Popular PEV models are outselling more than half of all vehicle models in the U.S. PEV sales are climbing more rapidly than sales of hybrid-electric vehicles when HEVs were first introduced roughly a decade ago.
SunSmart Electric Vehicle Program video at http://vimeo.com/59667117
A Decade Spreads Solar Parity Far and Wide

Energy Potential from Unsubsidized $4/W Commercial Solar (Capacity and % of Sales)

2012

Capacity (Megawatts)

- 3500 MW
- 500 MW
- 56 MW
- 1200 MW

Percent of Commercial Electricity Sales

- Less than 1%
- 1% to 5%
- 5% to 10%
- 10% or more

FLORIDA SOLAR ENERGY CENTER — A Research Institute of the University of Central Florida
By 2021, close to 10% of Florida’s electricity will come from rooftop solar power
Electric Vehicle Projections for Florida

300,000 (1.3%) Plug-In Electric Vehicles on Florida’s roads in 2021
Electric Vehicle Transportation Center
U. S. Department of Transportation

UCF’s FSEC will apply for: Tier 1 UTC
(UCF has Tier 1 Center under Georgia Tech)

Amount: $1.5 M from DOT/year
$1.5 M cost share/year

Proposal Due Date: March 19, 2013
Electric Vehicle Transportation Center

Partner Institutions:
Dr. Willett Kempton  Dr. Sesha Srinivasan  Dr. Rick Rocheleau
University of Delaware  Tuskegee University  University of Hawaii
Hawaii Natural Energy Inst.

• Optimize both a “Smart Grid” and a “Smart Transportation Network”
• Use existing Solar Schools Program in Florida adding on PEV Chargers
• PEVs can both use and supply power to the grid
• Study control of Two-Way Chargers and combined PV/Car battery inverters
• Real time two-way communication and data gathering
• Set the stage for EV transition through research, development, demonstration, education and public information
EVTC and the SunSmart Solar Electric Vehicle Program
A Collaboration with Florida Utilities, Automobile and Car Charger Manufactures, FSEC and Florida’s K-12 students.
The EV Everywhere Challenge

- Benchmark: 5-passenger vehicle suitable for an average American family
- Majority of vehicle-miles-traveled powered by electricity under standard drive cycles
- 5-year simple payback vs. equivalent gasoline powered vehicle
- Any “vehicle range-charging infrastructure” scenario to be considered must credibly allow for the majority of American consumers to be willing to purchase the PEV as a primary vehicle
- No reduction in grid reliability
## Charging Levels and Resulting Charging Times

<table>
<thead>
<tr>
<th>Charging Level</th>
<th>Setting</th>
<th>Supply Power</th>
<th>Representative Example</th>
<th>Where Charging Occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AC Level 1</strong></td>
<td>Residential/ Parking Lot, 5 mi/hour @ 1.7 kW</td>
<td>120/240 vac/20A (16A continuous)</td>
<td><img src="image1" alt="Charging Station" /></td>
<td>Residential: 2/3 of charging</td>
</tr>
<tr>
<td><strong>AC Level 2</strong></td>
<td>Residential/ Commercial, 10 mi/hour @ 3.4 kW</td>
<td>208/240 vac/20A (16A continuous)</td>
<td><img src="image2" alt="Charging Station" /></td>
<td>Residential: 2/3 of charging</td>
</tr>
<tr>
<td><strong>AC Level 2</strong></td>
<td>Commercial (up to) 60 mi/hour @ 19.2 kW</td>
<td>208/240 vac/100A (80A continuous)</td>
<td><img src="image3" alt="Charging Station" /></td>
<td>Residential: 2/3 of charging</td>
</tr>
<tr>
<td><strong>DC Level 1</strong></td>
<td>Commercial up to 500v @ 80A dc, (up to) 120 mi/hour @ 40 kW</td>
<td>208 vac/480 vac 3-phase (input current proportional to output power; ~20A-200A AC)</td>
<td><img src="image4" alt="Charging Station" /></td>
<td>Commercial: 1/3 of charging</td>
</tr>
<tr>
<td><strong>DC Level 2</strong></td>
<td>Commercial up to 500v @ 200A dc, (up to) 300 mi/hour @ 100 kW</td>
<td>208 vac/480 vac 3-phase (input current proportional to output power; ~20A-400A AC)</td>
<td><img src="image5" alt="Charging Station" /></td>
<td>Commercial: 1/3 of charging</td>
</tr>
</tbody>
</table>
## FL Utilities Add EV Chargers

<table>
<thead>
<tr>
<th>Utility Name</th>
<th>PV Schools</th>
<th>Sunsmart</th>
<th>E-Shelter</th>
<th>Plus-UP</th>
<th>Totals</th>
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<tbody>
<tr>
<td>Choctawhatchee Electric Cooperative</td>
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<td>City of Leesburg</td>
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<td>Gulf Power</td>
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<td>Ocala Electric Utility</td>
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<td>Sumter Electric Cooperative</td>
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<td>Tallahassee Electric</td>
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<td>Talquin Electric Cooperative, Inc.</td>
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<td>Tri-County Electric</td>
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<td>West Florida Electric</td>
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<td>Winter Park Utilities (City of)</td>
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<tr>
<td>Withlacoochee River Electric Cooperative</td>
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<td><strong>TOTALS</strong></td>
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<td><strong>84</strong></td>
<td><strong>20</strong></td>
<td><strong>154</strong></td>
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</tbody>
</table>
EV Everywhere Grand Challenge: DOE's 10-Year Vision for Plug-in Electric Vehicles

Vehicle Weight Reduction
Reduce vehicle weight by nearly 30%
(Includes body, chassis, interior, electric drive components, and compounding weight reductions)

Electric Drive System
Reduce cost from $30/kW in 2012 to $8/kW
(1.4 kW/kg, 4 kW/L, 94% efficiency)

Battery
Reduce cost from $500/kWh in 2012 to $125/kWh
(250 Wh/kg, 400 Wh/L, 2 kW/kg)
Battery Challenge
Battery advancements needed to enable a large market penetration of PEVs

2012 Battery Technology
$500/kWh, 100 Wh/kg, 200 Wh/l, 400W/kg
Lithium-ion batteries in today’s electric drive vehicles use a combination of positive active materials based on nickel, manganese, or iron; matched with a carbon or graphite negative electrode.

2022 Battery Technology
$125/kWh, 250 Wh/kg, 400 Wh/l, 2000 W/kg
New battery technologies may meet the challenges of EV Everywhere. New concepts in lithium-ion technologies have the potential to double the performance and significantly reduce the cost. “Beyond lithium-ion” technologies (lithium metal, lithium-sulfur, and lithium-air) may also meet the challenge.
Will Florida Be Prepared for 60¢ a gallon??

* Costs are relative to cost of $3.25 per gallon gasoline at a vehicle efficiency of 25 mpg
Extra Slides
EV Everywhere Grand Challenge

“Big Hairy Audacious Goal”:

Enable U.S. companies to produce plug-in electric vehicles that are as affordable and convenient as today’s gas-powered vehicles by 2022

President Obama announced the EV Everywhere Challenge on March 7, 2012
SunShot Grand Challenge

“Big Hairy Audacious Goal”

To achieve unsubsidized cost parity for solar power with traditional sources of electricity by 2020
Far Reaching Impacts of SunShot - 2 years later -

- Set very aggressive goals for module and BOS costs that have spurred innovation at all companies.

- Recognized importance of reducing BOS and soft costs.

- Recognized the importance of understanding grid impacts at high penetration.
Sunshot Incubator Spurs Solar Industry Cost Innovations

Source: James, T.; Kona, C.; Goodrich, A. (December 2012) NREL Internal Cost Model Results
“Game Changers”
The New Electric Cars

- 80% of VMT is less than 40 miles per day
- 26% of Florida vehicles are small cars
- 4,000 kWh/yr for 12,000 miles

**If all small cars electric**
- 1.4 billion gallons of gasoline saved per year
- $2.6 billion net cost savings per year if PV electric
- 15 TWh (billion kWh) additional energy needs per year (4 MORE LARGE POWER PLANTS)!

Nissan Leaf (all electric)

Chevy Volt (plug-in hybrids)

Total Cost of Electric Car ~ Cost of Gasoline Car at the end of 5 years
Residential Photovoltaic Power is Equivalent to $1.08 Per Gallon Gasoline

<table>
<thead>
<tr>
<th></th>
<th>Fuel Efficiency</th>
<th>Fuel Price</th>
<th>Cost per Mile</th>
<th>Cost per 12,000 Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gasoline Car</strong></td>
<td>25 mpg</td>
<td>$3.25 per gal</td>
<td>13¢ per mile</td>
<td>$1,560</td>
</tr>
<tr>
<td><strong>Electric Car</strong></td>
<td>3 miles per kWh</td>
<td>13¢/kWh ($1.08 per gal equiv.)</td>
<td>4.3¢ per mile</td>
<td>$520</td>
</tr>
</tbody>
</table>
Costs of PV modules are dropping below the power law experience curves

Sources: (CdTe) First Solar Earnings Presentation, SEC Filings; (c-Si) Navigant, Bloomberg NEF, NREL internal cost models

Global Module Average Selling Price (2009 $US/Wp)

Cumulative Production Volume (MWs)

- c-Si
- 2015 $1.05
- CdTe
- 2014 $0.68

2015 prediction

April 2012 Spot market price = $0.83
Installed Price of PV

National Weighted Average System Prices, 2010 –Q1 2012
PV Grid Parity?

- FL Residential Electricity Price
- FL Conservative Trendline
- FL 2000 to 2010 Trendline
- Residential PV LCOE
- Residential PV LCOE w/ ITC

GRID PARITY 2013

<table>
<thead>
<tr>
<th>Year</th>
<th>FL Residential Electricity Price</th>
<th>FL Conservative Trendline</th>
<th>FL 2000 to 2010 Trendline</th>
<th>Residential PV LCOE</th>
<th>Residential PV LCOE w/ ITC</th>
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</thead>
<tbody>
<tr>
<td>1990</td>
<td>8 c/kWh</td>
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<tr>
<td>1995</td>
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<td>2000</td>
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<td>2005</td>
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<td>2010</td>
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<td>2015</td>
<td>14 c/kWh</td>
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<tr>
<td>2020</td>
<td>16 c/kWh</td>
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<td>2025</td>
<td>18 c/kWh</td>
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<tr>
<td>2026</td>
<td>20 c/kWh</td>
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</tbody>
</table>

15.6 c/kWh
Future Price of Gasoline?

- US Retail Gasoline Price
- Average Price
- Trendline

$8.60 per gallon, 2025

$3.25 per gallon
Price of Gasoline?
LIGHT-DUTY VEHICLE FUEL ECONOMY STANDARDS, 1955-2025

- Leaded Regular
- Unleaded Regular
- Trendline
- PASSENGER CARS
- AVERAGE VEHICLE

Year

Gasoline Price, Dollars per Gallon
$0, $2, $4, $6, $8, $10, $12

Model Year Miles per Gallon, MPG
0, 10, 20, 30, 40, 50, 60

$8.60
$3.25
PV $1.08 a gallon today less than a $1 tomorrow
### Residential Electricity is Equivalent to $0.99 Per Gallon Gasoline

<table>
<thead>
<tr>
<th>Fuel Efficiency</th>
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<tr>
<td><strong>Electric Car</strong></td>
<td>3 miles per kWh</td>
<td>12 ¢/kWh ($0.99 per gal equiv.)</td>
<td>4¢ per mile</td>
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</tbody>
</table>