PREDICTING PV ENERGY LOSS CAUSED BY SNOW

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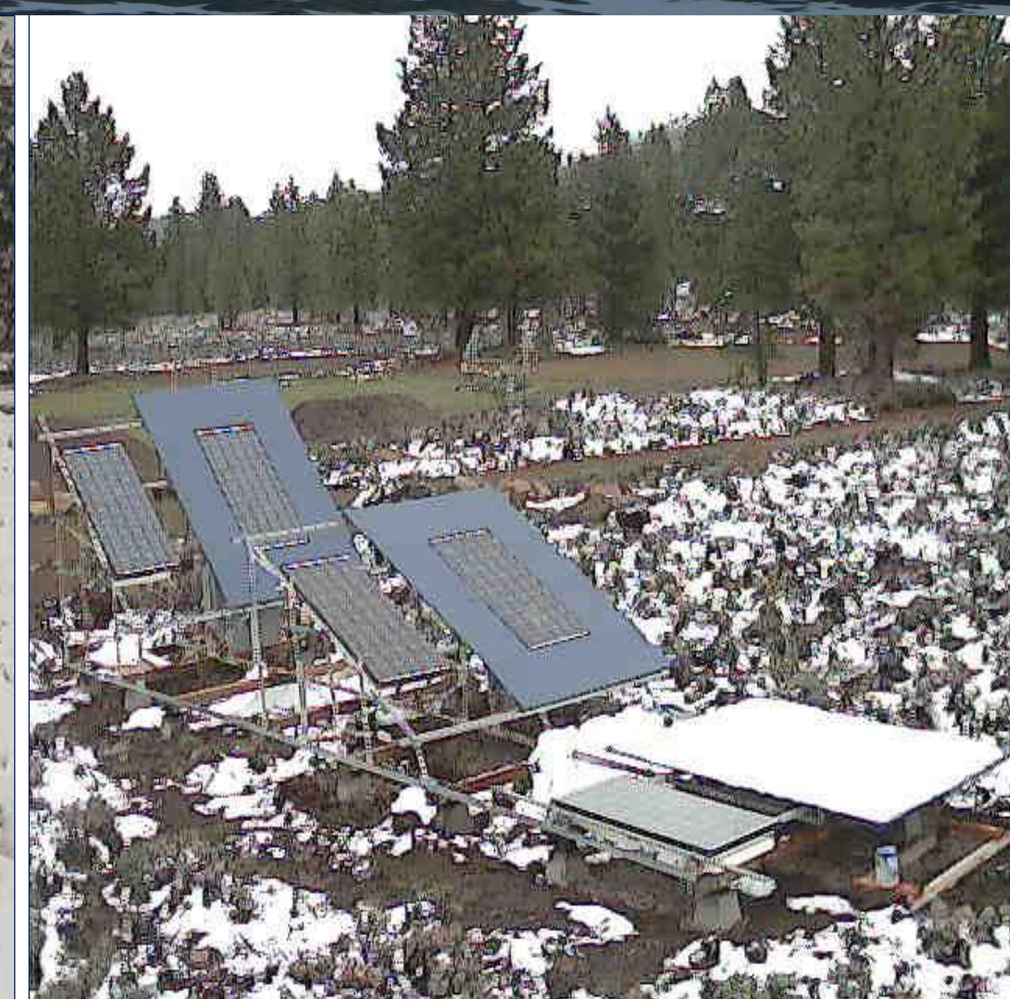
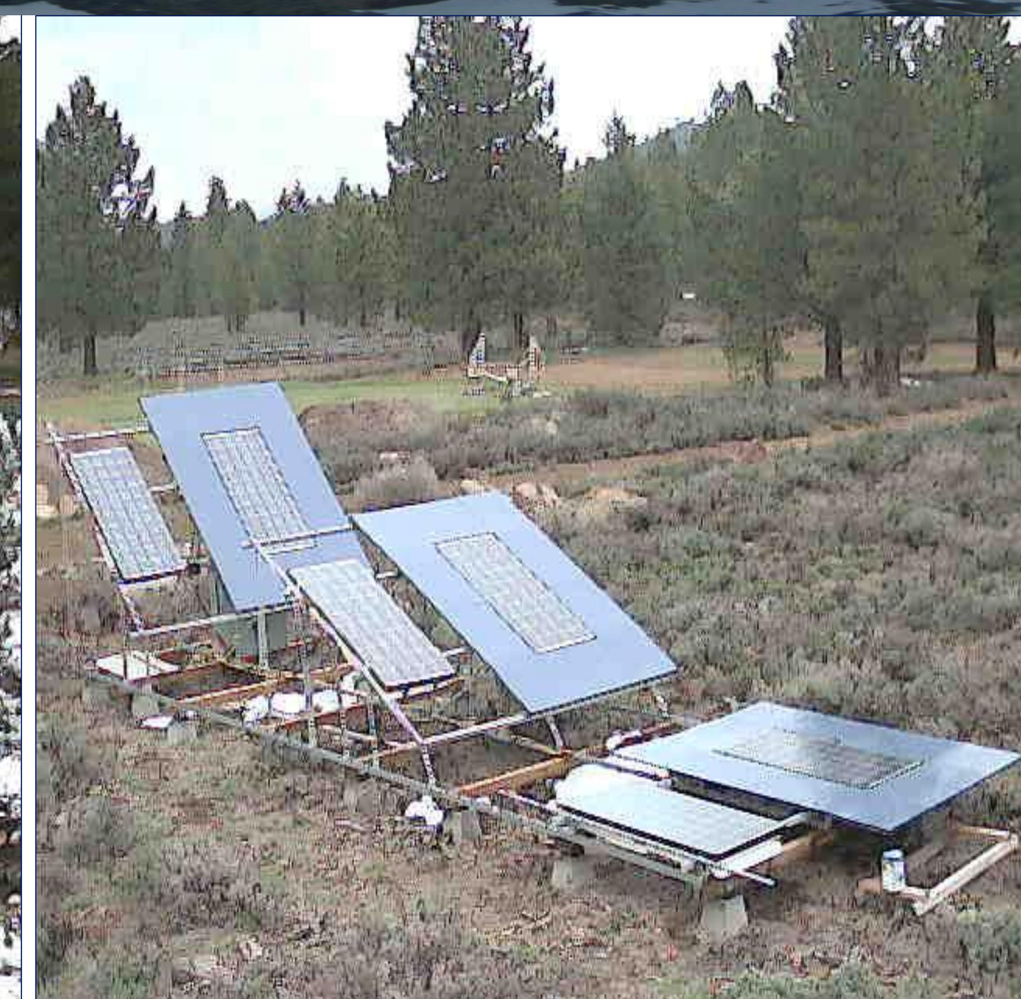
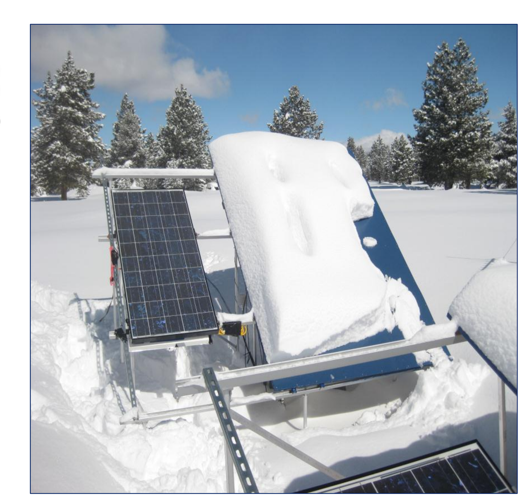



BRRR….WHO PUT THAT SNOW ON MY $PV SYSTEM?

♬ Humidity built the snowman – Sunshine brought him down ♬

(from Chicago's own John Prine)

- **THE FACTS/THE PROBLEM:**
  - **•Snowy climates like Chicago are now popular PV markets, and snow losses are significant**
  - **•Half of the world's 40 largest PV systems get snowed on each year (Germany, Ukraine, Canada)**
  - **•Solar resource data *do not* account for energy lost due to snow buildup**
  - **•The literature remains sparse and anecdotal – try Googling for a predictive model!**



- **THE SOLUTION:**
  - **•First – build a test rig to measure actual losses and relevant weather data**
  - **•Second – develop a generalized monthly model based on the test data above**
- **THE STRUCTURE(S):**
  - **•Photos show our 3-angle test rig installed near Lake Tahoe in 2009, where it snows 200" per yr.**
  - **•One module of each pair is heated and cleaned and compared to its identically positioned, uncleaned twin. We record hourly short-circuit current, radiation, humidity, and temperature.**
  - **•Four new stations, now featuring four tilt angles, are being installed in CA, CO, MI, & PA.**
- **THE MODEL:**
  - **•Monthly energy loss can now be predicted for use in PVSYST. The model applies to fixed tilt systems and accounts for situations w/ and w/o pileup interference after snow slides off**
  - **•Model inputs: monthly snowfall, # of events, humidity, air temp., insolation, tilt, row length, and drop height to roof or ground surface. *Model is readily adaptable to simple worksheets.***

$$\text{Monthly Loss, \%} = C_1 \times Se' \times \cos^2(T) \times GIT \times RH / T_A^{\,2} / POA^{0.67}$$

- **SAMPLE *MONTHLY* RESULT: *CHICAGO*, JAN. (25° tilt, no interf.)**
  - **9% = 5.7E04 x 6.7 x $\cos^2(25)$ x 0.49 x 76 / (270^2 x $68^{0.67}$)**
- **OTHER SITES, *ANNUAL* % LOSS (same type of PV system):**
  - **Lake Tahoe, 200" snow 15%**
  - **Denver, 60" snow 3%**
  - **Detroit, Chicago, 40" snow 3%**
  - **Philadelphia, 20" snow 2%**

DEFINITIONS

C_1=	fitted coefficient = 5.7×10^4
S=	snowfall, inches per month
Se=	"effective" monthly snow = S*[1 + 1/N]
N =	number of snow events ≥1"
Se'=	Rolling 6-wk average effective snowfall
GIT=	1 – C_2*exp(-γ); C_2= fitted coefficient = 0.51
γ=	snow received / snow discharged
	γ= R*cos(T)*Se' / [½*(1/tan(P))*(H^2 – Se'^2)]

T= tilt; GIT= ground interference term; RH= relative humidity; T_A= air temp.°K; POA=insol kWh/m²; R= row length, in.; P = stable snow pile angle, ≈ 40°; H= drop height, in.