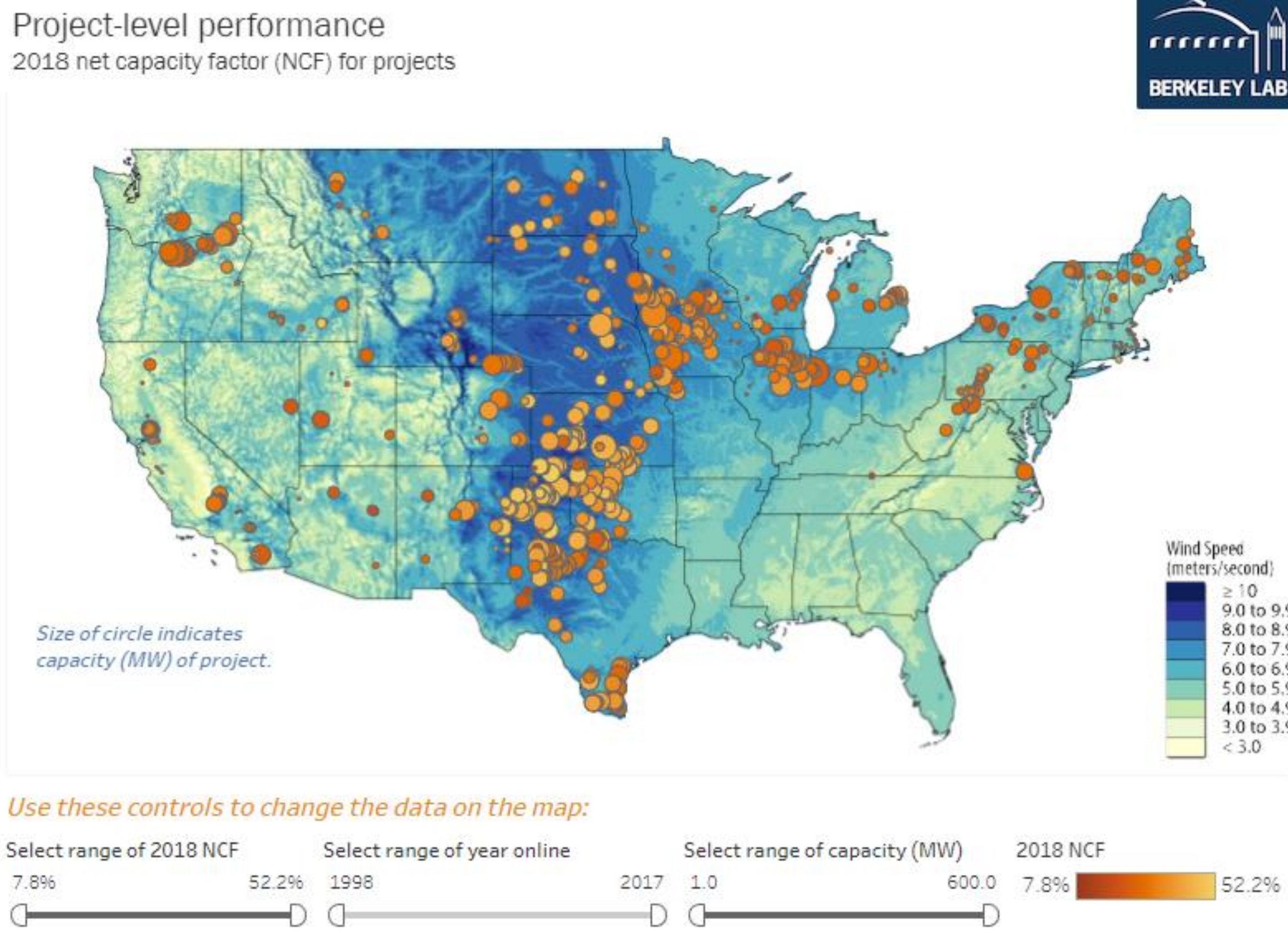
Renewable Utility Scale Resources: Wind

- Within Corn Belt, only the western part of the corn belt provides wind resources



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Electric Vehicles

- EV Vehicle Life Cycle GHG emissions depend on the Resource Mix and Emissions Rates of the Electricity Grid
- Emissions of Key Midwestern States (lbs/MWh):

MO:	1,712
IL:	818
IA:	1,077
IN:	1,748
KY	1,835
MN	1,003
SRMW	1,676
CA	**422**

eGRID Summary Tables 2018

Introduction

This document provides eGRID2018 data summary tables. The tables include subregion and state-level emission rates and resource mix as well as grid gross loss values. Please note that the tables presented here only show a subset of the eGRID2018 data. The entire dataset is in the eGRID2018 Excel file available on the eGRID website.

Table of Contents

Table	Description
1	Subregion Output Emission Rates
2	Subregion Resource Mix
3	State Emissions and Output Emission Rates
4	State Resource Mix

3. State Output Emission Rates (eGRID2018)

State	Total output emission rates (lb/MWh)						
	CO_2	CH_4	N_2O	CO_2e	Annual NO_x	Ozone Season NO_x	SO_2
AK	907.5	0.067	0.0[illegible]9	912.0	6.0	6.1	
AL	864.0	0.063	0.[illegible]09	868.3	0.4	0.4	
AR	1,211.3	0.114	0.017	1,219.1	0.7	0.7	
AZ	967.0	0.077	0.011	972.2	0.6	0.6	
CA	420.4	0.027	0.003	422.0	0.4	0.3	
CO	1,362.6	0.130	0.019	1,371.4	0.7	0.7	
CT	506.4	0.050	0.006	509.5	0.3	0.3	
DC	438.9	0.022	0.002	440.1	4.2	4.6	
DE	898.3	0.034	0.004	900.4	0.4	0.4	
FL	943.3	0.068	0.009	947.7	0.4	0.4	
GA	926.4	0.079	0.012	931.9	0.4	0.3	
HI	1,513.3	0.162	0.025	1,524.8	4.7	4.8	
IA	1,069.9	0.109	0.016	1,077.4	0.8	0.8	
ID	160.2	0.007	0.001	160.7	0.2	0.2	
IL	812.9	0.083	0.012	818.5	0.4	0.4	
IN	1,736.5	0.176	0.025	1,748.5	1.6	1.1	
KS	989.3	0.107	0.016	996.6	0.7	0.8	
KY	1,822.2	0.198	0.029	1,835.7	1.[illegible]	1.1	
LA	836.0	0.049	0.007	839.4	0.7	0.8	
MA	727.6	0.099	0.013	733.8	0.6	0.5	
MD	835.7	0.081	0.011	841.2	0.4	0.3	
ME	257.7	0.154	0.022	268.2	0.6	0.6	
MI	1,108.3	0.111	0.0[illegible]6	1,115.8	0.7	0.7	
MN	995.4	0.117	0.01[illegible]	1,003.1	0.7	0.7	
MO	1,699.6	0.195	0.028	1,712.9	1.3	0.8	

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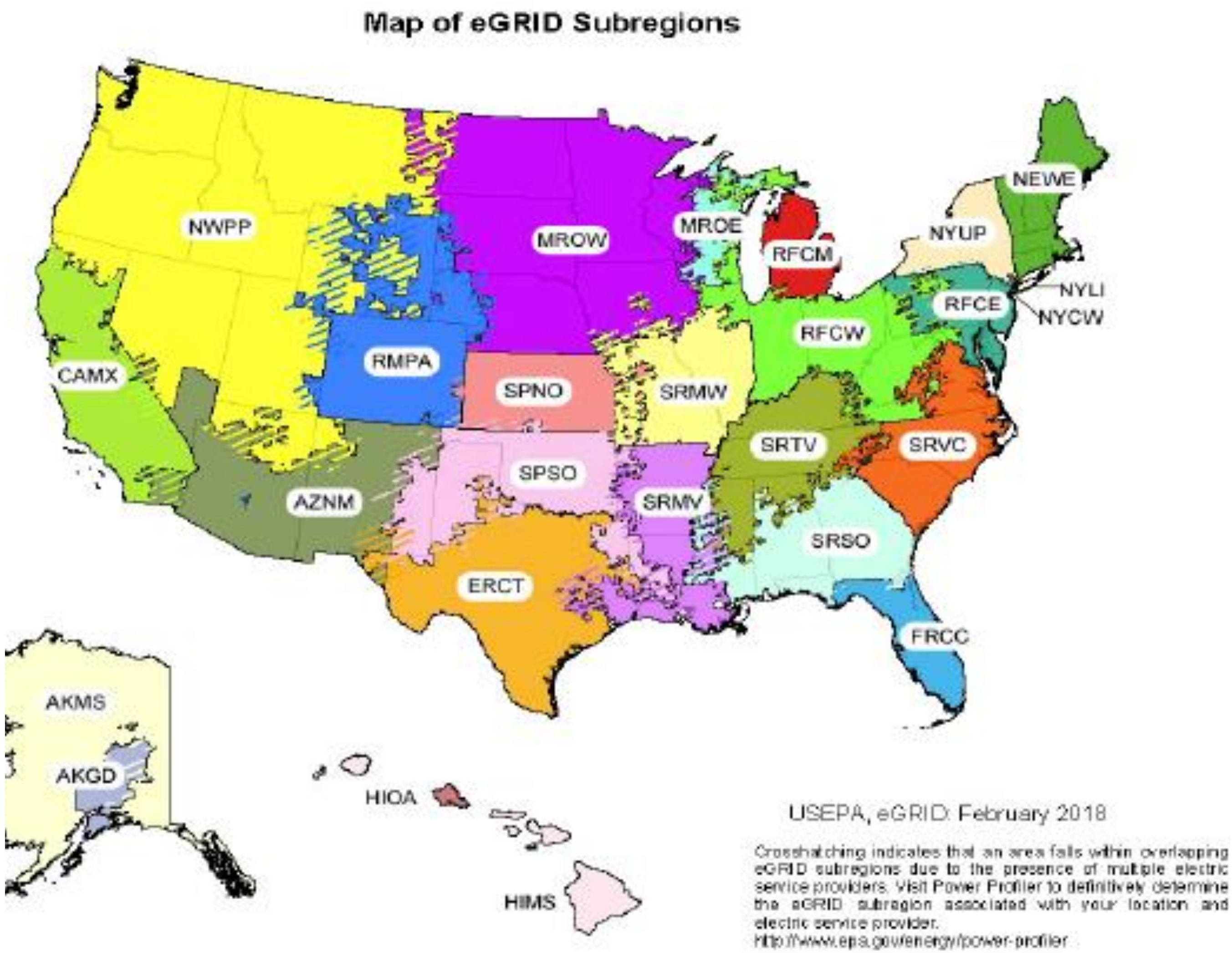
eGrid Electricity Regions

- Example: SRMW Grid covers large regions of Missouri, Illinois, and Southern Iowa



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Study Details

- We modeled life cycle greenhouse gas emissions with different parameterization of the US Department of Energy GREET model
- We considered different ethanol fueled vehicle: E15 (15% ethanol by volume), High Octane Fuel (HOF), E25 (25% ethanol by volume), E85 (85% ethanol by volume, Plug-in Hybrid Electric Vehicle (PHEV) fueled with E85.
- We considered different EV efficiencies during winter vs summer driving
- We considered different utility grid regions: CA vs. Midwest
- We considered different carbon intensity values for ethanol:
    - Current corn ethanol in GREET (57gCO_2/MJ)
    - USDA forward looking corn carbon intensity (48 gCO_2/MJ)
    - Corn stover cellulosic ethanol value in GREET (8gCO_2/MJ)

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Study Details

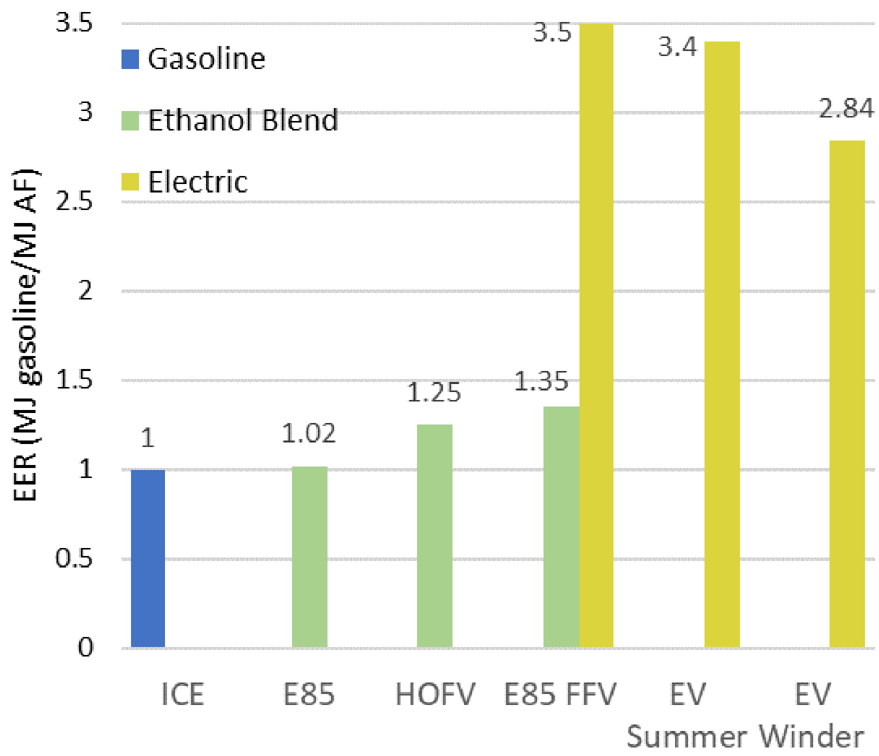
Assumptions behind the Delineation and Marginality of the Electricity Grid are very important and substantially drive the modeling results!

- MW LCFS
  - EV, E15, E85 PHEV
  - State Average Generation Mix
  - Utility Average Mix
- This Study
  - EV, E15, HOF, E85 PHEV, Summer/Winter
  - Regional Generation Mix
  - Marginal Power Generation

Energy Economy Ratio

Energy Economy

- VISION2015
- NAS Transitions Report
- ANL C2G Analysis
- MTE (EPA and NHTSA Midterm Evaluation
- EPA Fuel Economy Guide
- CA ARB
- 1.5 kW Winter space heat



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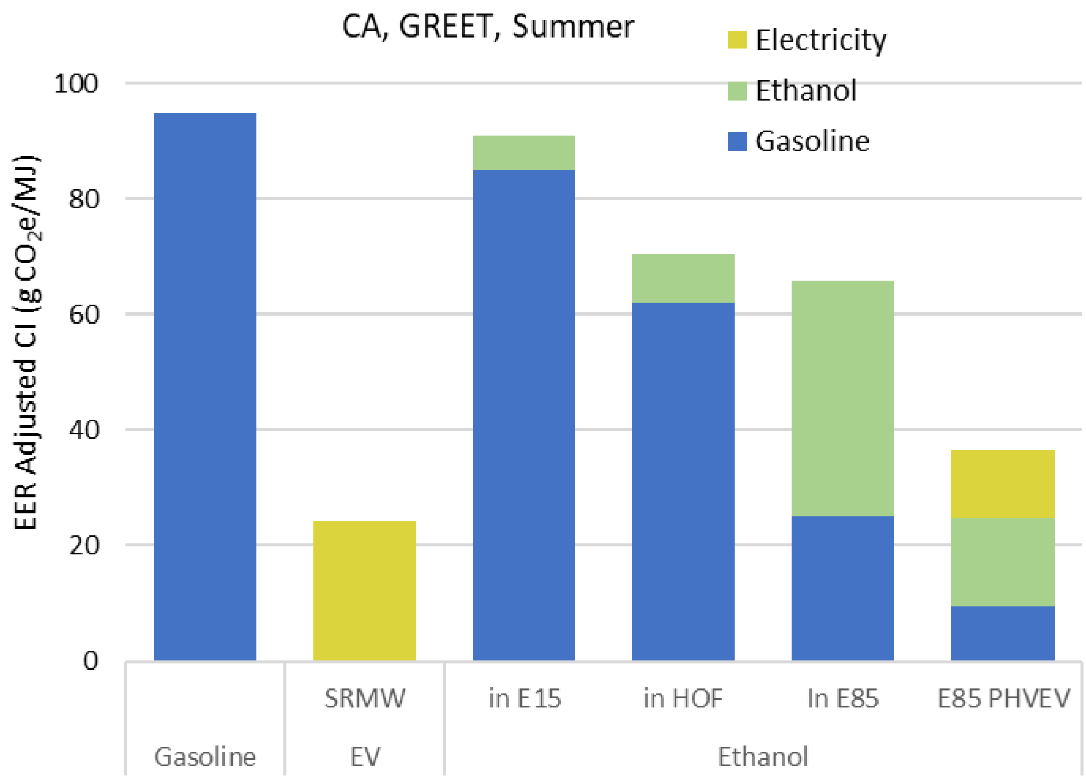
EV vs Biofuels: California Electric Utility Charging

- For California EV is the cleaner option



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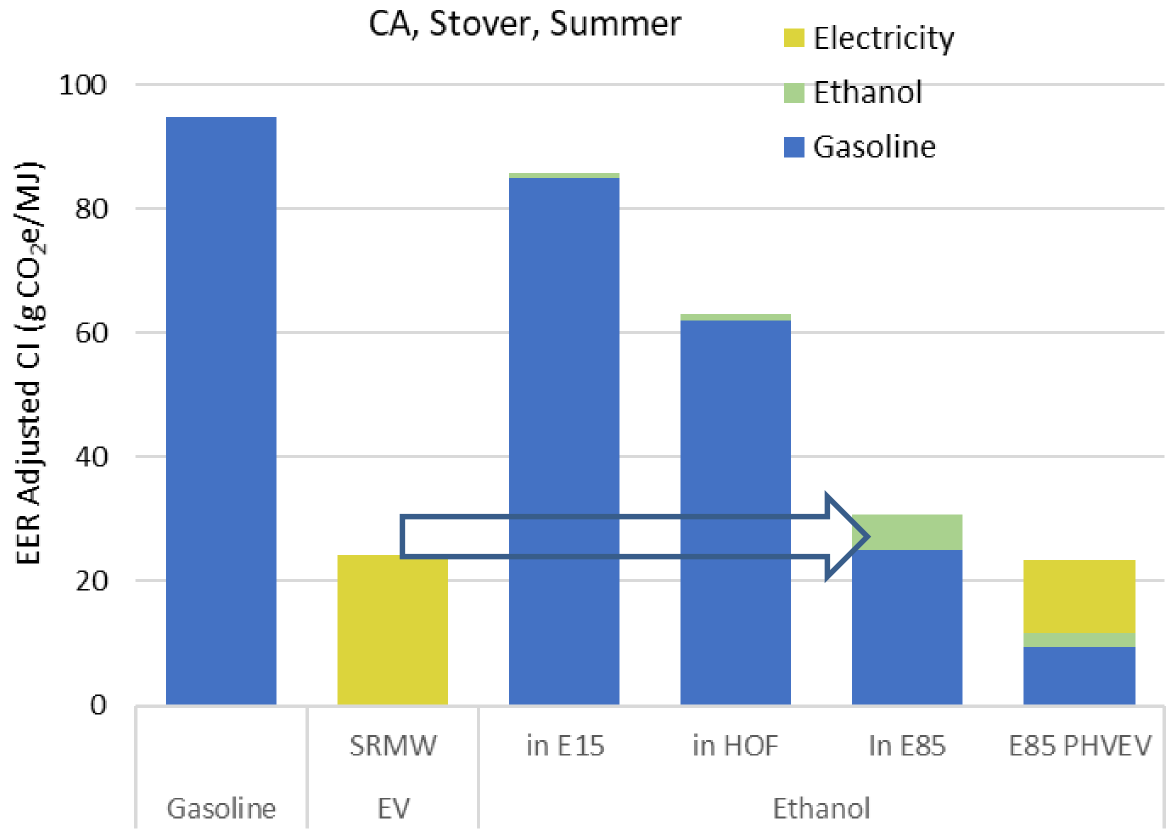
EV vs Biofuels: California Electric Utility Charging

- But Cellulosic Stover Ethanol is Competitive with EVs even in California



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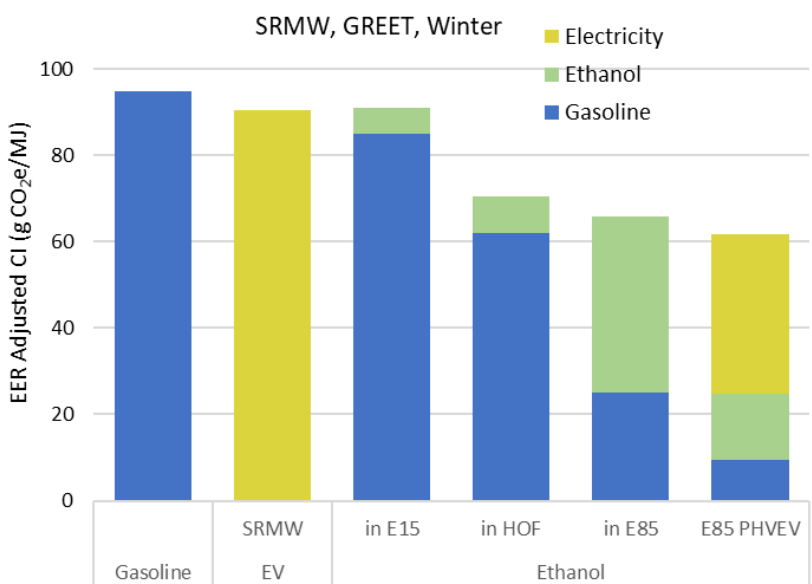
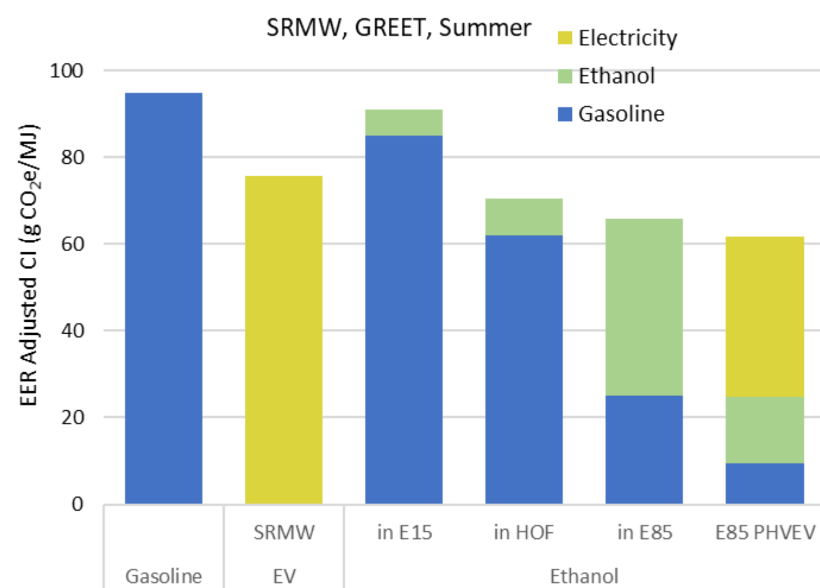
EV vs Biofuels: Midwest Electric Utility Charging

In Midwest: Ethanol is the Cleaner Fuel Option

- In Winter Driving Conditions: E15, HOF, E85 and PHEV cleaner than EV
- In Summer Driving Conditions: HOF, E85, PHEV are cleaner than EV and PHEV with high ethanol blends
- PHEV vehicles on E85 have the added advantage of making use of limited battery resources and providing space heating from IC engine.





2017 US Department of Agriculture Study on GHG Emissions of Corn Ethanol

- USDA report, titled "A Life-Cycle Analysis of the Greenhouse Gas Emissions of Corn-Based Ethanol," finds that greenhouse gas (GHG) emissions associated with producing corn-based ethanol in the United States are about <u>43 percent lower than gasoline</u>

- "GHG profile of corn ethanol will be almost <u>50 percent lower than gasoline in 2022 if current trends in corn yields, process fuel switching, and improvements in trucking fuel efficiency continue"</u>
  - <u>Note: This would result in 47.5 gCO_2e/MJ</u>

Analysis relies heavily on and cites repeatedly:
J. Dunn, Z. Qin, S. Mueller, H-Y. Kwon, M. Wander, M. Wang ; Carbon Calculator for Land Use Change from Biofuels Production (CCLUB) Manual; October 07, 2016; https://greet.es.anl.gov/publication-cclub-manual

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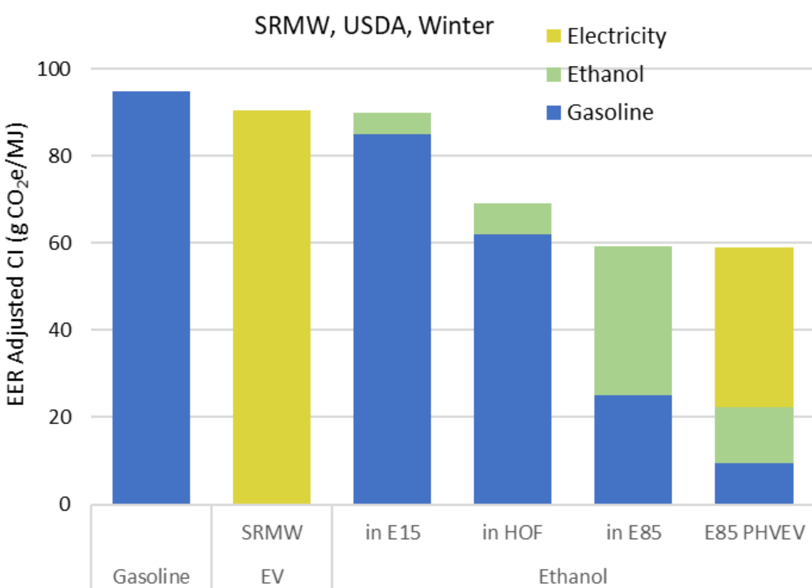
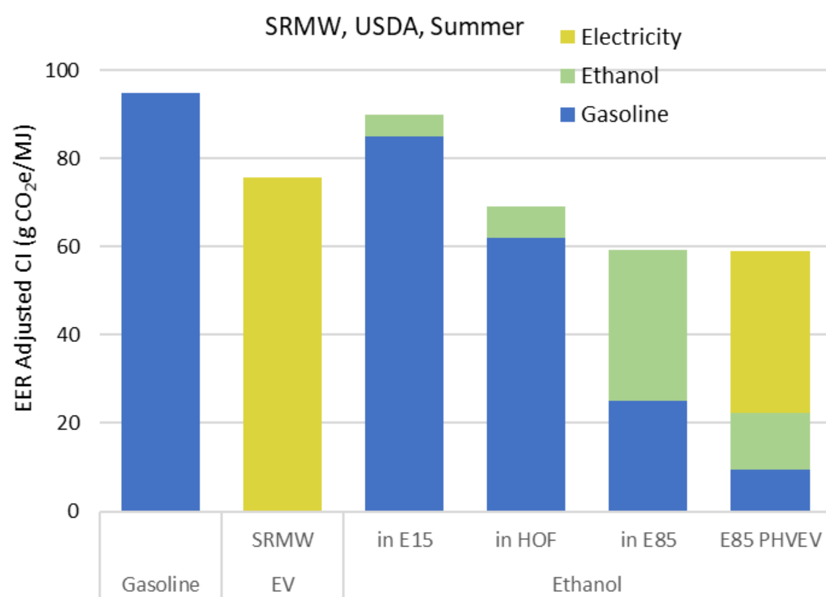
EV vs. Biofuels: Using latest USDA Life Cycle Data for Ethanol with Efficiency Improvements during Ag and Biorefining

- All higher ethanol blends (greater than E15) are cleaner than EVs





Socio-Economic-Environmental Considerations

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Battery Production: Lithium and Cobalt Considerations

McKinsey Consulting "Lithium and cobalt: A tale of two commodities"; June 2018 Report https://www.mckinsey.com/industries/metals-and-mining/our-insights/lithium-and-cobalt-a-tale-of-two-commodities:

- "More than 95 percent of the world's lithium supply occurs as a primary product in the form of brines or hard-rock ores, with a global production footprint including Australia, China, and Latin America."
- "Conversely, less than 10 percent of cobalt supply occurs as a primary product, with the remainder produced as a by-product of primarily copper and nickel mines and **more than 65 percent of global production concentrated in the Democratic Republic of the Congo (DRC). "**
- "Clearly, **cobalt represents the most pressing challenge**, and users will need to look at their battery R&D to find diversifying technologies that will avoid the potentially supply-constrained raw material. This strategy is already taking place, with the development of the NMC 811 battery and initiatives to use even less cobalt in future batteries. "

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Battery Production: Lithium and Cobalt Considerations

The Guardian Wed 18 Dec 2019 03.00 EST ’How the race for cobalt risks turning it from miracle metal to deadly chemical’

- “If the prophets of technology are to be believed, the best hope for solving the climate crisis is ever more efficient batteries. But the race to produce enough materials for this energy-storage revolution is creating a host of other environmental problems, as cobalt-producing nations like the Democratic Republic of the Congo, Zambia and Cuba are discovering.”
- “Lung disease and heart failure have been linked to high levels of this element, while the mines that produce it are **blamed for devastated landscapes, water pollution, contaminated crops and a loss of soil fertility.** Scientists are also investigating a possible link to cancer.”

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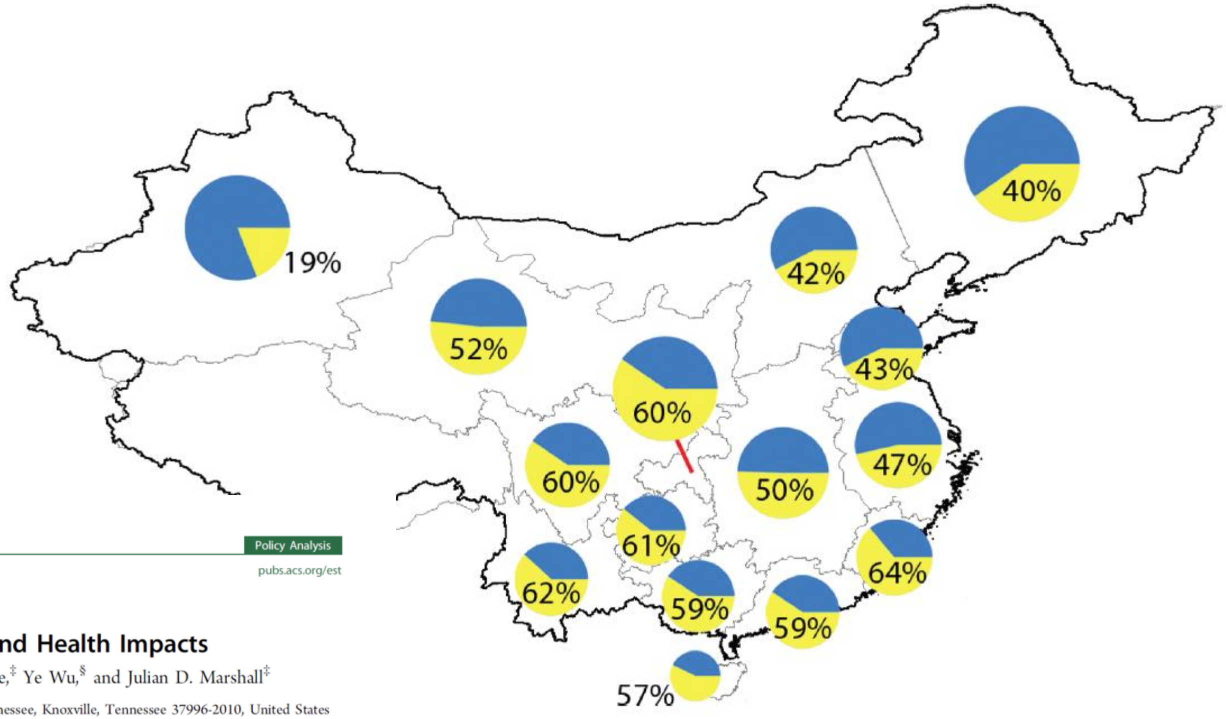
Shift of Emission to Non Urban Areas



Environmental Science & Technology
Policy Analysis
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Electric Vehicles in China: Emissions and Health Impacts

Shuguang Ji,[†] Christopher R. Cherry,[*,†] Matthew J. Bechle,[‡] Ye Wu,[§] and Julian D. Marshall[‡]

[†]Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, Tennessee 37996-2010, United States
[‡]Department of Civil Engineering, University of Minnesota, Minneapolis, Minnesota 55455, United States
[§]School of Environment, Tsinghua University, Beijing 100084, P R China

“Urban Use of Electric Vehicles rather than Conventional Vehicles typically moves the emissions (and, exposure and health impacts) to more rural locations

Figure 6. Portion of primary $PM_{2.5}$ health impacts from EGUs experienced by rural versus urban populations. Icon area is proportional to $PM_{2.5}$ emission factor (g km^{-1}) for an EV in that power grid. Numbers identify nonurban mortality impact proportions, i.e., of the total mortality impacts attributable to primary $PM_{2.5}$ from electricity generation – here, owing to urban use of EVs. Urban use of EVs rather than CVs typically moves the emissions (and, exposures and health impacts) to more rural locations. In general, a substantial proportion – on average, about half – of the emissions from urban use of EVs are inhaled by nonurban populations.

Shift of Emission to Non Urban Areas

- "For the first time at such a large scale, vehicle emissions are being transferred to power plants, potentially yielding dramatic exposure reduction."
- "In some but not all cases, this transfer of emissions is expected to improve overall public health. **However, this shift also transfers impacts** to nonusers of the urban EVs, including potentially **to low-income rural populations**."
- "With Conventional Vehicles, urban residents produce emissions and also bear the impacts (though causing within-urban distributional impacts)."

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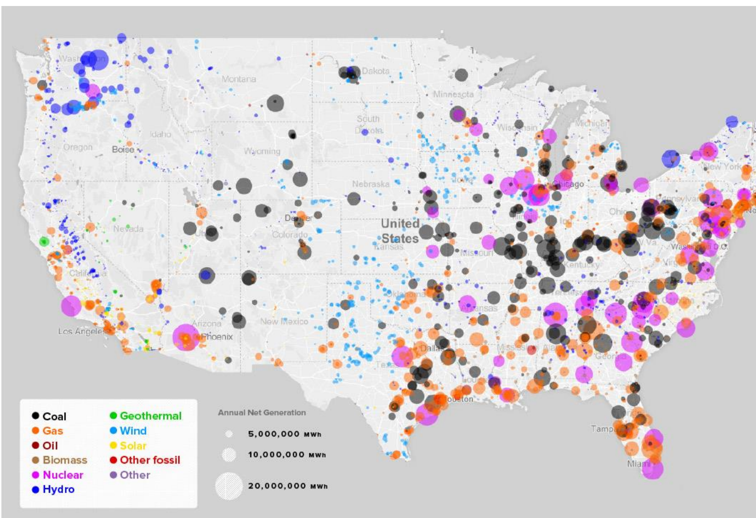
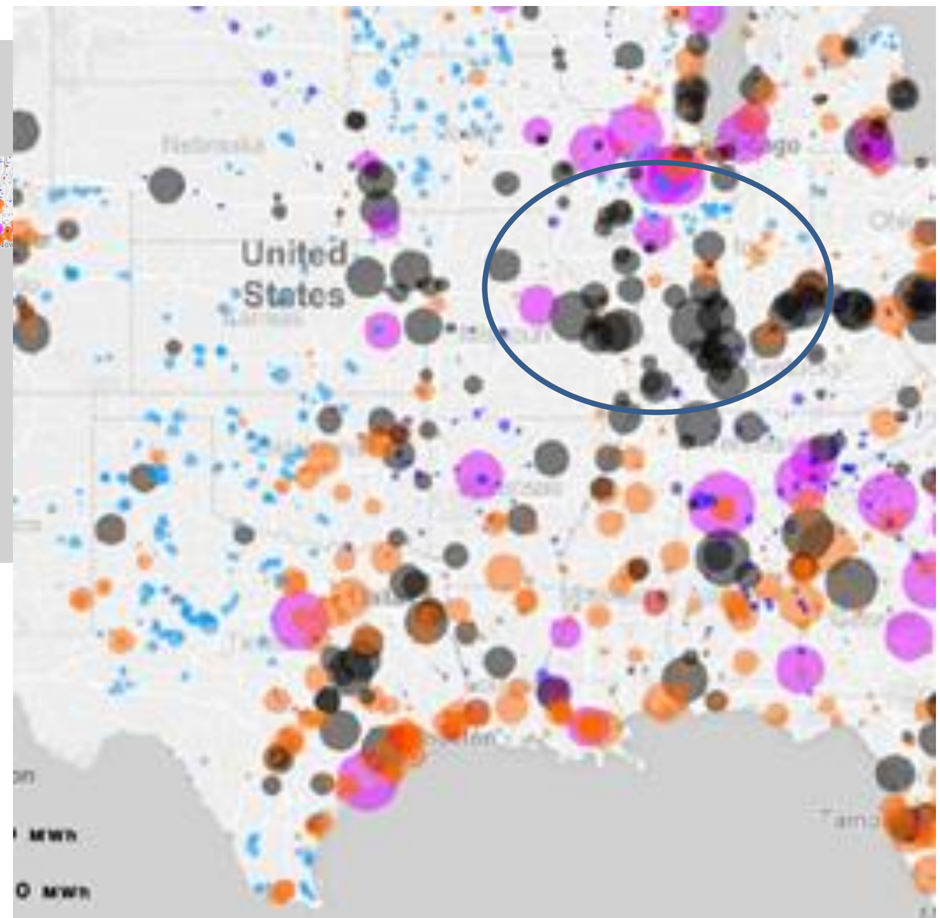
Shift to Rural Areas

- Midwest power plants in rural areas as well





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Environmental Equity Implications

BUSINESS 9/20/19

Electric cars: Low earners may never get to drive one

Already struggling to keep aging vehicles on the road, low-wage workers could be forgotten in the electomobility age. Climate crisis or not, policymakers face increasing pressure to ensure everyone can stay mobile.

https://www.dw.com/en/electric-cars-low-earners-may-never-get-to-drive-one/a-50517095

Joint Report by Sierra Club and Plug In America Promotes EV Vehicles but sees barriers for low income families.
Model State & Local Policies to Accelerate Electric Vehicle Adoption POLICY TOOLKIT Version 2.0 June 2018;

https://www.sierraclub.org/sites/www.sierraclub.org/files/blog/EV%20Policy%20Toolkit.pdf

EXPANDING EQUITY AND ACCESS

Though EV deployment has increased in recent years, people from disadvantaged communities are more likely to encounter the strongest barriers to EV adoption. EVs are much more affordable than gas-powered cars when factoring in lowered maintenance and fuel costs, but today, the up-front price tag can still be larger than gas-powered cars. For low-income families, the $7,500 federal tax credit doesn't fully remove the economic barrier many people face when buying or leasing their next car.

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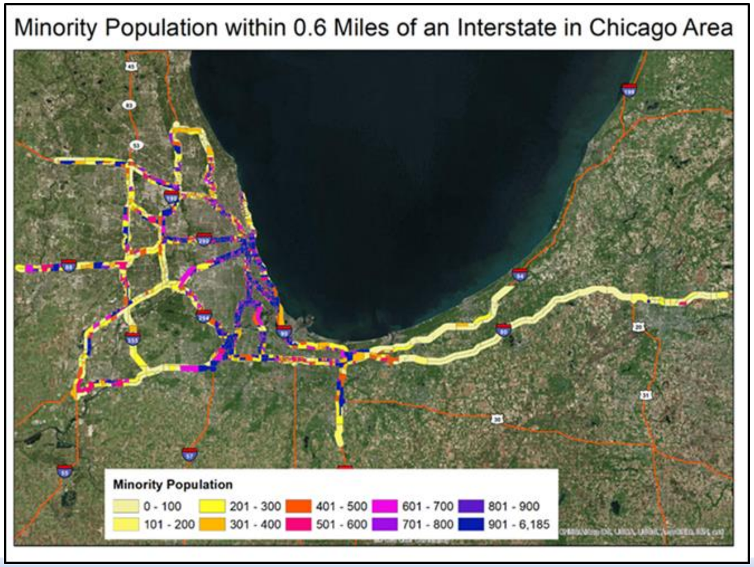
Near Term EV Emissions Savings Only in Higher Income Neighborhoods

Income: EVs may potentially face an Environmental Justice problem: EV proponents promote vehicles based on tailpipe emissions benefits (often ignoring power plant emissions) but **EV adoption in low income neighborhoods may be slower. Clean liquid fuels will benefit these neighborhoods.**

Race: Our air quality modeling has shown that Chicago-area minority populations are over-proportionally exposed to pollutants in the proximity of expressway systems. Ethanol blends which reduce emissions will benefit minority populations

Presented studies are posted on the UIC Bioenergy Website
http://www.erc.uic.edu/biofuels-bioenergy/research27



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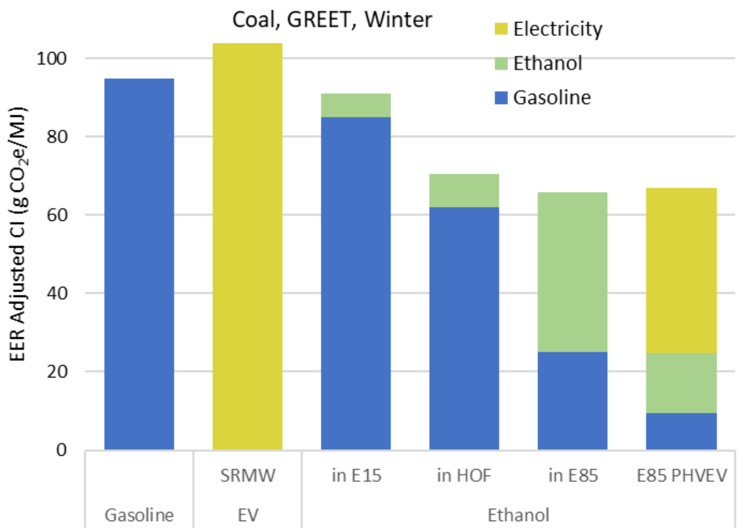
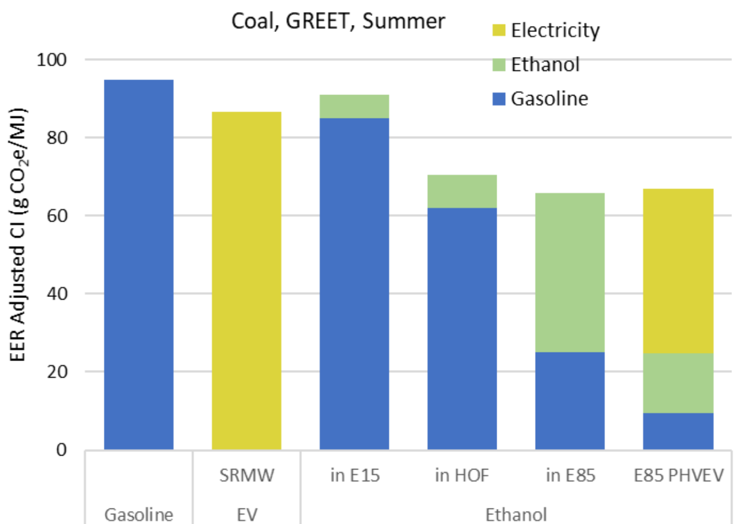
Global Impacts: EVs Will be Coal Cars in Many Regions

- Reuters July 11, 2019: "TOKYO (Reuters) - Japanese utilities will rely on the return of coal-fired power plants from maintenance to meet peak electricity demand this summer, highlighting the country's dependence on the more polluting fuel instead of natural gas.
- Coal-power stations capable of producing 10,437 megawatts (MW) of electricity will be fired up in the next few weeks, a Reuters survey of the companies shows.





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Environmental Benefits of Ethanol Blends Compared to EVs

- We compared the greenhouse gas emissions from Electric Vehicles (EVs) to vehicles fueled by various ethanol-gasoline blends (E15, HOF, E85, PHEV E85). The study focused on a central Midwest Electricity Grid Region.
- Battery only EVs are not the only low emission solution:
  - We find that given the Midwestern electricity grid infrastructure ethanol blends (rather than EVs) in many areas provide the larger greenhouse gas reductions across all studied ethanol blends.
  - Plug-in electric hybrids (PHEV) fueled with E85 make best use of a limited battery resource (smaller battery needed, engine for space heating).
  - In California, corn-based cellulosic ethanol provides the same emissions reductions benefits as EVs.
- For battery only EVs several trade offs exist:
  - Higher levels of battery production with global environmental impacts
  - Transfer of emissions to rural areas
  - Transfer of emissions to low income neighborhoods within cities
  - Globally, in many countries EV vehicles will be "coal cars"

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For Further Questions

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