Solar Electric
Reliable and Pollution-Free Electricity

Roger Manzolini
Power Systems Engineer at General Dynamics

Cara Humphrey
Solar Consultant at Astrum Solar
Outline

- Concept
- Plan
- Design
- Installation
  - Picture tour
- Rough estimates
- Risk
- How to proceed
Concept

- Provide your electrical needs by way of a solar power generation plant comprised of:
  - Solar panels
  - Inverters
  - Distribution system
  - Monitoring system

- You can own or lease the plant

- The plant can be roof or ground mounted

- You receive on-going financial benefits:
  - ~$0.15 per kW hour for electricity you produce and use
  - ~$0.15 per kW hour for electricity NET sent to the electric company
    - your surplus production
  - ~$0.20 per kW hour from the “market” for energy production via credits for SRECs
What is an SREC?

- SREC stands for Solar Renewable Energy Certificate
- An SREC is a tradable certificate that represents all the clean energy benefits of electricity generated from your solar electric system
- SREC's are issued to you regularly as your solar panels generate each 1000 kiloWatt hours
- A 5 kW system will generate almost 6 SREC Credits each year
Plan

- We wanted a system to exceed our use
  - Our use is modest and we can allocate surplus to another account
- Desired a ground mount system
  - Ease of maintenance (thought I’d own it)
  - Had plenty of room in the field
  - Just didn’t want it on our roof
  - Could ‘sweep’ off snow if needed
Plan
Power Flow / Use

Power used = Power from Array + Power from WMECO – Power to WMECO

Notes:
1. WMECO charges for the “NET” power sent to the house (power from WMECO minus Power to WMECO)
2. Power to and power from WMECO is the same rate (~$0.15/kWHR)
3. WMECO does not have visibility into what the house “uses”
4. Array production is metered and compensated for via SRECs (~$0.23/kWHR)
Plan
Average Daily Power Flow / Use

Note:
Our system was designed to produce 141% of our historical use of 22 kWhrs per day (669 monthly):
- 31 kWhrs per day (943 monthly)
Astrum Solar guaranteed:
- 29.5 kWhrs per day (897 monthly)
That should result in a savings of $11.78/day ($353/month)
Plan
Monthly kW Hours

KiloWatt Hours per month

- 897 kWhrs average guaranteed production
- 669 kWhrs average expected use
- 228 kWhrs average expected surplus

production
use
surplus

Roger Manzolini
June 6, 2013
# Our Worry-Free Solar Production Guarantee

<table>
<thead>
<tr>
<th>Year</th>
<th>Guaranteed Annual Output (kWh)</th>
<th>Guaranteed Cumulative System Output (kWh)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10,752</td>
<td>10,752</td>
</tr>
<tr>
<td>2</td>
<td>10,699</td>
<td>21,451</td>
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<tr>
<td>3</td>
<td>10,645</td>
<td>32,096</td>
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<tr>
<td>4</td>
<td>10,592</td>
<td>42,688</td>
</tr>
<tr>
<td>5</td>
<td>10,539</td>
<td>53,227</td>
</tr>
<tr>
<td>6</td>
<td>10,486</td>
<td>63,714</td>
</tr>
<tr>
<td>7</td>
<td>10,434</td>
<td>74,148</td>
</tr>
<tr>
<td>8</td>
<td>10,382</td>
<td>84,529</td>
</tr>
<tr>
<td>9</td>
<td>10,330</td>
<td>94,859</td>
</tr>
<tr>
<td>10</td>
<td>10,278</td>
<td>105,137</td>
</tr>
<tr>
<td>11</td>
<td>10,227</td>
<td>115,364</td>
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<tr>
<td>12</td>
<td>10,176</td>
<td>125,540</td>
</tr>
<tr>
<td>13</td>
<td>10,125</td>
<td>135,665</td>
</tr>
<tr>
<td>14</td>
<td>10,074</td>
<td>145,739</td>
</tr>
<tr>
<td>15</td>
<td>10,024</td>
<td>155,763</td>
</tr>
<tr>
<td>16</td>
<td>9,974</td>
<td>165,736</td>
</tr>
<tr>
<td>17</td>
<td>9,924</td>
<td>175,660</td>
</tr>
<tr>
<td>18</td>
<td>9,874</td>
<td>185,534</td>
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<tr>
<td>19</td>
<td>9,825</td>
<td>195,359</td>
</tr>
<tr>
<td>20</td>
<td>9,776</td>
<td>205,135</td>
</tr>
</tbody>
</table>

* Our Production Guarantee for the home solar ownership option is 95% of your estimated system production, with a 0.5% per year degradation rate, for 10 years.
Design

Before:

House
Main panel
Disconnect
Load breakers

Power from WMECO

WMECO

After:

House
Subpanel panel
Disconnect
Load CBs

Power to House

New
Main panel
Disconnect
Subpanel CBs

Power from Array

Array

Power to WMECO

WMECO

NET meter

Power from WMECO

Power from WMECO
Design

- Solar panels function
  - Convert the sun’s radiant energy to
  - 30 Volts direct current electrical power
Solar Panel(s) (40)
Sunmodule SW 240

- Maximum power: 240 Watts
- Max operating voltage: 30.6 Volts
- Max operating current: 7.87 Amps
- Open circuit voltage: 37.6 Volts
- Short circuit current: 8.22 Amps
- Operating temperature: -40°C to 85°C

- Cells per module (panel): (10x6) 60
- Cell type: Mono crystalline
- Cell dimensions: 6.14 in x 6.14 in

- Front: Tempered glass EN 12150
- Frame: Black anodized aluminum
- Size: 37.44 in x 65.94 in x 1.22 in
- Weight: 46.7 lbs.
- Warranty: 25-year
- Performance degradation: 0.7% p.a.
Design

- Inverters function
  - Convert 30 Volts direct current energy to
  - 240 Volts, single phase, 60 cycle alternate current power
  - Synchronize themselves to the power grid (WMECO)
  - Provide open circuit output when grid goes down (power is lost)
    - Required by WMECO in order to get approval to connect to their grid

The solar array is not a backup system
Inverter(s) (40)

Microinverter M215

- Input power: 190-270W
- Max input voltage: 45V
- Peak power tracking voltage: 22-36V
- Operating range: 21-36V
- Min / Max start voltage: 22V / 45V
- Max DC Short circuit current: 15A
- Max input current: 10.5A
- Max output power: 215W
- Nominal output current: 0.9A
- Nominal voltage / range: 240V / 206-269V
- Nominal frequency / range: 60.0 / 59.3-60.5 Hz
- Max units per 20A circuit: 17
- Efficiency: 96%
- Off power consumption: 46mW
- Operating temperature: -40°C to 85°C
- Size (WxHxD): 6.8” x 6.45” x 1.0”
- Weight: 3.5 lbs.
- Warranty: 25-year
Design

- Distribution system function
  - connects / disconnects
    - solar system to
    - electric company (WMECO) power grid
      - electric meter changed to a “NET-meter”

- Distribution system components
  - PV junction box - mounted on the Array(4)
  - PV meter - mounted outside on the garage near the array(6)
  - PV disconnect - mounted outside on the garage near the array(7)
  - PV Load Center - Subpanel mounted inside the garage(5)
  - AC Disconnect - Main panel mounted inside the house(9)
  - Net meter - mounted outside on the house
Design – satellite view
**Equipment Schedule**

<table>
<thead>
<tr>
<th>Tag</th>
<th>Description</th>
<th>Part Number</th>
<th>Quantity</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PV String</td>
<td>N/A</td>
<td>3</td>
<td>One of 3 strings is shown; Additional strings follow same wiring to PV Load Center</td>
</tr>
<tr>
<td>2</td>
<td>Solar PV Module</td>
<td>SW 240 Poly</td>
<td>40</td>
<td>Total of 40 modules in system which are split into 3 strings. Max of 17 per string.</td>
</tr>
<tr>
<td>3</td>
<td>DC/AC Inverter</td>
<td>M215-60-2L-S22</td>
<td>40</td>
<td>Micro-inverters are mounted under solar panels</td>
</tr>
<tr>
<td>4</td>
<td>Junction Box</td>
<td>Carlon 6 x 6 x 4 PVC</td>
<td>1</td>
<td>Junction box groups multiple strings. One is typical per continuous roof surface.</td>
</tr>
<tr>
<td>5</td>
<td>PV Load Center</td>
<td>45 Amp Subpanel</td>
<td>1</td>
<td>MLD - Solar PV Load center, (1) 2-pole circuit breaker per circuit.</td>
</tr>
<tr>
<td>6</td>
<td>PV Production Meter</td>
<td>Revenue Grade Meter</td>
<td>1</td>
<td>Included when applicable</td>
</tr>
<tr>
<td>7</td>
<td>PV Disconnect</td>
<td>Cutler Hammer, C-H DG222NFB</td>
<td>1</td>
<td>Visible Break Disconnect; Minimum of 60 Amps and sized according to system output.</td>
</tr>
<tr>
<td>8</td>
<td>Existing CB Panel</td>
<td>200 Amp</td>
<td>N/A</td>
<td>System will interconnected using a Load Side Tap connection in the Waterproof J-Box</td>
</tr>
<tr>
<td>9</td>
<td>Utility Disconnect</td>
<td></td>
<td></td>
<td>Visible Break Disconnect; 200 Amps, Fused</td>
</tr>
</tbody>
</table>

**Electrical Diagram for Manzolini**

![Diagram of PV system and electrical connections](attachment:image)

**Conduit and Conductor Schedule**

<table>
<thead>
<tr>
<th>Tag</th>
<th>Description or Conductor Type</th>
<th>Conductor Gauge</th>
<th>Number of Conductors</th>
<th>Conduit Type</th>
<th>Conduit Size</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PV Wire</td>
<td>12</td>
<td>2 (single)</td>
<td>N/A</td>
<td>N/A</td>
<td>Solar Panel to inverter (Typ)</td>
</tr>
<tr>
<td>2</td>
<td>Enphase Branch Cable</td>
<td>12</td>
<td>3</td>
<td>N/A</td>
<td>N/A</td>
<td>Solar Array Inverters to J-Box</td>
</tr>
<tr>
<td></td>
<td>Bare Copper Eq. Ground Conductor</td>
<td>6</td>
<td>1</td>
<td>N/A</td>
<td>N/A</td>
<td>Array rack bonding</td>
</tr>
<tr>
<td>3</td>
<td>THWN-2 Insulated Copper</td>
<td>10</td>
<td>9</td>
<td>PVC</td>
<td>Min 3/4&quot;</td>
<td>J-Box to Solar PV Load Center</td>
</tr>
<tr>
<td>4</td>
<td>THWN-2 Insulated Copper Grounding</td>
<td>8</td>
<td>1</td>
<td>PVC</td>
<td>Min 3/4&quot;</td>
<td>J-Box to Solar PV Load Center</td>
</tr>
<tr>
<td>5</td>
<td>4 AWG Aluminum Copper Grounding Electrode</td>
<td>4</td>
<td>4</td>
<td>PVC</td>
<td>Min 3/4&quot;</td>
<td>Solar PV Load Center Disconnect to kWh Meter</td>
</tr>
<tr>
<td>6</td>
<td>4 AWG Aluminum Copper Grounding Electrode</td>
<td>6</td>
<td>1</td>
<td>PVC</td>
<td>Min 3/4&quot;</td>
<td>Junction box to home CB panel and to meter for line side tap.</td>
</tr>
<tr>
<td>7</td>
<td>SEU Utility Service Cable</td>
<td>4/0</td>
<td>3</td>
<td>N/A</td>
<td>N/A</td>
<td>Existing service cable to net meter</td>
</tr>
</tbody>
</table>
Design

- Monitoring system components
  - 120 Vac ‘array-sourced’ outlet
  - Envoy controller / monitor
    - Collects array data over the ‘power-line’
  - Wireless transmitter in garage
  - Wireless receiver in house
  - Wireless router connected to the internet
  - Web-based data collection and analysis system
Design

- **Enphase Envoy Communications Gateway**
  - The networking hub connecting every module and microinverter in your solar array to the internet.
  - The Envoy uses advanced powerline communications technology to connect to each microinverter without additional wiring or wireless configuration. System owners can easily check the status of their solar system using the Envoy’s LCD display, or get more detailed information through the Enlighten website.
Design

- Enlighten Website features
  - Measures performance of each panel
  - Panel and system power production (Watts)
    - daily, past 7 days, custom range
  - Panel and system energy production (kWHRs)
    - daily, past 7 days, month to date, lifetime, custom range
  - Reports
    - Site Energy Production
    - Site Recent Power Production
    - Monthly Energy Production
  - Environmental benefits ‘data’
    - Carbon Offset
Solar Project Cost
plan and actual

- System Cost $40,078
- Federal Credit ($13,824)
- State Credit ($2,400)
- Contracted amount $23,854 - Plan
- Other expenses $ 698 (transformer, trenching)
- Tier credit ($1,920)
- Referral credit ($ 250)

$22,382 - Actual

- What we’ll save (plan to save)
  - $1,700 Electric bill(s) reduction (annually)
  - $2,600 Solar Renewable Energy Credits (annually)

- 5.2 year pay back period
- After that, continue annual savings

Roger Manzolini
Solar Installation
Picture Tour

System layout for the footings

Footprint 8’ by 68’

Footings are ten galvanized screws
Solar Installation
Picture Tour

Galvanized screws - 6’ 10” long
Foundation Supports – in place
Foundation Supports – in place
Solar Installation
Picture Tour

Close-up of screws
Aluminum supports
Installation complete - looking north
Installation complete – looking west
Installation complete – looking south
Panel Fastener
Panel Fastener
Production meter

PV disconnect switch
Sub Panel in Garage
Sub Panel in Garage
Envoy Communications Gateway in Garage
New Main Panel in cellar
‘new’ WMECO NET meter
‘old’ WMECO meter
So How’s it doing?
Production results to date
System turned on on March 25th
Daily energy production (kWHrs) May 2 – May 22

Roger Manzolini
Daily energy production (kWHrs)
May 2 – May 22
Power production (Watts)
May 17 – May 22
Power production (Watts)
May 3rd & May 19th

May 3rd
A real good sunny day
70 kWhrs

May 19th
A cloudy overcast day
8 kWhrs
Production results to date
System turned on March 25th

To date, actual production exceeds guaranteed production by more than 30%
My brother enjoys similar results with his system
Results to date (through May 16\textsuperscript{th})
Average Daily Power Flow / Use

Average numbers as of June 5\textsuperscript{th}:

1. Array produced 46 kWhrs / day
   - 38 kWhrs sent to WMECO
   - 8 kWhrs consumed by House
2. House used 20 kWhrs / day
   - 8 kWhrs from Array during the day
   - 12 kWhrs from WMECO at night
3. NET to WMECO was 26 kWhrs / day
Results to date (through May 16\textsuperscript{th})

Average Daily Benefit ($)

Average savings as of May 16th:
1. Didn’t pay about $3 per day for electrical use
2. Received about $4 per day NET credit from WMECO
3. Will receive about $9 per day from SREC revenue (~0.20/kWHr)
4. Results in about $16 per day ($780 in 46 days)
## Results to date (through May 16\(^{th}\))

<table>
<thead>
<tr>
<th>Date</th>
<th>kWhrs Produced</th>
<th>kWhrs used</th>
<th>Electric Bill without Solar</th>
<th>Electric Bill Actual</th>
<th>Electric Bill Net Savings</th>
<th>SREC Income</th>
<th>Monthly Electric Bill (Gain)</th>
<th>Cumulative Cash Flow</th>
<th>Pending SREC Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(22,382)</td>
<td>$ 0.20</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>2213</td>
<td>1050</td>
<td>$ 175</td>
<td>(164)</td>
<td>$ 338</td>
<td>-</td>
<td>$ 338</td>
<td>(22,043)</td>
<td>$ 443</td>
</tr>
<tr>
<td>9-Apr-13</td>
<td>707</td>
<td>420</td>
<td>$ 70</td>
<td>(39)</td>
<td>$ 109</td>
<td>-</td>
<td>$ 109</td>
<td>(22,273)</td>
<td>$ 141</td>
</tr>
<tr>
<td>10-May-13</td>
<td>1506</td>
<td>630</td>
<td>$ 105</td>
<td>(125)</td>
<td>$ 230</td>
<td>-</td>
<td>$ 230</td>
<td>(22,043)</td>
<td>$ 301</td>
</tr>
</tbody>
</table>
Western Massachusetts Electric
A Northeast Utilities Company

Contact Information
Emergency: 1-877-659-6326 (anytime)
Web Site: www.wmeco.com
Email: WMECOCustomerService@wmeco.com

Residential customers:
Customer Service: 1-877-659-6326
413-781-4300 Springfield area
(M-F 7-7 & Sat 10-3:30 pm)

Business customers:
Customer Service: 1-888-783-6610
413-504-8020 (local)
(M-F 8-5)

Simplify your life
Use eBill and ePay at www.wmeco.com
Or Pay by Phone 1-888-783-6618

Electricity Supplier
Western Massachusetts Electric
P.O. Box 150494
Hartford, CT 06115-0494
1-877-659-6326

Due Date
Jun 10, 2013
Total Amount Due
- $163.60

Your account summary
Amount due on Apr 12
- $38.99

Balance Forward
- $38.99

New Charges/Credits
Delivery Services
- $124.61
Electricity Supply Services
$0.00
Total new charges
- $124.61

Credit Balance
- $163.60

Detail for Service at:
725 CANAAN RD, RICHMOND MA 01254-5122
Service reference:
Billing cycle: 06

Your meter reading for meter
For billing period: Apr 9 - May 10 (31 days)
Next read date on or about: Jun 10, 2013
Actual reading on May 10, 2013 purchases
665
Actual reading on Apr 9, 2013 purchases
298
Billed usage
= 367

Your meter reading for meter
For billing period: Apr 9 - May 10 (31 days)
Next read date on or about: Jun 10, 2013
Actual reading on May 10, 2013 sales
1828
Actual reading on Apr 9, 2013 sales
585
Billed usage
= 1,243
WMECO Delivery Services Detail
RATE R1
Customer Chrg $6.00
Net Generation Credit 876.00KWH x $0.149100 - $130.61
Subtotal - $124.61

Electricity Supply Detail
RATE R1 - BASIC FIXED

Account messages

IMPORTANT!
Effective May 13, we are changing our address for mailing payments. Beginning with this bill, please send payments to:
WMECO
P O Box 650851
Dallas, TX 75265-0851
Business customers: Please update your records with the new address now to avoid any delays in processing payments. You will find the new address at the bottom of your bill. If you have questions or concerns, call 1-888-783-6610 (business customers) or 1-877-659-6326 (residential customers). We would be happy to help you.

Scan this with your smartphone! It will simplify your life.
Go to your app store to get a list of barcode reader apps for your mobile device.
Other Interesting stuff
Manzolini, Roger
Energy: Month to Date  May 1, 2013 – May 17, 2013

<table>
<thead>
<tr>
<th>Date</th>
<th>Energy (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1, 2013</td>
<td>20.3</td>
</tr>
<tr>
<td>May 2, 2013</td>
<td>20.8</td>
</tr>
<tr>
<td>May 3, 2013</td>
<td>20.3</td>
</tr>
<tr>
<td>May 4, 2013</td>
<td>20.4</td>
</tr>
<tr>
<td>May 5, 2013</td>
<td>20.1</td>
</tr>
<tr>
<td>May 6, 2013</td>
<td>20.2</td>
</tr>
<tr>
<td>May 7, 2013</td>
<td>20.9</td>
</tr>
<tr>
<td>May 8, 2013</td>
<td>20.0</td>
</tr>
<tr>
<td>May 9, 2013</td>
<td>20.1</td>
</tr>
<tr>
<td>May 10, 2013</td>
<td>20.6</td>
</tr>
<tr>
<td>May 11, 2013</td>
<td>19.9</td>
</tr>
<tr>
<td>May 12, 2013</td>
<td>20.2</td>
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<tr>
<td>May 13, 2013</td>
<td>19.9</td>
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<tr>
<td>May 14, 2013</td>
<td>20.2</td>
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<tr>
<td>May 15, 2013</td>
<td>20.7</td>
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<tr>
<td>May 16, 2013</td>
<td>20.5</td>
</tr>
<tr>
<td>May 17, 2013</td>
<td>20.1</td>
</tr>
</tbody>
</table>

**System Energy**
814 kWh

Average of 20.4 kWhr per panel
1.20 kWhr per panel per day
Manzolini, Peter
Energy: Month to Date   May 1, 2013 – May 17, 2013

System Energy 703 kWh

Note 4 things:
1. His south panels did the same as my south panels
2. His East panels did about (93%) as well as his south panels
3. All the ‘same facing’ panels do about the same
4. His total system produced 1.15 kWhr per panel per day, 96% as good as my system

Average of 19.5 kWhr per panel
1.15 kWhr per panel per day
Rough conclusion

- To get the production you use, you need one 240W panel for each average daily kWhr used
  - Each 240W panel:
    - provides 225 Watts after inversion to AC
      - 15 ft² (3’x5’), 15 Watts / ft²
    - produces 1.0 to 1.2 kWhr per day
- For the national average daily use of 30 kWhrs, you need
  - 30 panels, 450 ft²
- Note:
  - my system is 40 panels, it produces 47 kWhrs / day
    - Quality factor 0.98 (all at 35° facing south)
  - Peter’s system is 36 panels, it produces 36 kWhrs / day
    - Quality factor 0.89 (18 facing ~east, 18 facing ~south)
Real rough, real easy, quick estimate

- Divide your average electric bill by 5
  - That is how many 240W panels you need
    - (e.g. 150 / 5 = 30 panels)

- Multiply your average electric bill by 3
  - That is how much surface area you need
    - (e.g. 150 x 3 = 450 ft²)

- Multiply your electric bill by 120
  - That is about what it would cost to own the system
    - (e.g. 150 x 120 = $18,000)
    - Payback period about 6 to 8 years
### WMECO Residential rates as of May 2013

<table>
<thead>
<tr>
<th>kWused</th>
<th>1050</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>over 600</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution Energy Charge first 600</td>
<td>$0.040190</td>
<td>$24.11</td>
</tr>
<tr>
<td>Distribution Energy Charge over 600</td>
<td>$0.050190</td>
<td>$22.59</td>
</tr>
<tr>
<td>Transition charge</td>
<td>$0.006820</td>
<td>$ 7.16</td>
</tr>
<tr>
<td>Transmission Charge</td>
<td>$0.016190</td>
<td>$17.00</td>
</tr>
<tr>
<td>Res Assist Adj Clause</td>
<td>$0.003850</td>
<td>$ 4.04</td>
</tr>
<tr>
<td>Pension/PBOP Adj Mechn PPAM</td>
<td>$0.005760</td>
<td>$ 6.05</td>
</tr>
<tr>
<td>Basic Srvc Coat Adj</td>
<td>$0.000120</td>
<td>$ 0.13</td>
</tr>
<tr>
<td>Net metering recovery Surcharge</td>
<td>$0.000170</td>
<td>$ 0.18</td>
</tr>
<tr>
<td>Solar Program Cost Adjustment</td>
<td>$0.000300</td>
<td>$ 0.32</td>
</tr>
<tr>
<td>Energy Conservation Charge</td>
<td>$0.002500</td>
<td>$ 2.63</td>
</tr>
<tr>
<td>Energy Efficiency Program Charge</td>
<td>$0.007650</td>
<td>$ 8.03</td>
</tr>
<tr>
<td>Renewable Energy Charge</td>
<td>$0.000500</td>
<td>$ 0.53</td>
</tr>
<tr>
<td>Atty Genrl consultant exp adj</td>
<td>$0.000030</td>
<td>$ 0.03</td>
</tr>
<tr>
<td>Storm recovery adjustment</td>
<td>$0.001220</td>
<td>$ 1.28</td>
</tr>
<tr>
<td>Revenue Decoupling Adj</td>
<td>$(0.001270)</td>
<td>$(1.33)</td>
</tr>
<tr>
<td>Distributionsubtotal</td>
<td>$ 92.73</td>
<td></td>
</tr>
<tr>
<td>Generation Service Charge</td>
<td>$0.073150</td>
<td>$ 76.81</td>
</tr>
<tr>
<td>Cost of power</td>
<td>$ 169.54</td>
<td></td>
</tr>
<tr>
<td>Customer charge fixed cost</td>
<td>$    6.00</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$ 175.54</td>
<td></td>
</tr>
</tbody>
</table>
Other things to ponder

- A system size (kW) about ¼ of your average daily energy use is needed to cover your entire electric bill.
- Trees (peaks of other buildings?) need to be twice as far from the system as they are tall.
  - E.g. a 100 foot tree is not an issue if it 200 feet away.
- Most roofs can accept the added system load without modification.
  - If bracing is needed that is part of the ‘assessment’ and Astrum Solar will do the work as part of the job.
- Typical time line form now to power on is 6 months.
Solar Installation

Risks

- Roof leaks are more difficult to fix
  - AS guarantees within 5” of penetrations
- Market value of SRECs may collapse
- SREC income may become taxable
- Rates from WMECO may change
- Tax benefits may disappear
- Real estate tax exemption may be eliminated
- Home insurance premiums may rise
- Warrantees might not be honored
- Astrum Solar could go out of business
Our experience with Astrum Solar

- The positives
  - Astrum Solar has taken the mystery out of solar systems
  - They do it all:
    - Design, paperwork, installation, coordination with electric company
  - They provide post installation services:
    - Monitoring, SREC management, customer service
  - Employees were very accommodating, pleasant and like the company

- The negative
  - After the contract was signed, it seemed like they disappeared; however, in reality they were engaged performing detailed behind the scenes tasks and plans necessary to get the job underway

- Once started, the mechanical and electrical work was performed to very high standards
- Overall, the Manzolini’s are very pleased
Solar Installation
How to proceed

- Sign up on sheet you were given
- Astrum Solar will contact you for a site survey
- You provide record of your annual electrical use
- Astrum Solar will follow up with:
  - Site assessment, concept design, guaranteed production numbers, proposal options, cost of options, estimated payback period, approximate time line for installation
- You decide to go forward with one of the options or to discontinue pursuit
Name: __________________________________________

Address of proposed system:
_____________________________________________
_____________________________________________

Phone no: ______________________________________

E-mail: ________________________________________
Deleted slides
YOUR SOLAR CALCULATOR QUOTE

Roger Manzolini
725 Canaan Road,
Richmond, MA 01254

Your Solar System Overview

9.6 kW system
40 SolarWorld 240 watt solar panels
M215 Enphase Energy microinverters
Enlighten website monitoring for system lifetime

141% of your electricity will be solar
11,318 kWh of solar electricity generated annually

Only available for Solarize Pittsfield Lenox

SEE A SUNNY DAY IN A WHOLE NEW WAY*
## Performance Under Standard Test Conditions (STC)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SW 240</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum power $P_{\text{max}}$</td>
<td>240 Wp</td>
</tr>
<tr>
<td>Open circuit voltage $V_{oc}$</td>
<td>37.6 V</td>
</tr>
<tr>
<td>Maximum power point voltage $V_{mp}$</td>
<td>30.6 V</td>
</tr>
<tr>
<td>Short circuit current $I_{sc}$</td>
<td>8.22 A</td>
</tr>
<tr>
<td>Maximum power point current $I_{mp}$</td>
<td>7.87 A</td>
</tr>
</tbody>
</table>

*STC: 1000W/m², 25°C, AM 1.5

## Thermal Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOCT</td>
<td>48 °C</td>
</tr>
<tr>
<td>$T_C I_C$</td>
<td>0.004 %/K</td>
</tr>
<tr>
<td>$T_C V_{mp}$</td>
<td>-0.30 %/K</td>
</tr>
<tr>
<td>$T_C P_{mp}$</td>
<td>-0.45 %/K</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>-40°C to 85°C</td>
</tr>
</tbody>
</table>

## Performance at 800 W/m², NOCT, AM 1.5

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SW 240</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum power $P_{\text{max}}$</td>
<td>175.4 Wp</td>
</tr>
<tr>
<td>Open circuit voltage $V_{oc}$</td>
<td>34.2 V</td>
</tr>
<tr>
<td>Maximum power point voltage $V_{mp}$</td>
<td>27.9 V</td>
</tr>
<tr>
<td>Short circuit current $I_{sc}$</td>
<td>6.63 A</td>
</tr>
<tr>
<td>Maximum power point current $I_{mp}$</td>
<td>6.30 A</td>
</tr>
</tbody>
</table>

Minor reduction in efficiency under partial load conditions at 25°C at 200W/m². 95% (4%, 5%) of the STC efficiency (1000 W/m²) is achieved.

## Component Materials

- **Cells per module**: 60
- **Cell type**: Mono crystalline
- **Cell dimensions**: 6.14 in x 6.14 in (156 mm x 156 mm)
- **Front**: Tempered glass (EN 12150)
- **Frame**: Black anodized aluminum
- **Weight**: 46.7 lbs (21.2 kg)

## System Integration Parameters

- **Maximum system voltage SC II**: 1000 V
- **Max. system voltage USA NEC**: 600 V
- **Maximum reverse current**: 16 A
- **Number of bypass diodes**: 3
- **UL Design Loads**: Two rail system 113 psf downward, 64 psf upward
- **UL Design Loads**: Three rail system 170 psf downward, 64 psf upward
- **IEC Design Loads**: Two rail system 113 psf downward, 50 psf upward

*Please refer to the Sunmodule installation instructions for the details associated with these load cases.

## Additional Data

- **Power sorting**: -4.0 Wp / +4.5 Wp
- **J-Box**: IP65
- **Connector**: MC4
- **Module efficiency**: 14.31%
- **Fire rating (UL 790)**: Class C
## M215 — MICROINVERTER TECHNICAL DATA

### Input Data (DC)

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended input power (STC)</td>
<td>190 - 270W</td>
</tr>
<tr>
<td>Maximum input DC voltage</td>
<td>45V</td>
</tr>
<tr>
<td>Peak power tracking voltage</td>
<td>22V - 36V</td>
</tr>
<tr>
<td>Operating range</td>
<td>16V - 36V</td>
</tr>
<tr>
<td>Min./Max. start voltage</td>
<td>22V/45V</td>
</tr>
<tr>
<td>Max. DC short circuit current</td>
<td>15A</td>
</tr>
<tr>
<td>Max. input current</td>
<td>10.5A</td>
</tr>
</tbody>
</table>

### Output Data (AC)

<table>
<thead>
<tr>
<th>Feature</th>
<th>@208 Vac</th>
<th>@240 Vac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum output power</td>
<td>215W</td>
<td>215W</td>
</tr>
<tr>
<td>Nominal output current (arms at nominal duration)</td>
<td>1.0A</td>
<td>0.9A</td>
</tr>
<tr>
<td>Nominal voltage/range</td>
<td>208V/183-229V</td>
<td>240V/211-264V</td>
</tr>
<tr>
<td>Extended voltage/range</td>
<td>208V/179-232V</td>
<td>240V/206-269V</td>
</tr>
<tr>
<td>Nominal frequency/range</td>
<td>60.0/59.3-60.5 Hz</td>
<td>60.0/59.3-60.5 Hz</td>
</tr>
<tr>
<td>Extended frequency range</td>
<td>60.0/59.2-60.6 Hz</td>
<td>60.0/59.2-60.6 Hz</td>
</tr>
<tr>
<td>Power Factor</td>
<td>&gt;0.95</td>
<td>&gt;0.95</td>
</tr>
<tr>
<td>Maximum units per 20A branch circuit</td>
<td>25 (three phase)</td>
<td>17 (single phase)</td>
</tr>
<tr>
<td>Maximum output fault current</td>
<td>1.05 Arms, over 3 cycles; 25.2 Apeak, 1.74ms duration</td>
<td></td>
</tr>
</tbody>
</table>

### Efficiency

- CEC weighted efficiency: 96.0%
- Peak inverter efficiency: 96.3%
- Static MPPT efficiency (weighted, reference EN50530): 99.6%
- Dynamic MPPT efficiency (fast irradiation changes, reference EN50530): 99.3%
- Night time power consumption: 46mW

### Mechanical Data

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature range</td>
<td>-40°C to + 65°C</td>
</tr>
<tr>
<td>Operating temperature range (internal)</td>
<td>-40°C to + 85°C</td>
</tr>
<tr>
<td>Dimensions (WxHxD)</td>
<td>17.3 cm x 16.4 cm x 2.5 cm (6.8&quot; x 6.45&quot; x 1.0&quot;)*</td>
</tr>
<tr>
<td>Weight</td>
<td>1.6 kg (3.5 lbs)</td>
</tr>
<tr>
<td>Cooling</td>
<td>Natural convection - No fans</td>
</tr>
<tr>
<td>Enclosure environmental rating</td>
<td>Outdoor - NEMA 6</td>
</tr>
</tbody>
</table>

* Without mounting bracket

### Features

- Compatibility: Pairs with most 60-cell PV modules
- Communication: Power line
- Warranty: 25-year limited warranty
- Monitoring: Free lifetime monitoring via Enlighten software
- Compliance: UL1741/IEEE1547, FCC Part 15 Class B, CAN/CSA-C22.2 NO. 0-M91, 0.4-04, and 107.1-01
Different plans are available now
Your account summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous balance on Mar 25</td>
<td>$96.27</td>
</tr>
<tr>
<td>Payment Apr 15</td>
<td>-$99.27</td>
</tr>
<tr>
<td>Balance Forward</td>
<td>$0.00</td>
</tr>
<tr>
<td>New Charges/Credits</td>
<td></td>
</tr>
<tr>
<td>Delivery Services</td>
<td>$58.22</td>
</tr>
<tr>
<td>Supplier Services</td>
<td>$47.27</td>
</tr>
<tr>
<td>Total new charges</td>
<td>$105.49</td>
</tr>
<tr>
<td>Total amount now due</td>
<td>$105.49</td>
</tr>
</tbody>
</table>

Your account is enrolled in an electronic payment program. The payment is scheduled to be processed from your designated bank account on May 18, 2011.

For service at:

<table>
<thead>
<tr>
<th>Service reference:</th>
<th>Billing cycle:</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your meter reading for meter #</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For billing period: Mar 25 - Apr 27 (33 days)</td>
<td>Next read date on or about: May 26, 2011</td>
<td></td>
</tr>
<tr>
<td>Actual reading on Apr 27, 2011 purchases</td>
<td>15107</td>
<td></td>
</tr>
<tr>
<td>Actual reading on Mar 25, 2011 purchases</td>
<td>-14161</td>
<td></td>
</tr>
<tr>
<td>Billed usage</td>
<td>= 946</td>
<td></td>
</tr>
</tbody>
</table>

| Your meter reading for meter # |                |    |
| For billing period: Mar 25 - Apr 27 (33 days) | Next read date on or about: May 26, 2011 |
| Actual reading on Apr 27, 2011 sales | 3300 |
| Actual reading on Mar 25, 2011 sales | -3030 |
| Billed usage | = 270 |

Delivery Services Detail

<table>
<thead>
<tr>
<th>Description</th>
<th>RATE R1</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Chrg</td>
<td></td>
<td>$6.00</td>
</tr>
<tr>
<td>Distribution Energy Charge*</td>
<td>600.00KWH x $0.04250</td>
<td>$24.15</td>
</tr>
<tr>
<td>Transition Chrg Per KWH</td>
<td>76.00KWH</td>
<td>$0.01705</td>
</tr>
<tr>
<td>Transmission Chrg</td>
<td>676.00KWH</td>
<td>$0.01470</td>
</tr>
<tr>
<td>Res Assist Adj Clause</td>
<td>676.00KWH</td>
<td>$0.00300</td>
</tr>
<tr>
<td>Pension/PBO Adj Mech PPAM</td>
<td>676.00KWH</td>
<td>$0.00390</td>
</tr>
<tr>
<td>Basic Srv Cost Adj</td>
<td>676.00KWH</td>
<td>$0.00270</td>
</tr>
<tr>
<td>Net metering recovery surcharge</td>
<td>676.00KWH</td>
<td>$0.00007</td>
</tr>
<tr>
<td>Solar Program Cost Adjustment</td>
<td>676.00KWH</td>
<td>$0.00250</td>
</tr>
<tr>
<td>Energy Conservation Chrg</td>
<td>676.00KWH</td>
<td>$0.00250</td>
</tr>
<tr>
<td>Energy Efficiency Program Chrg</td>
<td>676.00KWH</td>
<td>$0.003190</td>
</tr>
<tr>
<td>Renewable Energy Chrg</td>
<td>676.00KWH</td>
<td>$0.00500</td>
</tr>
<tr>
<td>Atty Geni consultant exp adj</td>
<td>676.00KWH</td>
<td>$0.000050</td>
</tr>
<tr>
<td>Storm recovery adjustment</td>
<td>676.00KWH</td>
<td>$0.000050</td>
</tr>
<tr>
<td>Total Delivery Services</td>
<td></td>
<td>$58.22</td>
</tr>
</tbody>
</table>

Supplier Services Detail

<table>
<thead>
<tr>
<th>Description</th>
<th>RATE R1 - BASIC</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation Srv Chrg***</td>
<td>676.00KWH x $0.009930</td>
<td>$47.27</td>
</tr>
<tr>
<td>Total Supplier Services</td>
<td></td>
<td>$47.27</td>
</tr>
</tbody>
</table>

What you owe for this month's electricity (including solar credits).

How much electricity from WMECO you used this month.

How much solar electricity you delivered to WMECO.

WMECO charges for the electricity you used from them (946 kWh) minus the solar electricity you gave back (270 kWh) = 676 kWh.
Solar Installation
Some ‘very rough estimates’ for early planning

# 240W panels needed as a function of average monthly electric bill

National average 30 kWhrs per month
Solar Installation
Some ‘very rough estimates’ for early planning

roof area (sq. ft.) needed as a function of average monthly electric bill

National average 30 kWhrs per month
WMECO Utility Meter
P.V. Disconnect Located
at S.W. corner of Garage
Massachusetts SREC Market

The Massachusetts Department of Energy Resources (DOER) created an SREC market which began in January 2010. Massachusetts's market is unique as it's final goal is 400MW of solar capacity. This has led to DOER to adopt a policy of setting requirements annually, based on a formula incorporating build rates and SREC data from past years. In addition to this, the state has implemented the MA Solar Credit Clearinghouse as a last resort, fixed-price auction in the last quarter of each year with a fixed price of $300 per SREC less a 5% fee. This fixed price auction acts as a price floor mechanism with the goal of creating a sustainable SREC market. This is not a concrete price floor as compliance buyers are not required to buy all of the SRECs that are put into the auction.

- **Solar Requirement:** Set at 30MW (0.0680% or 34,164 SRECs) in 2010. Each year the requirement will increase by 30% more than the previous year's increase. It will then be adjusted by the previous year's oversupply or shortage of SRECs. The total requirement in any given year is capped at 400MW and shall never decrease.
Plan
Average Monthly kW Hours

KiloWatt Hours per month

897 kWhrs average guaranteed production
669 kWhrs average expected use
228 kWhrs average expected surplus
### Summary of results to date

<table>
<thead>
<tr>
<th>Days On</th>
<th>kWhrs from Array daily (F)</th>
<th>kWhrs from WMECO daily (4) (G)</th>
<th>Total kWhrs sent to house (F+G)</th>
<th>kWhrs to WMECO daily (10) (I)</th>
<th>kWhrs used daily (F+G-I)</th>
<th>kWhrs used Received from Array (F-I)</th>
<th>kWhrs NET WMECO daily (G-I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>45</td>
<td>12</td>
<td>58</td>
<td>37</td>
<td>21</td>
<td>9</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>3024</td>
<td>928</td>
<td>3757</td>
<td>2455</td>
<td>1352</td>
<td>555</td>
<td>-1608</td>
</tr>
<tr>
<td></td>
<td>79%</td>
<td>21%</td>
<td>100%</td>
<td>64%</td>
<td>36%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>($1.83)</td>
<td>81%</td>
<td>($3.10)</td>
<td>19%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$10.45</td>
<td>59%</td>
<td>$5.52</td>
<td>100%</td>
<td>41%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Roger Manzolini

June 6, 2013