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.
  (3) 1992 MY high-eff. 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
PROCESS DEVELOPMENT

PVARRAY Module Configurations

STANDARD MODULE

LARGE MODULE

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

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

CELL SPECS ➔ PV ARRAY ➔ LCP ➔ PRE-REVENUE ➔ N/P/V ➔ SYSTEM NET PRESENT VALUE
CIRCUIT DESIGN ➔ WEATHER DATA ➔ INSOLATION vs TIME ➔ DEPRECIATION & TAXES ➔ (LOAD SERVICED BY PV)
MAX POWER ➔ AEC & PBOS COSTS ➔ D&M COSTS ➔ NOMINAL COST STREAM ➔ (ELEC. PURCHASES)
CELL FAILURE RATE ➔ SOILING PROFILE ➔ RATE STRUCTURE ➔ MODULE COSTS
REPLACEMENT RATE ➔ GEN. ECON. DATA ➔ PROCESS VALUE ADDED
PROFIT DESC. ➔ SAMICS ➔ PROCESS VALUE ADDED ➔ IPEG COEFFICIENTS
COST ANALYSIS ➔ SAMICS ➔ ANNUAL PRODUCTION

SAMICS: SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS
LCP: LIFETIME COST AND PERFORMANCE MODEL
### PROCESS DEVELOPMENT

<table>
<thead>
<tr>
<th></th>
<th>SOA Cz 1985</th>
<th>SOA Cz 1992</th>
<th>High-Efficiency Cz 1992</th>
</tr>
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<tbody>
<tr>
<td><strong>Mfg. yr</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mod. Size</strong></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><strong>Cell Eff.</strong></td>
<td>11.9%</td>
<td>11.9%</td>
<td>18.7%</td>
</tr>
<tr>
<td><strong>Mod Eff.</strong></td>
<td>9.5%</td>
<td>9.5%</td>
<td>16.2%</td>
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<tr>
<td><strong>Wp/Mod.</strong></td>
<td>147</td>
<td>147</td>
<td>233</td>
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<tr>
<td><strong>Annual Prod.</strong></td>
<td>5 MW</td>
<td>25 MW</td>
<td>25 MW</td>
</tr>
<tr>
<td><strong>Si Cost, 82$</strong></td>
<td>$34/kg</td>
<td>$18/kg</td>
<td>$18/kg</td>
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<td><strong>Value Added</strong></td>
<td></td>
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<tr>
<td>$/Wp</td>
<td>3.52</td>
<td>2.40</td>
<td>1.65</td>
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<tr>
<td>$/m²</td>
<td>359</td>
<td>245</td>
<td>274</td>
</tr>
</tbody>
</table>

### Sensitivity of Net Benefit to Module Cost Change

![Graph showing sensitivity of net benefit to module cost change](image)
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 x 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