# Planning for Electric Vehicle Charging Infrastructure: Opportunities for Illinois

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# Outline

- **Introduction**
  - Research Objectives
  - Electric Vehicles & Charging Overview
- **Electric Vehicle Charging Infrastructure**
  - Value of Charging Infrastructure
    - Importance
    - Methods
    - Results
- **Concluding Remarks / Questions Break**

# Research Interests

GOALS

## Sustainable Transportation Futures

- conserve natural resources
- minimize externalities
- equitable allocation of benefits

MEANS

## Emerging Transportation Technologies & Services

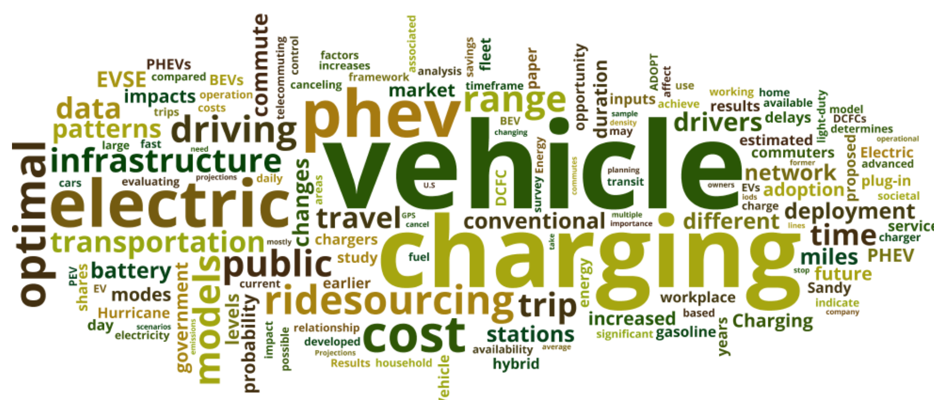
- electrification of mobility
- shared mobility & multimodal
- connectivity & automation

METHODS

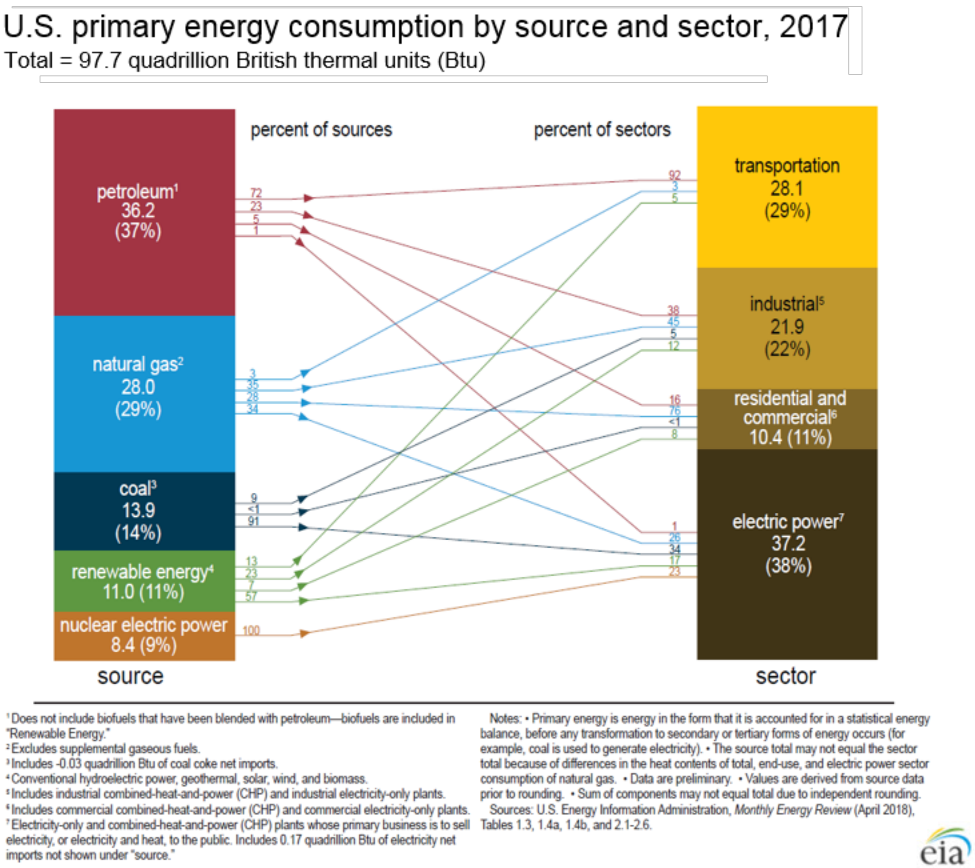
## Modeling

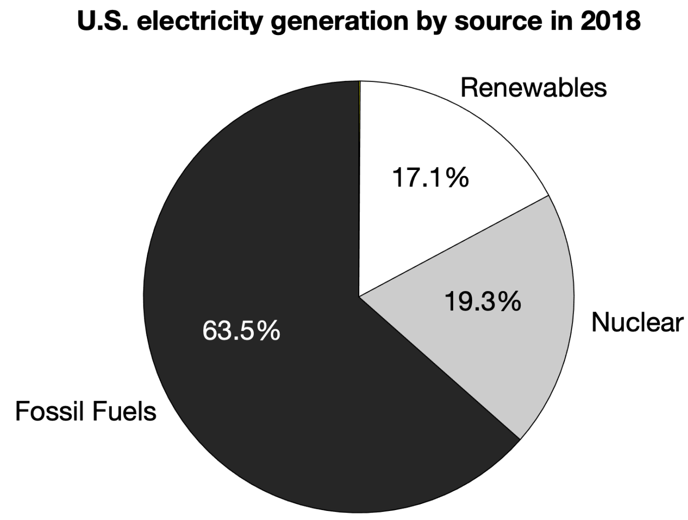
- operations research
- econometrics
- simulation

word cloud based on my published work



# Transportation Energy Use




Sources: US Energy Information Administration (2018)

# Plug-in Electric Vehicles Overview

## Plug In Hybrid (PHEV)

Electricity + Gas

Examples:


## Battery Electric (BEV)

Electricity Only

Examples:


Smart, 2019

# Charging Levels Overview

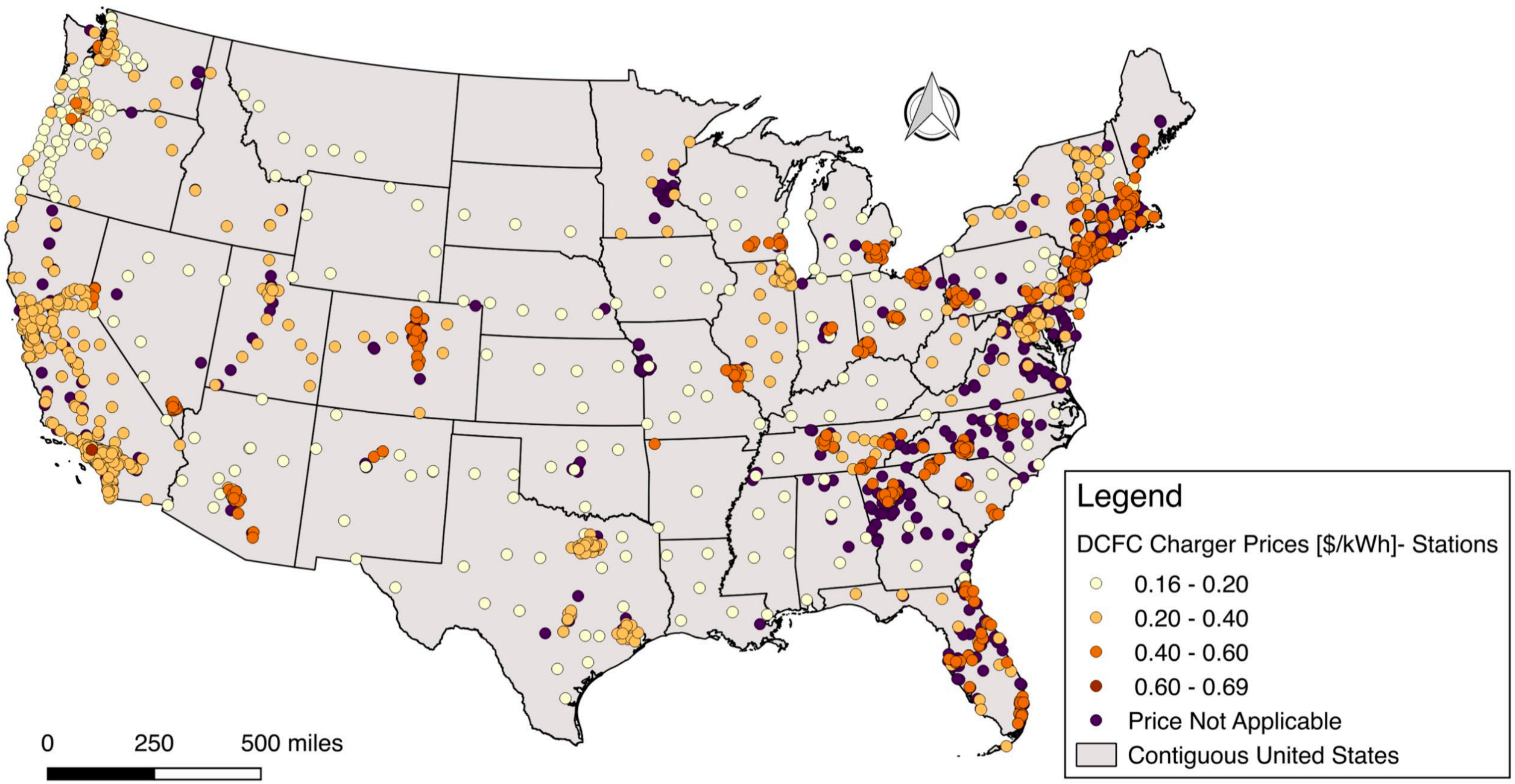
| | Home Charging<br>Level 1 | Workplace<br>Level 2 | Public Charging<br>DC Fast |
|---|---|---|---|
| Electrical Specs | 110 – 120 Volts AC<br>12 – 16 Amps<br>(home appliance) | 208/240 Volts AC<br>32 Amps<br>(home washer/dryer, commercial standard) | 208 to 480 Volts DC<br>70 – 125 Amps<br>(commercial standard) |
| Range Per Hour of Charging | ~3 – 5 miles | ~12 – 25 miles | 100 - 200 miles + |
| Typical Time for Full Charge[1] | 18+ hours | ~2 - 4 hours | ~15 - 45 mins |

Smart, 2019

# Public Fast Charging Stations Overview

**Known prices: 1,294 stations [EVgo, Tesla, Blink, Webasto]**

- Mean: 0.35 $/kWh
- Standard Deviation: 0.22 $/kWh



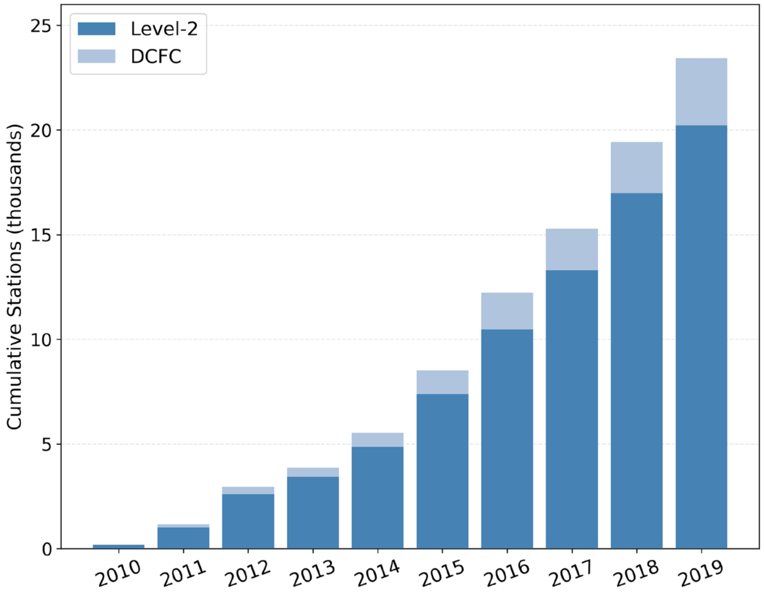
Paper's title

## Public Charging Infrastructure for Plug-in Electric Vehicles: What is it worth?

# Public Charging Infrastructure Role

While the majority of plug-in electric vehicle (PEV) charging is expected to occur in residential locations, **a network of public chargers** provides tangible and intangible value by:

- supporting adopters that cannot reliably charge at residences & workplaces
- enabling long-distance travel
- coping with range anxiety
- building confidence in the future of PEVs




Data Source:
Alternative Fuel Data Center, 2019

# Research Question

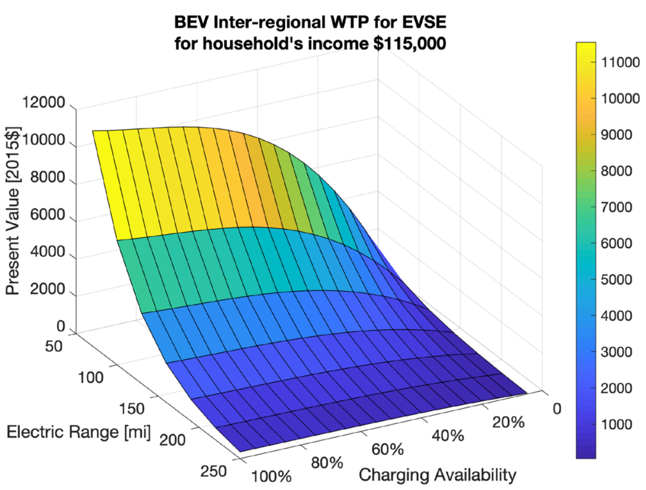
## What is the value of public PEV charging?

- Estimate the **tangible value of the existing public charging infrastructure network to the PEV driver**
- Provide a critical measure for **assessing the costs and benefits of investments in public chargers**

## WTP for Charging Infrastructure

function of:

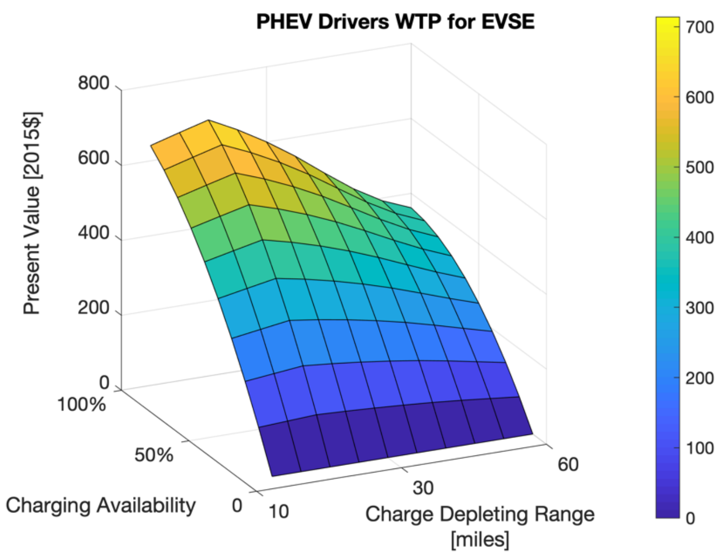
- electric range
- charging availability & location
- annual VMT
- vehicle type
- income



# WTP for Charging: PHEV Driver

**PHEV WTP** (at location $j$ and vehicle $i$) **for charging infrastructure:** value of **energy savings from additional miles conducted in charge-depleting mode**

$$WTP_{ij} = \underbrace{[f(I_j, R_i) - f(0, R_i)]}_{\text{fraction of charge-depleting miles when infrastructure } I \text{ is and is not available}} \overbrace{M_{ij}}^{\text{annual VMT}} \underbrace{\left(p_{jG} e_{iGs} - (p_{jG} e_{iGd} + p_{jE} e_{iEd})\right)}_{\text{fuel savings per mile in charge depleting versus charge sustaining mode}} \overbrace{D_{ij}}^{\text{discounted lifetime value}}$$




**Observations**

- WTP ↑ at a decreasing rate when charging availability ↑
- WTP ↓ as when electric range ↑

# WTP for Charging: BEV Driver (1)

## WTP for BEV intra-regional charging:

**value of added electrified miles** (depends on the value of an enabled mile and the value of reduced time to access a charger)

e-miles decreased with increased range R

$$WTP_{ij} = \left[\left(a_0 + a_1 ln(I_j)\right)\left(\frac{b_0}{R_i^{b_1}}\right) M_j \left(v_j - \left(w_j K(\phi_j^a - 1)\frac{1}{CR_i}\right)\right)\right] D_j$$

enabled e-miles depend on log of charging availability I

value per mile of additional enabled travel minus time cost of accessing charging

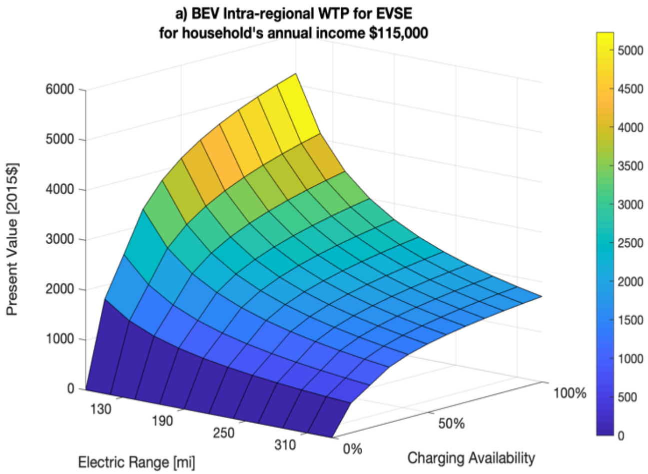
$v_j$ value of enabled electric mile

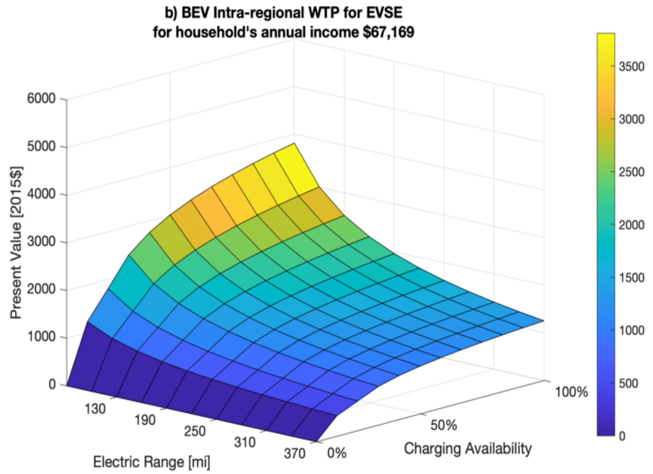
$w_j$ value of time

$K(\phi^a - 1)$ additional time to access a charger compared to gasoline case

# WTP for Charging: BEV Driver (1)

## Intra-regional Charging WTP




**Observations**

- WTP relationship with income
- for low electric ranges, high charging availability worth more than $5,000

# WTP for Charging: BEV Driver (2)

**WTP for BEV inter-regional charging:**

based on the **value of added miles** (considering only direct current fast charging stations)

$$WTP_{ij} = \left[\left(\alpha_0 + \alpha_1 ln(I_j)\right)\left(e^{-b(R-R_0)}\right)m_j\left(v_j - \frac{w_j}{\vartheta R_i}\left(K(\phi^a - 1) + \underbrace{\frac{\vartheta R_i e_i}{d}}_{\text{time cost of recharging BEV}}\right)\right)\right]D_j$$

$\vartheta R$ practical electric driving range
$e_i$ energy consumption
$d$ charger's electricity delivery rate
maximum charge of $\vartheta$100%

# WTP for Charging: BEV Driver (2)

## Inter-regional Charging WTP

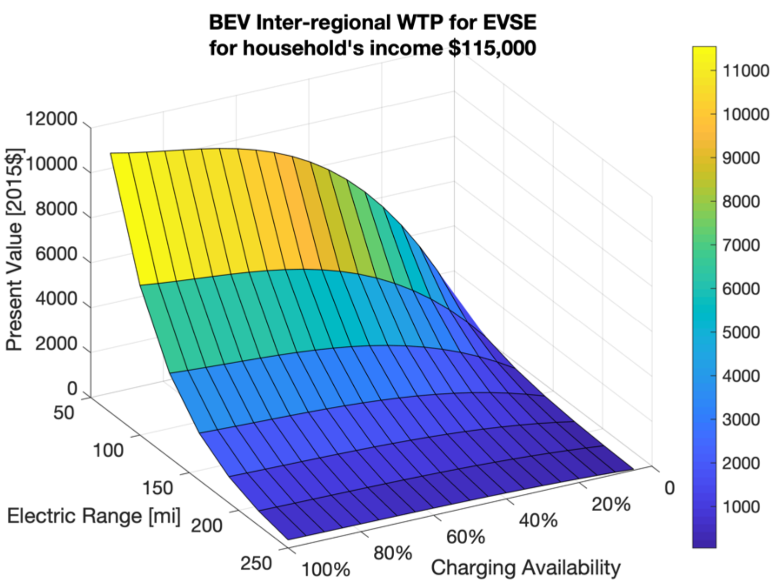


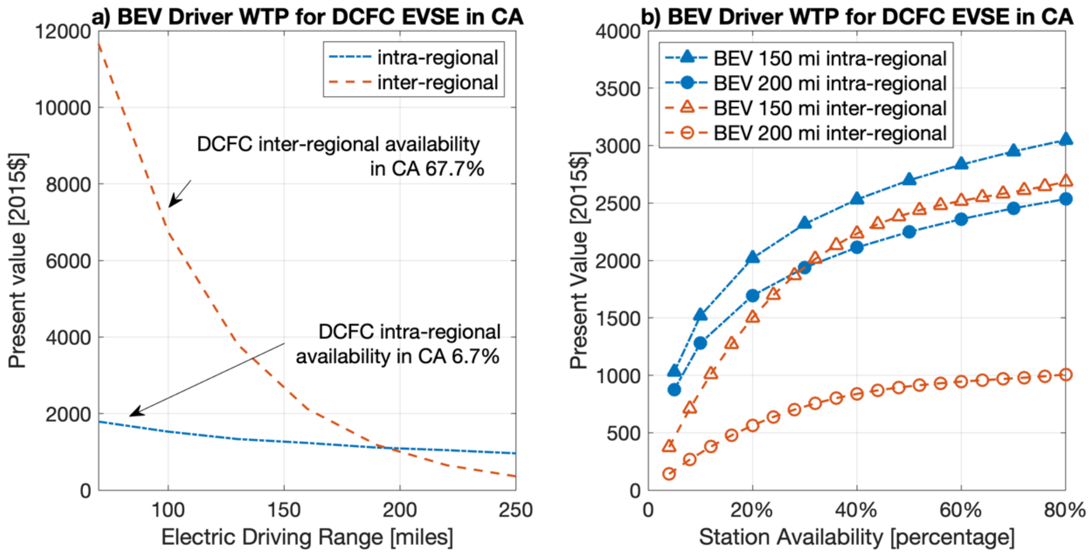

Figure assumptions: $0.35 per enabled mile

**Observations**
- for low ranges, high charging availability is worth >$10K

# Case Study: BEV Drivers WTP

## BEV Driver Willingness to Pay for Direct Current Fast Chargers

- intra-regional charging availability much lower
- when range ≤ 200 mi high value of dense inter-regional fast charging network
- value of charging increases as charging availability increases with diminishing returns, for both intra- and inter-regional travel



# Illinois Opportunities (1)


Daily Herald

**Will Illinois start charging electric car owners a road fee?**

Chicago Tribune SUBSCRIBE

BUSINESS

**Illinois will hike fee for Teslas, Bolts and other EVs — but to $248, not $1,000: 'They've cut it back from an outrageous number'**

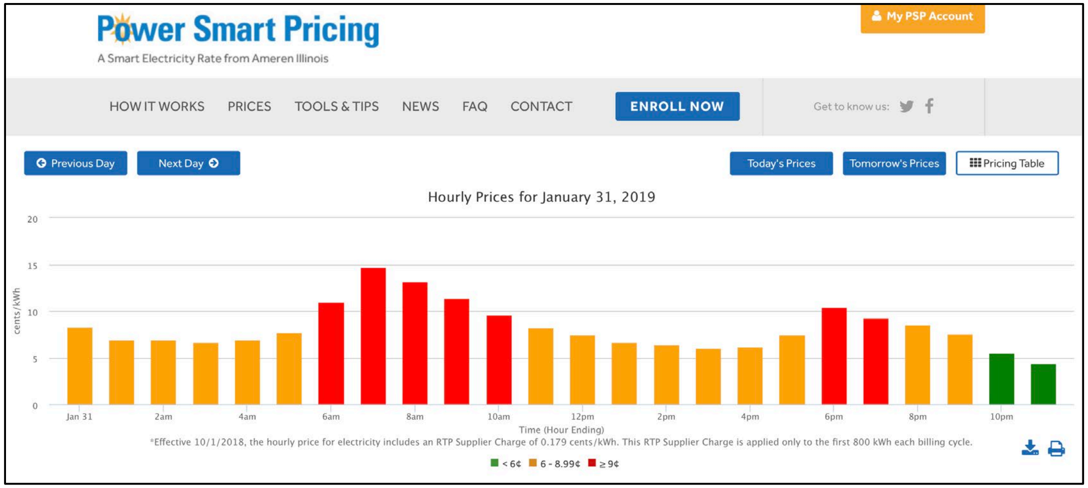
**Highway Funding** function of:

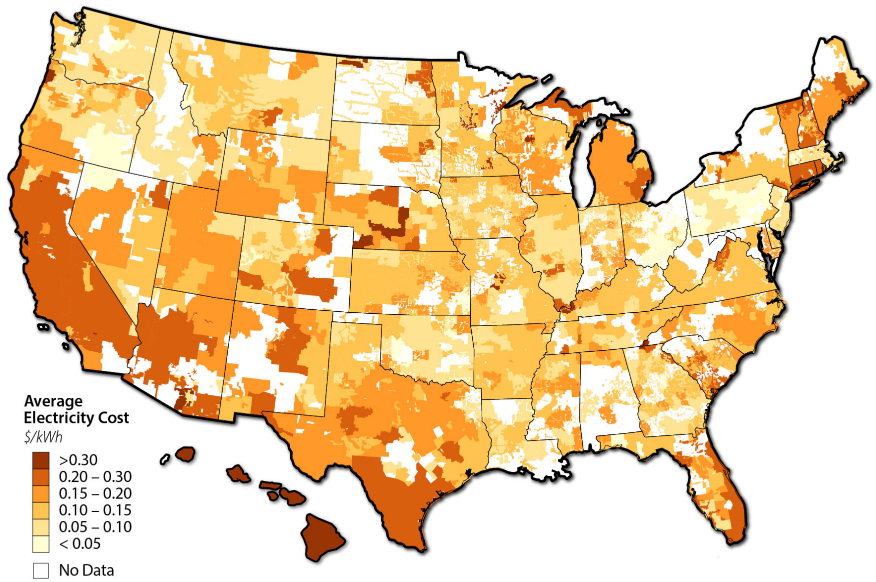
- Federal & State user fees
- gas tax (19 cents/gallon)
- motor vehicle licenses

**Funding solutions** in the era of:

- increased efficiency
- electrification
- intelligent systems

# Illinois Opportunities (2)

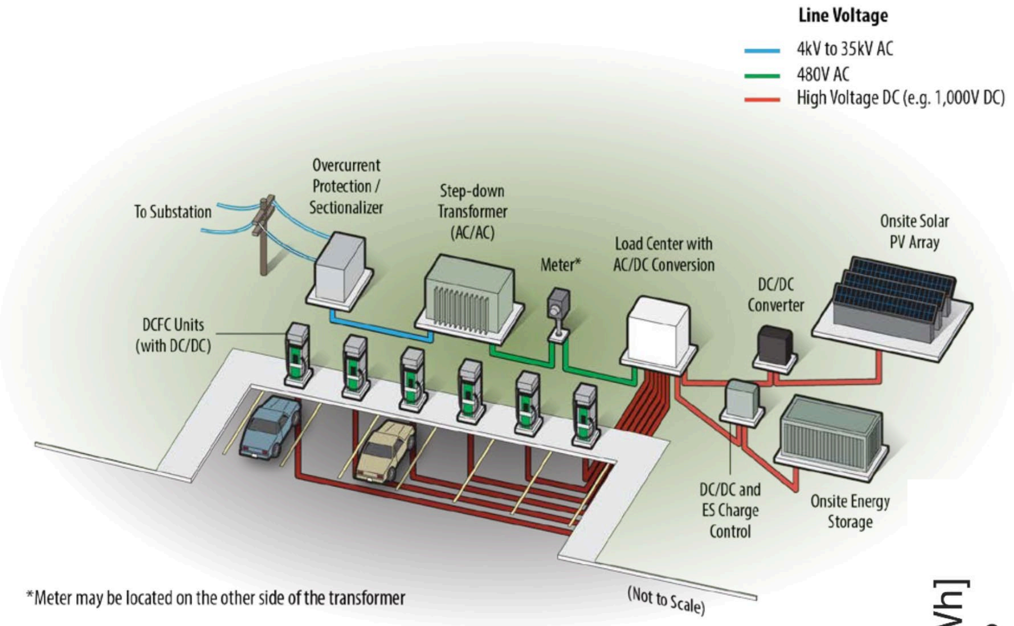


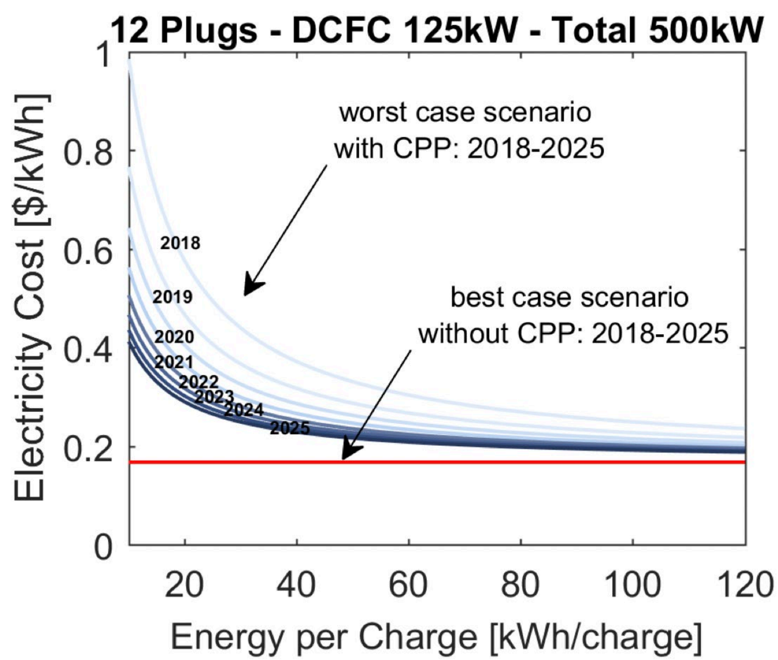

**Utilities** electricity rates design to:

- maintain grid reliability
- financial viable operation of charging providers
- nudge off-peak charging
- take advantage of renewables generation

# Illinois Opportunities (3)




Site picture from: Francfort et al. (2017)




## Charging Hubs

- Renewables Integration at stations
  - Solar panels
  - Energy storage (batteries)

# Thank you!

**Questions?**