



Emerging Issues and Data Needs for LCA Modeling of Electricity

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This Briefing Draws on Insights from a Few of Our Recent Journal Papers

- We would like to acknowledge the hard work of the coauthors

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- C.S.-Norman Shiau
- Lester Lave
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Life Cycle Assessment and Grid Electricity: What Do We Know and What Can We Know?

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Incorporating uncertainty analysis into life cycle estimates of greenhouse gas emissions from biomass production

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ABSTRACT

More further investments are made in utilizing biomass as a source of renewable energy, policy makers and the energy industry need estimates of the net greenhouse gas (GHG) reductions expected from substituting biomass fuels for fossil fuels. Such GHG actions depend greatly on how the biomass is cultivated, transported, processed, and converted into fuel or electricity. Any policy aiming to reduce GHGs with biomass-based energy must account for uncertainties in emissions at each stage of production, or else it yielding marginal reductions, if any, while potentially imposing great costs. This paper provides a framework for incorporating uncertainty analysis specifically into the life cycle GHG emissions from the production of biomass. We outline the uses of uncertainty, discuss the implications of uncertainty and variability on the limits life cycle assessment (LCA) models, and provide a guide for practitioners to best practices in modeling these uncertainties. The suite of techniques described herein can be used to improve the understanding and the representation of the uncertainties associated with emissions estimates, thus enabling improved decision making with respect to the use of biomass for energy and fuel production.

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Valuation of plug-in vehicle life-cycle air emissions and oil displacement benefits

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We assess the energy value of life-cycle air emissions and oil consumption from conventional vehicles, hybrid-electric vehicles (HEVs), plug-in hybrid-electric vehicles (PHEVs), and battery electric vehicles in the US. We find that plug-in vehicles may reduce or increase externality costs relative to grid-independent HEVs, depending largely on greenhouse gas and SO_x emissions produced during vehicle charging and battery manufacturing. However, even if future marginal damages from emissions of battery and electricity production drop dramatically, the damage reduction potential of plug-in vehicles remains small compared to ownership cost. As such, to offer a socially efficient approach to emissions and oil consumption reduction, lifetime cost of plug-in vehicles must be competitive with HEVs. Current subsidies intended to encourage sales of plug-in vehicles with large capacity battery packs exceed our externality estimates considerably, and taxes that optimally correct for externality damages would not close the gap in ownership cost. In contrast, HEVs and PHEVs with small battery packs reduce externality damages at low (or no) additional cost over their lifetime. Although large battery packs allow vehicles to travel longer distances using electricity instead of gasoline, large packs are more expensive, heavier, and more emissions intensive to produce, with lower utilization factors, greater charging infrastructure requirements, and life-cycle implications that are more sensitive to uncertain, time-sensitive, and location-specific factors. To reduce air emission and oil dependency impacts from passenger vehicles, strategies to promote adoption of HEVs and PHEVs with small battery packs offer more social benefits per dollar spent.

The electrification of passenger vehicles has the potential to address three of the most critical challenges of our time: plug-in vehicles may (i) produce fewer greenhouse gas (GHG) emissions when powered by electricity instead of gasoline, depending on the electricity source; (ii) reduce tailpipe emissions, which impact people and the environment; and (iii) reduce gasoline consumption, helping to diminish dependency on imported oil. Recognizing these benefits, US policymakers have provided federal tax credits of up to \$7,500 per vehicle to encourage electrified transportation, with additional supporting policies created in many states (1, 2). Ideally, these policies would compensate for the externalities of energy use, such as damages to human health and to resources caused by emissions of oil consumption. Because such externality damages are not priced explicitly in the marketplace, they are not adequately accounted for in decision making, and users consume and emit more than they would have if they had born the full costs (3). Policymakers understand the impossibility of eliminating all externality damages; instead, laws favor determining which externality-reducing measures are worth paying for and which approaches reduce externality damages most efficiently.

In this study we assess, under a wide range of scenarios, how much externality damage reduction plug-in vehicles can offer in the US and at what cost. To answer this question, we gathered data on (i) the quantity and location of emissions released from

tailpipes and from upstream processes to produce and operate vehicles, (ii) the externality costs of damages caused by the release of these emissions, and (iii) estimates of externalities and other costs to the US associated with oil consumption. We compare externality and oil consumption costs to the costs of owning and operating these vehicles and to subsidies designed to encourage their adoption. *SI* Text provides a detailed review of relevant literature.

Results

Emissions Damage Reduction Potential. We estimate life-cycle emissions damages for comparable new midsize vehicles, including a conventional vehicle (CV), a hybrid-electric vehicle (HEV), plug-in hybrid-electric vehicles (PHEV) with battery packs sized for storing 20 km (PHEV20) or 60 km (PHEV60) of grid electricity (with the remainder powered by gasoline), and a battery electric vehicle (BEV) with a 240-km pack (and no gasoline engine). We estimate location-specific externality damages for releases of CO₂, nitrogen oxides (NO_x), particulate matter (PM), SO₂, and volatile organic compounds (VOCs) using data from a 2010 National Research Council (NRC) study (3, 4) with their \$6 million estimate for value of statistical life, and we examine a range of estimates for damages from GHG emissions (3, 5). We combine these externality values with data on US driving patterns from the 2009 National Household Travel Survey (NHTS) (6) and data on manufacturing, fuel cycle, and operation emissions from Argonne National Laboratory (ANL) (7, 8) to estimate US life-cycle damages for each vehicle. Fig. 1 summarizes the results. In our base case, we assume average US values for emissions and damage valuation of electricity generation, oil refining, vehicle and battery production, driving location, and upstream supply chain emissions; we use a medium global valuation for GHG emissions, and we assume the battery will last the life of the vehicle. Although gasoline production and combustion produce significant emissions, battery and electricity production emissions are also substantial. We find that, in the base case, plug-in vehicles (PHEVs and BEVs) may produce more damage on average than today's HEVs. This fact is due in large part to SO₂ and GHG emissions from coal-fired power plants.

Author contributions: J.J.M., M.C., P.J., and C.S. designed research; J.J.M., M.C., P.J., C.S., and C.N.S. performed research; J.J.M., M.C., P.J., C.S., and C.N.S. contributed new reagents/analytic tools; J.J.M., M.C., P.J., C.S., C.N.S., and L.B.L. analyzed data; and J.J.M., M.C., P.J., C.S., and L.B.L. wrote the paper.

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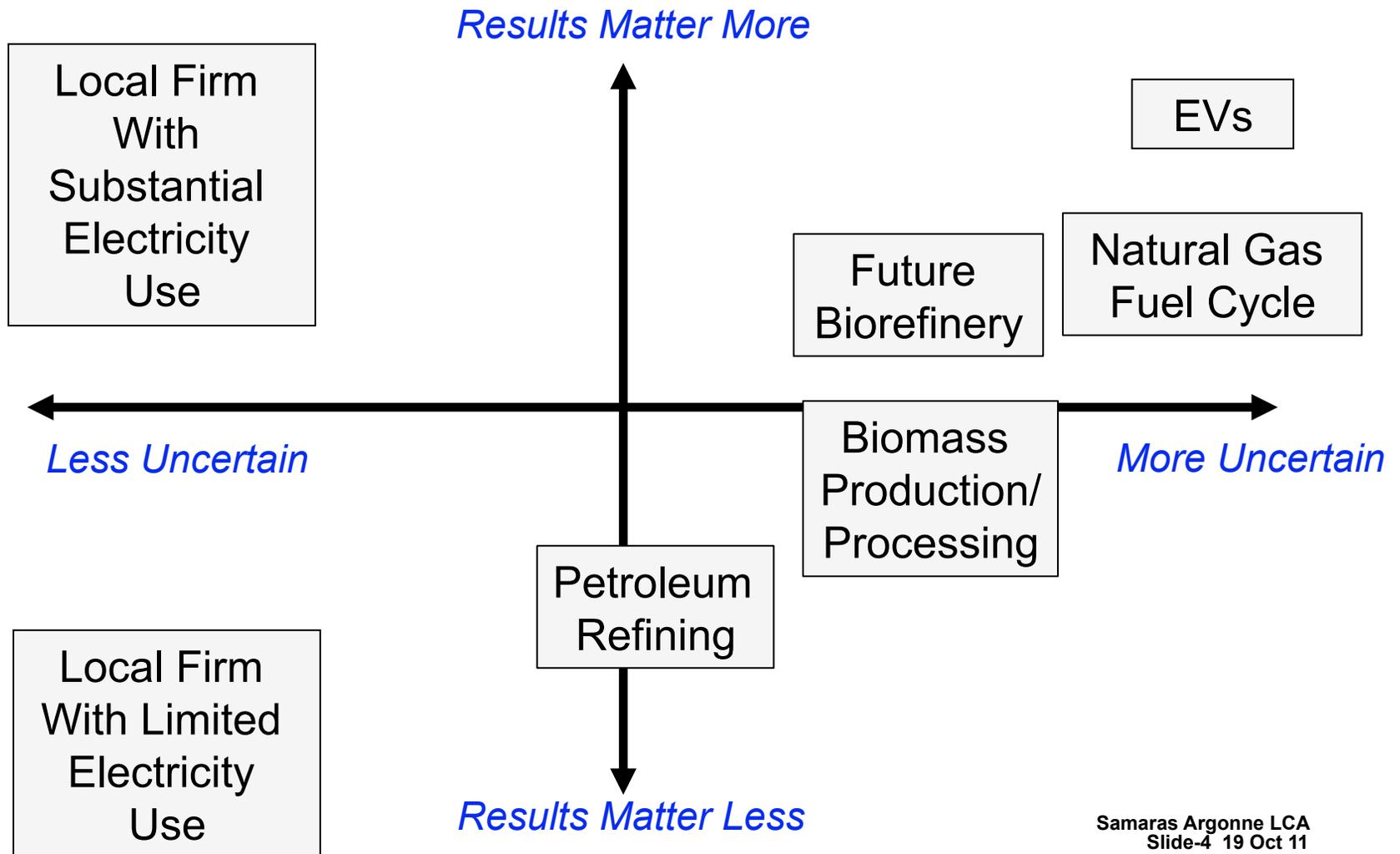
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Samaras Argonne LCA
Slide-2 19 Oct 11

This Briefing Continues the Discussion on Some Critical LCA Issues

- **What are some outstanding and emerging issues for electricity LCA?**
- **Are current modeling methods sufficient?**
- **What are the key LCA inputs needed in the next year or two ?**
- **Figuring out what matters and establishing consistency for policymakers**

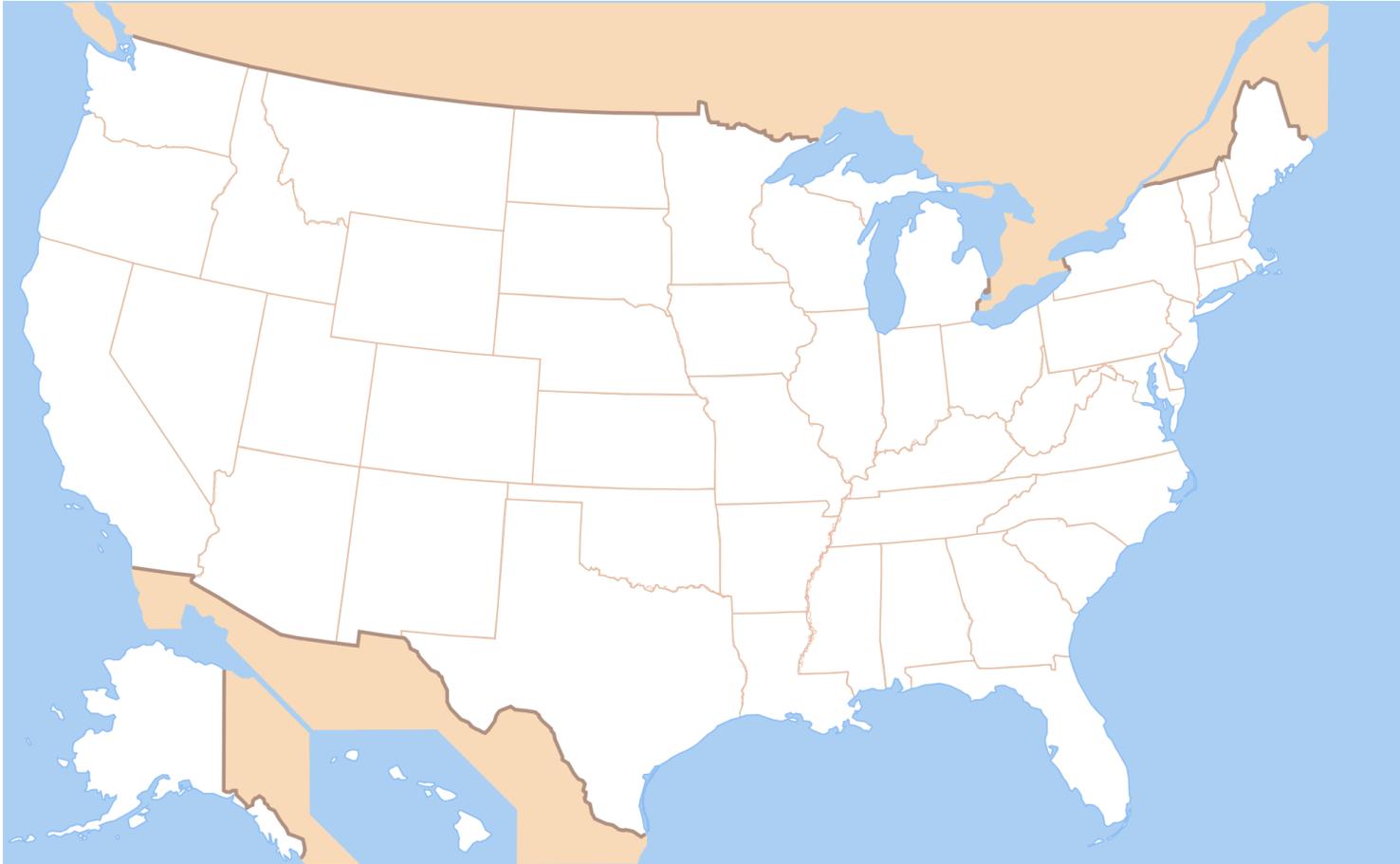
Electricity LCAs Have Varying Levels of Importance and Uncertainty



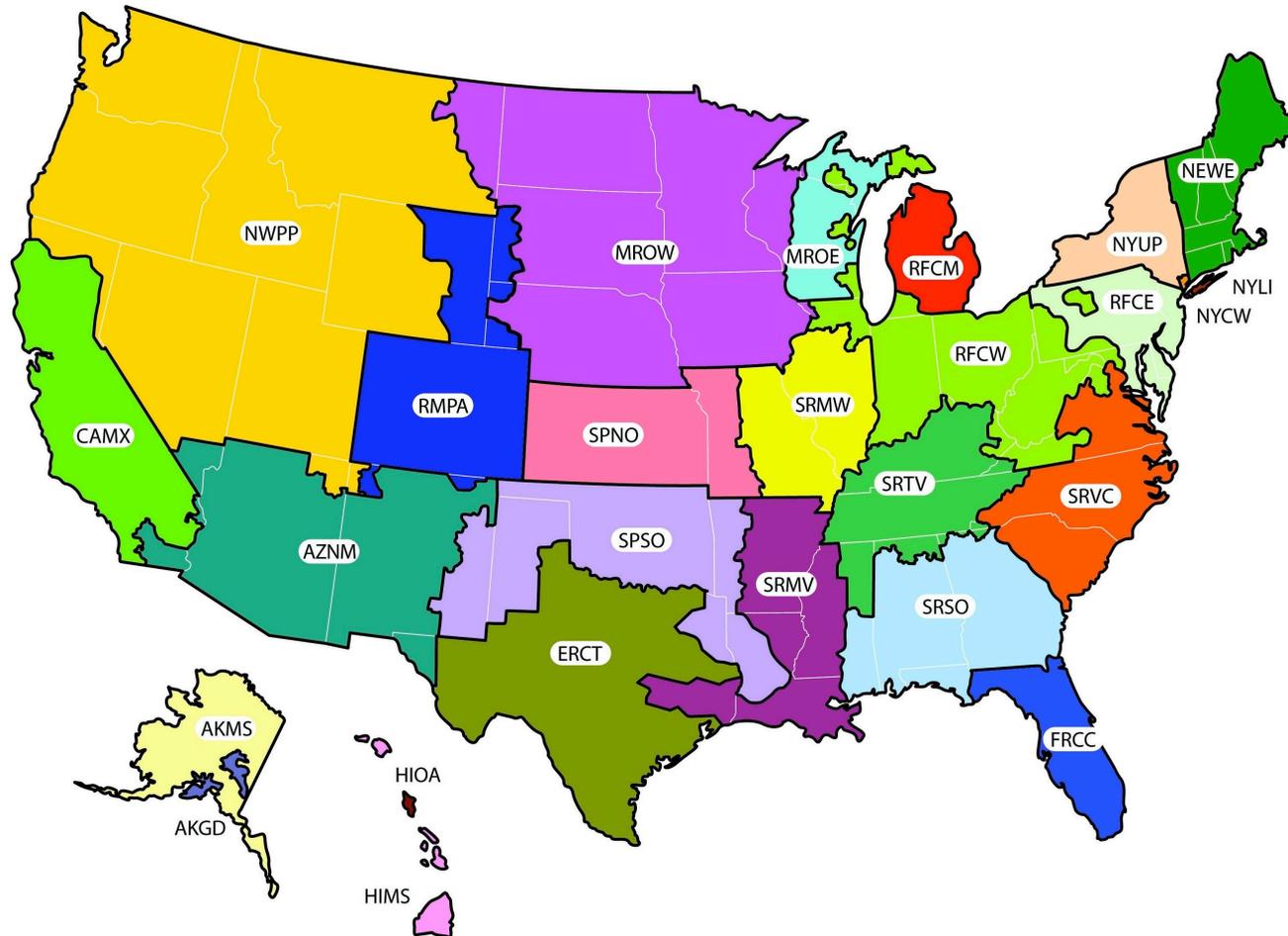
Emerging Issues Will Be Defining Baselines, Boundaries, and Acceptable Uncertainty Ranges

- **Two separate and challenging tasks:**
 - **Understand electricity generation impacts for a functional unit**
 - **Understand electricity fuel cycle impacts for that case**

Emerging Issues Will Be Defining Baselines, Boundaries, and Acceptable Uncertainty Ranges

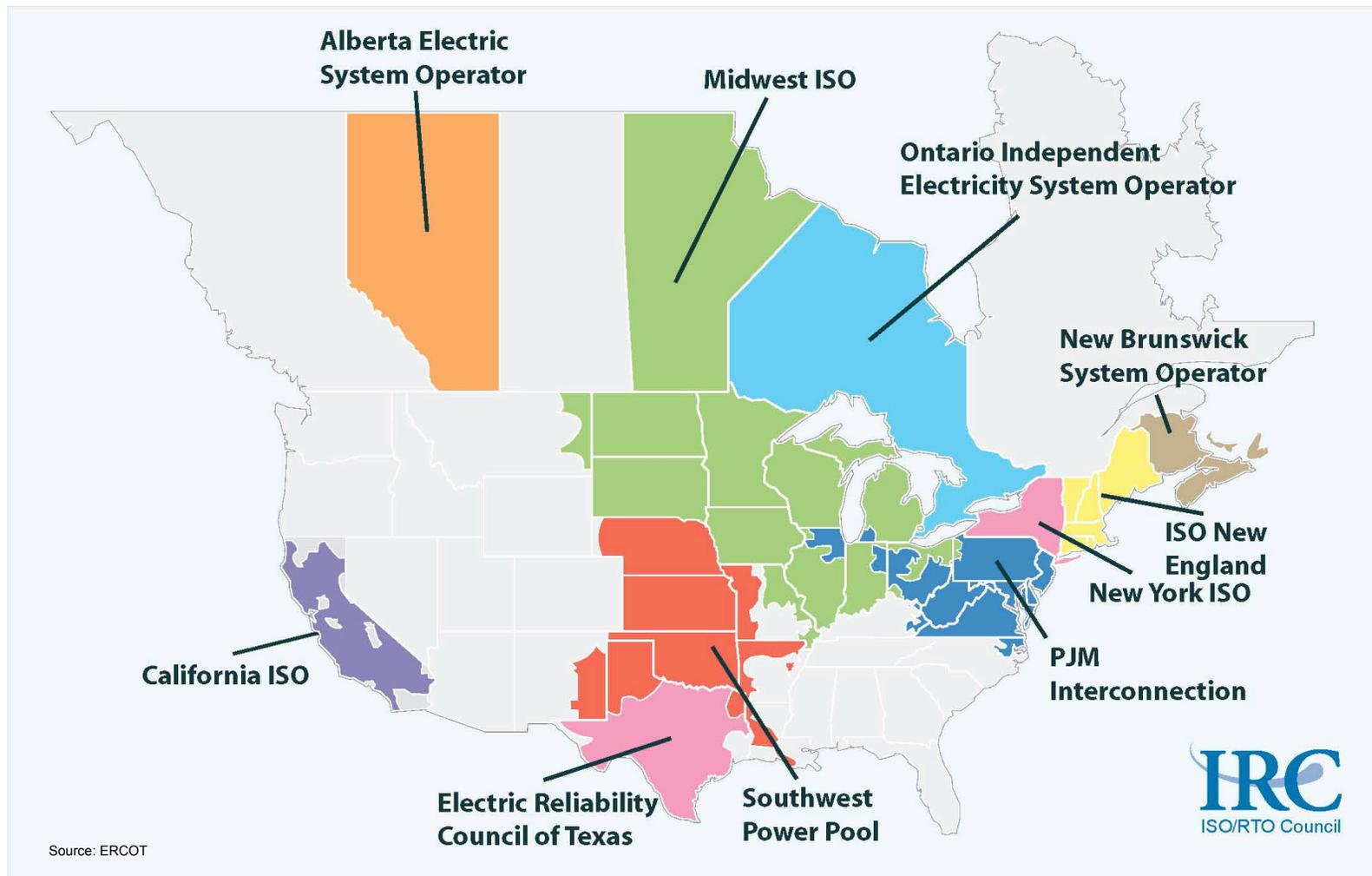


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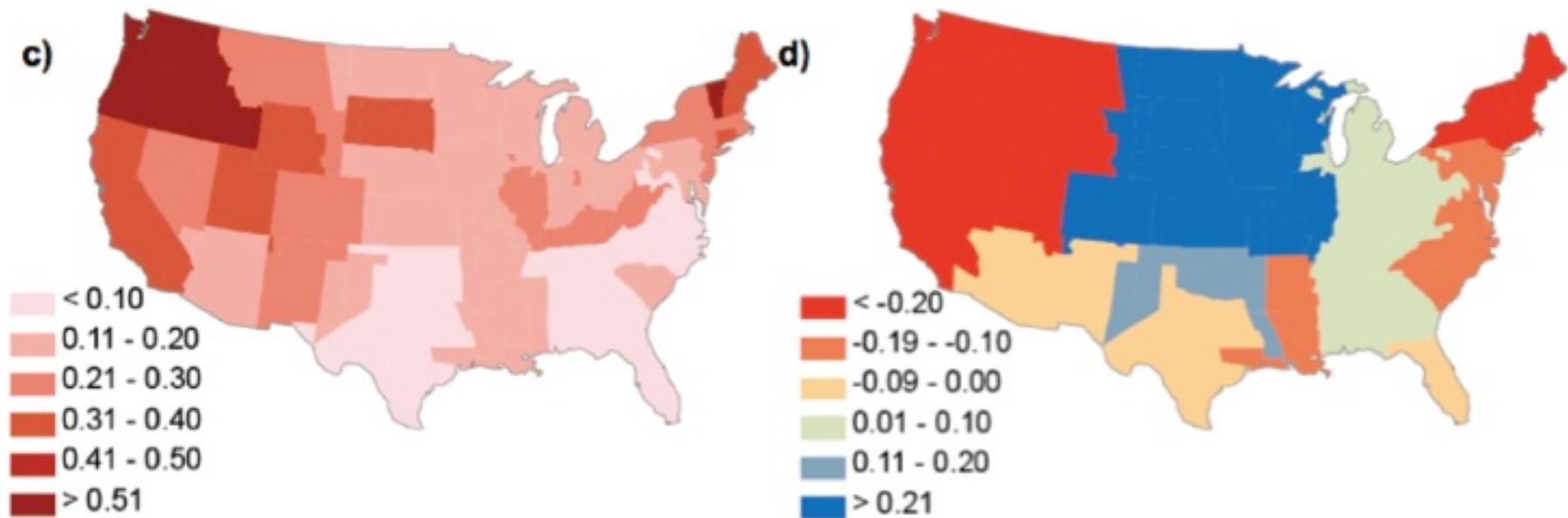


Source: EPA

Emerging Issues Will Be Defining Baselines, Boundaries, and Acceptable Uncertainty Ranges



Emerging Issues Will Be Defining Baselines, Boundaries, and Acceptable Uncertainty Ranges



Source: Weber, C., Jaramillo, P., Marriott, J., Samaras, C., 2010. Life cycle assessment of grid electricity: What do we know and what can we know? *Environmental Science and Technology*, 44(6) 1895-1901.

Emerging Issues Will Be Defining Baselines, Boundaries, and Acceptable Uncertainty Ranges

- **Two separate and challenging tasks:**
 - **Understand electricity generation impacts for a functional unit**
 - **Understand electricity fuel cycle impacts for that case**
- **Use of state or eGrid subregions omits life cycle impacts and results in “winners” and “losers”**
 - **Right now, an entity can choose the most favorable boundaries and baselines for purchased electricity impacts**
- **Arguments for and against marginal electricity impacts and consequential electricity LCAs will intensify**
 - **How do we sort out the “good” LCAs and how can the and their inherent uncertainty be best utilized by policymakers?**

This Briefing Continues the Discussion on Some Critical LCA Issues

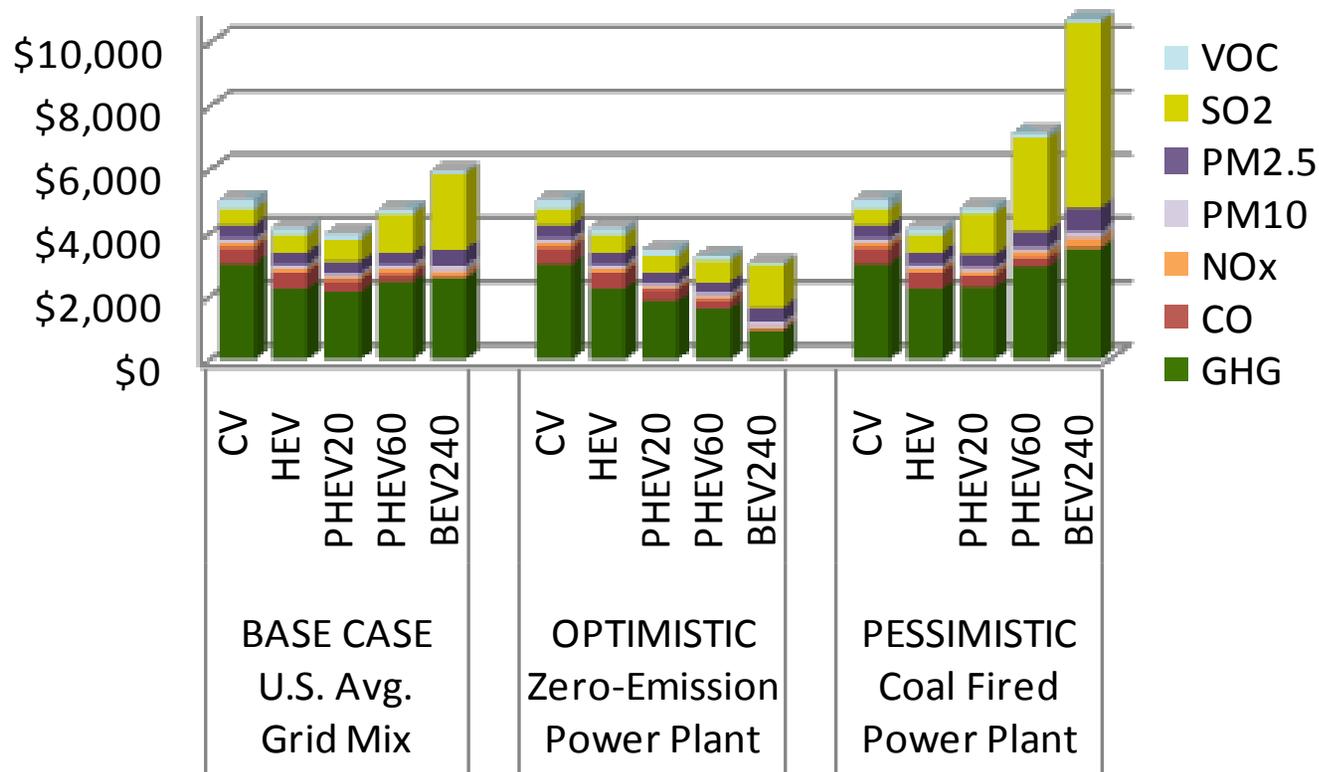
- **What are some outstanding and emerging issues for electricity LCA?**
- **Are current modeling methods sufficient?**
- **What are the key LCA inputs needed in the next year or two ?**
- **Figuring out what matters and establishing consistency for policymakers**
- **Need to make decisions under uncertainty but need transparent inputs**

Current Modeling Methods Are Helpful But Subject to Model, Data, and Scenario Uncertainty

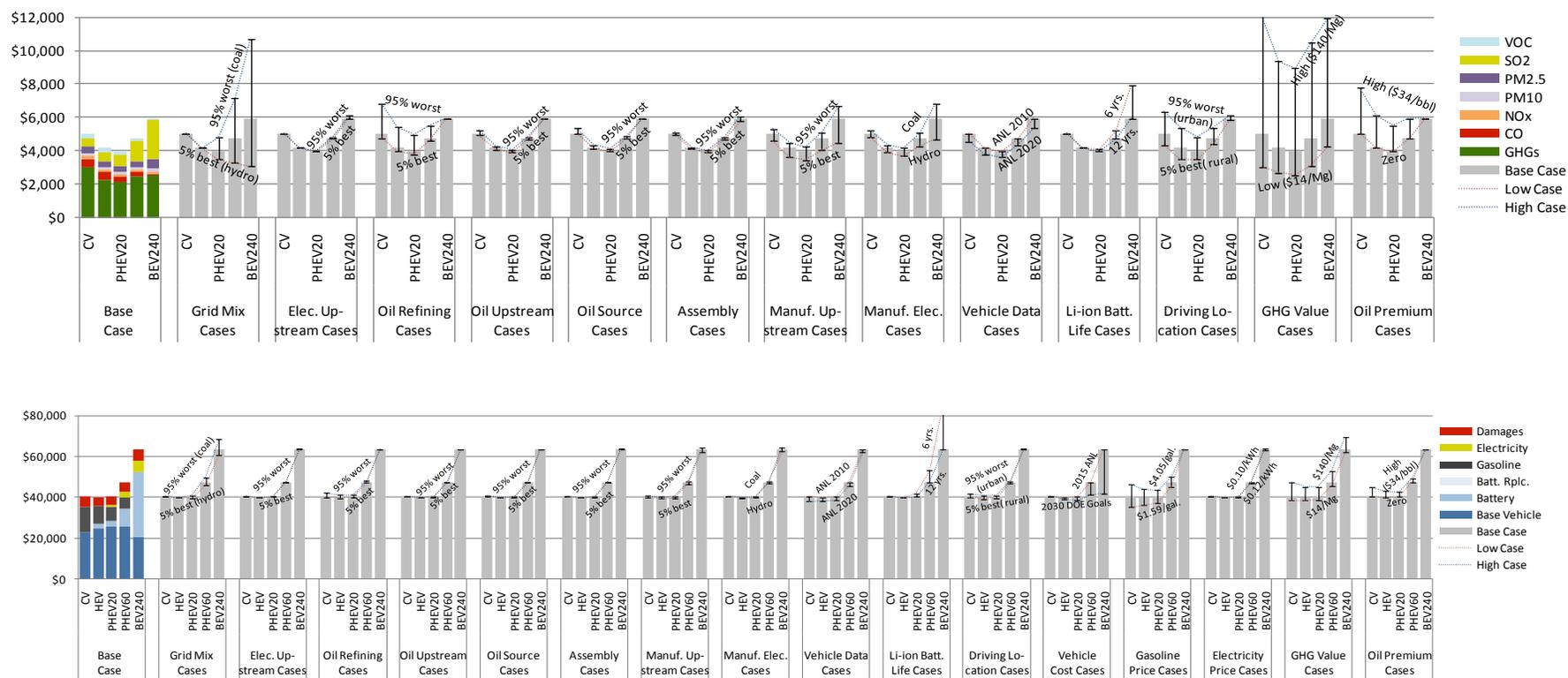
- **We can use or edit GREET, or attempt to append eGrid with upstream impacts**
- **We can develop our own process-based, input-output, or hybrid models**
- **We can parameterize and use bounding analysis**
- **We can conduct grid dispatch analyses in certain areas**

Example: Lifetime Emissions Damages Could be Higher With Evs

- Emissions damage reduction potential of plug-in vehicles
 - Optimistic: \$1000 damage reduction over the life
 - Pessimistic: \$6000 damage increase over the life

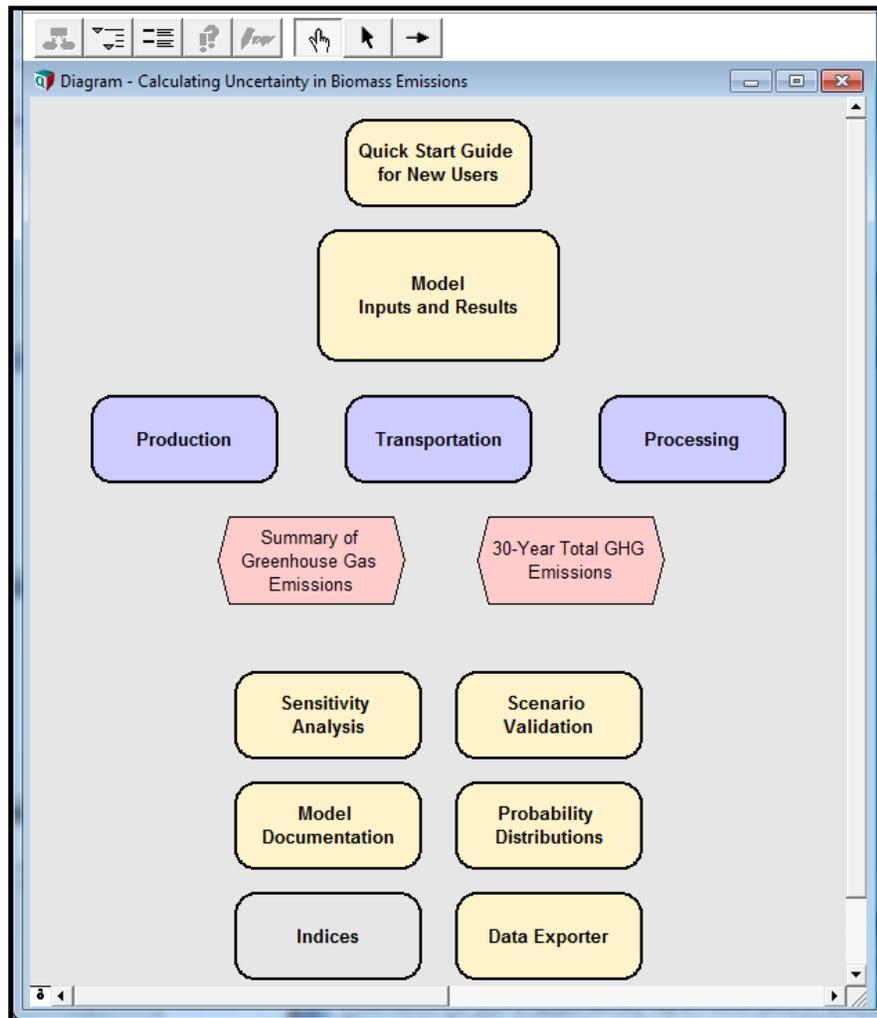


Sensitivity Analyses Essential, But Complexity Can Get Overwhelming



Source: Michalek, J.J., Chester, M., Jaramillo, P., Samaras, C., Shiao, C-S.,N., Lave, L.B. 2011. Valuation of Plug-in Vehicle Life Cycle Air Emissions and Oil Displacement Benefits. *Proceedings of the National Academies of the USA*. 108(40) 16554-16558.

The Most Useful Models Are Transparent, Documented, Peer-Reviewed and Revised Regularly



The Calculating Uncertainty in Biomass Emissions (CUBE) model:

- A tool for analyzing the life cycle inventory of emissions from biomass production
- Includes seven feedstocks:
 - switchgrass, mixed prairie biomass, corn grain, corn stover, hybrid poplar, forest residue, mill residue
- Impacts examined across region, feedstock and prior land use
- Based on literature and consultation with biomass-energy experts
- Publicly available at:
www.rand.org/ise/projects/bioemissions.html

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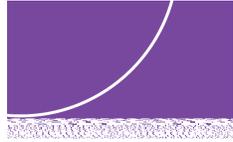
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- Need to make decisions under uncertainty but need transparent inputs
- **Capture impacts from evolving grid and important upstream processes and think about long-term evolution of current tools**

Key Near-term Data Will be How Grid Changes and Upstream Natural Gas Impacts

- **As the electricity fleet continues to evolve, eGrid and GREET should have frequent updates**
 - **What if GREET evolved into a documented, peer reviewed, and crowd sourced model that is updated every three years? What if eGrid and GREET were coupled? What if they used electricity balancing areas rather than subregions?**
 - **This would allow **satisficing** for large policy questions and allow individual researchers to use components for individual analyses and checks**
- **As more shale gas comes online and is used for electricity production, we need an understanding of how this affects life cycle electricity GHGs from electricity**

Summary

- **What are some outstanding and emerging issues for electricity LCA?**
- **Are current modeling methods sufficient?**
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