FLORIDA SOLAR ENERGY CENTER™

Creating Energy Independence

PV, EV and Your Home: How Transportation and Grid Integration Work Together

OST-R Transportation Innovation Series

U.S. Department of Transportation

Wednesday, July 15, 2015

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A Research Institute of the University of Central Florida

Outline

- FSEC Energy and Transportation Research and Education
- "PV, EV and Your Home" *Interface* Magazine of Electrochemical Society
- Energy Prices Today and in 2025
- Power Generation Capacity Additions 2010 – 2030
- Zero Energy Homes & PV for EV
- Switching Small Cars to EVs
- Utilities in Solar Transportation Business
- Transportation in Solar Infrastructure Business
- Wireless Charging, V2G/V2X, Electric Bus, Fuel Cell Vehicles w/Backup Power Capability

UCF's FSEC Leads in Energy

Building AMERICA
U.S. Department of Energy

EVTC
Electric Vehicle Transportation Center

Central Florida Clean Cities Coalition

U.S. PHOTOVOLTAIC MANUFACTURING CONSORTIUM
PVMC

U.S. DEPARTMENT OF ENERGY
Solar Instructor Training Network
Southeast Region

Regional Test Centers
Differentiating PV Quality

Drive ELECTRIC Florida

FEEDER
Foundations for Engineering Education for Distributed Energy Resources

GO SOLAR | FLORIDA

ENERGYWHIZ
Connecting Schools, Teachers, and Students with Solar Energy

PV, EVs, Energy Efficient Buildings, Load Management, Batteries, Alternative Fuels, Hydrogen, Fuel Cells, Smart Grid Electronics, V2X, Training & Education

FSEC

www.electrochem.org/dl/interface

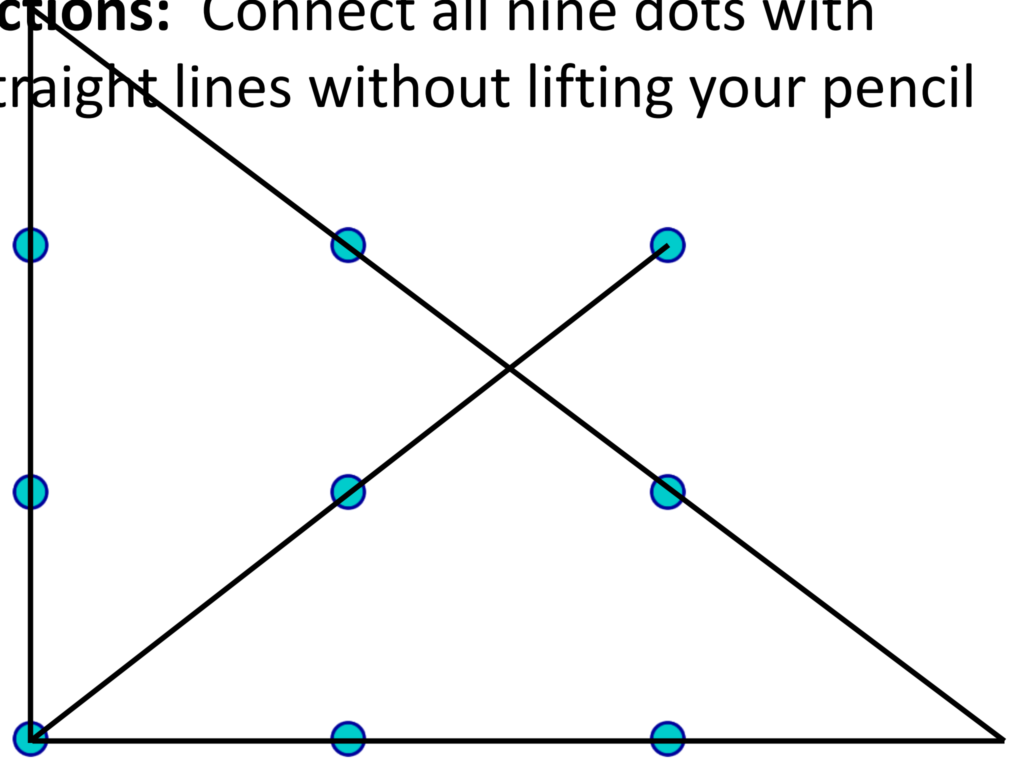
DOT Sustainability/Energy

- **Exceeded greenhouse gas reduction targets four years in a row** (23% relative to FY2008)
- **Doubled renewable energy use** (19% of DOT's electricity consumption)
- **Exceeded Petroleum Reduction Target, three years in a row** (865,000 gallons or 24% 2005)
- **DOT has tripled its alternative fuel use** since 2005.
- **DOT has reduced building energy use by 113 billion BTUs** (19% of FY2003).
- **For the second year in a row, DOT exceeded its water reduction target** (90 M gallons or 19% of FY2007).

http://www.transportation.gov/mission/sustainability/jan-2015-dot-sustainabilityenergy-scorecard
Update June 2015

"Thinking Outside The Box"

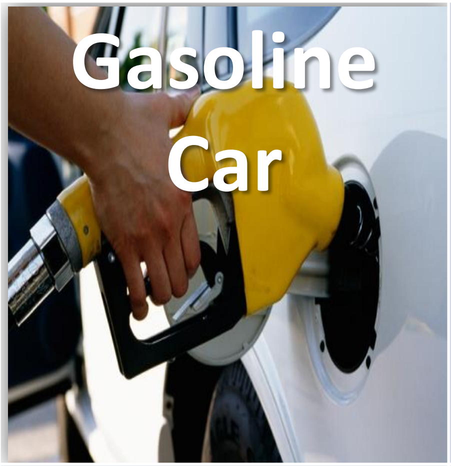
Instructions: Connect all nine dots with four straight lines without lifting your pencil



Watch out for the **perceived** boundaries of the problem!

Energy is Fungible

- Drive our Cars and Operate our Buildings with electricity from renewables and energy efficiency
- Cheaper than Gasoline Today!
- Fossil Fuel Prices Going Up, Solar and Wind Going Down!
- Reduce greenhouse gases
- PV, EVs, Energy Storage and Energy Efficient Buildings Integrated Together
  - Increase Renewable Energy Penetration thereby further decreasing costs
  - Reliability and Resiliency of Transportation and Grid Infrastructures Improved

	Fuel Efficiency	Fuel Price	Cost per Mile	Cost per 12,000 Miles
 Gasoline Car	24.9 mpg	$3.00 per gal	12.0¢ per mile	$1,446
 Electric Car	3 miles per kWh	11.88 ¢/kWh ($0.99 per gal equiv.)	3.96¢ per mile	$475

U.S. 232 M Cars and Light Trucks

(Gasoline: $3.00/gal; 12,000 miles/yr)

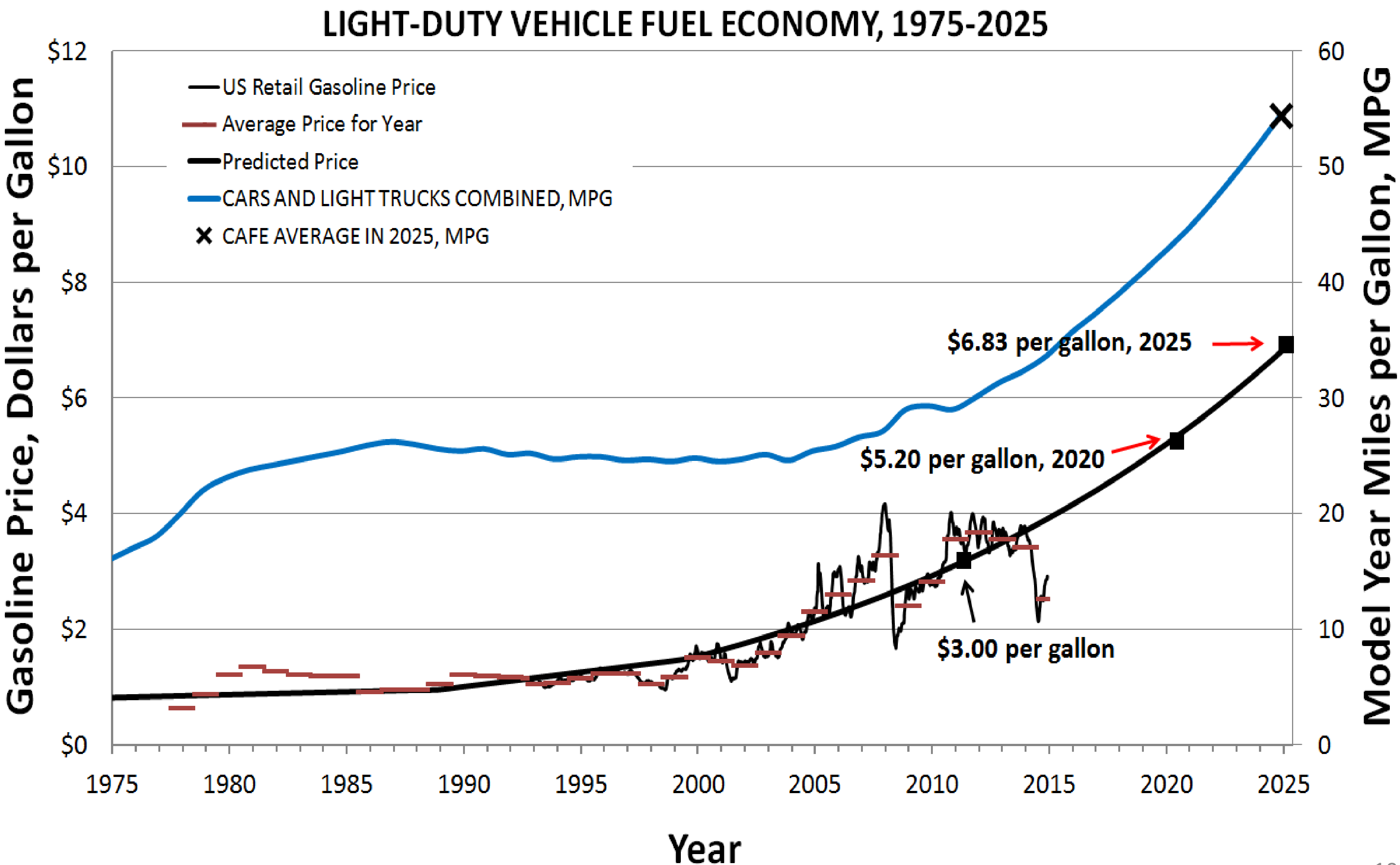
	Fuel Efficiency	U.S. Vehicle Use per year	U.S. Bill $ B/yr
Cars (111 M)	24.9 mpg	53.6 B gal/yr	$161 B/yr
Light Trucks (121 M)	18.5 mpg	78.4 B gal/yr	$235 B/yr
Small Cars (61 M)	30 mpg	24.4 B gal/yr	$73 B/yr
If EV Small Cars (61 M)	3 miles/ kWh	244 TWh/yr	$29 B/yr

U.S. 127 M Residential Electricity Customers

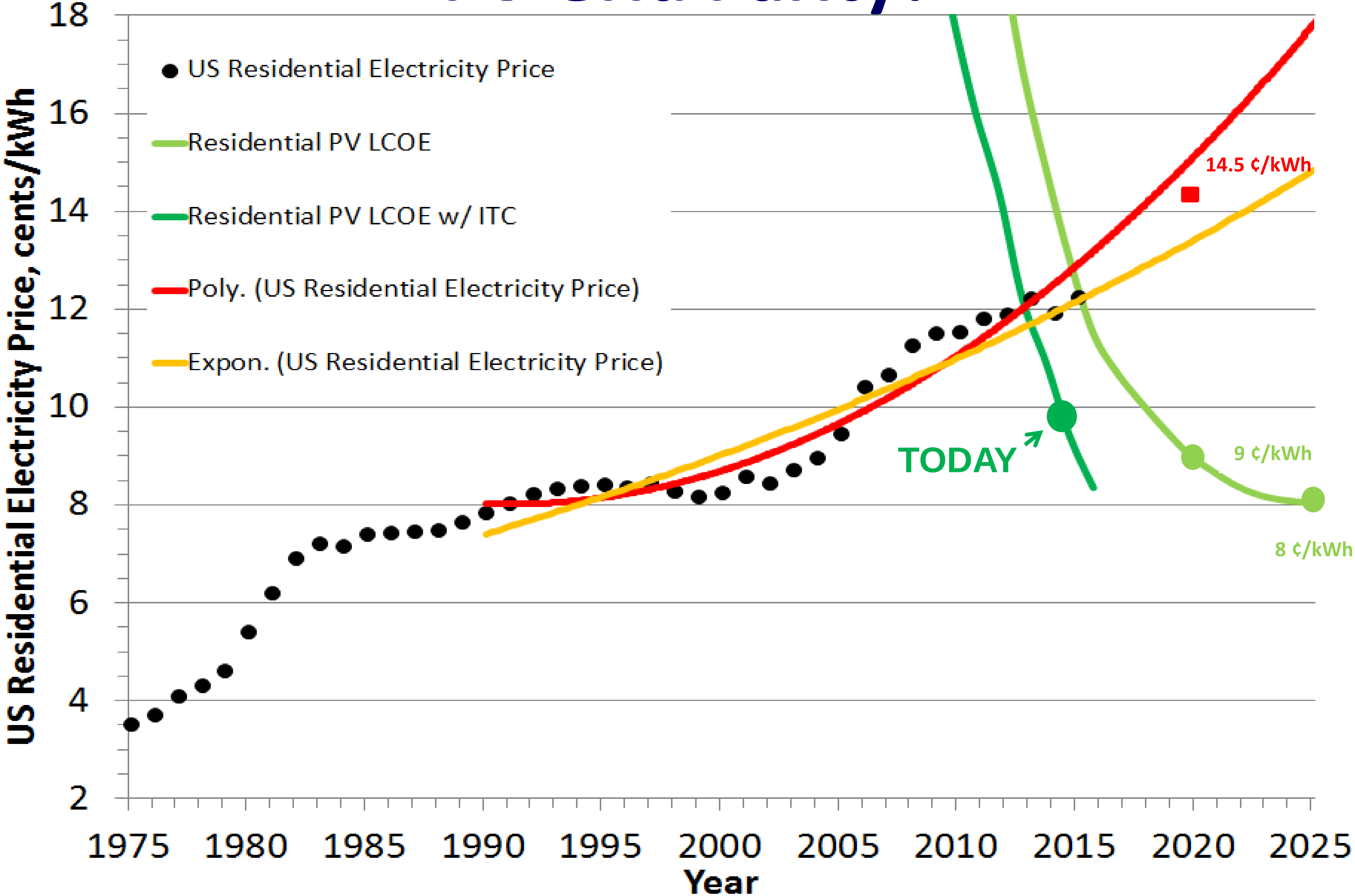
(paying $0.1188 per kWh)

	Use per year	Bill per year	U.S. Use per year	U.S. Electric Bill $ B per year
Residential Energy (Elec. + Thermal)	Elec.: 10,836 kWh/yr	Elec. ($1,287)+ Thermal ($713) = $2000	Elec: 1,376 TWh/yr	$163.5 B/yr

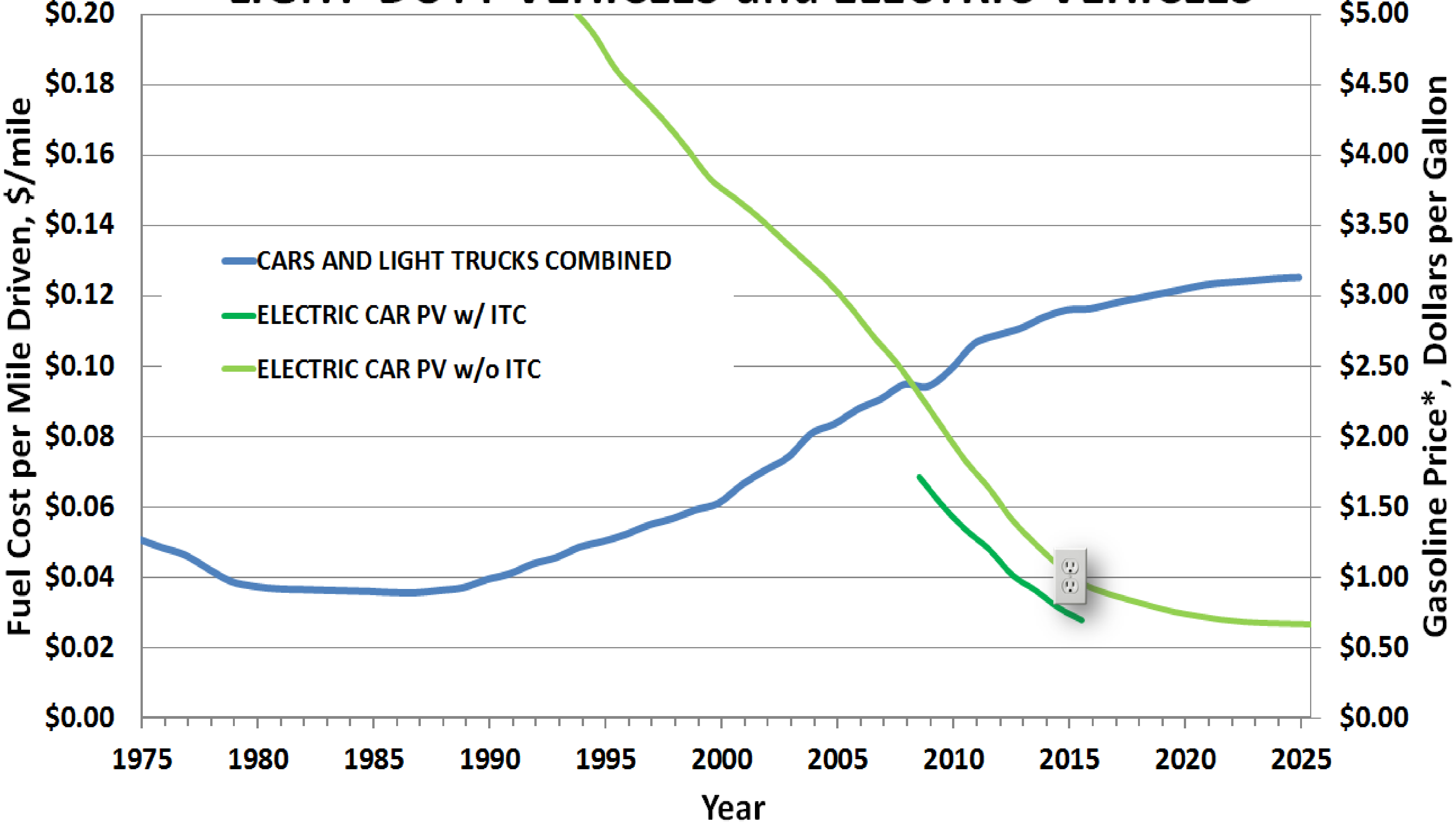
Price of Gasoline?



PV Grid Parity?



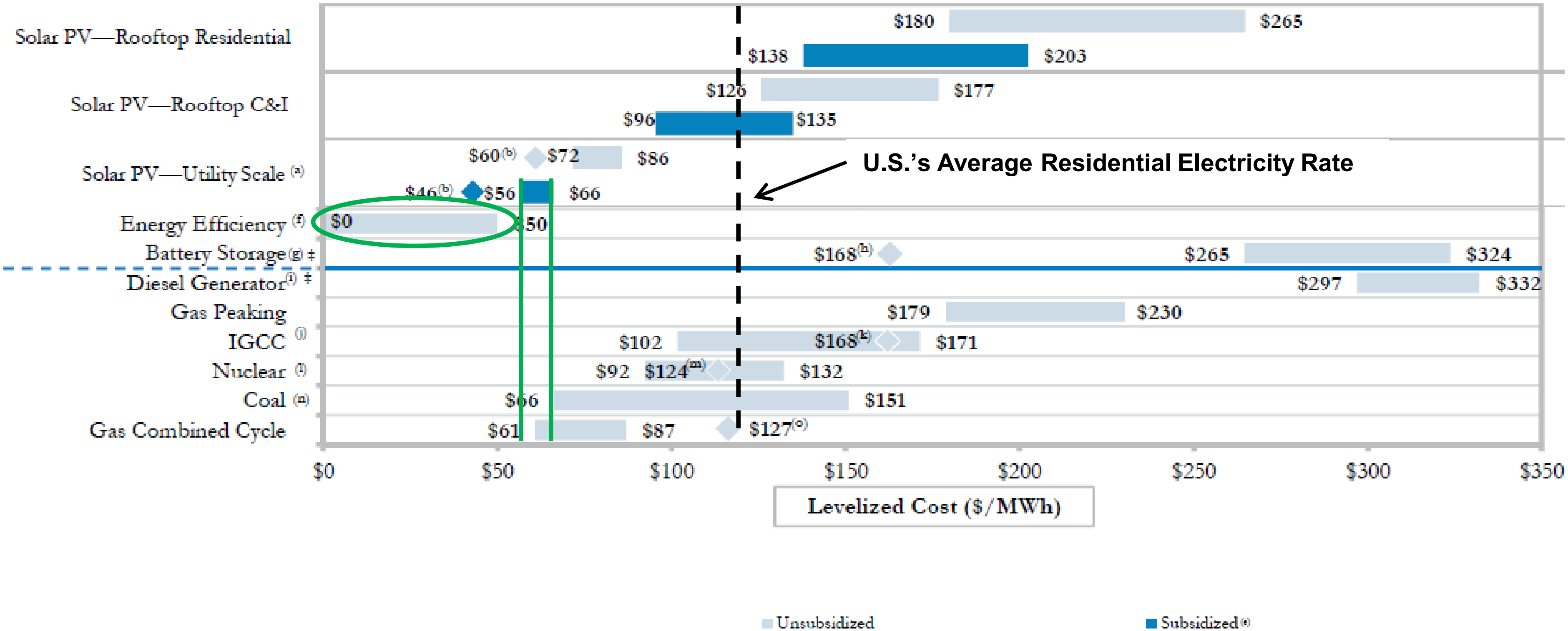
GASOLINE PRICE EQUIVALENT (Cost Per Mile)
LIGHT-DUTY VEHICLES and ELECTRIC VEHICLES



* Costs are relative to cost of $3.00 per gallon gasoline at a vehicle efficiency of 25 mpg

Utility Solar Cheaper than Gas CC

(in 2014 w/ITC; 2017 w/o ITC)



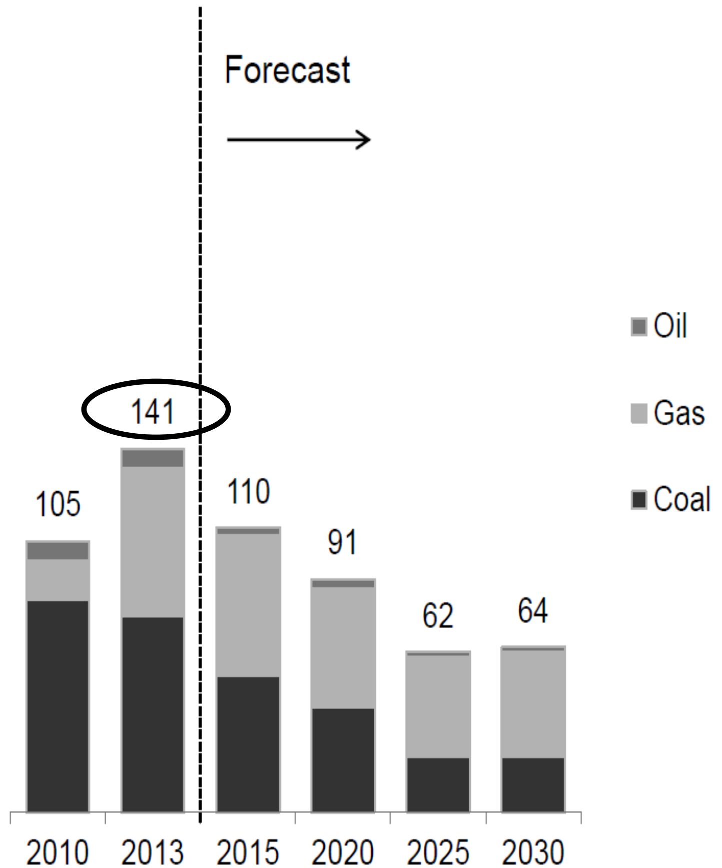
Source: *Lazard estimates.*
(a) Low end represents single-axis tracking. High end represents fixed-tilt installation. Assumes 10 MW fixed-tilt installation in high insolation jurisdiction (e.g., Southwest U.S.).
(b) Diamonds represent estimated implied levelized cost of energy in 2017, assuming $1.25 per watt for a single-axis tracking system.

Adapted from Lazard's Levelized Cost of Energy Analysis Version 8.0 September 2014

GLOBAL GROSS POWER GENERATION CAPACITY ADDITIONS, 2010–30 (GW)

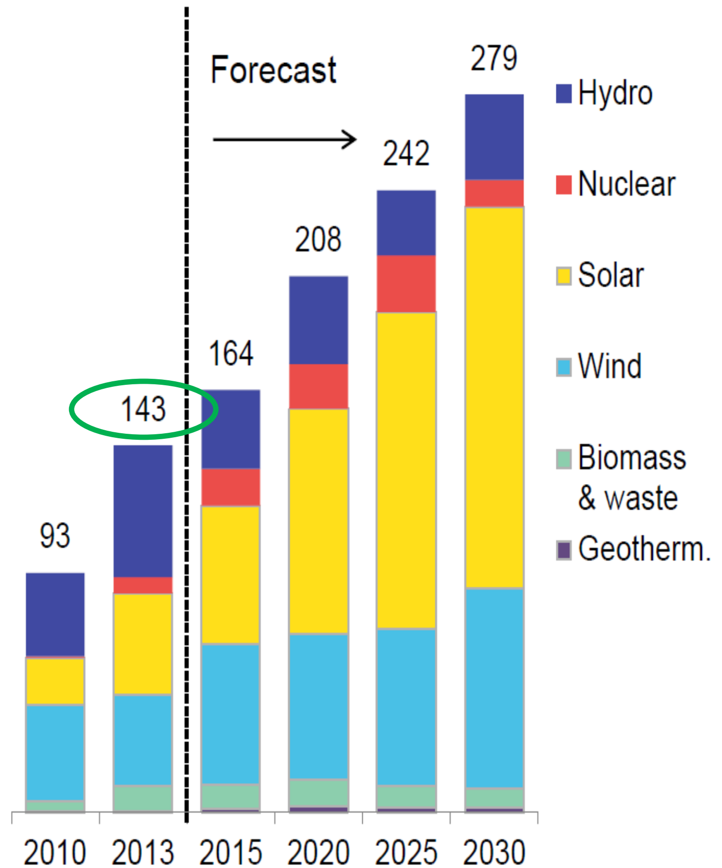
Bloomberg NEW ENERGY FINANCE

FOSSIL FUEL



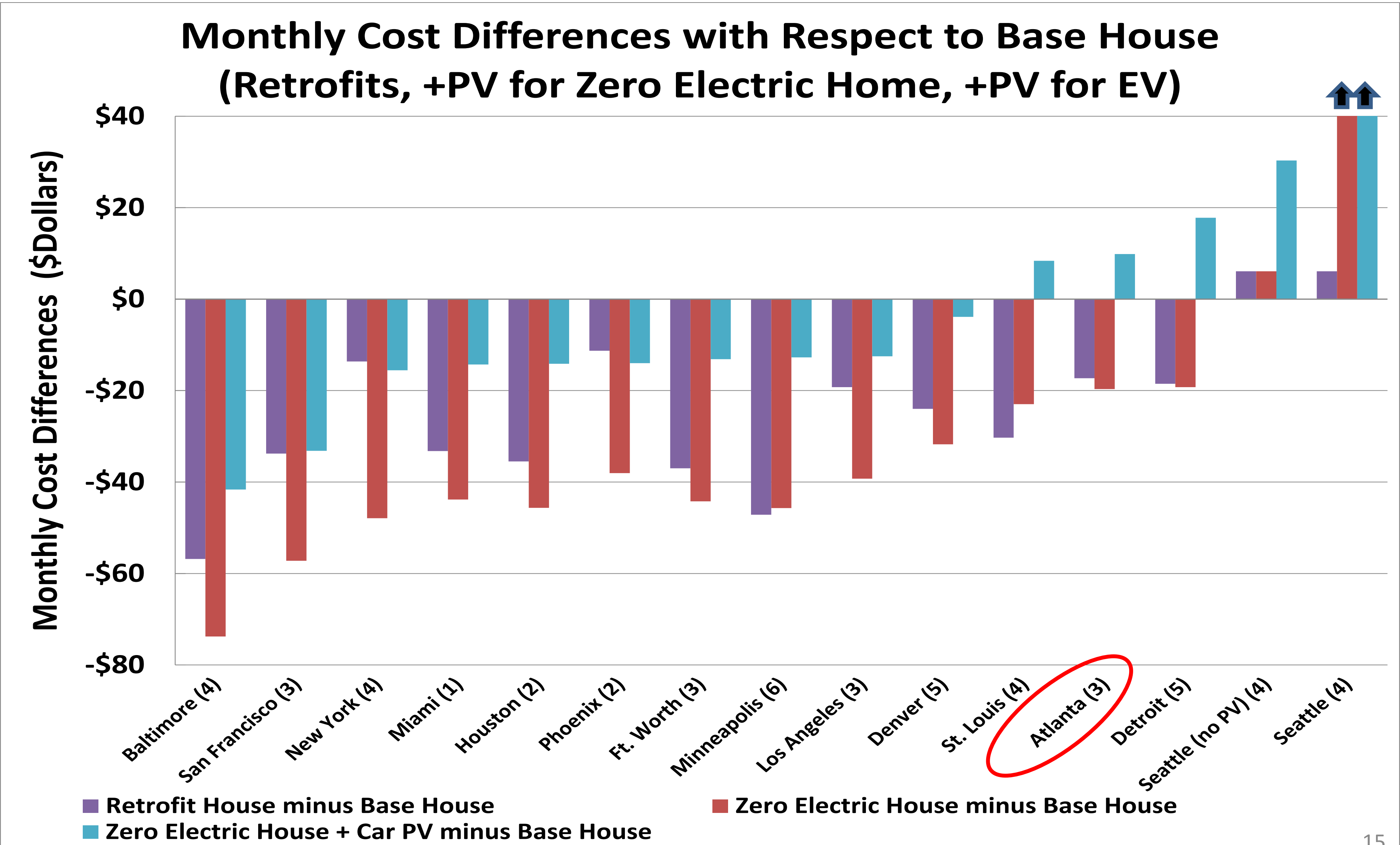
Note: Underlying data is from GREMO 2014

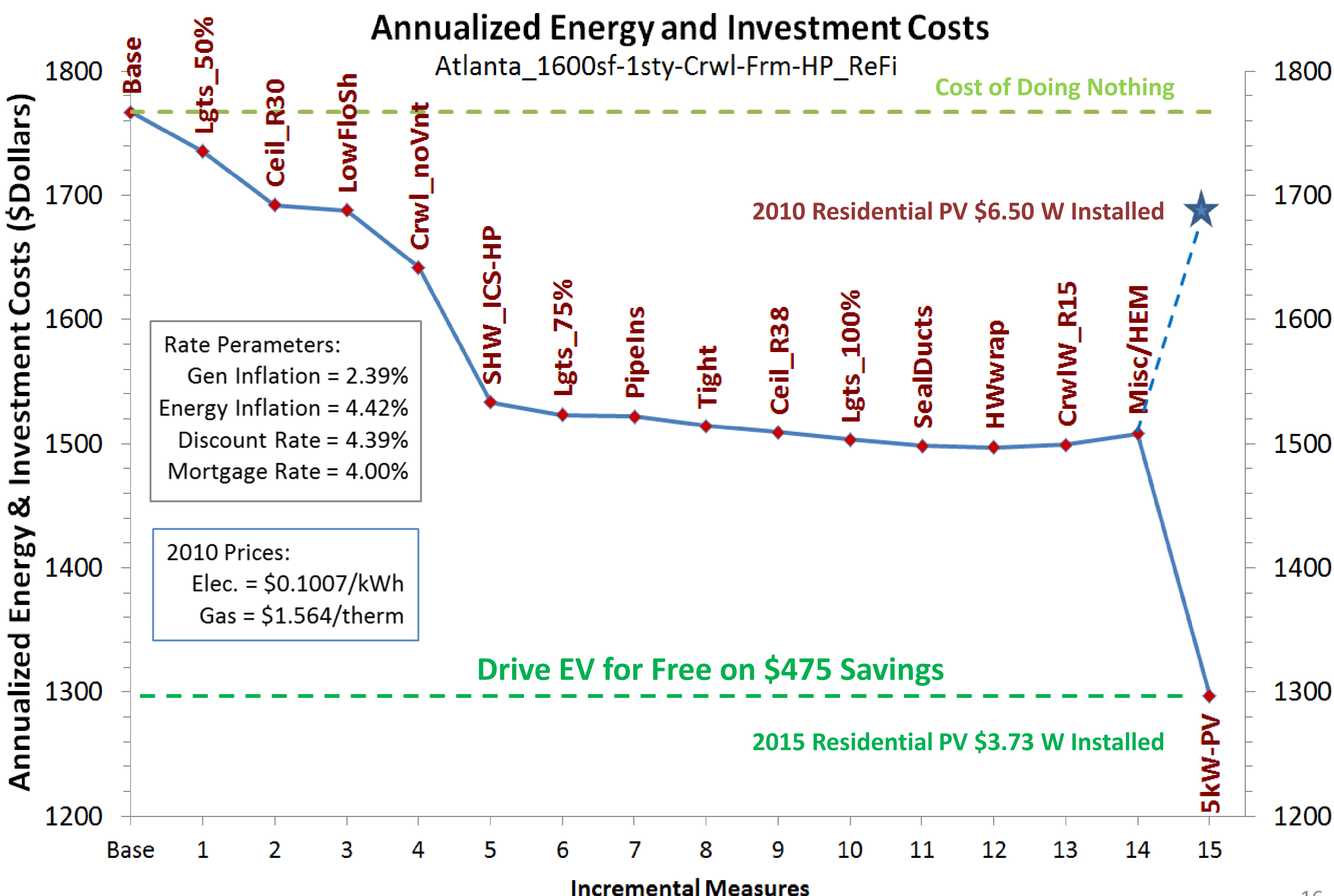
CLEAN ENERGY



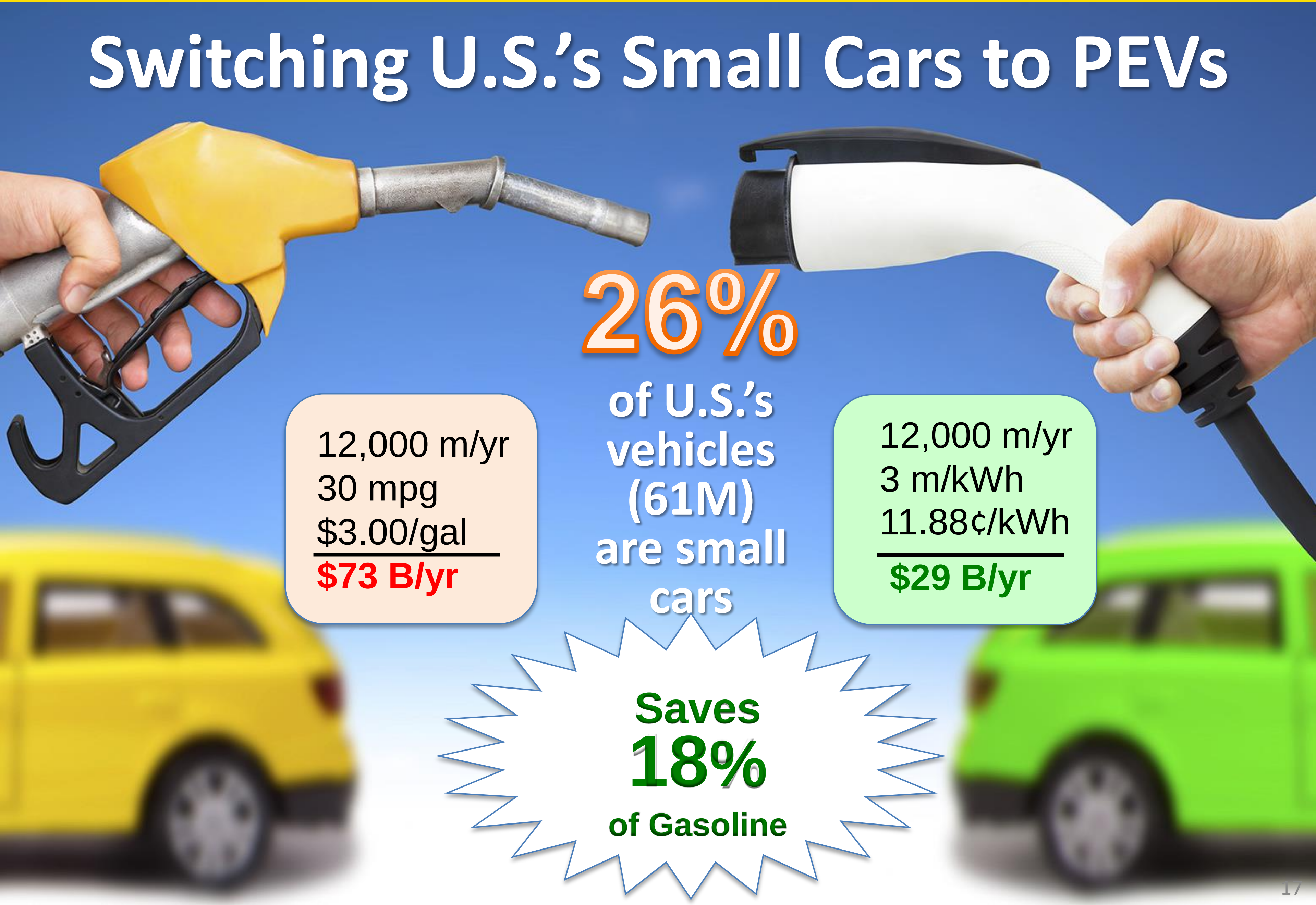
Source: Bloomberg New Energy Finance

Cost Effective Zero Energy Homes & PV for EV




Annualized Energy and Investment Costs
Atlanta_1600sf-1sty-Crwl-Frm-HP_ReFi
Cost of Doing Nothing
2010 Residential PV $6.50 W Installed
Drive EV for Free on $475 Savings
2015 Residential PV $3.73 W Installed
Base
Lgts_50%
Ceil_R30
LowFloSh
Crwl_noVnt
SHW_ICS-HP
Lgts_75%
PipeIns
Tight
Ceil_R38
Lgts_100%
SealDucts
HWwrap
CrwlW_R15
Misc/HEM
5kW-PV
Rate Perameters:
Gen Inflation = 2.39%
Energy Inflation = 4.42%
Discount Rate = 4.39%
Mortgage Rate = 4.00%
2010 Prices:
Elec. = $0.1007/kWh
Gas = $1.564/therm
Annualized Energy & Investment Costs ($Dollars)
1800
1700
1600
1500
1400
1300
1200
Base
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Incremental Measures

Switching U.S.'s Small Cars to PEVs



12,000 m/yr
30 mpg
$3.00/gal
$73 B/yr

26%
of U.S.'s vehicles (61M) are small cars

12,000 m/yr
3 m/kWh
11.88¢/kWh
$29 B/yr

Saves 18% of Gasoline

Switching U.S.'s Small Cars to PV PEVs

- **163 GW of PV Would Power ALL Small Cars**
  - Utility-Installed PV
    $1.77/W w/ ITC = $202B
    [2.8 yrs of Gasoline Savings]
  - Utility-Produced PV
    5.6¢/kWh w/ITC =
    $0.47 gallon equivalent

Utilities Should Be in the Solar Transportation Fuel Business!
Transportation Should Be in the Solar Infrastructure Business?


Aerial view of Oregon DOT's Solar Highway Demonstration Project
Photo credit: Oregon DOT


German 2.8 MW solar array on the roof of a 2.7 km long noise-barrier tunnel on the A3 highway near Aschaffenburg, Germany. Photo source: www.ralos.de


Florida Turnpike's Solar Demonstration Project under construction in 2012

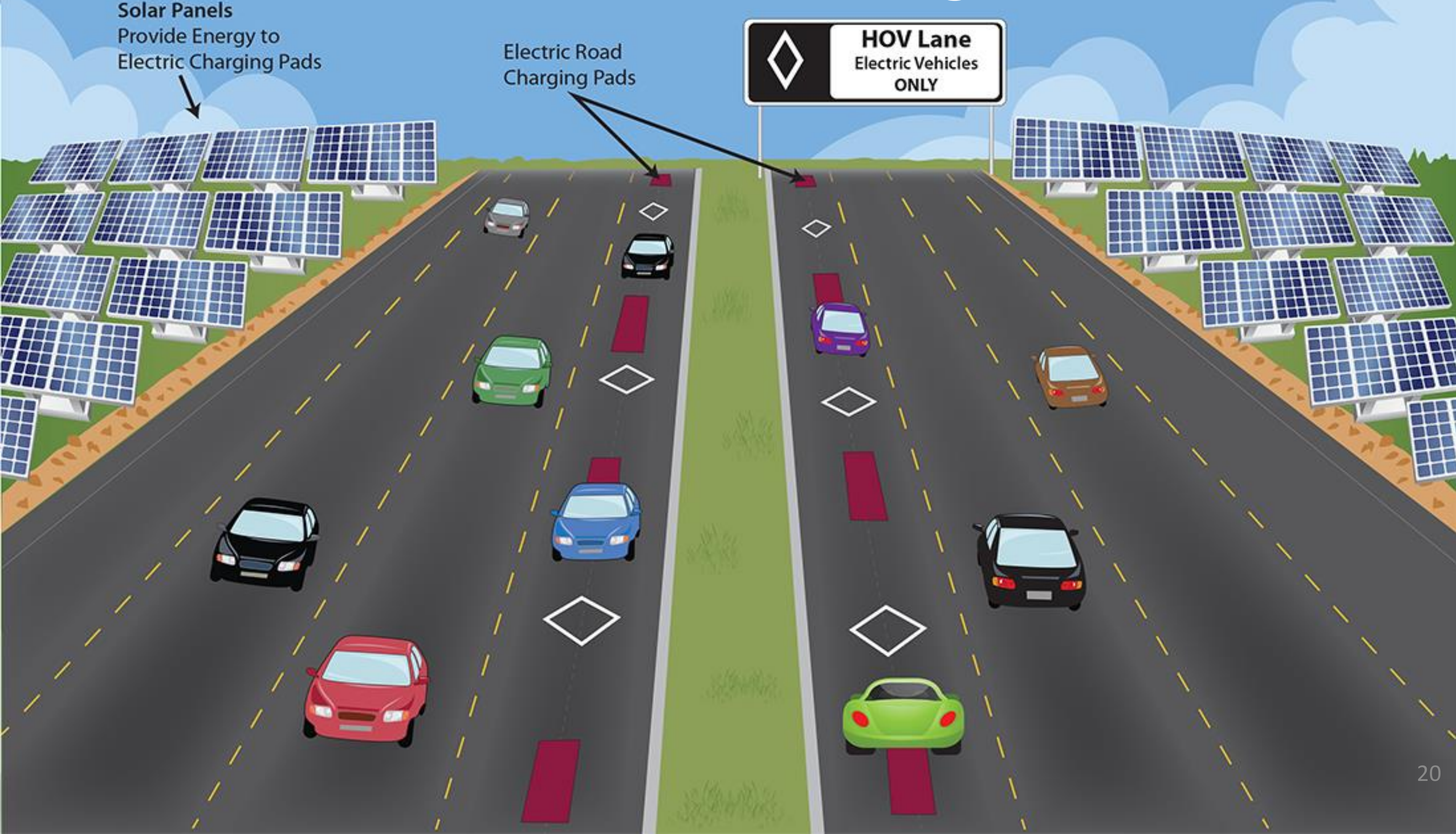

Solar EV Charging Station, UCF

U.S. Interstate System is 46,876 miles long

Assuming 10 feet width of Highway Right-of-Way for solar and 10W/ft^2

Fuel for 9.3 M EVs

Produced at $0.47/gal



Benefits of Switching to EVs

Consumer Fuel Savings

300k EVs today	= **$265 M**
4 M EVs in 10 years	= **$3.5 B**
50% Gov. fleet	= **$265 M**

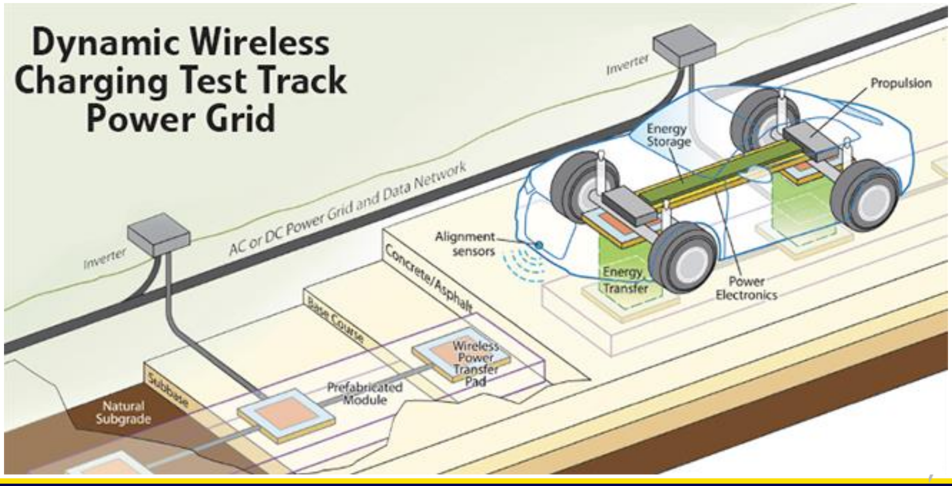
Annual Societal Benefits (4 M EVs)

Urban Air Pollution	= $1.5 Billion
Human Health	= 43,900 (DALY)
Employment	= 136,000 jobs
U.S. GDP	= $16.6 Billion
Business Profit	= $10 Billion
Additional Income	= $5.8 Billion

DALY – disability-adjusted life year

Wireless Charging

[Dynamic Wireless Charging](#) can be installed beneath the top surface of the roadway. Utah State University.

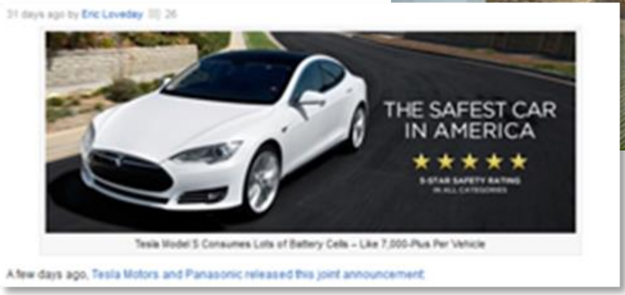


V2G Use of PEV Batteries

Chevrolet

Nissan

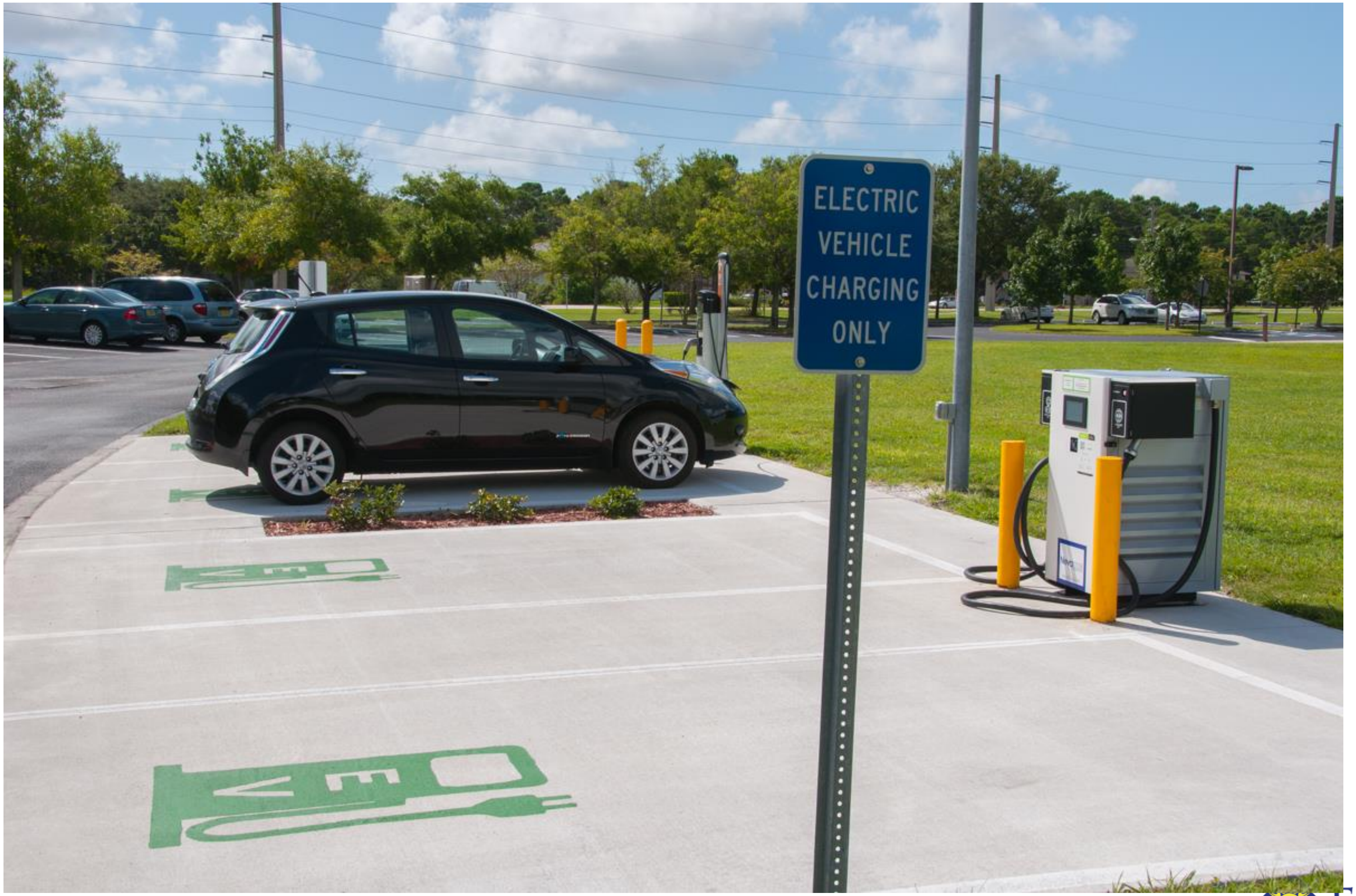
Tesla/SolarCity



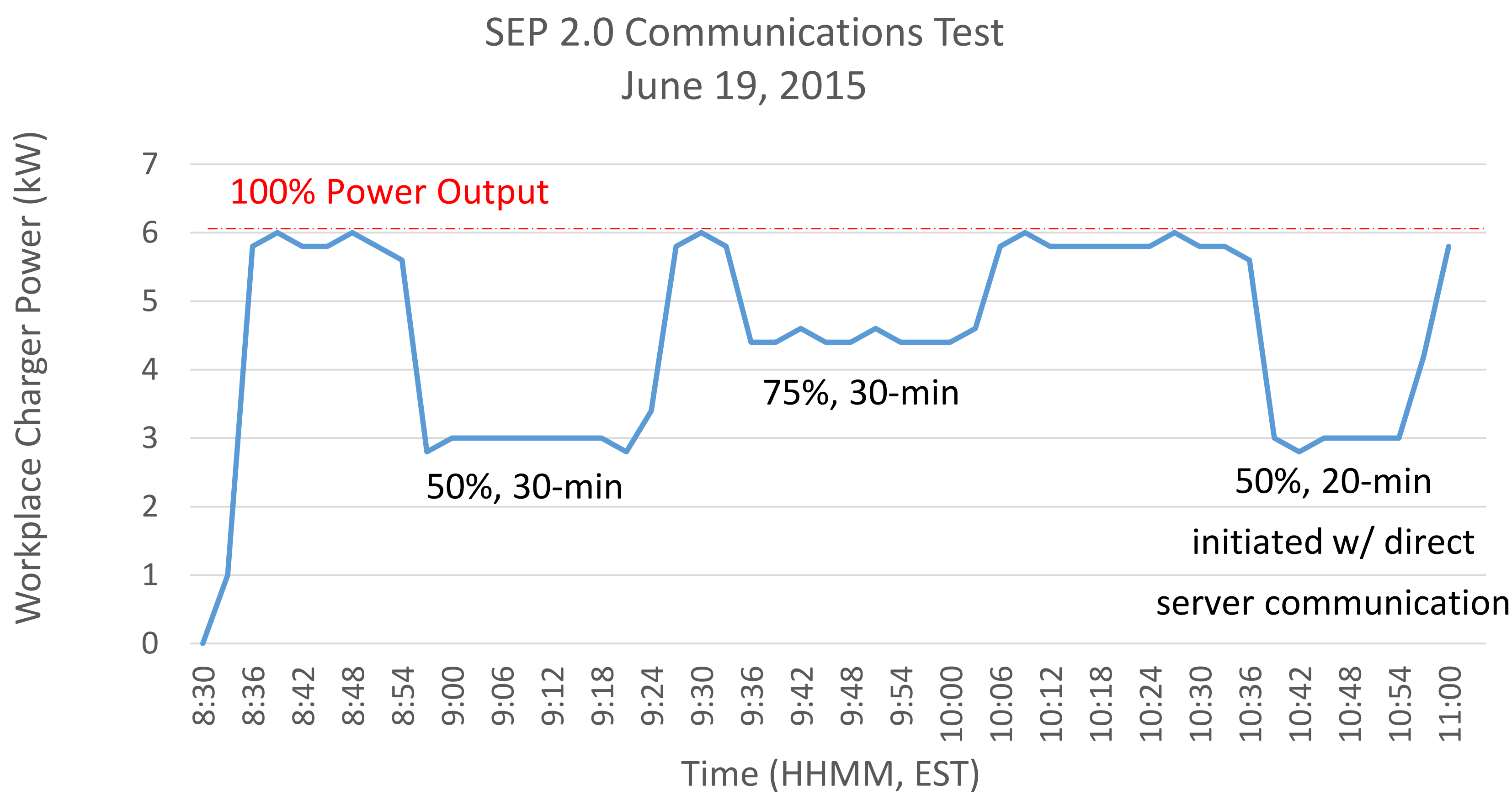
UCF V2X Integration Technology

- Operative EV charger with computer controlled two-way feature
- Laboratory demonstration of two-way feature with Nissan Leaf
- V2X in lab environment

UCF's FSEC Public Charging



Utility Demand Modifications at UCF Charging Station



SEP 2.0 – Smart Energy Profile V2.0 Communication Standard

Tallahassee StarMetro Electric Bus

UCF Program

Elec. vs Diesel

Route Analysis

Demand Strategies

Battery R&D

University of Hawai'i

- Cell level testing
- Accelerated durability tests

Tuskegee University Physics Lab

- Li-Ion Polymer Battery Lab

Toyota Mirai Fuel Cell Car

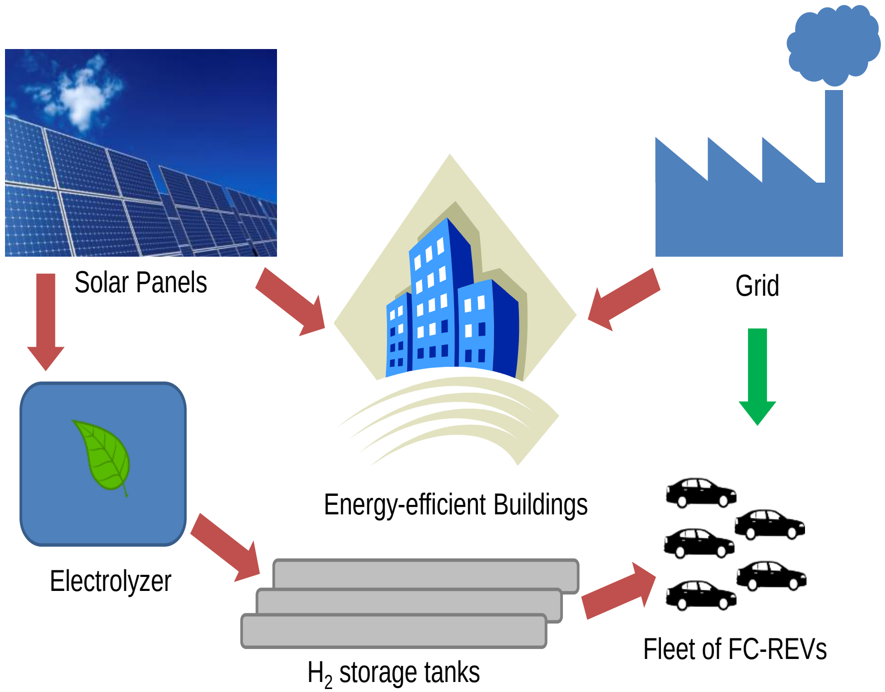
Energy content is 165 kWh (Tesla S = 85 kWh)

Power connection can provide 60 kWh to household in power outage

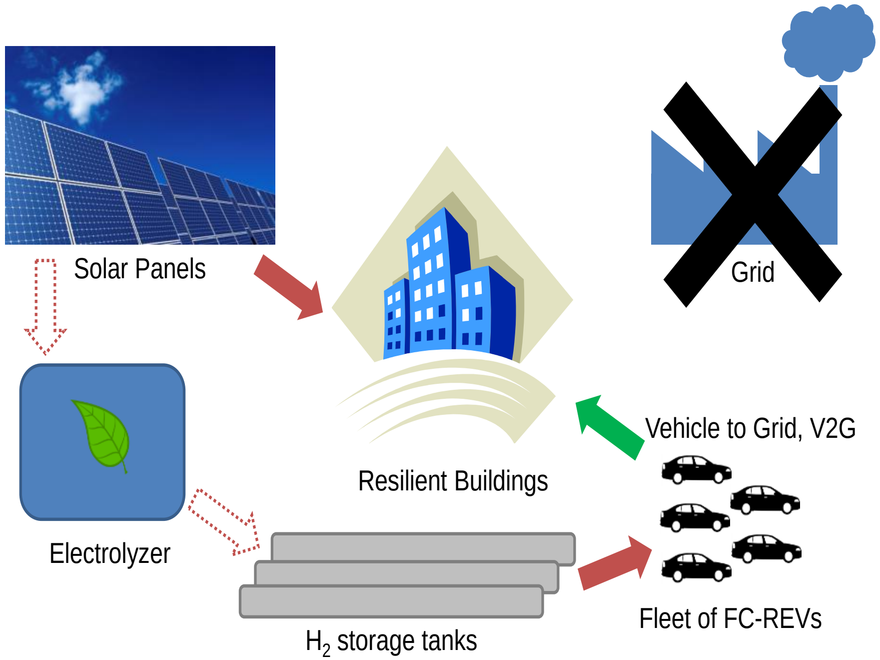
2016 Toyota Marai hydrogen fuel cell car, New Port Beach, CA, November 2014 *(Photo: www.greencarreports.com)*

Buildings can "Island" from the Grid using Electric Vehicles with Range Extenders (gasoline, then renewable hydrogen fuel cell)

Grid-Connected



Grid-Disconnected



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Most Fueling at Home or From Building

Nissan LEAF to home. (Photo: Nissan.)

Princeton Power System bi-directional charger at LA AFB (Photo: Tech Sgt Sarah Corrice, AFSC)


Full Service
Electric
Gas
H_2 Hydrogen
Electric
Gas
Hydrogen
Electric Charging
Electric Charging
Gas
Gas

Summary

- Cars and Buildings can operate on PV electricity, less than $1 a gallon
- PV Grid Parity is today, PV Gasoline Parity is a "long distance in the rearview mirror"
- New Electric Power Renewable Generation Capacity Additions are Greater than Fossil Fuel Additions, 2013 – 2030
- By Integrating PV, EVs, Energy Storage and Energy Efficient Buildings
  - Reduced costs
  - Increase Reliability and Resiliency
  - Reduce Greenhouse Gases
- Utilities in Solar Transportation Business, Production at < $0.47/gal
- Transportation in Solar Infrastructure Business, Production at < $0.47/gal
- EVTC Research in: Wireless Charging, V2G/V2X, Electric Bus, Fuel Cell Vehicles w/Backup Power Capability helping to take Transportation and the Grid into a "Bright Future"

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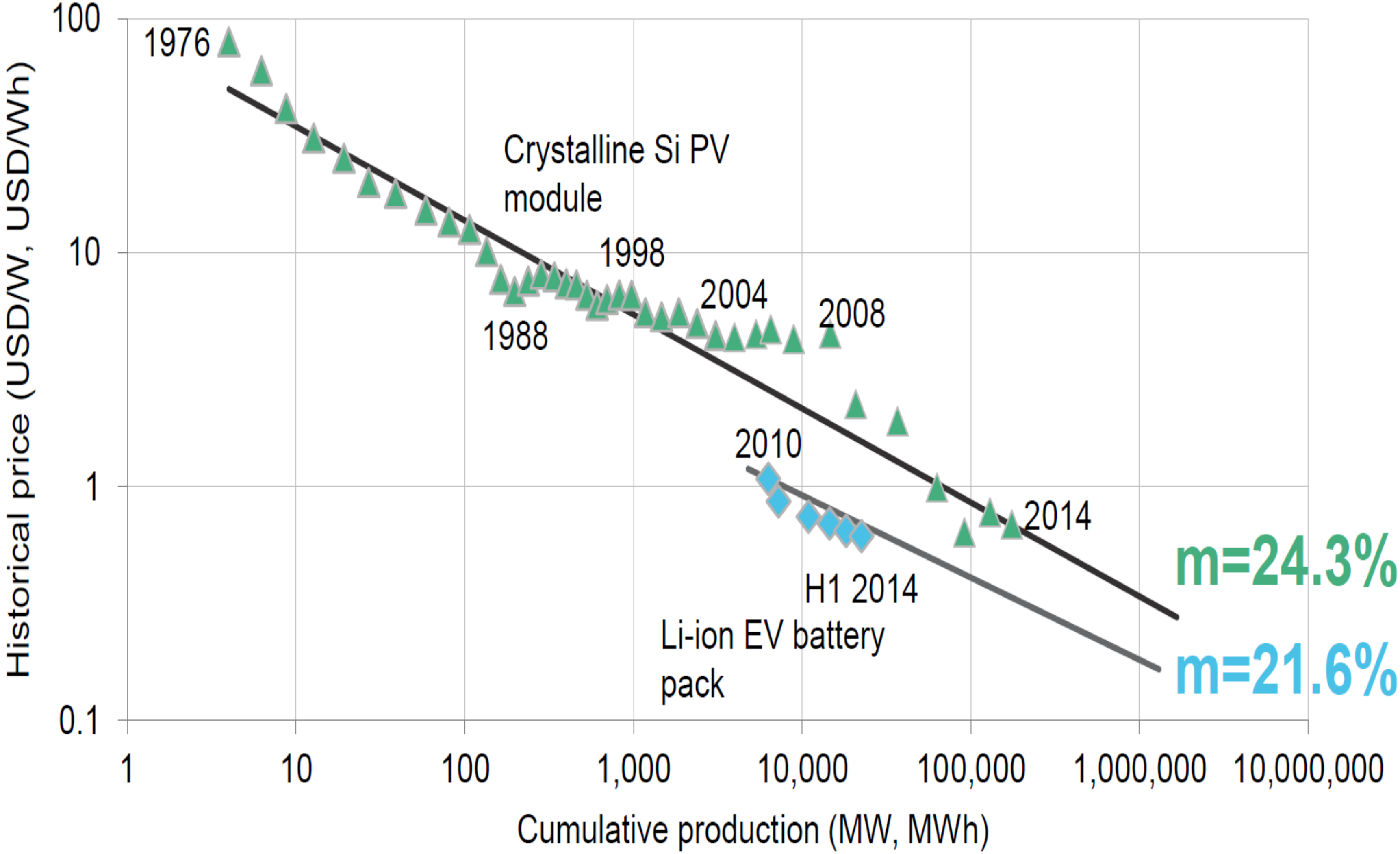
FSEC™

EXTRA SLIDES

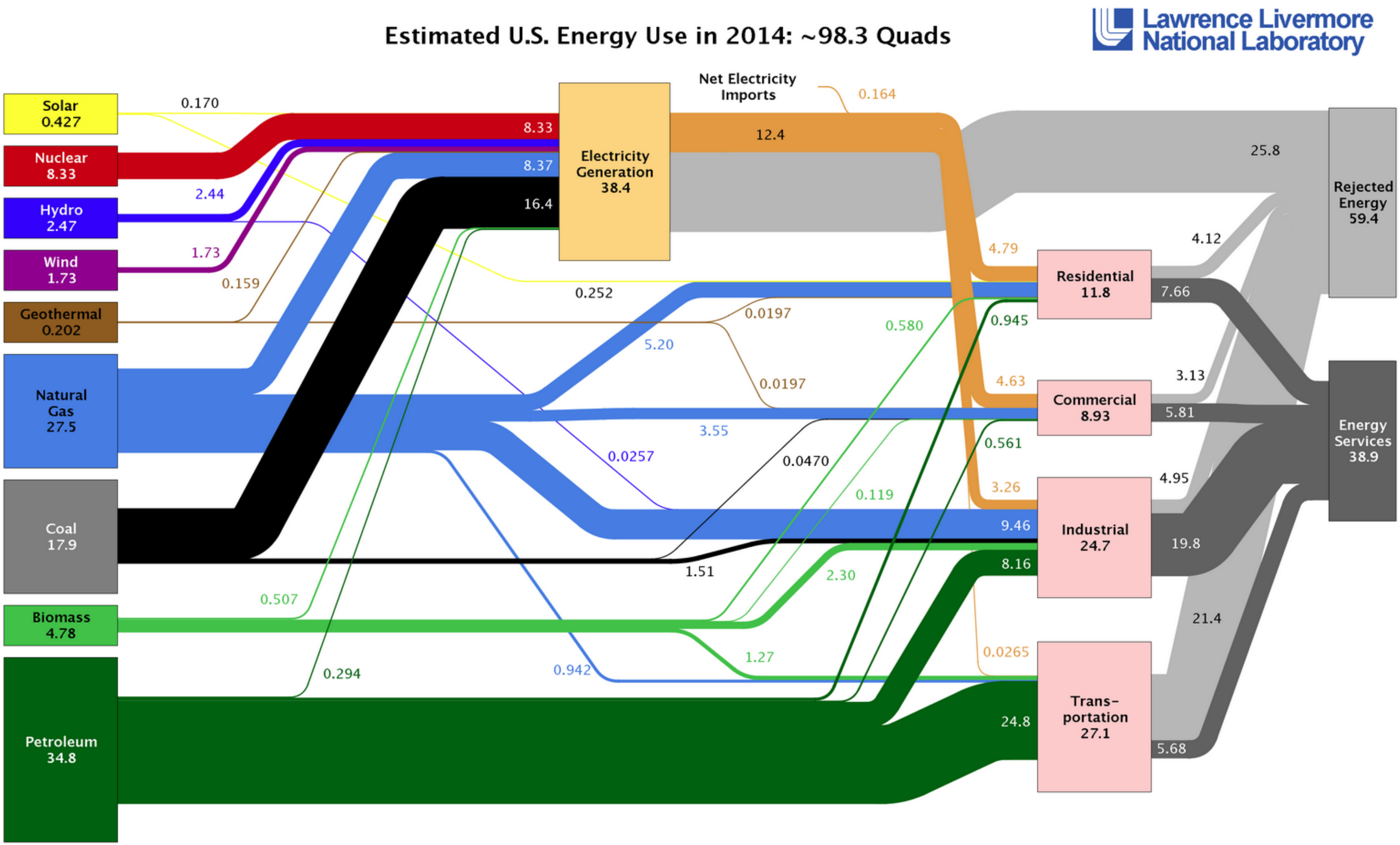
LITHIUM-ION EV BATTERY EXPERIENCE CURVE COMPARED WITH SOLAR PV EXPERIENCE CURVE

Bloomberg NEW ENERGY FINANCE



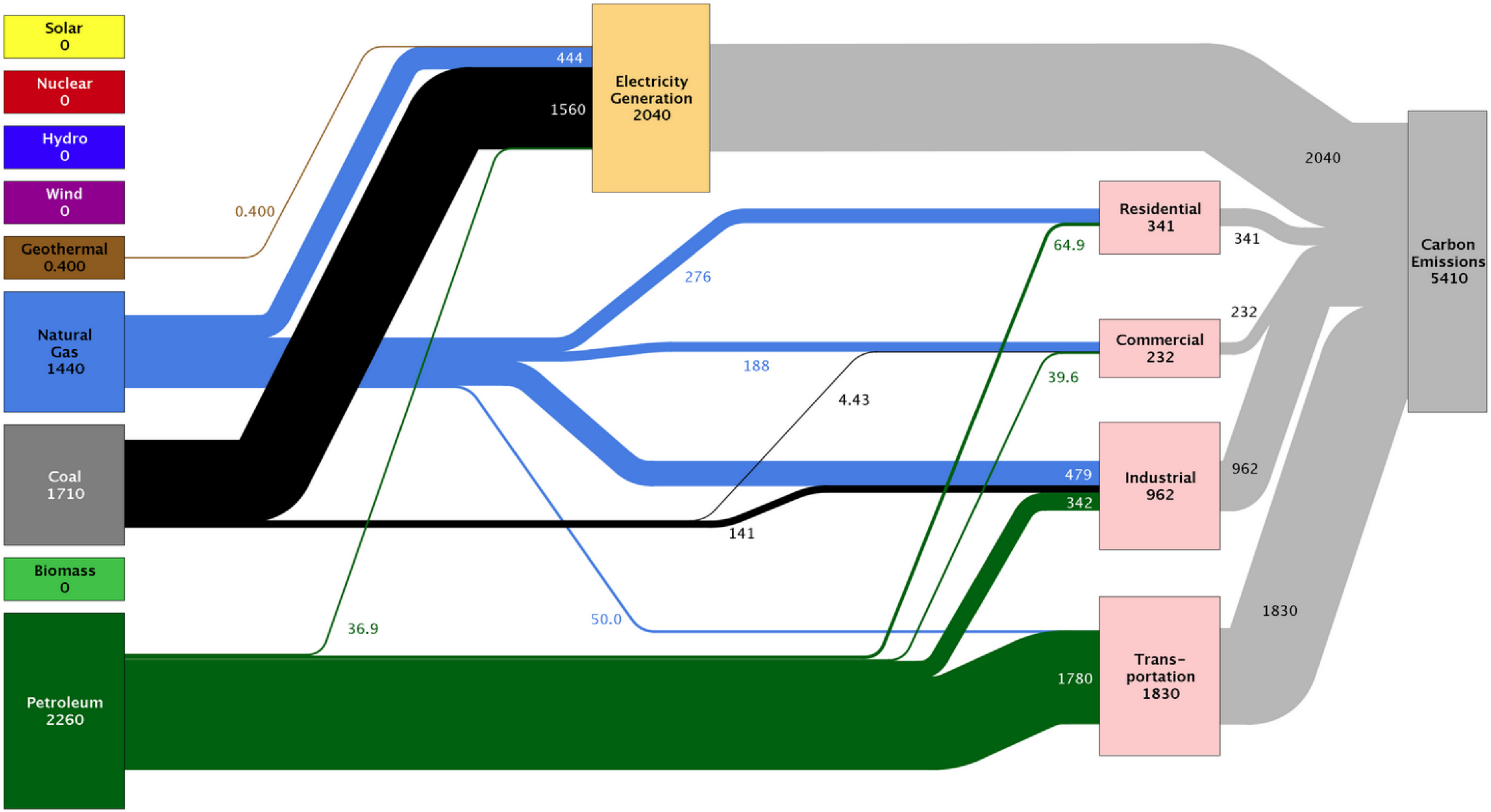
Note: Prices are in real (2014) USD.

Source: Bloomberg New Energy Finance, Maycock, Battery University, MIIT



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Estimated U.S. Carbon Emissions in 2014: ~5,410 Million Metric Tons

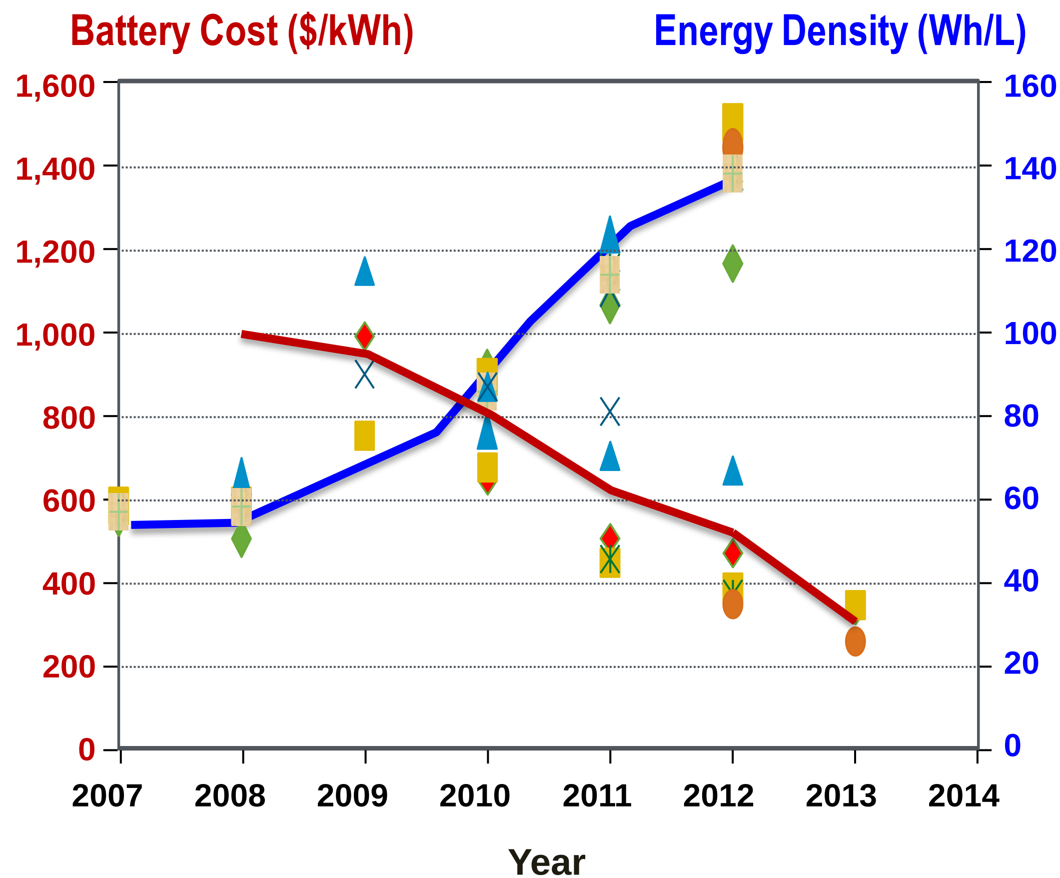


Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2015. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon emissions are attributed to their physical source, and are not allocated to end use for electricity consumption in the residential, commercial, industrial and transportation sectors. Petroleum consumption in the electric power sector includes the non-renewable portion of municipal solid waste. Combustion of biologically derived fuels is assumed to have zero net carbon emissions - the lifecycle emissions associated with producing biofuels are included in commercial and industrial emissions. Totals may not equal sum of components due to independent rounding errors. LLNL-MI-410527

VTO Battery R&D Progress: Cost Reduction & Energy Density

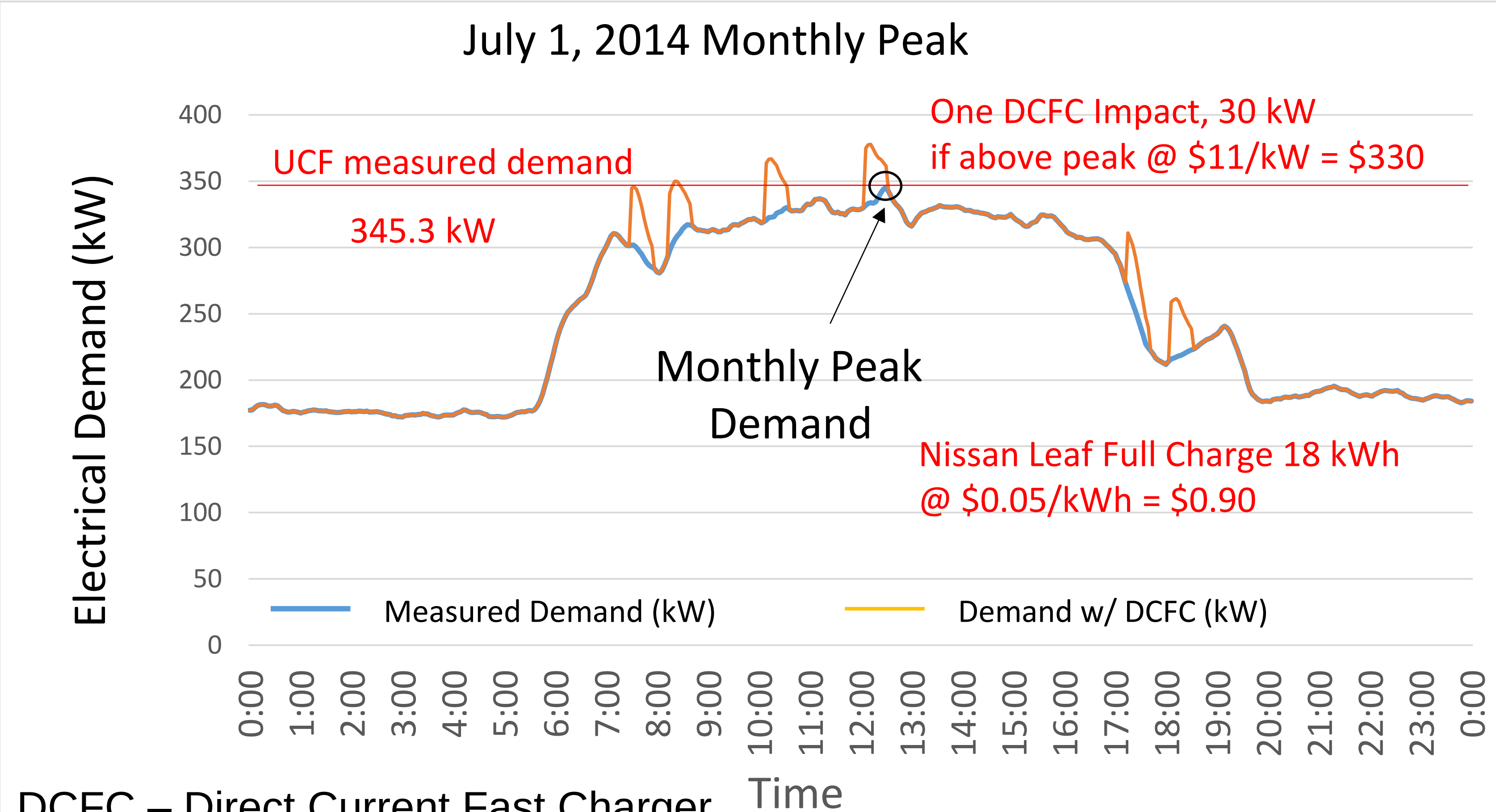
DOE/USABC reduced the cost of PEV batteries by 70% and doubled their energy density during the past 5 years

- Current cost of advanced PHEV battery technology estimates average **$325/kWh**, useable
- Results based on prototype cells & modules meeting DOE/USABC performance targets.
- Detailed USABC battery cost model used to estimate the cost of PEV battery packs assuming that 100,000 batteries are manufactured annually.



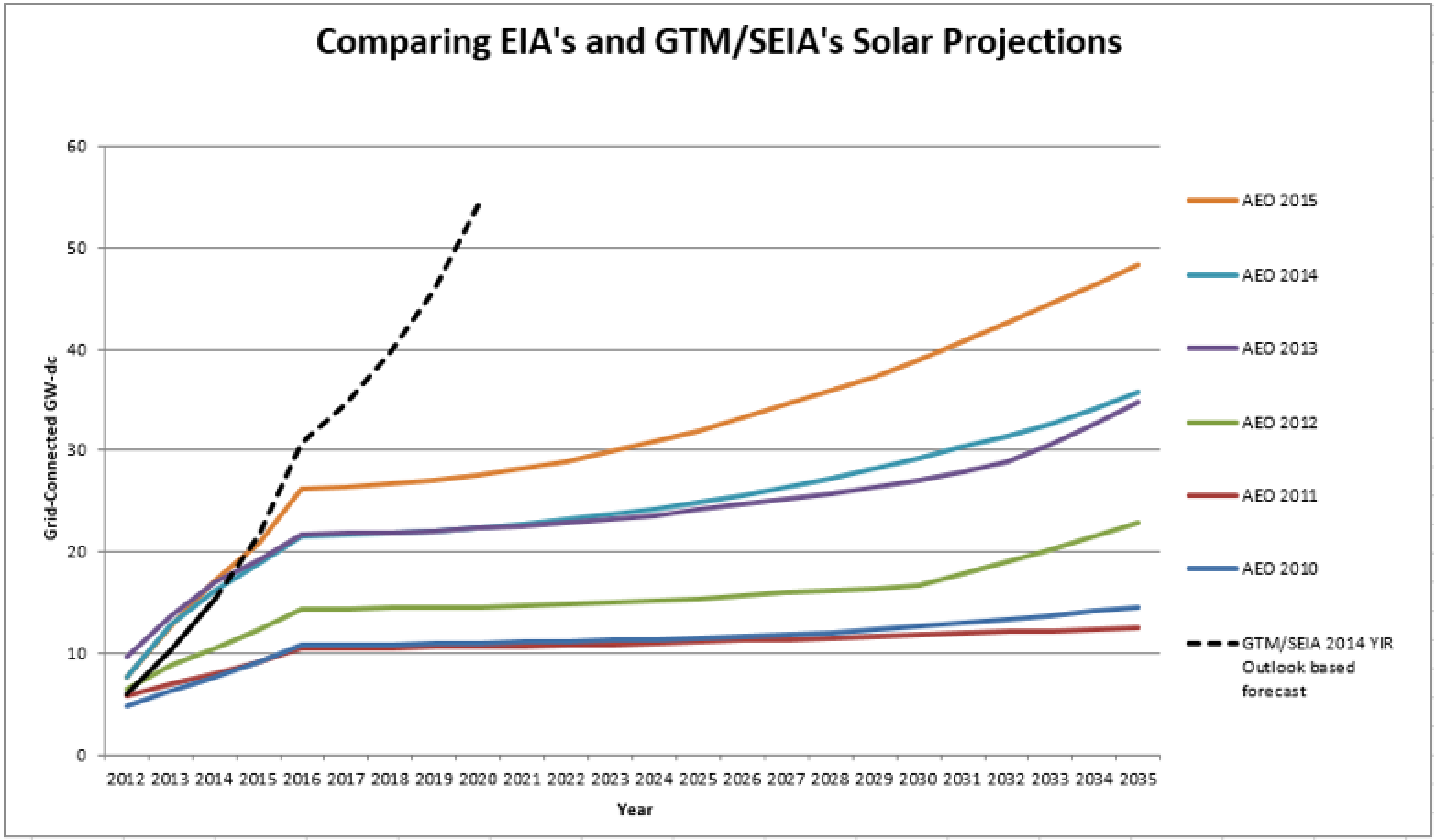
- Batteries ranged from PHEV 40 packs (~14 kWh) to EV packs (40kWh).
- These battery development projects focus on advance cathodes, processing improvements, cell design and pack optimization.
- Standard electrolyte & graphite anode were used.

UCF's FSEC Office & Lab Building Utility Demand Charges



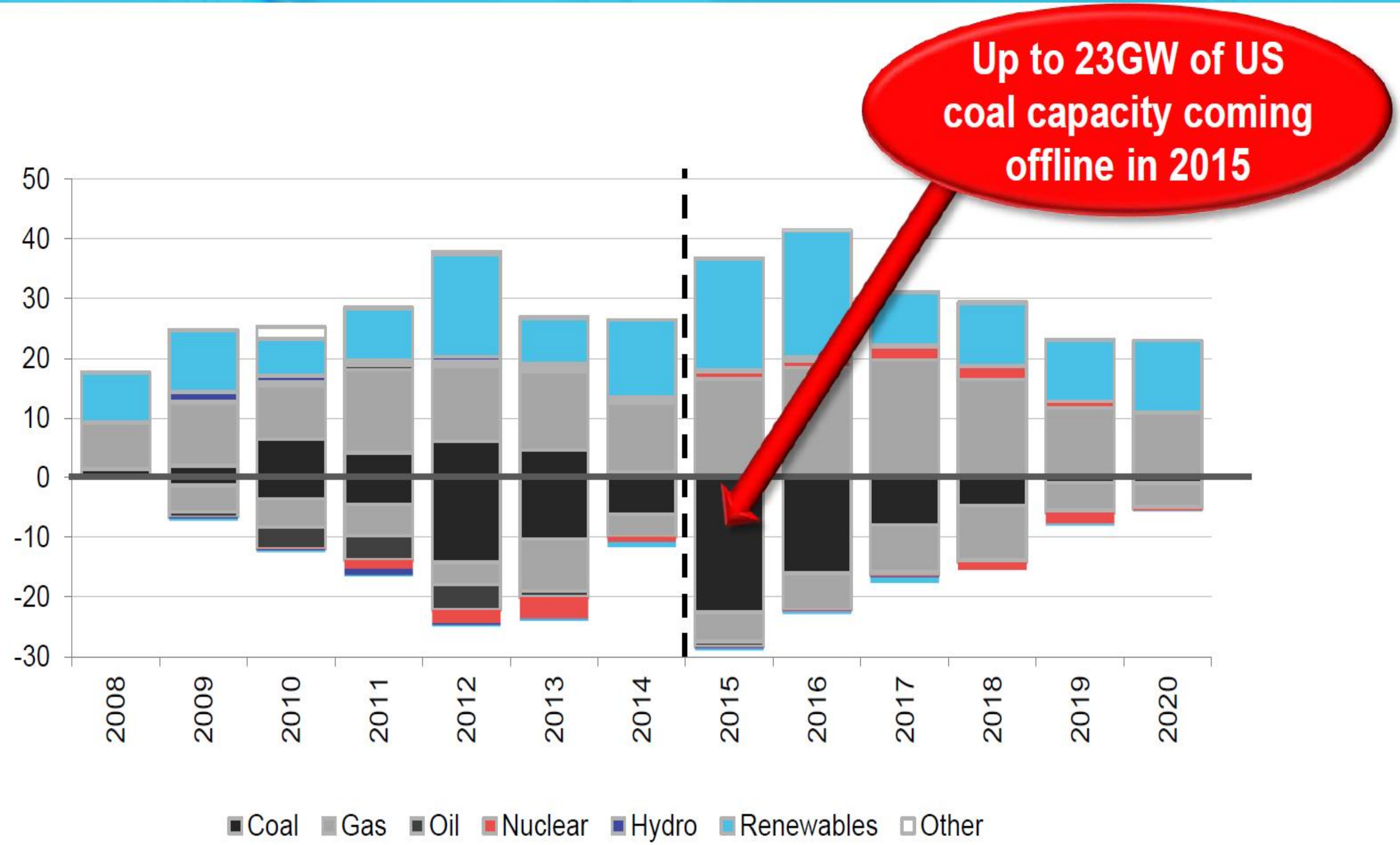
DCFC – Direct Current Fast Charger

Electricity Cost = $ 0.05/kWh, Demand = $11/kW


Comparing EIA's and GTM/SEIA's Solar Projections
Grid-Connected GW-dc
60
50
40
30
20
10
0
2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
Year
AEO 2015
AEO 2014
AEO 2013
AEO 2012
AEO 2011
AEO 2010
GTM/SEIA 2014 YIR Outlook based forecast

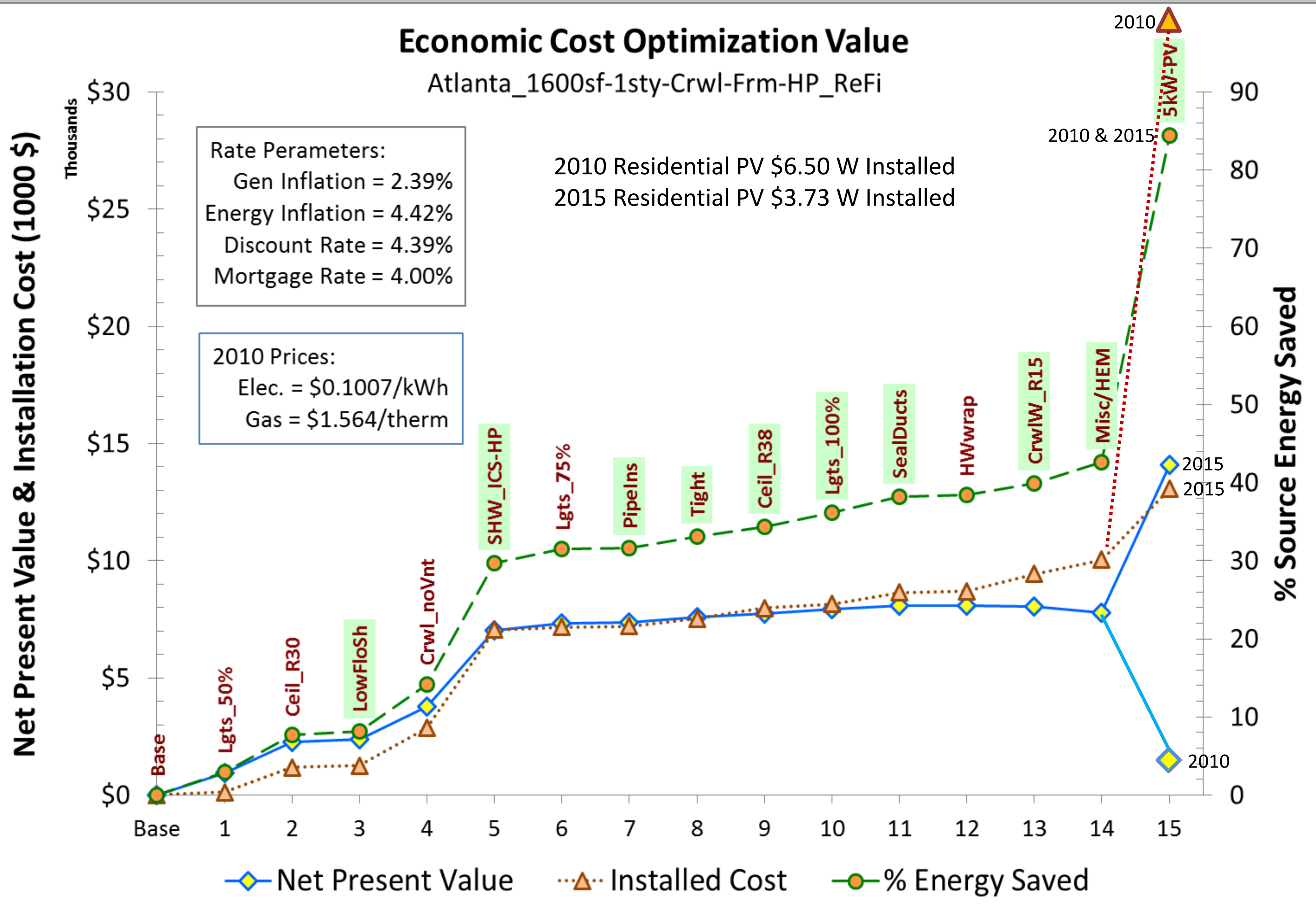
US CAPACITY BUILD, 2008–20
(GW)

Bloomberg NEW ENERGY FINANCE



Notes: Bloomberg New Energy Finance base case build forecasts; historical build from EIA Form 860

Source: Bloomberg New Energy Finance



Economic Cost Optimization Value
Atlanta_1600sf-1sty-Crwl-Frm-HP_ReFi
Rate Perameters:
Gen Inflation = 2.39%
Energy Inflation = 4.42%
Discount Rate = 4.39%
Mortgage Rate = 4.00%
2010 Prices:
Elec. = $0.1007/kWh
Gas = $1.564/therm
2010 Residential PV $6.50 W Installed
2015 Residential PV $3.73 W Installed
Net Present Value & Installation Cost (1000 $)
Thousands
% Source Energy Saved
$30
$25
$20
$15
$10
$5
$0
90
80
70
60
50
40
30
20
10
0
Base
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Base
Lgts_50%
Ceil_R30
LowFloSh
Crwl_noVnt
SHW_ICS-HP
Lgts_75%
PipeIns
Tight
Ceil_R38
Lgts_100%
SealDucts
HWwrap
CrwlW_R15
Misc/HEM
5kW-PV
2010
2010 & 2015
2015
2015
2010
Net Present Value
Installed Cost
% Energy Saved