

Planning for Electric Vehicle Charging Infrastructure: Opportunities for Illinois

Eleftheria (Ria) Kontou, PhD

Assistant Professor CEE

kontou@illinois.edu



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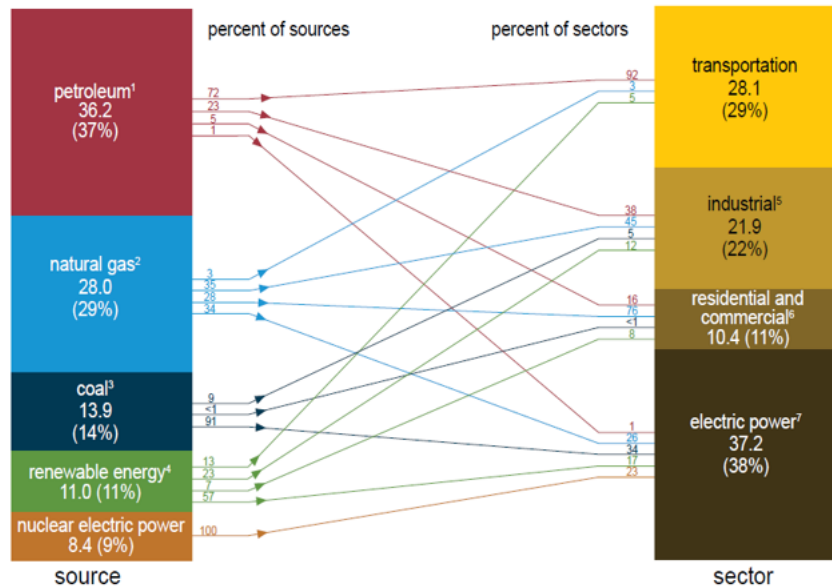
Outline

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

Transportation Energy Use

U.S. primary energy consumption by source and sector, 2017

Total = 97.7 quadrillion British thermal units (Btu)

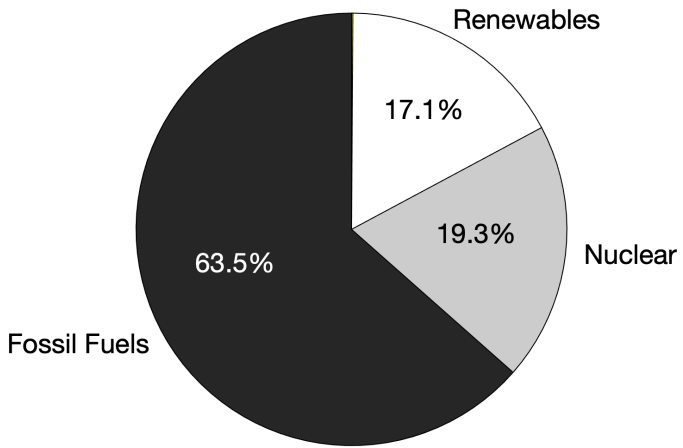


¹ Does not include biofuels that have been blended with petroleum—biofuels are included in "Renewable Energy."
² Excludes supplemental gaseous fuels.
³ Includes -0.03 quadrillion Btu of coal coke net imports.
⁴ Conventional hydroelectric power, geothermal, solar, wind, and biomass.
⁵ Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
⁶ Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
⁷ Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes 0.17 quadrillion Btu of electricity net imports not shown under "source."

Notes: • Primary energy is energy in the form that it is accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy occurs (for example, coal is used to generate electricity). • The source total may not equal the sector total because of differences in the heat contents of total, end-use, and electric power sector consumption of natural gas. • Data are preliminary. • Values are derived from source data prior to rounding. • Sum of components may not equal total due to independent rounding.
 Sources: U.S. Energy Information Administration, *Monthly Energy Review* (April 2018), Tables 1.3, 1.4a, 1.4b, and 2.1-2.6.



U.S. electricity generation by source in 2018



Sources: US Energy Information Administration (2018)



Plug-in Electric Vehicles Overview

Plug In Hybrid (PHEV)

Electricity + Gas

Examples:



Toyota Prius Prime



Ford C-Max Energi



Hyundai Sonata Plug-In



Chrysler Pacifica Plug-In



Audi A3 e-tron



Mitsubishi Outlander PHEV

Battery Electric (BEV)

Electricity Only

Examples:



Nissan LEAF



BMW i3



Tesla Model S



Chevy Bolt EV





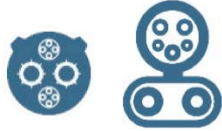
Kia Soul EV



Tesla Model 3

Smart, 2019

Charging Levels Overview

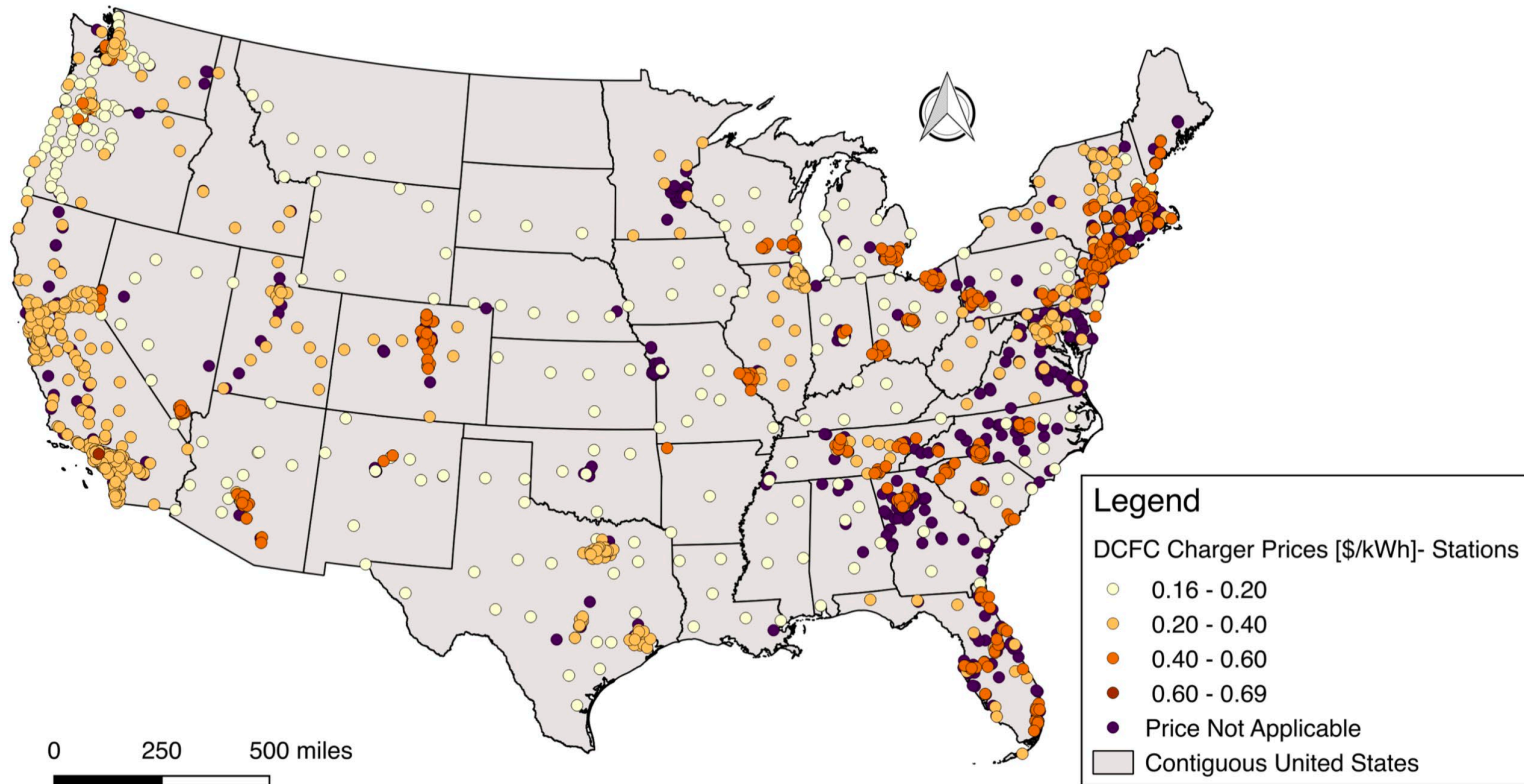
	Home Charging	Workplace	Public Charging
	 <p>Level 1</p>	 <p>Level 2</p>	 <p>DC Fast</p>
Electrical Specs	110 – 120 Volts AC 12 – 16 Amps (home appliance)	208/240 Volts AC 32 Amps (home washer/dryer, commercial standard)	208 to 480 Volts DC 70 – 125 Amps (commercial standard)
Range Per Hour of Charging	~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?



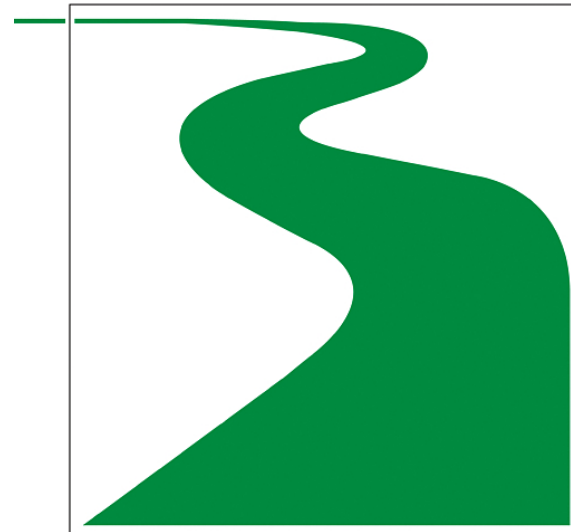
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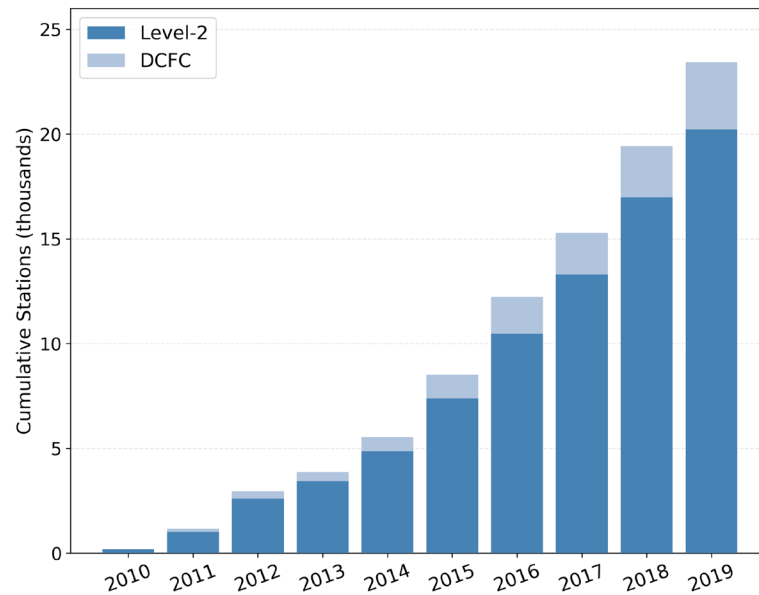


Editors-in-Chief: Jason Cao and Robert Noland

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

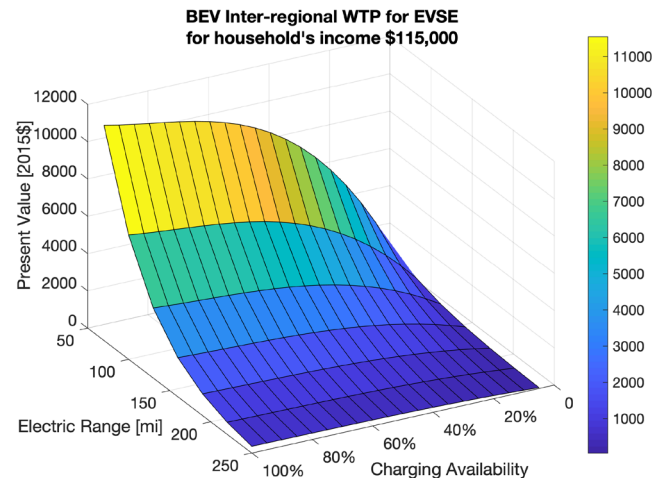
What is the value of public PEV charging?

- 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:

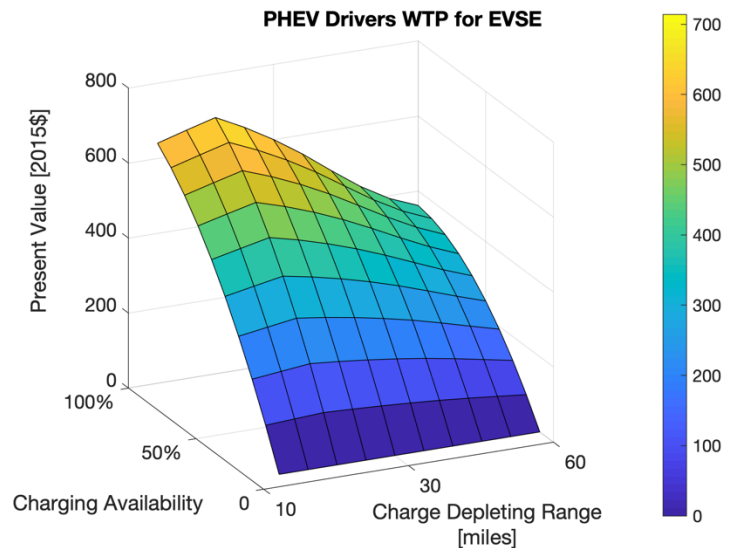
- electric range
- charging availability & location
- annual VMT
- vehicle type
- income



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

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



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

WTP for Charging: BEV Driver (I)

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)

$$WTP_{ij} = \left[\underbrace{\left(a_0 + a_1 \ln(I_j) \right)}_{\text{enabled e-miles depend on log of charging availability } I} \overbrace{\left(\frac{b_0}{R_i^{b_1}} \right)}^{\text{e-miles decreased with increased range } R} M_j \underbrace{\left(v_j - \left(w_j K (\phi_j^a - 1) \frac{1}{CR_i} \right) \right)}_{\text{value per mile of additional enabled travel minus time cost of accessing charging}} \right] D_j$$

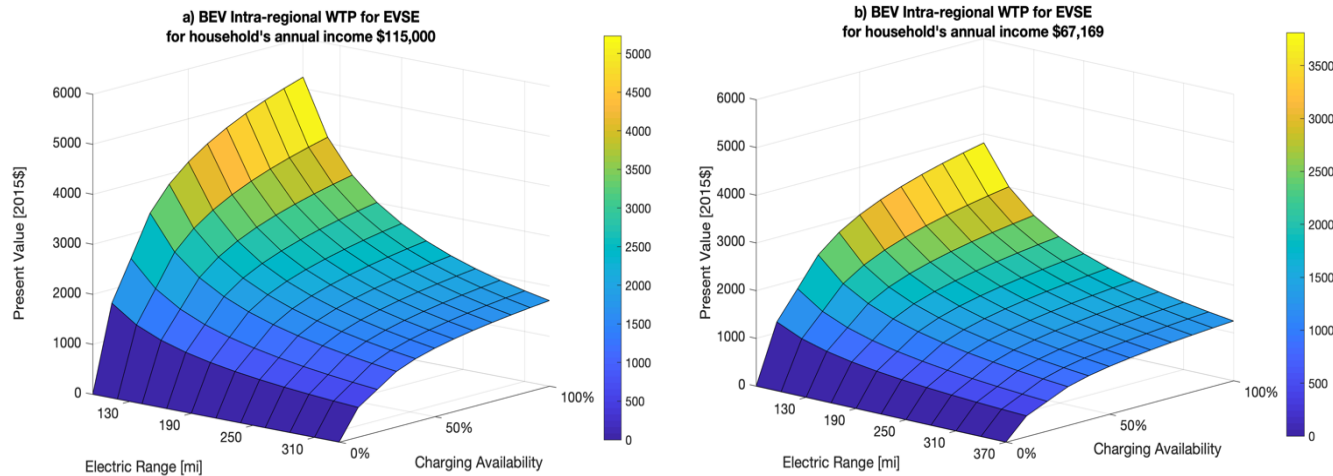
v_j value of enabled electric mile

w_j value of time

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

WTP for Charging: BEV Driver (I)

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)

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

time cost of recharging BEV

ϑR practical electric driving range

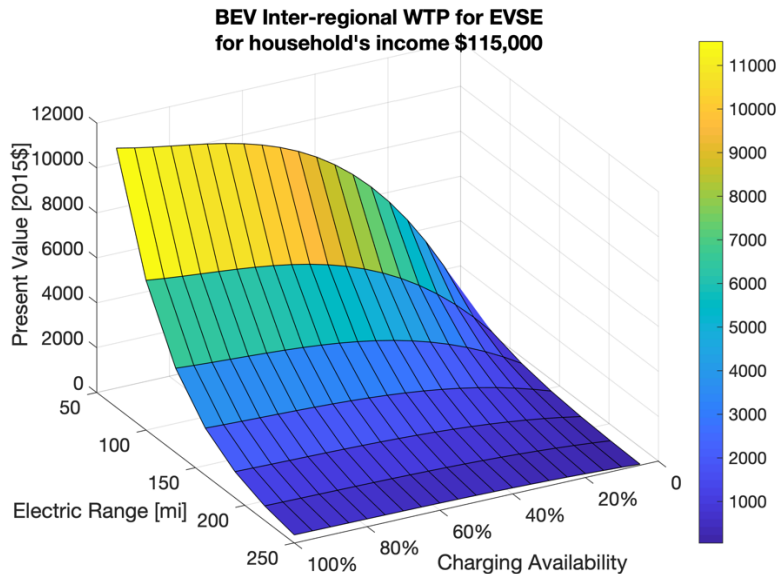
e_i energy consumption

d charger's electricity delivery rate

maximum charge of $\vartheta 100\%$

WTP for Charging: BEV Driver (2)

Inter-regional Charging WTP



Observations

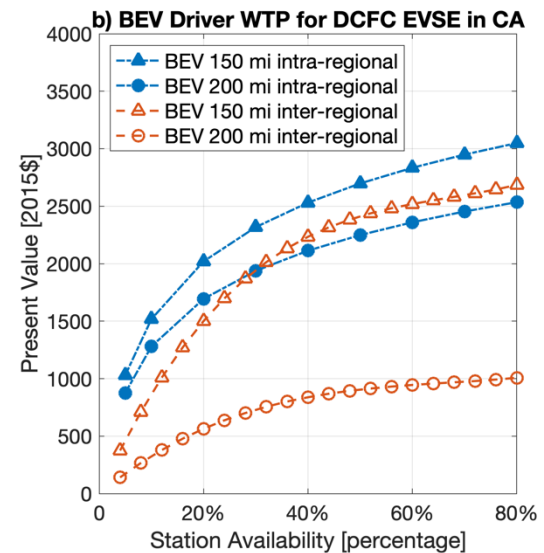
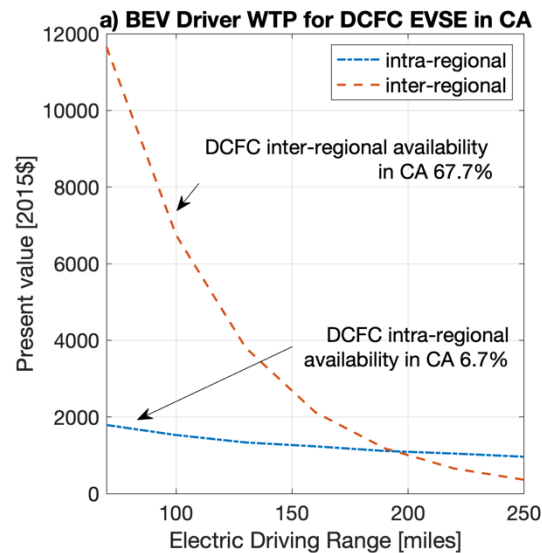
- for low ranges, high charging availability is worth >\$10K

Figure assumptions: \$0.35 per enabled mile

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 (I)



Daily Herald

Will Illinois start charging electric car owners a road fee?



Chicago Tribune

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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'

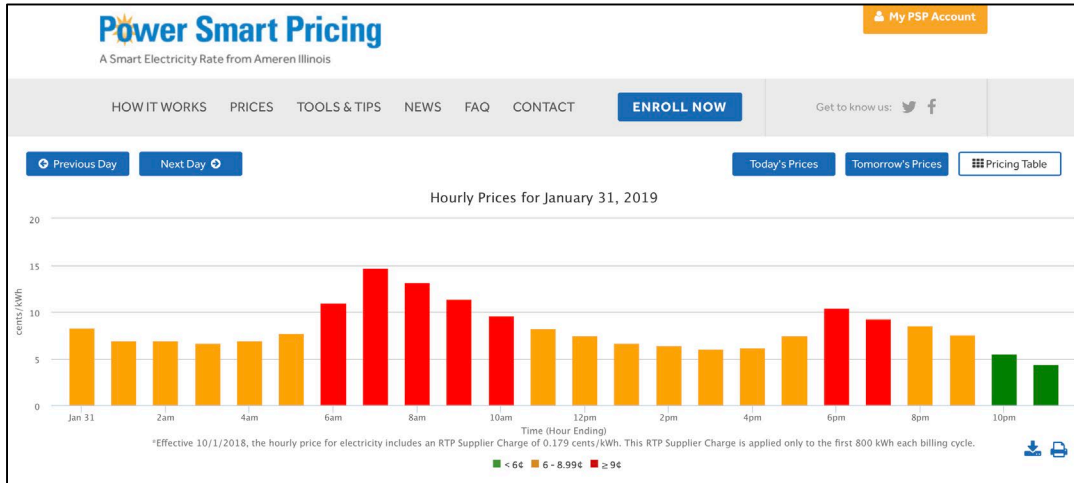
Highway Funding function of:

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

Funding solutions in the era of:

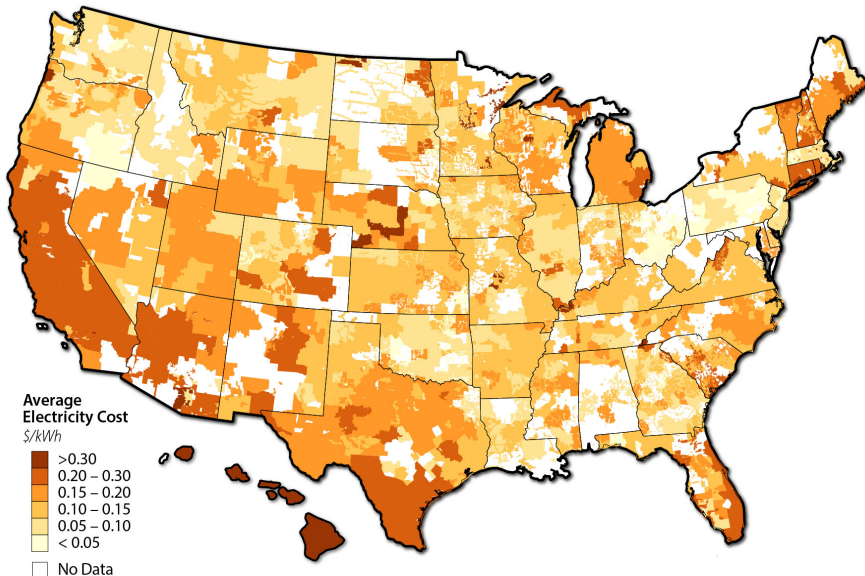
- increased efficiency
- electrification
- intelligent systems

Illinois Opportunities (2)

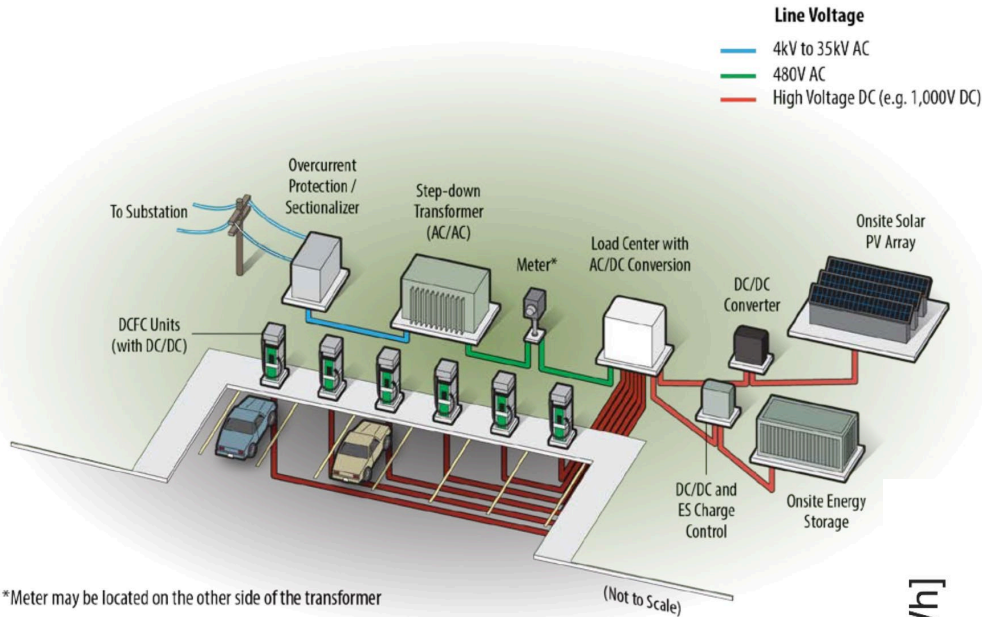


Utilities electricity rates design to:

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



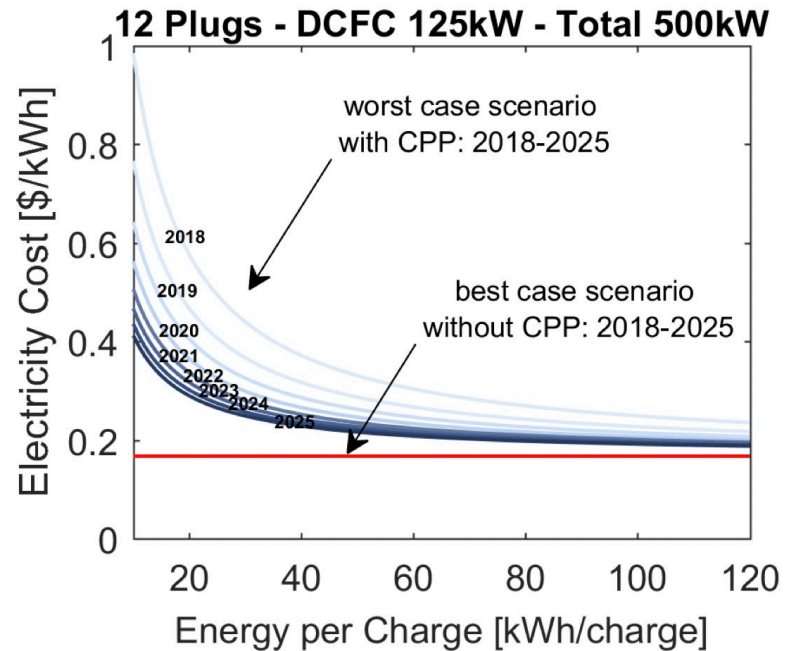
Illinois Opportunities (3)



Site picture from: Francfort et al. (2017)

Charging Hubs

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



Thank you!

Questions?

