



UNCERTAINTY AND VARIABILITY IN ACCOUNTING FOR GRID ELECTRICITY IN LIFE CYCLE ASSESSMENT

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**Christopher Weber
Constantine Samaras
Paulina Jaramillo
Joe Marriott**

OUTLINE

- The issue: treatment of electricity emissions in LCA and policy analyses
- Temporal and Geographical Delineations for attributional allocation
- Advice for Protocol/Standard Development

GRID MIXING: WHAT AND WHY?

- In LCA, making or using almost any product involves grid electricity
- Mixture of generation/consumption (and thus, emissions factors) varies in time and space
- **Question at issue: given a consumer of electricity at a given place and time, what emissions should they be allocated?**
 - *In other words*, what is the proper geographic and temporal averaging to utilize for grid electricity?
- Case study of Continental US
 - Large interconnected grid, similar issues in UCTE, emerging China grid

EXAMPLES: WHY DOES IT MATTER?

- Fuel Economy/LCFS for Plug-in Hybrids/EVs
- Border Taxation for Electricity-intensive goods
 - EAF Steel, Aluminum, Glass
- Including electricity in life cycle assessments of products
- Carbon neutrality claims
 - Company wants to be “carbon neutral”, how many offsets must they buy for electricity?
 - Emissions associated with purchased electricity often a large component of company’s “footprint”

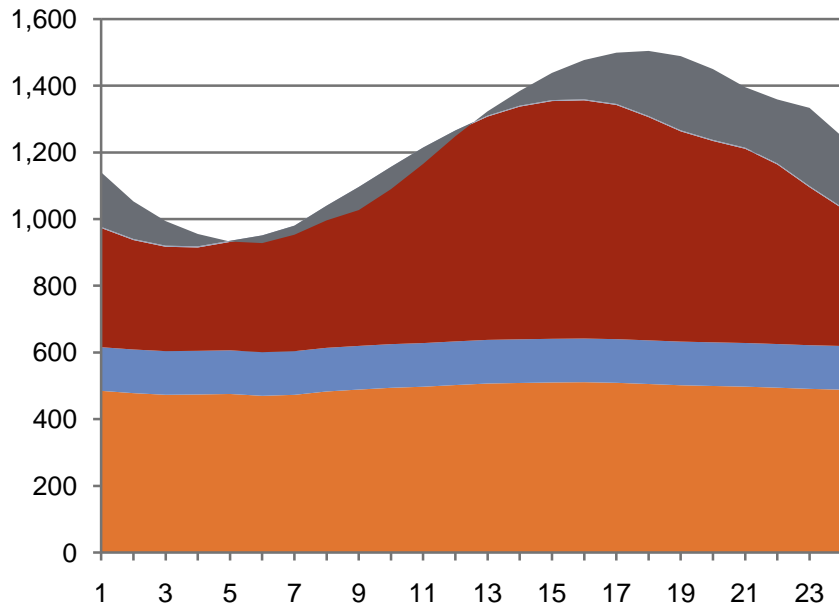
WHAT SAY THE STANDARDS?

- PAS 2050: for electricity and heat delivered via a larger energy transmission system, secondary data that is as specific to the product system as possible (e.g. average electricity supply emission factor for the country in which the electricity is used)
- ISO 14044: for the production and delivery of electricity, account shall be taken of the electricity mix, the efficiencies of fuel combustion, conversion, transmission and distribution losses
- GHG Protocol: NERC Subregion for US, national for all other

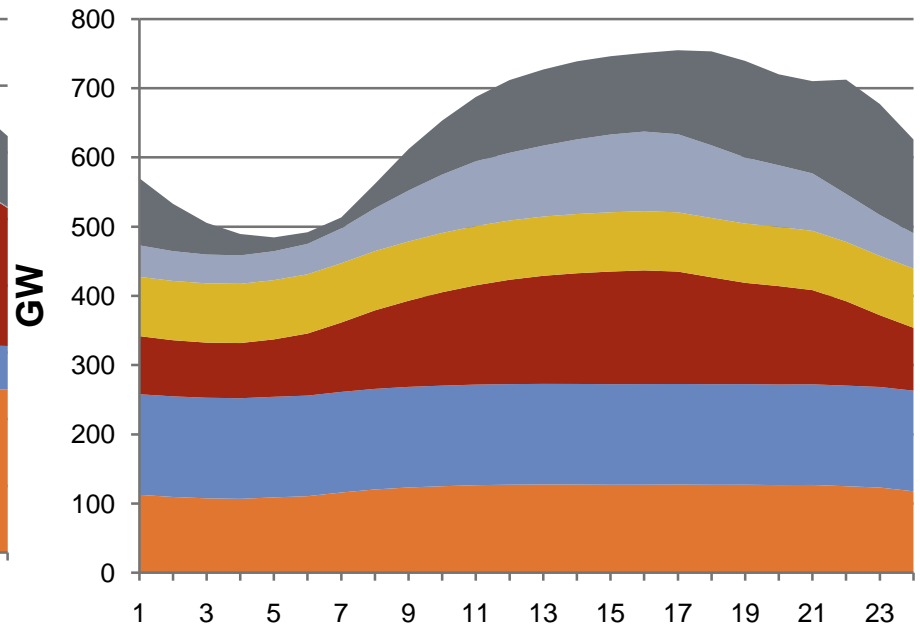
TEMPORAL DIMENSION

- In a single location, grid mixes will vary most
 - Diurnally (peak/non peak mix, solar and wind variance)
 - Seasonally (hydroelectric output, some solar and wind variance)
 - Yearly (capital changes—changes to grid itself, new generators)
- Here we assume yearly averages are time dimension of choice
 - Maybe impractical to match hourly emissions factors and uses
 - Many sustainability accounts and LCAs performed with a single year's production patterns
 - Preliminary analysis shows diurnal variation somewhat small

PRELIMINARY ANALYSIS OF DIURNAL: ERCOT AND NY-ISO DIURNAL PRODUCTION (JULY)



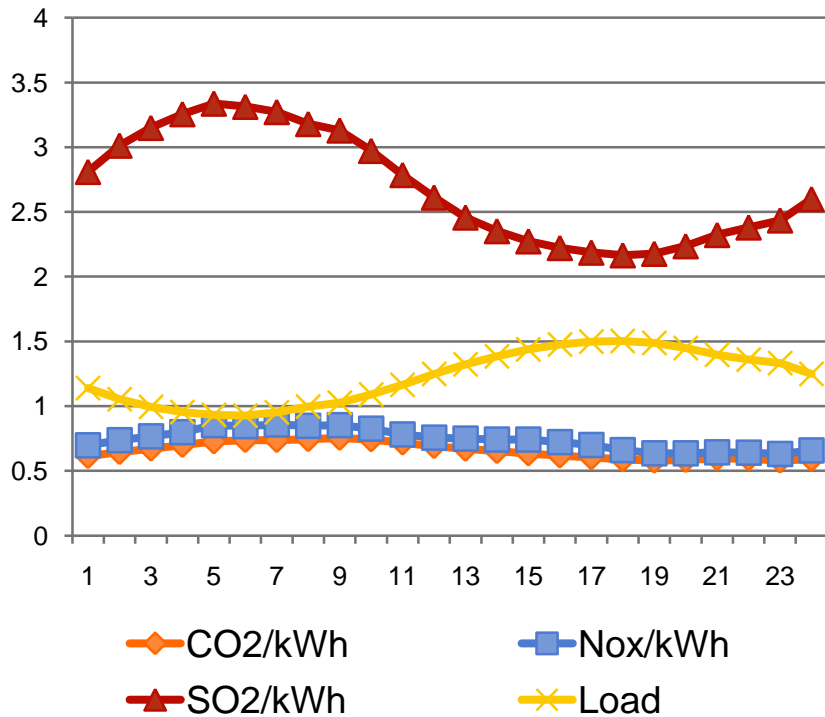
Coal Nuc Gas Hydro Oil Oth/Trade



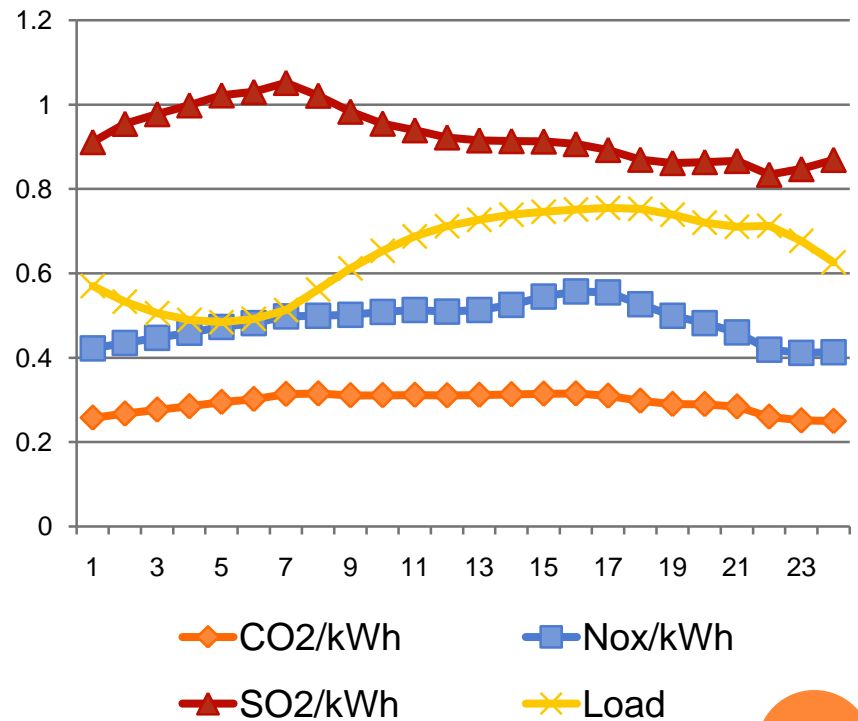
Coal Nuc Gas Hydro Oil Other/Trade

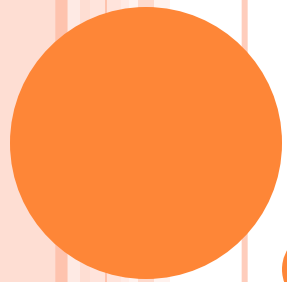
ERCOT AND NY-ISO DIURNAL PRODUCTION (JULY)

ERCOT



NY ISO





GEOGRAPHICAL VARIATION

GEOGRAPHICAL GRID MIXING—HOW IS IT DONE NOW?

- Many databases provide country averages (production and/or consumption), i.e.
 - IEA, GHG Protocol, etc provide production mixes
 - Ecoinvent provides country production and consumption
- Some data for subnational
 - Particularly for US—eGrid subregions, NERC regions, Interconnect, etc
- Some data for multinational
 - Ecoinvent includes European grid data
- What are possible mixes for US?
 - Note only point emissions here, not LCI, LCI (inc grid losses) will increase uncertainty

POLITICAL BORDERS

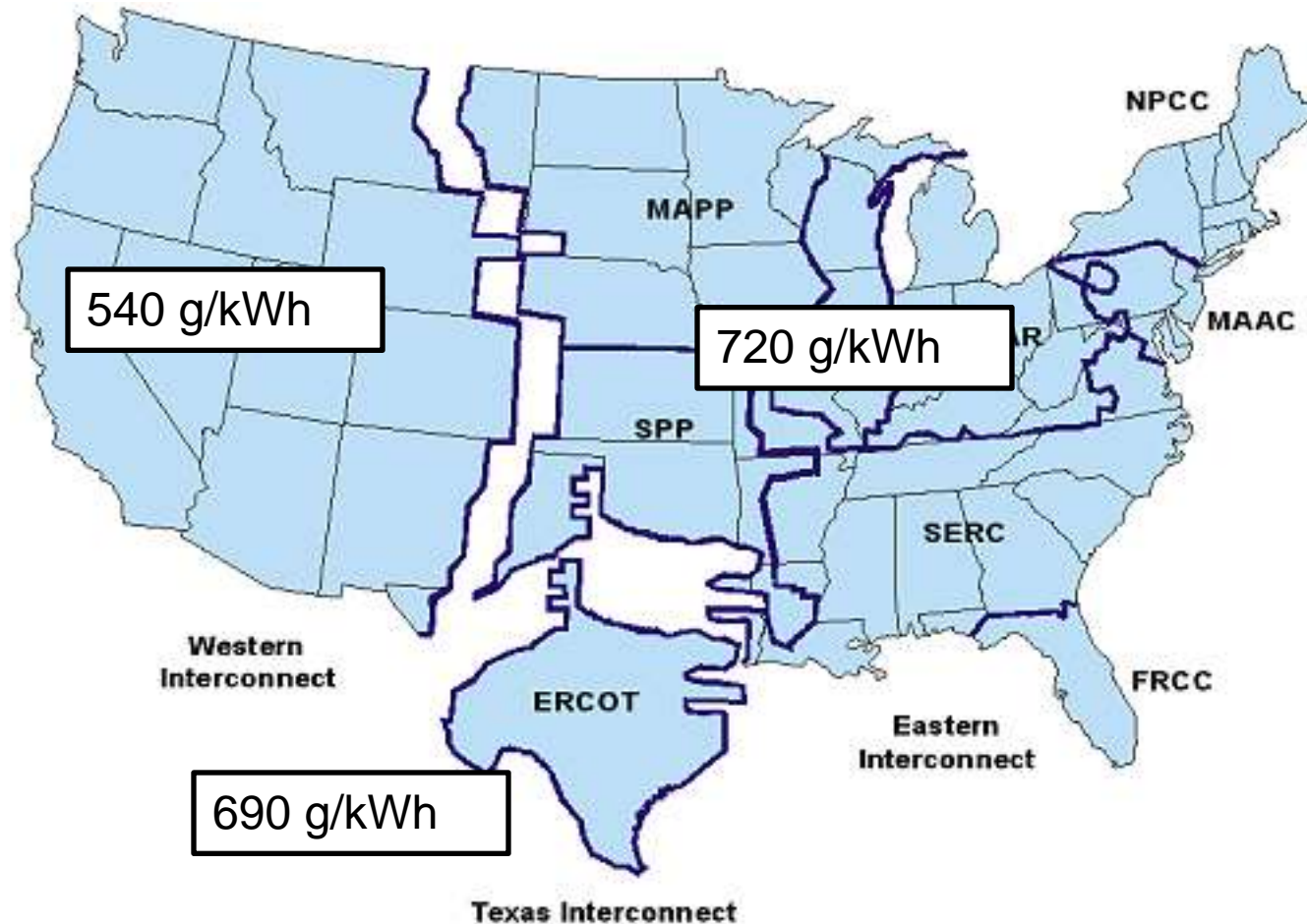
- North America (~ 590 g CO₂/kWh)
- US (continental) (~ 650 g CO₂/kWh)
 - Production vs. consumption
- States (15 g CO₂/kWh – 1080 g CO₂/kWh)
 - Production vs. consumption
 - Ex: CA = 290 g CO₂/kWh Production, 440 g CO₂/kWh Consumption¹

¹Marriott, J. and Matthews, H.S. Environ. Sci. Technol., 2005, 39 (22), pp 8584–8590

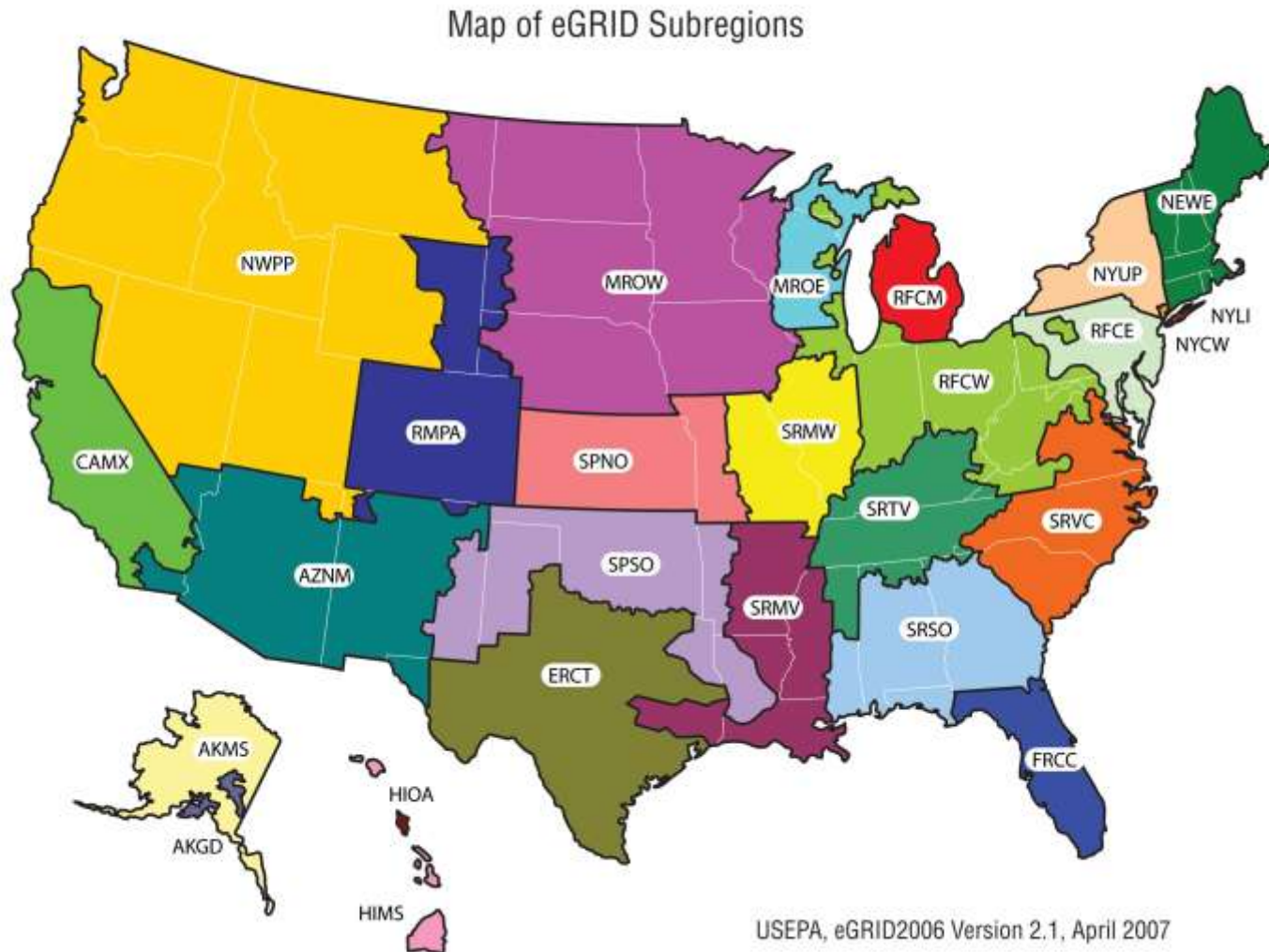


FIGURE 3. California transfers from optimization model (TWh).

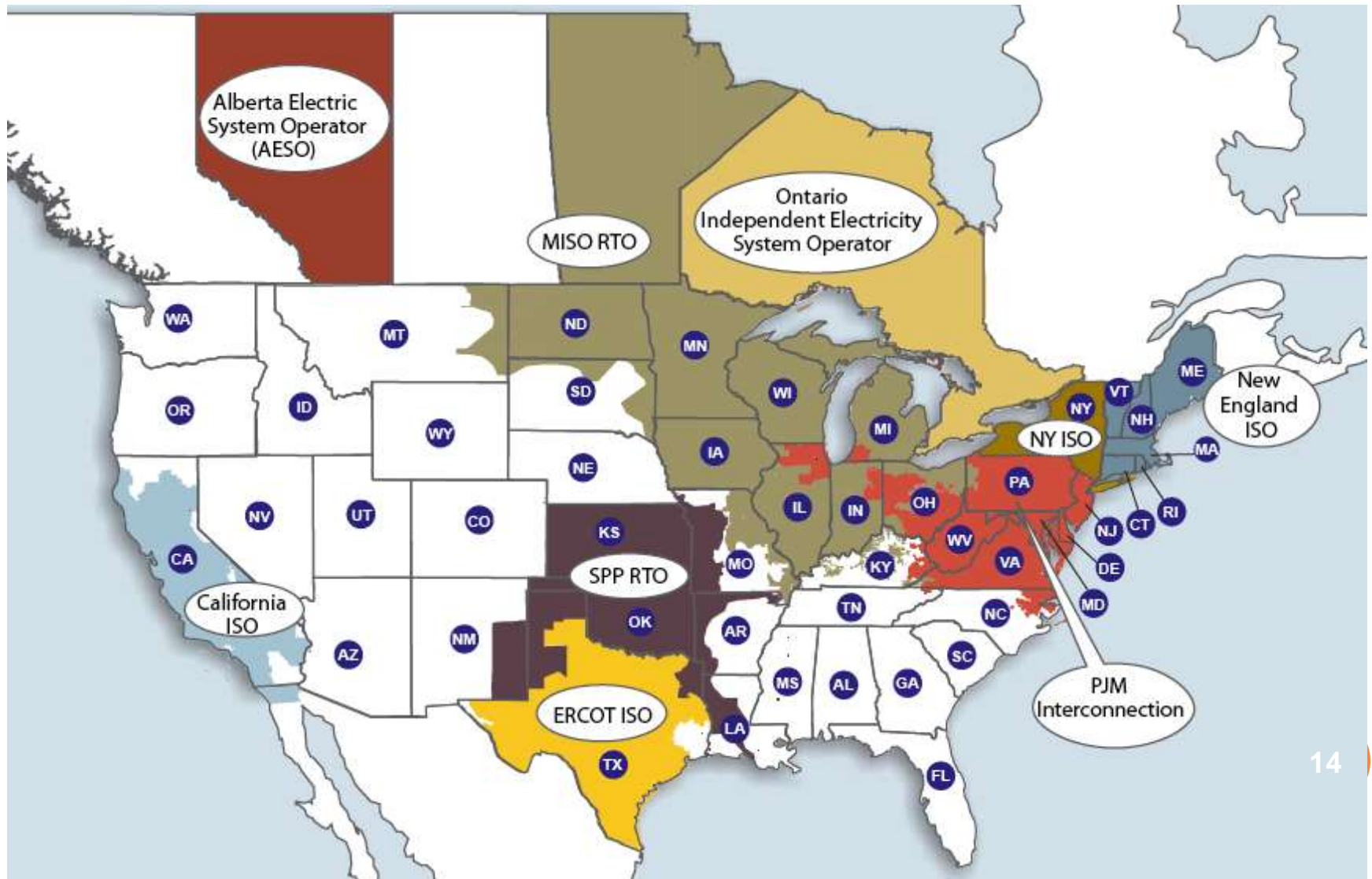
NON-POLITICAL BORDERS: 1) GRID DELINEATION: EAST/WEST INTERCONNECT



2) eGRID/NERC SUBREGIONS



3) REGIONAL TRANSMISSION ORGS (RTOs)

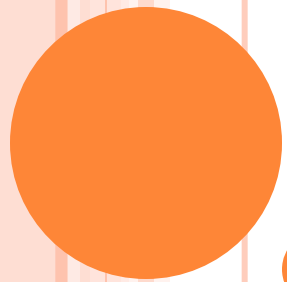


DATA SOURCES

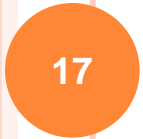
- eGrid (plants, emissions, lat/long, subregion)
- Mapping eGrid to ISOs/RTOs by sight, political borders, etc
- ZIP Code Data (lat/long) and Great Circle distances
- Load data from RTOs (ERCOT and NY-ISO)
- EPA hourly CAMD (Clean Air Markets) Data
- NRC on/off for nuclear production
- Statistics Canada for provincial mixes, interprovincial & international trade

HOW TO MEASURE UNCERTAINTY AT A GIVEN POINT?

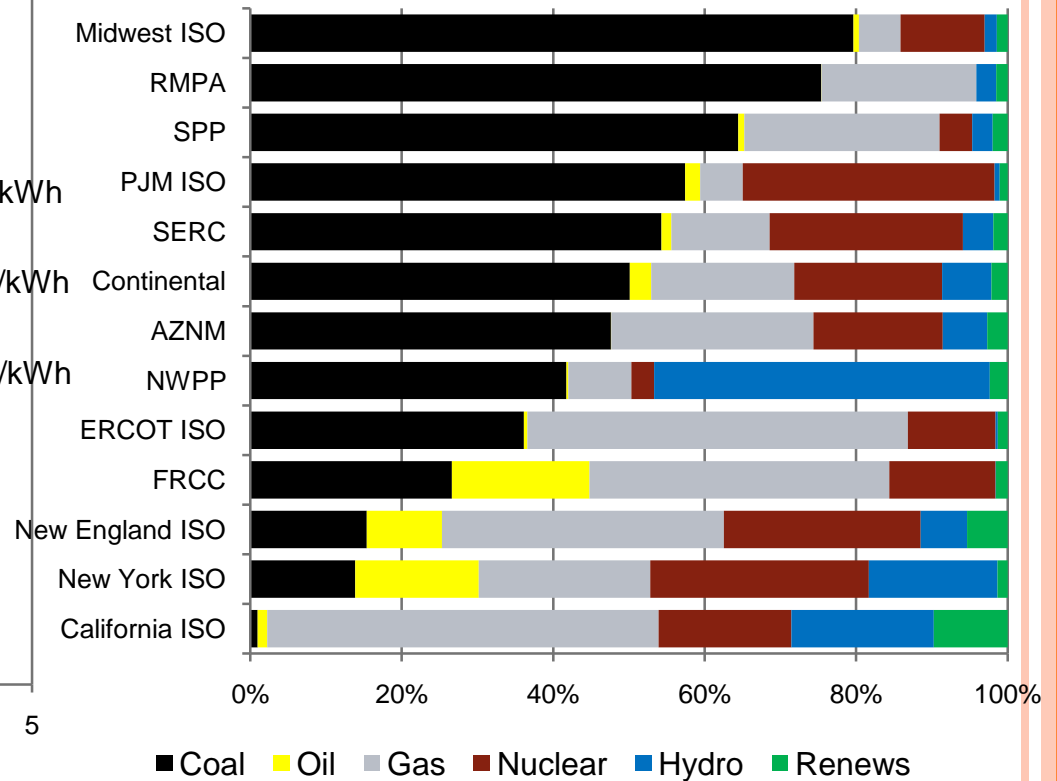
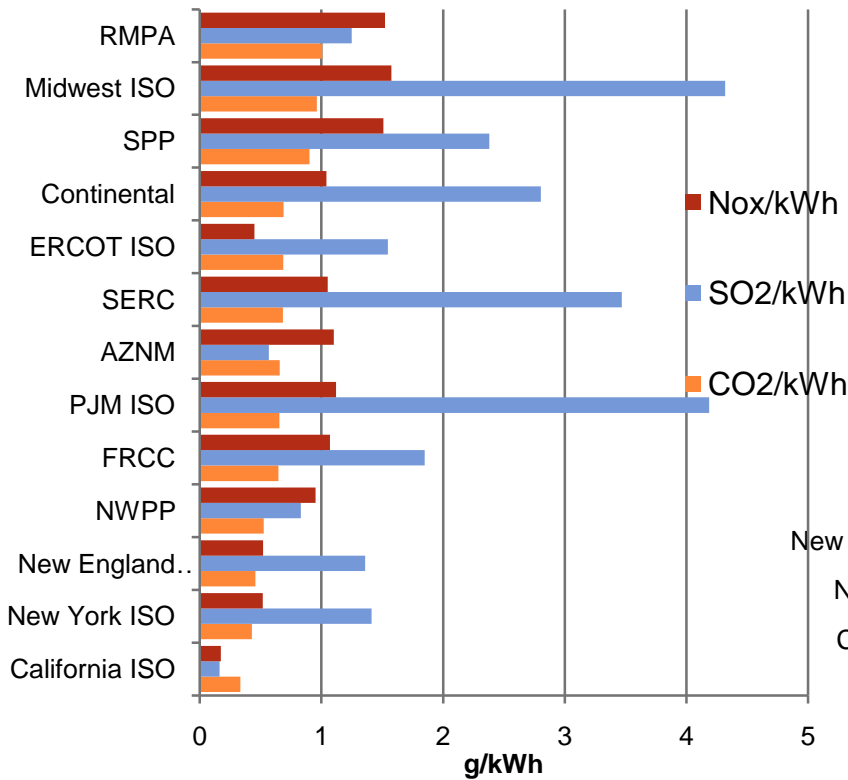
- Simple method: assess uncertainty in different estimates for same location
 - National mix (largest borders)
 - Interconnect mix
 - Grid operator (ISO/RTO)
 - State production
 - State Consumption
 - State grouping (EIA voluntary GHG reporting method)
 - NERC subregion (GHG Protocol method) (smallest borders)
- Reminder: $COV = \sigma/\rho$
 - A normalized measure of uncertainty



RESULTS

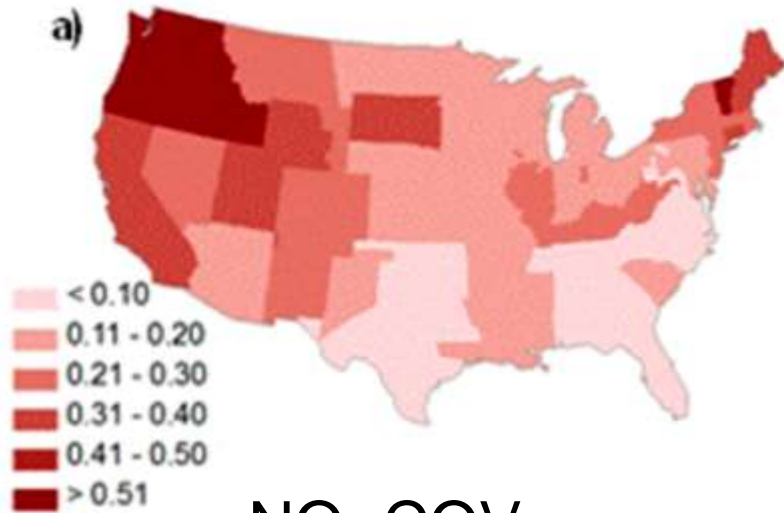


GEOGRAPHICAL VARIATION: GRID OPERATOR (ISO/RTO/NERC)

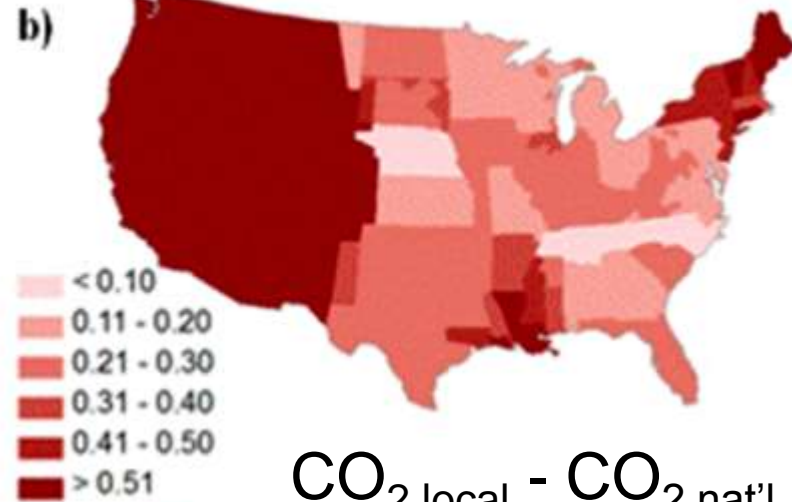


UNCERTAINTY IN ELECTRICITY EMISSIONS FACTORS BY REGION

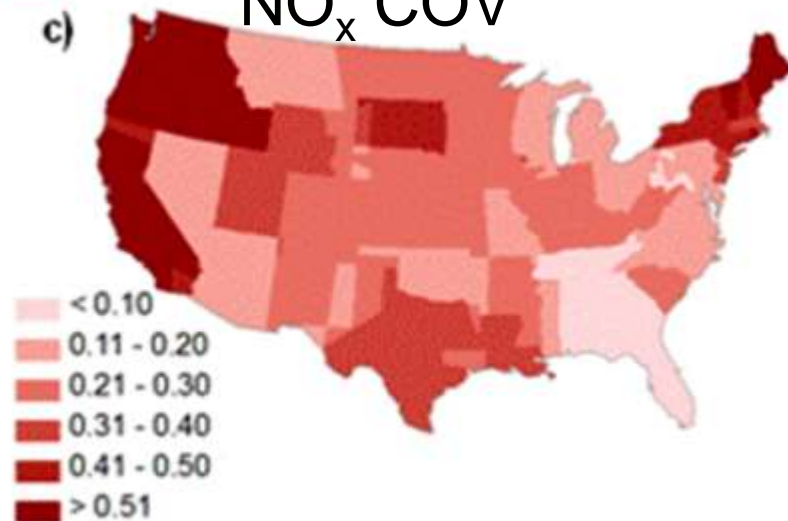
CO₂ COV



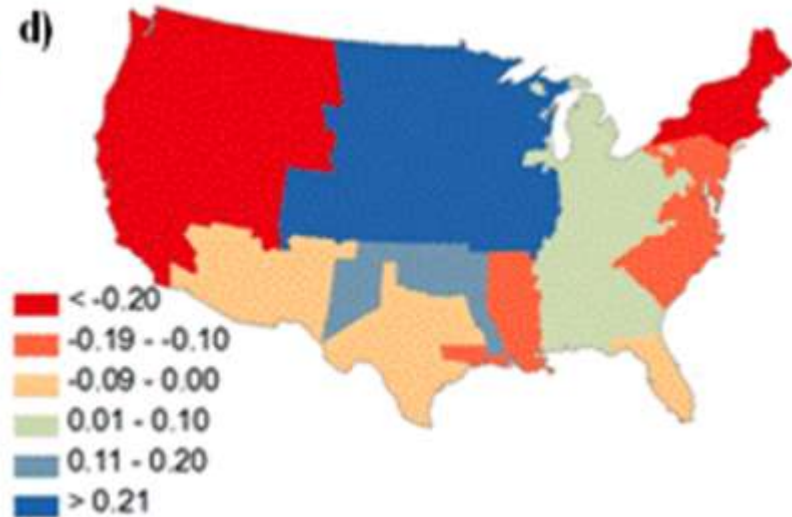
SO₂ COV



NO_x COV

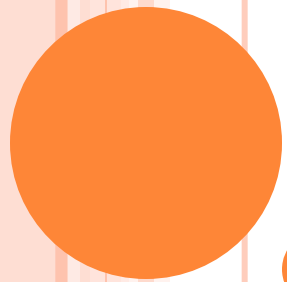


CO_{2,local} - CO_{2,nat'l}



WHAT ABOUT ELECTRICITY TRADE?

- Electricity is traded through all the boundaries discussed
- How much does this trade affect emission factors?
 - At the state level, this has significant effects.
 - Surprising lack of data here (and security-protected)
- Data we have used in geographic analysis only accounts for production emission (exc state cons)
- Will state level emission that account for trade move closer to the NERC/RTO Emissions?



DISCUSSION

AVERAGE VS. MARGINAL

- FERC lists marginal fuel type in each region:
 - NWPP: Hydro and gas
 - CA ISO: Gas
 - ERCOT: Coal and Gas
 - SERC: Coal and Gas
 - PJM: Coal and Gas
- Long-run marginal vs. short-run marginal?
 - Depends on analysis type and size of demand
 - Current studies often confuse long run and short run

EQUITY ISSUES

- How much control does a single actor have over its grid mix?
 - Issue of offsets and RECs
- Should we penalize a plant for its location?
 - Every regional delineation (including national) makes winners and losers in carbon accounting

GUIDANCE FOR GRID MIXING

- Transmission constraints (“electrical distance”)
- Equity
- Electricity market conditions
- Physical reality
- Economic (direct purchases)

- Big picture: however you delineate, it must be consistent!
- Standards orgs should specify which mix to use for comparability so assumptions don’t dominate uncertainty

SUMMARY

- Question 1: Do we need more than kWh?
Sometimes not, depends on goal of study
- Applicable ranges (NOT 3 sig dig values) set by:
 - Transmission constraints
 - Equity
 - Electricity market conditions
 - Physical reality
- If need a single number, must be standardized so high impact plants are taken into account
 - Should be based on physical reality of grid, ie “electrical distance”

QUESTIONS?

- Contact: clweber@cmu.edu