Smart Grid Ready AC Residential Solar Electric System

Presentation at Building America Spring Meeting

March 16-18, 2011

Charles S. Korman
Christian Wagner
Neil Johnson
U.S. Solar Electric Market: Channel Breakdown

**Fast Facts**

- Average growth in U.S. 69% over past 10 years – will pass 0.5GW in cumulative installations this year
  - U.S. ranks 4th in world behind Germany, Japan, Italy
- Residential sector grew 50% in first half of 2010
  - Lots of module availability due to cooling off of EU markets resulting in lower prices
  - Continuation of strong U.S. subsidies
- State by State: CA leads with 125MW – 50% residential, AZ with 20W, 85% residential; NJ primarily commercial driven by SRECs
- 21,597 residential system installed 1st half of 2010 almost 50% in CA. 100,000 residential systems have been installed in the U.S.

*Source SEIA U.S. Solar Market Insight 2010 edition*
U.S. Solar Electric Market Projections to 2015

**Base Case**
- Demand is driven by regulatory requirements and incentives (e.g. RPS), state incentives
- Stagnation in German market accounted for
- Residential and commercial market growth both reach equality at 1GW by 2015

**Upside Case**
- All planned projects are executed
- Grid parity is reached ahead of time so that demand exceeds RPS and new states enter into the market

**Downside Case**
- Regulatory requirements are not met
  - Economic conditions do not permit, e.g. large planned, financed project do not occur
  - Prices do not decline as expected

*Note that the large increase in utility share is based primarily on state RPS and does not account for the percentage of installations that have to be distributed generation (up to 30%)*

U.S. 2010 Residential Installed System Prices


- Since 2007 overall system prices have fallen by 5.3% per year while at the same time module prices have been cut in half
- Market having the lowest prices are dominated by larger system integrators or national chains such as CO and TX, but also note that these states do not have large incentives - paid to the installers influence system pricing.
- California prices are under $7.00 even with high labor, and permitting costs due to competition.

All values are $/W
Key Solar Metric: Levelized Cost of Electricity (LCOE)

Levelized Cost of Electricity (LCOE) = f (installed cost, energy yield, term, O&M, cost of money)

Solar PV Levelized Cost of Electricity (LCOE)
Solar PV Module Production Cost Roadmap

Module Cost Roadmap

- Silicon
- Thin Film

Year

- 2008
- 2009
- 2010
- 2011
- 2012
- 2013

$ per W

- 2010 Best c-Si Price $1.80/W
- 2011/12 Best c-Si Price $1.50/W
- 2013/15 Best c-Si Price $1.30/W

Sources: Photon, Green Tech Media

March 16, 2011
C.S. Korman (GE)
Residential Solar Electric Balance of System Costs

Buildup to Residential Solar Electric System Price ($/W)

- **PV Module**
- **Inverter (including software)**
- **Mechanical (hardware and labor)**
- **Electrical (components, wiring, labor)**
- **Other (project admin, design, permitting)**
- **Markup**
- **Installed Price to Customer**

Sources: Photon Consulting

Business as Usual 2010

Balance of System Costs

$ per W

0 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00
GE’s Smart Grid Ready Solar Electric System

A residential solar electric system that can be installed by standard roofing and electrical contractor trades at parity with retail cost of electricity
- Unique comprehensive energy management solution
- Greatly increased penetration into the residential market
- Opportunity for present and future revenue and margin growth

### 3 Defining Elements

- **Plug and play electrical connection with tool-less insert and capture mounting system**
- **AC module with direct 240 Vac output**
- **Home energy management and smart grid interface**
Central vs. Distributed Power Architecture
Distributed micro-inverters reduce installed cost and increase safety

Central Inverter Architecture
- Performance of string determined by poorest performing module – Susceptible to shadowing

Distributed Micro-inverter
- Simpler grounding – no conduit or disconnect.
- Each module has peak power tracking

1. Lower cost of installation by standard trades
2. Increased safety
3. Increased performance (up to 12% more energy)
4. Simplified distribution with fewer SKU’s
Solar AC Appliance
Each PV module functions as a standalone 240 Vac appliance

- Laminate
- Module Frame
- Module Bottom Edge
- Backside of PV Module
- Integrated, Replaceable Micro-Inverter
- Junction Box
- Inverter Attachment Bracket
- Module Top Edge
- All Metal Surfaces Have Common Ground Through Wiring Harness

4 Electrical Pins:
- 120 Vac
- 120 Vac
- Neutral
- Chassis Ground
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE Insert and Capture System: Path to Low Cost Installation
GE 5 kW Solar Electric System Kit
60% fewer components than current industry standard

- 2 Extension Harnesses
- 2 Locking Covers
- 2 Home Run Cables
- 2 Junction Boxes
- 3 Rail Connector Bars
- 4 Side Grounding Bars
- 6 Rail Sections
- 20 Modules
- 21 Mounting Stanchions with L-Brackets

March 16, 2011
C.S. Korman (GE)
Simpler System Delivery and Installation

Conventional Residential Solar Electric System

15%
- Lead Generation
- Site Visit
- System Sale

20%
- System Design and Engineering
- Order Hardware
- Permits/Approvals (Building, Utility)

40%
- Mounting System Installation
- Install Grounding Clips/Wire

25%
- Install DC Disconnects/Safety Hardware
- Install Central Inverter
- Install Conduit and Run DC Wiring to Inverter
- Run AC Wiring to Load Panel

GE Smart Grid Ready Residential Solar Electric System

70%
- Customer Needs a New Roof!
- Roofing Estimate, Solar Estimate
- Simplified Permitting Process

30%
- Order Standardized Solar Kit
- Insert and Capture Plug and Play Installation
- Run AC Wiring to Load Panel

Comparison of Residential Solar Electric System Prices ($/W)

<table>
<thead>
<tr>
<th>Installer Costs</th>
<th>Business as Usual 2010</th>
<th>GE Insert and Capture System 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverter and Monitoring Software</td>
<td>$0.47</td>
<td>$0.00</td>
</tr>
<tr>
<td>Mechanical Materials and Installation</td>
<td>$0.81</td>
<td>$0.20</td>
</tr>
<tr>
<td>Electrical Materials and Installation</td>
<td>$0.75</td>
<td>$0.10</td>
</tr>
<tr>
<td>Other (including admin., design, permitting)</td>
<td>$0.44</td>
<td>$0.20</td>
</tr>
<tr>
<td>PV Module</td>
<td>$2.05</td>
<td>$3.20</td>
</tr>
<tr>
<td>Markup</td>
<td>$2.26</td>
<td>$0.55</td>
</tr>
<tr>
<td><strong>Installed Price to Customer</strong></td>
<td><strong>$6.78</strong></td>
<td><strong>$4.25</strong></td>
</tr>
</tbody>
</table>

Shared responsibility for roofing and solar sales
- No additional overhead

Use of the AC-module greatly reduces need for complicated system engineering
- AC-module as an appliance should also simplify the certification and permitting processes

Simplified installation process
- Fewer components to install
- A single installer can insert and capture module
- Plug and play eliminates manual connection of wires
- Grounding is automatically made through the micro-inverter

The micro-inverter string is wired directly into the load panel through a dedicated circuit breaker

imagination at work

March 16, 2011
C.S. Korman (GE)
Residential Solar Electric System Cost Comparison

Buildup to Residential Solar Electric System Price Comparison ($/W)

Business as Usual 2010

GE Insert and Capture System 2012

Sources: Photon Consulting

March 16, 2011
C.S. Korman (GE)
Customer Acceptance and Home Owner Economics

If we meet LCOE we future-proof the cost of electricity for the consumer over the life of the system and generate a positive cash flow at the same time.

**Assumptions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Size (kW)</td>
<td>4.8</td>
</tr>
<tr>
<td>GE Module Motech 60-cell, 230 W</td>
<td></td>
</tr>
<tr>
<td>Inverter Enphase M190</td>
<td></td>
</tr>
<tr>
<td>Installed Cost ($/W)</td>
<td>$4.50</td>
</tr>
<tr>
<td>COE ($/kWhr)</td>
<td>$0.179</td>
</tr>
<tr>
<td>Annual COE Escalation</td>
<td>2%</td>
</tr>
<tr>
<td>System Life (Years)</td>
<td>20</td>
</tr>
<tr>
<td>Annual AC Energy (kWhr)</td>
<td>7,710</td>
</tr>
<tr>
<td>Annual System Degradation</td>
<td>0.40%</td>
</tr>
<tr>
<td>State ITC</td>
<td>10%</td>
</tr>
<tr>
<td>Federal ITC</td>
<td>30%</td>
</tr>
<tr>
<td>Depreciation (if applicable)</td>
<td>0%</td>
</tr>
<tr>
<td>Sales Tax (if applicable)</td>
<td>0%</td>
</tr>
<tr>
<td>O&amp;M (annual)</td>
<td>$25.00</td>
</tr>
<tr>
<td>Finance Rate</td>
<td>5.0%</td>
</tr>
<tr>
<td>Finance Period (years)</td>
<td>15</td>
</tr>
</tbody>
</table>

**System Cost**

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Cost</td>
<td>$21,600</td>
</tr>
<tr>
<td>Sales Tax</td>
<td>–</td>
</tr>
<tr>
<td>System Cost</td>
<td>$21,600</td>
</tr>
<tr>
<td>CA Incentive</td>
<td>$2,160</td>
</tr>
<tr>
<td>Federal Tax Credit</td>
<td>$5,832</td>
</tr>
<tr>
<td>Net Price</td>
<td>$13,608</td>
</tr>
<tr>
<td>Monthly payment</td>
<td>$(107.61)</td>
</tr>
<tr>
<td>Value of Energy</td>
<td>$128.96</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>$25</td>
</tr>
</tbody>
</table>

**Net Cash Flow**

$231.20
**New Market Channels for Solar**

- **PPA’s**
- **Leases**
- **ESCO**
- **Pension Funds**

**New Construction**
- Even in down economy 240,000 new housing starts projected for 2011
- Appliances has 50% market share in new construction

**Direct Sale to Utility**
- Utilities have 2GW of solar RPS commitments in next 5 years
- 30% in distributed generation

**Roofing Contractor**
- 7 million asphalt rooftops are replaced each year in the U.S.
- 6:10 homes are solar compatible

---

March 16, 2011
C.S. Korman (GE)
Whole Home Energy Management is path to Higher Efficiency

GE Solar Electric System

Direct Tie to Meter ZigBee Smart Energy Profile 802.15.4

Home Plug Interface ZigBee Transmitter

ZigBee Smart Energy Profile 802.15.4 Custom Commands for HEM Mesh Network Communication

Home Energy Manager

Programmable Digital Thermostat

Water Meter

Gas Meter

Refrigerator

GE Range Advantium™ Oven

GE Range

Hybrid Water Heater

Washer and Dryer

Dishwasher

imagination at work

March 16, 2011
C.S. Korman (GE)
Electric Peak Shaving through Demand Response

Premier Gardens Community

- 94 homes near Sacramento, CA
- Solar (2.2kW) + Energy Star
  - 30% better than Title 24 compliance
- 3x savings in electricity costs
NYSERDA Demonstration Plan