Electric Vehicles and Clean Power: Potential Synergies*

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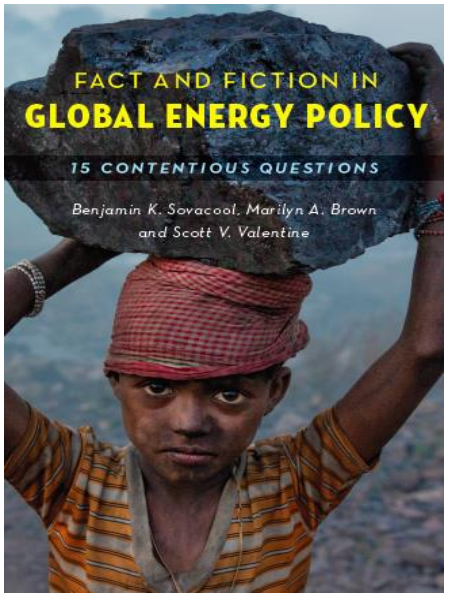
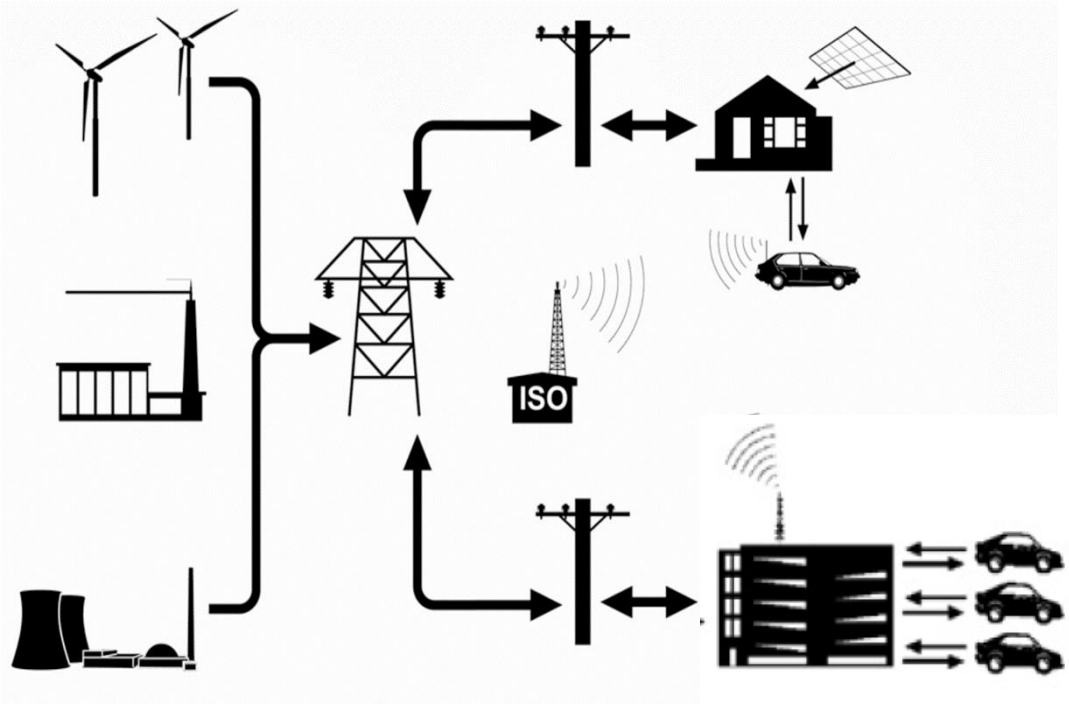
*Electric vehicles can be good for the grid, and a clean grid can make EVs more valuable



Fact and Fiction in Global Energy Policy by B. K. Sovacool, M.A. Brown, & S. Valentine, Johns Hopkins University Press, 2016.

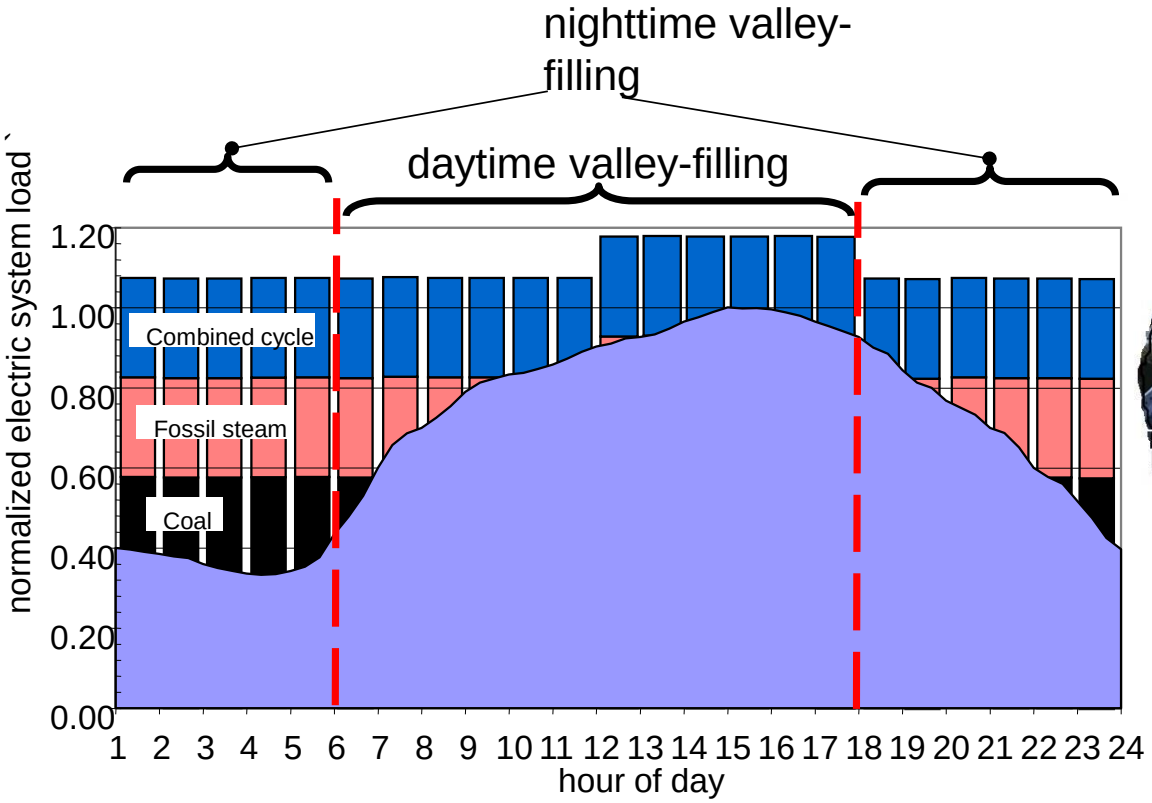
With V2G and Clean Power, EVs can Reduce Oil Use, Reduce Pollution, & Support the Grid

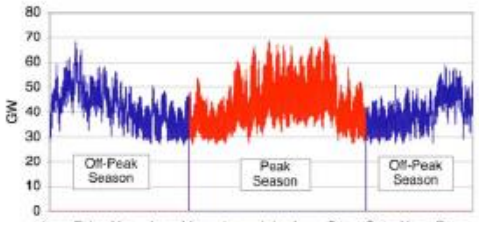


- Most vehicles are not in use 90% of the time
- Electricity is cheaper than liquid fuel per mile driven
- Recharging at night would not need significant new power plant infrastructure
- EVs can provide grid services

A V2G configuration means that EVs have the opportunity to become mobile, self-contained resources interconnected to homes and power grids

Principle 1: "Valley Filling" Improves Grid Economics



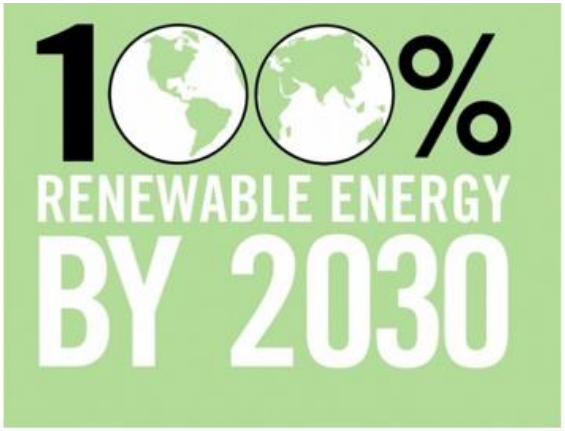


Significant idle generation capabilities in the U.S. grid: potential to support about 73% of light duty vehicles stock using today's grid

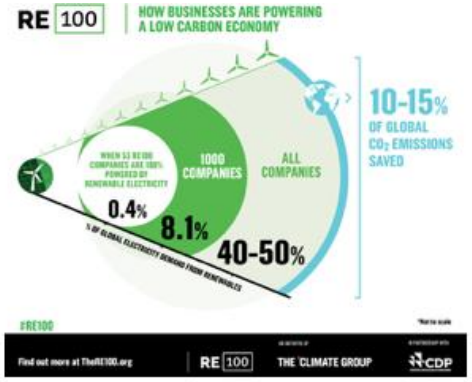
Source: EIA, Annual Energy Review 2005

See: Michael Kintner-Meyer, et al., 2007. "Impact Assessment of Plug-in Hybrid Vehicles on Electric Utilities" LERDWG Meeting, Washington, DC, February 7th

Principle 2: EV Benefits depend on the Fuels Used to Generate Electricity



The Grid Needs to be Greener



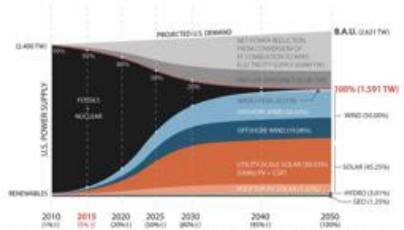
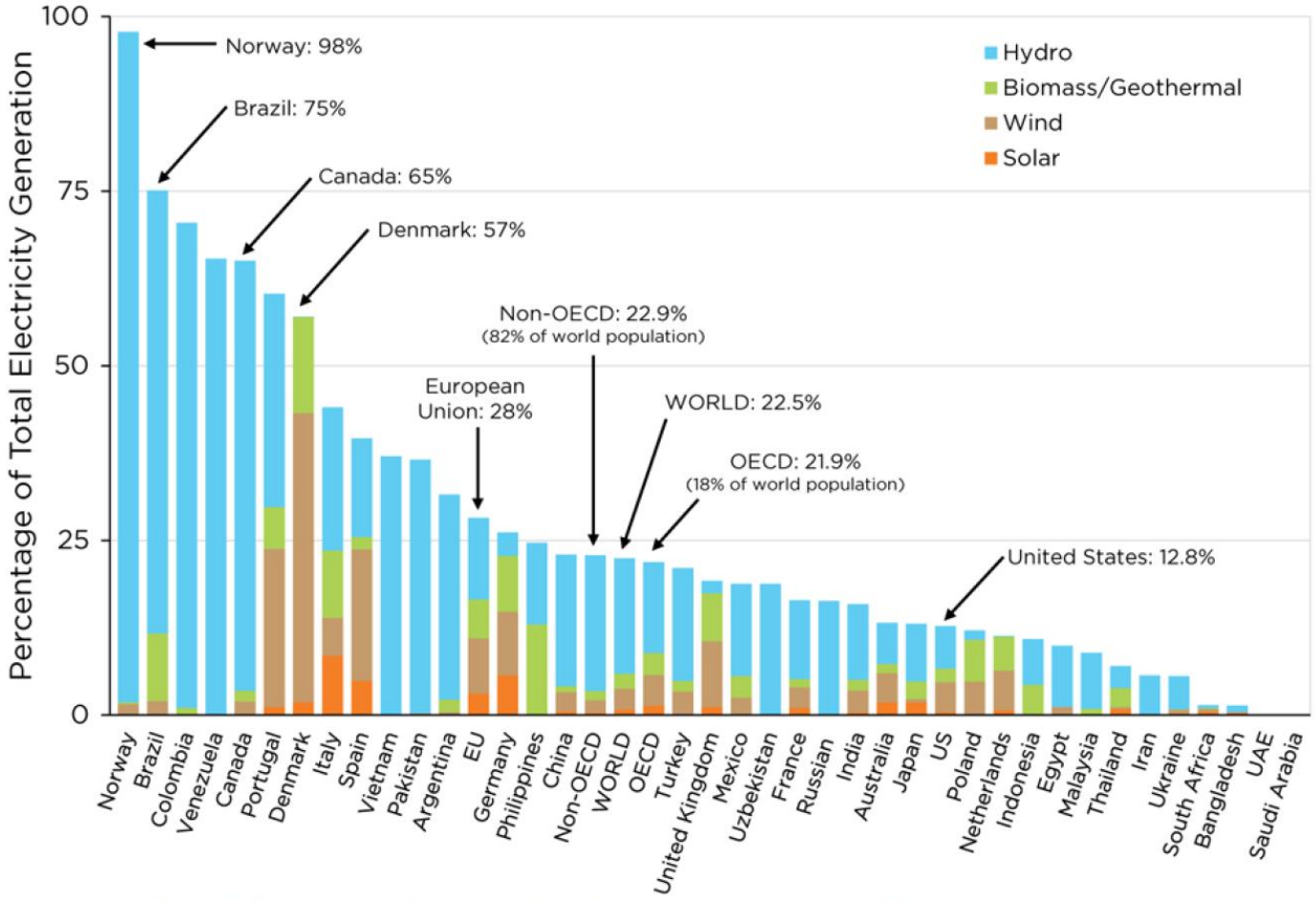


Fig. 5 Time-dependent change in U.S. end-use power demand for all purposes (electricity, transportation, heating/cooling, and industry) and its supply by conventional fuels and WWS generators based on the state roadmaps proposed here. Total power demand decreases upon conversion to WWS due to the efficiency of electricity over combustion and end-use energy efficiency measures. The percentages on the horizontal date axis are the percent conversion to WWS that has occurred by that year. The percentages next to each WWS source are the final estimated penetration of the source. The 100% demarcation in 2050 indicates that 100% of all-purpose power is provided by WWS technologies by 2050, and the power demand by that time has decreased. Karl Burkart, personal communication

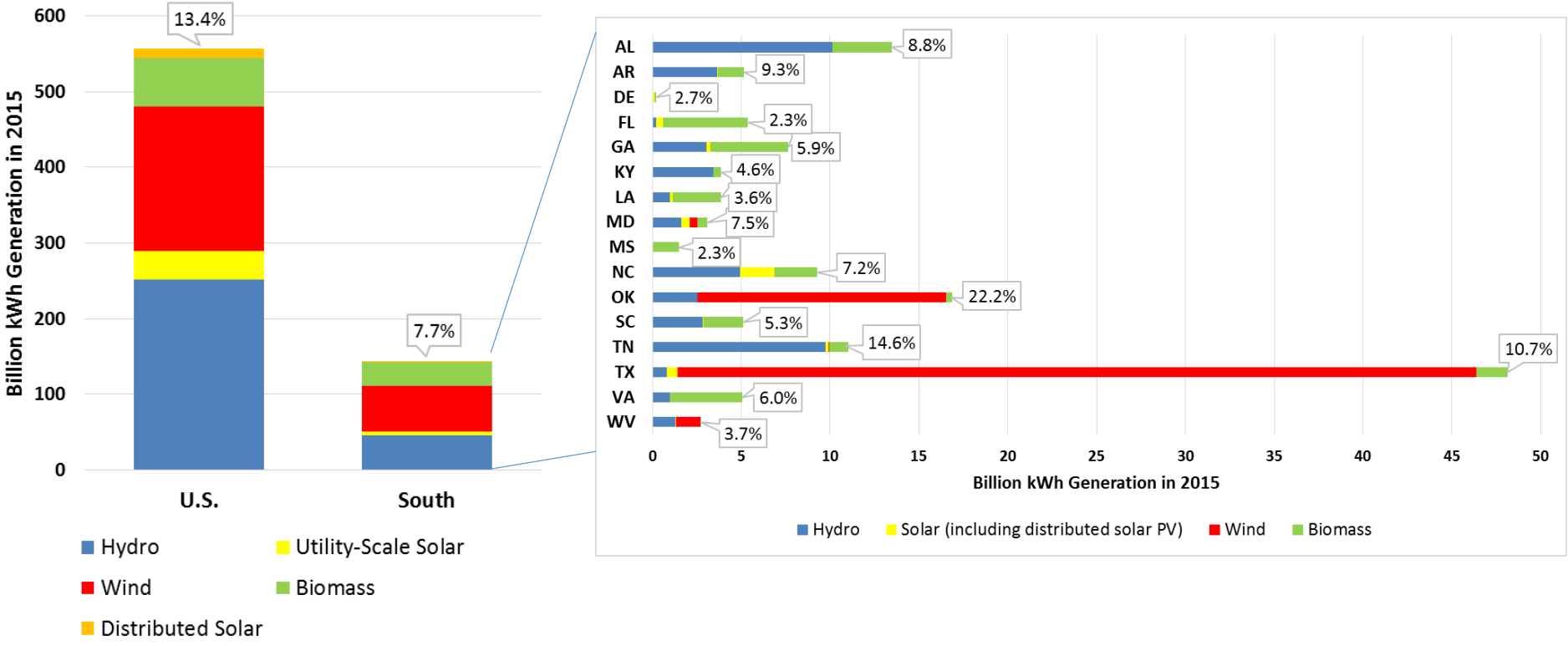
The Portfolio of Grid Fuels Varies Widely Across the U.S. & the Globe



Percentage of electricity generated by renewables in selected countries, 2014.

Source: J. David Hughes, Global Sustainability Research, Inc. (data from *BP Statistical Review*, 2015)

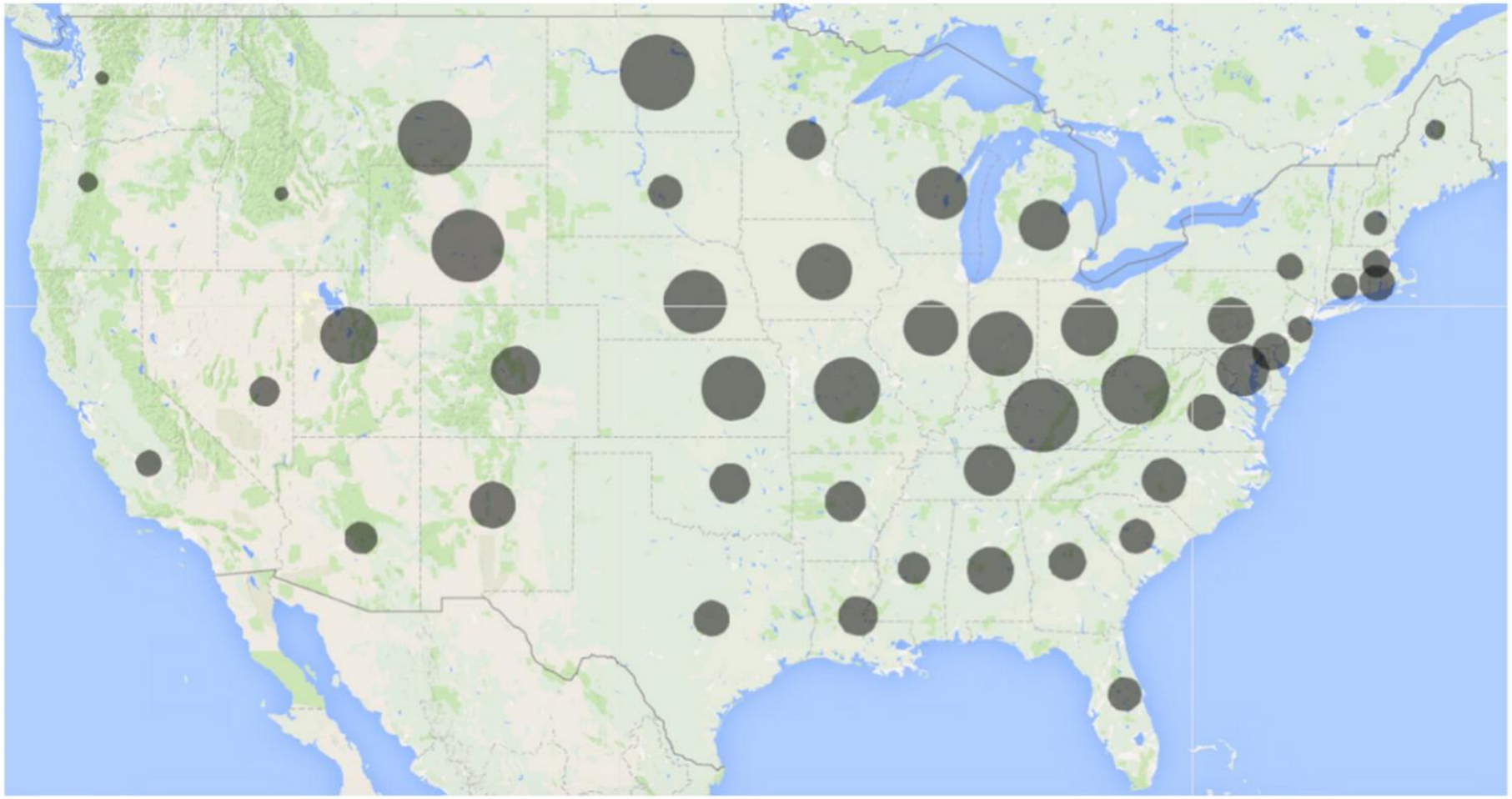
13% of U.S. Electricity is Fueled by Renewables (7% in the South)



Source: *U.S. Energy Information Administration, Electric Power Monthly, Table 1.1A, 1.2C-E, 6.2B. State level data is also available at https://www.eia.gov/electricity/data/state/*

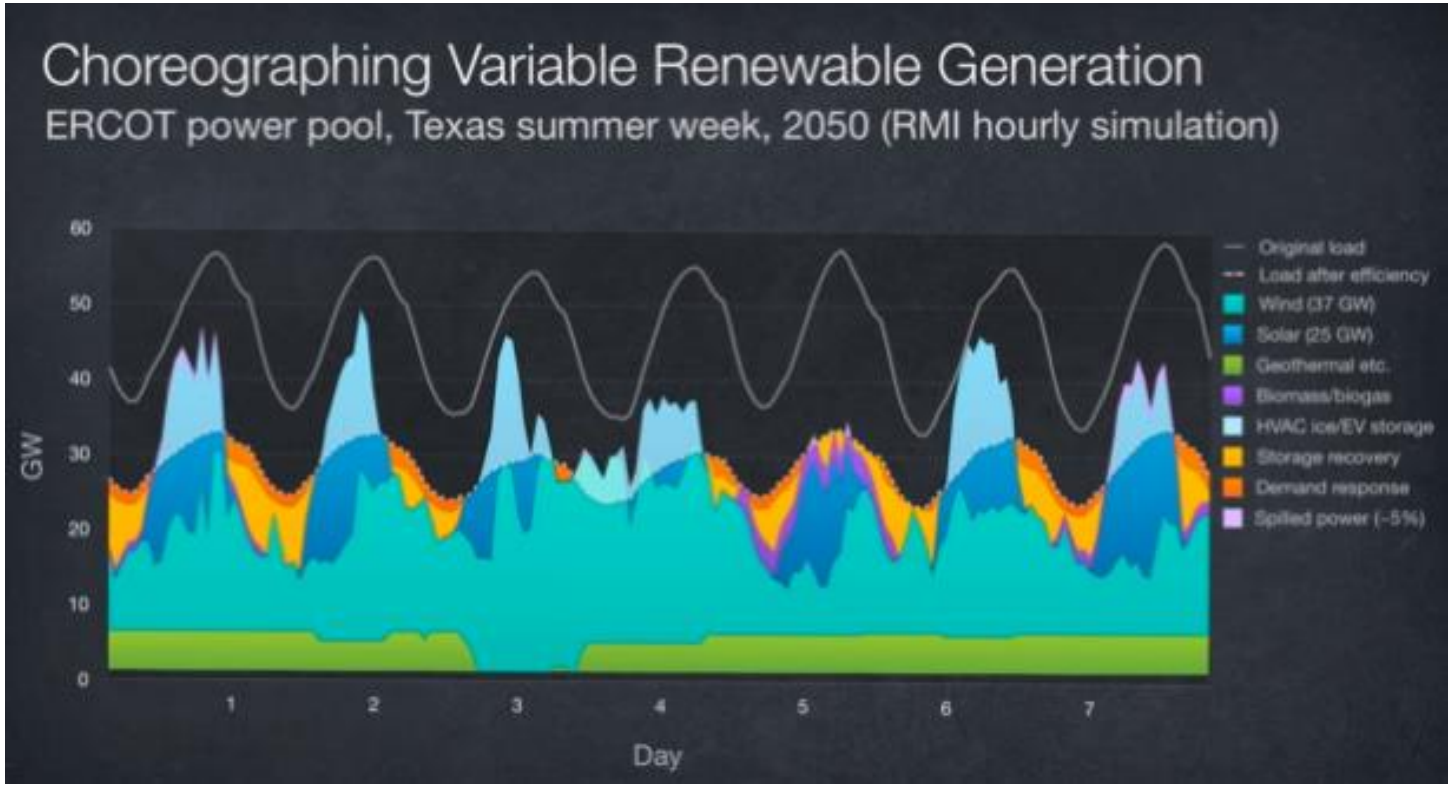
Note: *Distributed generations are estimated. Utility-scale generations are based on reported generation data.*

EPA's Carbon Intensity Targets for 2030



Principle 3: Clean Electricity Needs more Overall Grid Balancing

- Loads fluctuate (but nuclear power cannot follow loads)
- Wind and solar fluctuate with natural resource availability



http://cleantechnica.com/2014/08/08/rmi-blows-lid-baseload-power-myth-video/

Principle 4: EVs Can Help to Balance and Green the Grid

- Use plugged-in EVs for frequency regulation and energy storage available to the grid
  - ✓Create alternative uses when the car is parked (socializing the asset)*
  - ✓Bring payments to the EV owner, thus lowering TCO
  - ✓Help the grid deal with intermittent resources
- Repurpose used EV batteries for energy storage**
  - ✓On the customer side of the meter (e.g., with solar homes)
  - ✓On the utility side of the meter (e.g., TVA)

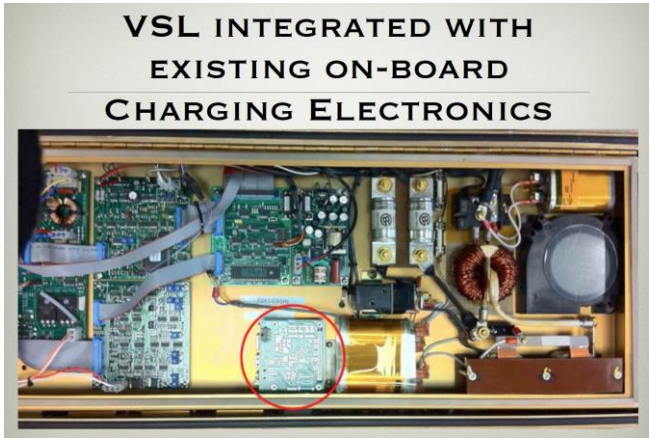
*Cars are parked an average of 23 h/day

**Post 80% capacity

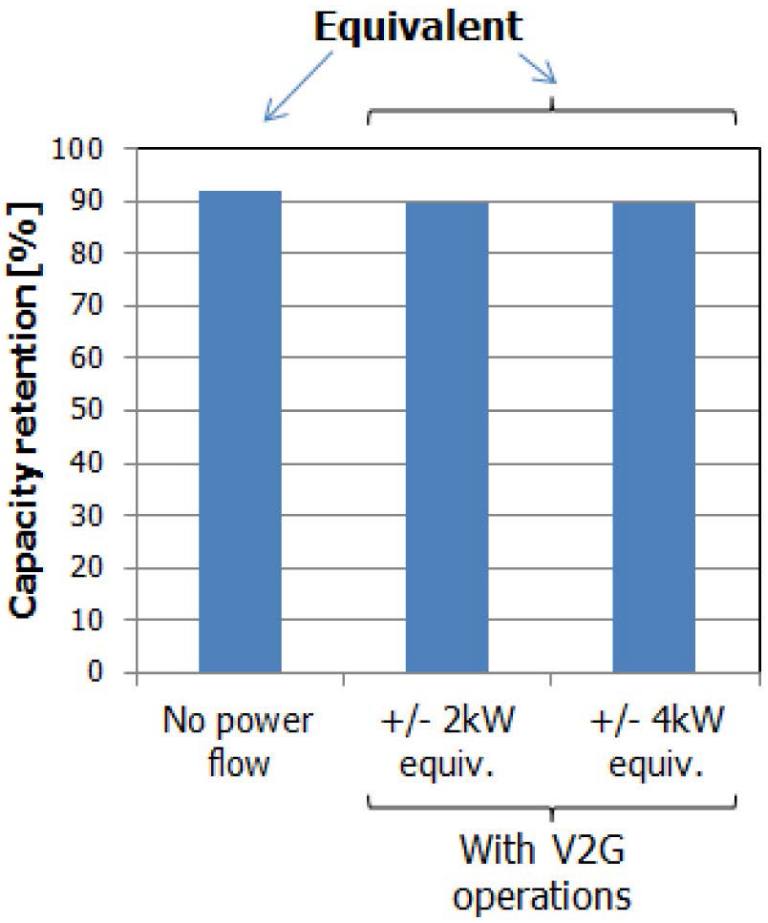
How EVs Could Bid Into Wholesale Markets

Three components to the System

- Aggregation Server (in central location)
  - Real time operation of vehicles
- Vehicle Smart Link (VSL, in car)
  - Control charging, report to server
- Electric Vehicle Supply Equipment (EVSE)
  - Grid location, internet portal, power connection, interconnect permit



But won't the Battery Degrade & Fail?



"… the extra degradation caused by V2G operations is negligibl[y] small.

As a further test, we conducted durability tests at high temperature, which reveal that battery degradation with V2G operations is almost identical with that without V2G operations."

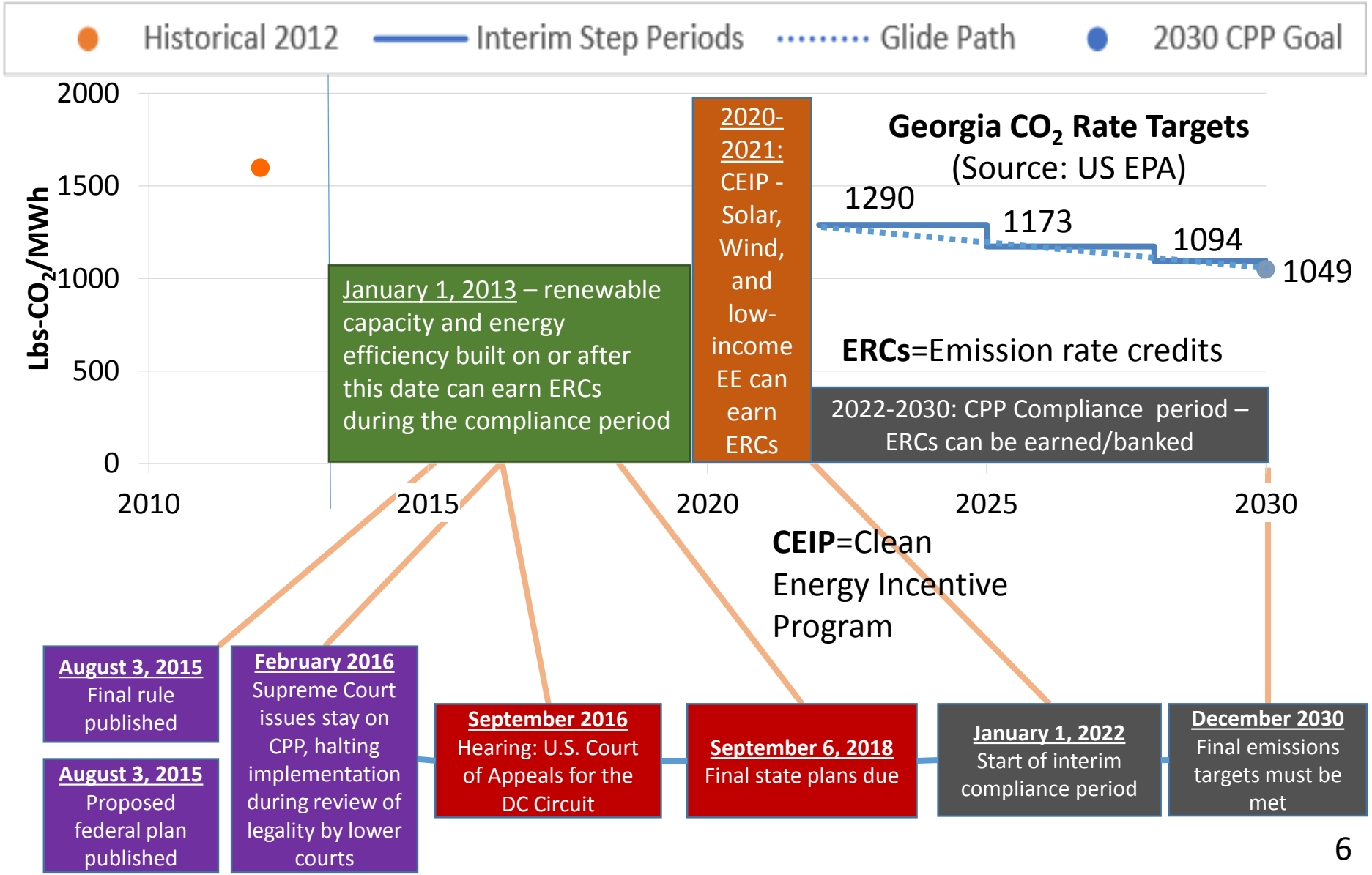
Source: Willett Kempton (University of Delaware) Research Workshop on the Social and Historical Dimensions to Transport, Copenhagen, Denmark, February 2016.

So, EVs Can Support the Paris Accord

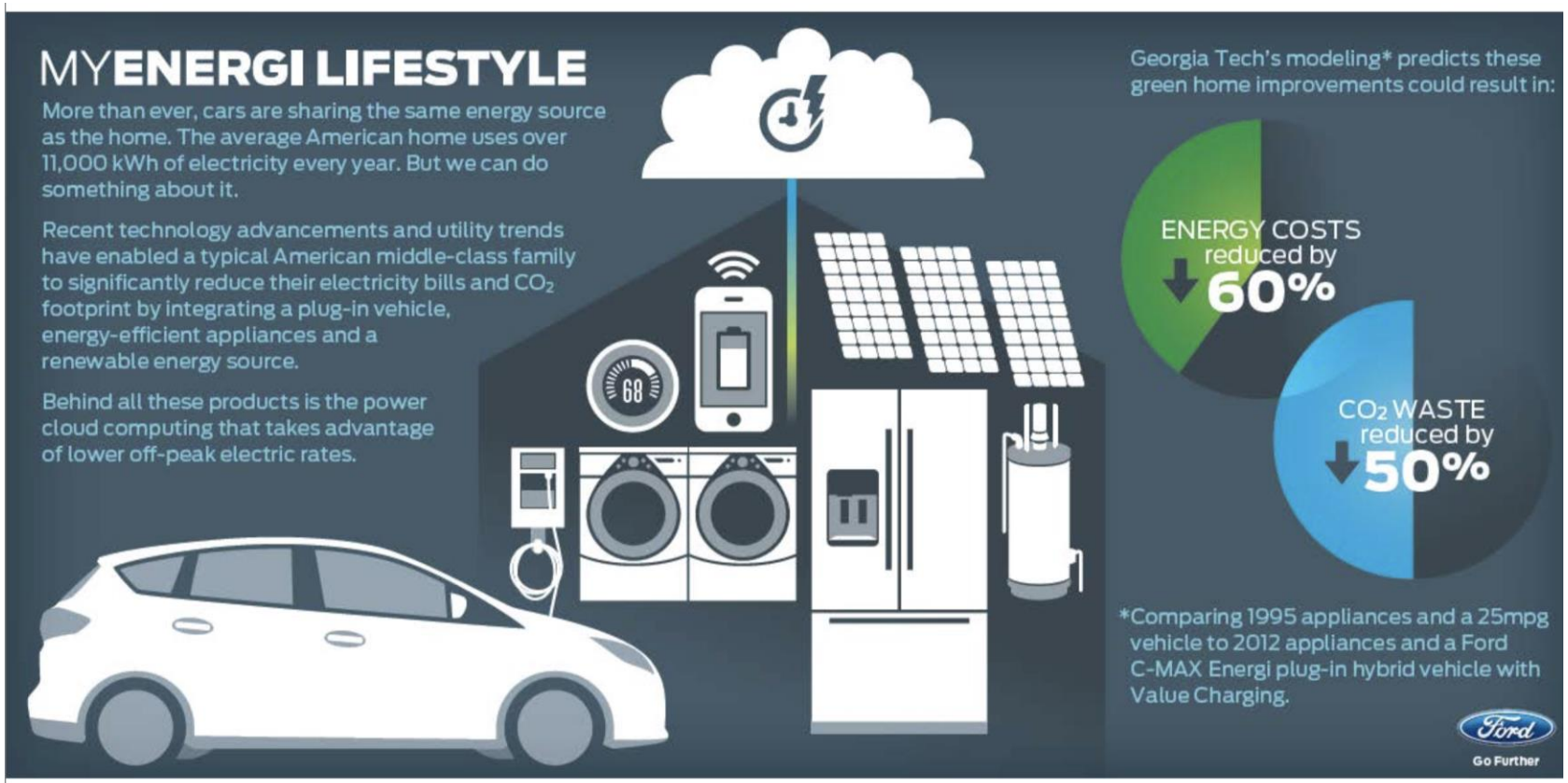
The Paris Agreement:

- **"…achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century"**
- "Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."

And EVs Can Support the Clean Power Plan



Visions from Georgia Tech: The Energy Lifestyle



Ford SUNPOWER EATON Powering Business Worldwide Infineon Whirlpool Corporation Georgia Institute of Technology

Source: Bert Bras (2016)
http://cepl.gatech.edu/sites/default/files/attachments/BB_100Renewable_Aug4_2016.pdf#

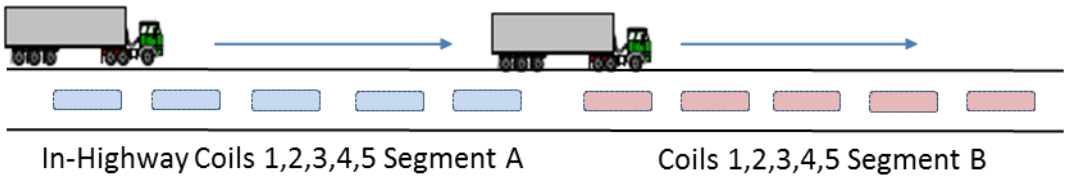
Visions from Georgia Tech: Freight on The Electric Highway

THE U.S. SUPERTRUCK PROGRAM

Mobile Power Supply Options:

- **Conduction Charging of EVs via Catenary**

- **Dynamic Wireless On-Road Charging of EVs**



Electrical coils in the road surface power vehicles via contactless electronic induction

For More Information

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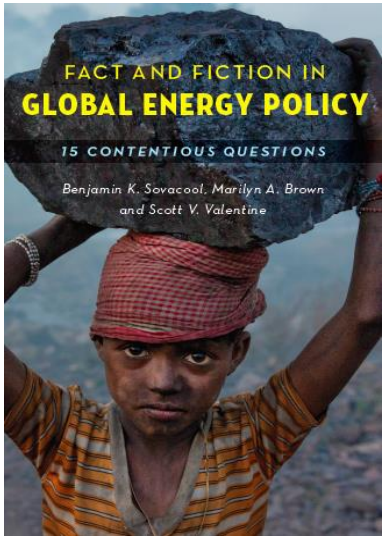

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