# A Simplified Cost Model for Photovoltaic Energy

## Solar 2007 Conference

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# Topics

- Conceptual Overview
- Features of the Model
- Installed Cost of PV
- The Term of Financing
- Cost of Money
- The Solar Resource
- System Efficiency
- Comparison of Four Hypothetical Systems
- Conclusions





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# What Defines the Cost of PV Energy?

- Fundamental Equation:
  - (Principal + Interest + Maintenance)/kWh





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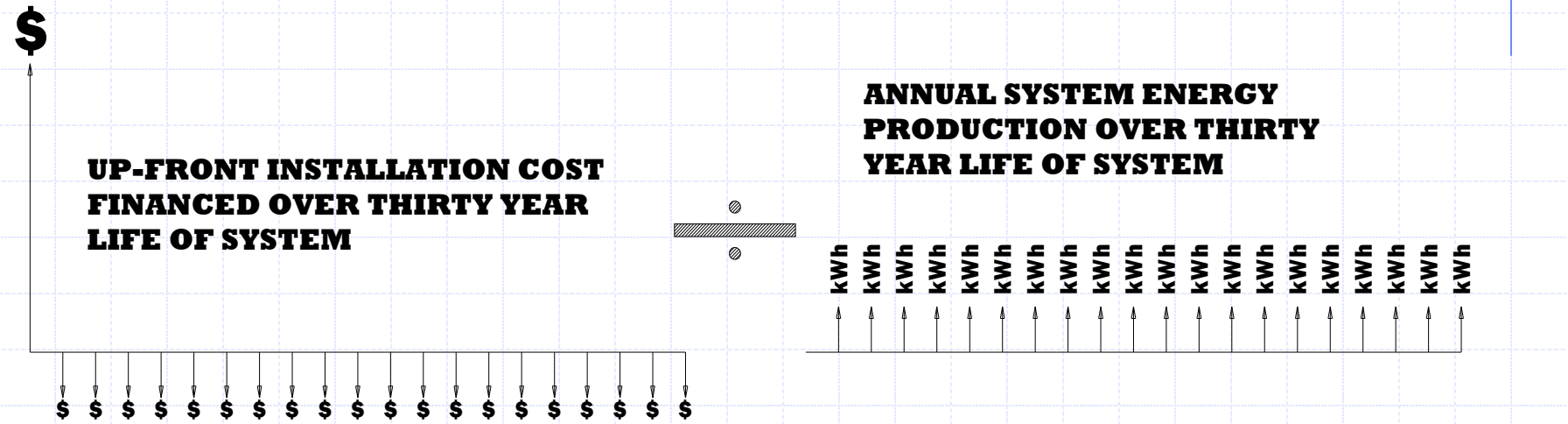
# COST OF PV ENERGY CALCULATION





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# What Goes into the Cost of PV Energy?

- Installed unit cost, $C_U$, ($/Wp)
- System size, $W$, (Wp)
- System installed cost, $P$, ($)
- Cost of Money, $i$ , (%)
- Term of financing, $n$ , (yr)
- Solar resource characteristics, (Wh/m$^2$/yr)
- System conversion efficiency, (%)

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# Installed Cost of PV

- Hypothetical System:
  - $W$ = 2.625kW (STC) BP3125 array
  - $C_U$ = \$9/Wp

$$P = C_U \times W$$

- System installed cost: $P$ = \$23,625

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# Term of Financing: *n* = 30 years

- Module warrantees: 20 to 25 years
- Inverter warrantees: 5, 7, 10 years
- Case study: 100kWp, Beverly, Massachusetts:
  - 25 years of operation and +85% of original power rating





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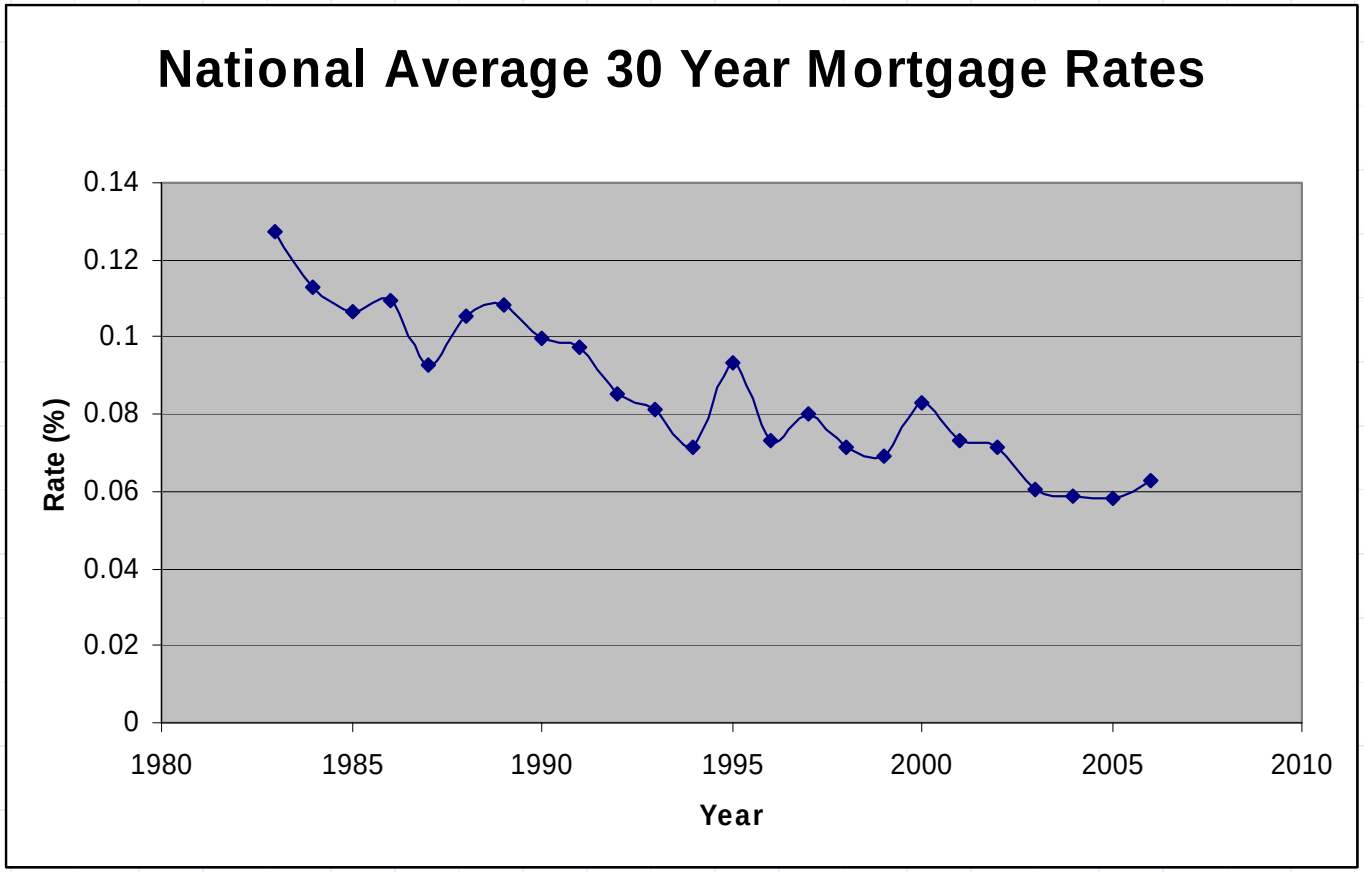
# Interest Rate: *i*




SOURCE: HSH Associates, Financial Publishers. National average 30 year mortgage rates 1983 to present.

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# Cost of Money

$$A = \left( \frac{\left( i \times (1+i)^n \right)}{(1+i)^n - 1} \right) \times P$$

(The same calculation can be performed using any of several on-line loan calculators such as http://www.bankrate.com/brm/popcalc2.asp )

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# Solar Resource

- Typical Meteorological Year 2 (TMY2) Data
- Four State Scenarios:
  - Boston, Massachusetts
  - Portland, Oregon
  - Los Angeles, California
  - Honolulu, Hawaii

  (All sites: no shading, azimuth = 180, tilt = latitude)





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# Photovoltaic System Efficiency

- PVDesignPro simulation model (Sandia Photovoltaic Array Performance Model)
- PVWatts, Version 1, (NREL)

| Location | Annual E PVDesignPro (kWh) | Annual E PVWatts (kWh) | Ratio PV-D/PVW |
|---|---|---|---|
| Boston, MA | 3359 | 3265 | 1.029 |
| Portland, OR | 2788 | 2671 | 1.044 |
| Los Angeles, CA | 3871 | 3858 | 1.003 |
| Honolulu, HI | 3757 | 3832 | 0.980 |

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# Cost of PV Energy: Residential 4 Scenarios

- 2.7kW DC STC PV System, assume $9/Wp Installed, 30 Year Financing @ 8%
  - Boston, MA, Latitude 42: $0.61/kWh
  - Portland, OR, Latitude 45: $0.74/kWh
  - Los Angeles, CA, Latitude 34: $0.53/kWh
  - Honolulu, HI, Latitude 21: $0.55/kWh





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# Cost of PV Energy: Residential 4 Scenarios

- 2.7kW DC STC PV System, assume $9/Wp Installed, 30 Year Financing @ 5%
  - Boston, MA, Latitude 42: $0.45/kWh
  - Portland, OR, Latitude 45: $0.54/kWh
  - Los Angeles, CA, Latitude 34: $0.39/kWh
  - Honolulu, HI, Latitude 21: $0.40/kWh





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# Cost of PV Energy: Residential 4 Scenarios

- 2.7kW DC STC PV System, assume $7/Wp Installed, 30 Year Financing @ 5%
  - Boston, MA, Latitude 42: $0.36/kWh
  - Portland, OR, Latitude 45: $0.43/kWh
  - Los Angeles, CA, Latitude 34: $0.31/kWh
  - Honolulu, HI, Latitude 21: $0.32/kWh





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# Cost of PV Energy: Residential 4 Scenarios

- 2.7kW DC STC PV System, assume $7/Wp Installed, 30 Year Financing @ 5% and a $4.00 buy-down:
  - Boston, MA, Latitude 42: $0.15/kWh
  - Portland, OR, Latitude 45: $0.18/kWh
  - Los Angeles, CA, Latitude 34: $0.13/kWh
  - Honolulu, HI, Latitude 21: $0.14/kWh

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# Conclusions

- The cost of PV energy is highly site dependant
- To a first order PV energy cost can be calculated with a simple spreadsheet
- The values calculated in this analysis are for ideally sited systems. Poorer site conditions would result in higher PV energy costs.

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