Introduction

- Value of PV system must include all costs and revenues associated with the system over its lifetime

- Methodology used in this study determines:
  1. The value of improvements to the lifetime power output of a PV system
  2. How much additional expense could be added during cell and module fabrication to achieve that added performance

- How does the initial cost relate to the final value?

Study Activities

- To compare the NPV of the life-cycle cost of four PV module production technologies
  1. 1985 MY SOA Cz at 5 MW annual prod.
  2. 1992 MY SOA Cz at 25 MW annual prod.
  4. 1992 MY high-eff. web at 25 MW annual prod.

- Look at various module and system configurations:
  - Large and standard module size
  - Series — parallel circuitry
  - Cross strapping
  - Bypass diodes around each cell
  - Series — parallel modules
  - Bypass diodes around each series block, module and parallel module group

- Module replacement
  - Cell failure (opens only; 1 per 10,000 per year), causing module back bias of 0.5 volt
PROCESS DEVELOPMENT

Methodology

- Use three PA&I-developed simulation models
  - PVARRAY — system array performance
  - SAMICS — simulated module manufacturing industry
  - LCP — simulates the energy output, cost and value of a PV power plant over its useful lifetime

PV Array Design Economic Evaluation Methodology

PVARRAY Terminology

- Series String (SS) with 4 Solar Cells (SC)
- Series Block (SB) with 3 Series Strings
- Module Module with 3 Series Blocks
- Parallel Module Group (PMG) with 4 Modules
- Branch Circuit (BC) with 20 Parallel Module Groups
PROCESS DEVELOPMENT

PVARRAY Module Configurations

STANDARD MODULE

12SC, 3SS
or
3SC, 3SS, 4SB
(W/CROSS STRAPS)

LARGE MODULE

12SC, 12SS
or
3SC, 12SS, 4SB
(W/CROSS STRAPS)

input Parameters

LCP
Mfg. yr 1985 1992
ABOS ($/m^2) 115 60
PBOS ($/kW) 600 150
O&M ($/m^2/yr) 1.30 1.30

Rate Structure ($/kWh) – 8.5 peak, 7.1 mid-peak, 6.0 off-peak
Insulation – 2300 kWh/yr

NPV
Inflation rate – 5%
Discount rate – 9%
Depreciation – 15-yr life
PROCESS DEVELOPMENT

SAMICS: SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

LP: LIFETIME COST AND PERFORMANCE MODEL
PROCESS DEVELOPMENT

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mod. Size</td>
<td>1.2 x 1.2 m</td>
<td>1.2 x 1.2 m</td>
<td>1.2 x 1.2 m</td>
</tr>
<tr>
<td>Cell Eff.</td>
<td>11.9%</td>
<td>11.9%</td>
<td>18.7%</td>
</tr>
<tr>
<td>Mod Eff.</td>
<td>9.5%</td>
<td>9.5%</td>
<td>16.2%</td>
</tr>
<tr>
<td>Wp/Mod.</td>
<td>147</td>
<td>147</td>
<td>233</td>
</tr>
<tr>
<td>Annual Prod.</td>
<td>5 MW</td>
<td>25 MW</td>
<td>25 MW</td>
</tr>
<tr>
<td>Si Cost, 82$</td>
<td>$34/kg</td>
<td>$18/kg</td>
<td>$18/kg</td>
</tr>
<tr>
<td>Value Added</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$/Wp</td>
<td>3.52</td>
<td>2.40</td>
<td>1.65</td>
</tr>
<tr>
<td>$/m²</td>
<td>359</td>
<td>245</td>
<td>233</td>
</tr>
</tbody>
</table>

Sensitivity of Net Benefit to Module Cost Change
Sensitivity of Net Benefit to Efficiency Change

Summary

- Models PVARRAY, SAMIS and LCP provide a tool for evaluating PV technologies and PV systems
- Two evaluation rankings possible, system performance and NPV
- Can identify system and performance tradeoffs

Preliminary Conclusions

- Parallel redundancy recommended
- For large modules, value of bypass diodes is marginal
- High efficiency and lower module cost are needed for PV to be economically attractive
PROCESS DEVELOPMENT

Future Work

- High-efficiency web
- Standard-size modules (0.30 × 1.2 m)
- Cross strapping
- Diodes around series blocks and individual cells
- A look at several specific processes and their effects on module cost and efficiency