Assessment of Solar Energy Applications on US Military Bases

ENERGY 2004
Aug 9, 2004
Rochester, New York

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Outline

- Purpose of the DoD Solar Energy Assessment
- Phase I, Solar Technology Assessment
- Phase II, Economic Analysis
- General Conclusions
- Next Steps

The Solar Assessment is part of the DoD Renewable Energy Assessment Project

- Requested by Congress to assess the potential for widespread application of Renewable Energy by DoD
  - DoD is largest federal energy consumer
  - Want a 35% reduction in building energy use by 2010
- Assess the potential of wind, geothermal, and solar
- Goals & Objectives
  - Identify cost effective applications on US military bases
  - Reduce the cost of projects
  - Improve energy surety
  - Identify and reduce barriers
  - Justify with detailed Business Case Analysis
  - Encourage private sector investment
- Final Report to be delivered to Congress

Project Participants

- Pacific Northwest National Laboratories (PNNL); Program Coordination
- **Sandia National Laboratories (SNL); Solar**
- National Renewable Energy Laboratory (NREL); Wind
- Navy China Lake; Geothermal
- DoD Tri-Service Renewable Energy Committee (TREC)
- Military Representatives; Air Force, Army, Navy, Marines

Phase I, Solar Technology Assessment

- Assess solar technologies; reviewed 29
- Selected 6 proven solar technologies for application at DoD facilities
  - Selected for DoD ownership and operation
  - Private ownership could consider other technologies
- Technology demonstration projects are not a goal of this effort
- Assess solar resource at military facilities, (>500)

Recommended Solar Technologies

- Crystalline photovoltaic (PV) grid-tied systems.
- Crystalline PV stand-alone / hybrid.
- Domestic hot water systems.
- Swimming pool heat.
- Solar vent / transpired collectors (solar wall).
- Daylighting. (similar to skylights)

Recommended Solar Technologies

Department of Defense Facilities

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

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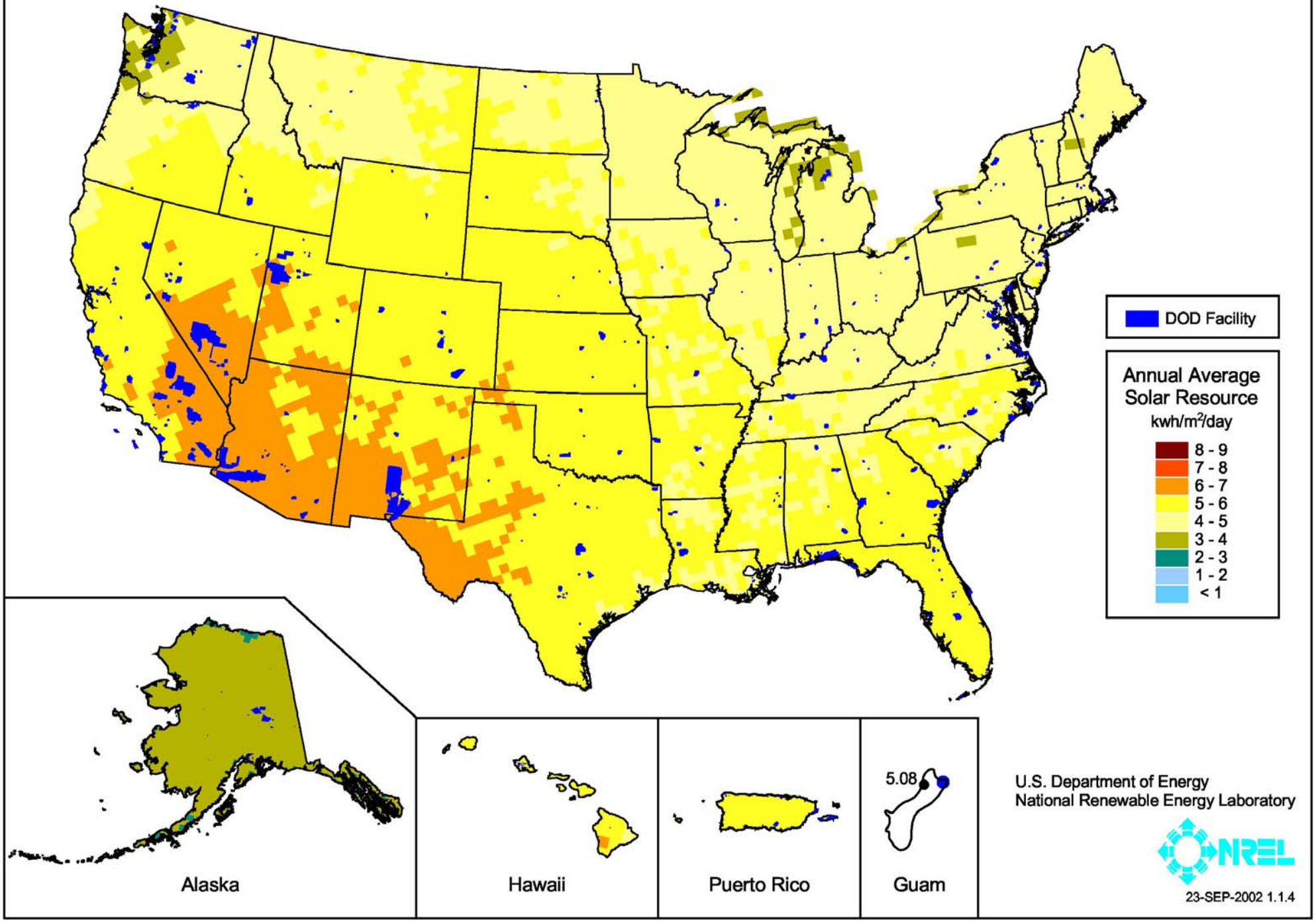
Flat Plate Tilted South at Latitude Solar Resource and DOD Facilities



Phase II, Economic Analysis

- Goals
  - Identify economically viable solar projects on “specific” military bases
  - Identify the “next steps” to implement solar projects in the near term.

Solar Screening Models Were Developed

- Screened ~ 500 military bases
- Developed 1st order economic models for the 6 selected solar technologies
- Screening based on simple payback
  - Assumes private ownership with federal & state financial incentives
- Cost-effective applications ***may be possible*** at most bases
  - 24 “representative” bases selected for further detailed analysis
  - 31 Business Case Analyses performed

Screening Model for PV-Grid Systems

Installed **C**ost
$7/W$_{AC}$

Financial **I**ncentive Factor
0.6 to 0.3

$$SPB = \frac{C_{PVGrid} * FI}{E_{PVGrid} * C_e * V_{PVGrid}}$$

Annual **E**nergy
PV-Design Pro

Avg. Electricity **C**ost
PV is Saving
1.2 to 22 cents/kWh

Peak Power **V**alue
1.3

Screening Model Output with Simple Payback (Yrs)

Red < 3, Orange < 6, Yellow < 9

	SDHW	SDHW	Indoor Pool	Outdoor Pool	PV grid	TSC	Day light
	Saves electric	Saves gas	Saves gas	Saves gas	Saves electric	Saves gas	Saves electric
	Financial Incentives	Financial Incentives	No Incentives	No Incentives	Financial Incentives	Financial Incentives	No Incentives
Base 1	4.4	25	9.9	39	14	10.7	3.5
Base 2	13	21	8.8	35	40	9.6	11
Base 3	11	19	7.7	30	33	8.3	8.3
Base 4	3.5				8.1		3.1
Base 5	2.9				6.6		2.6
Base 6	5.5	12	6.4	16	13	5.6	4.6
Base 7	3.5	4.9	2.9	5.2	8	1.1	3.0

If solar projects are owned by private sector, economics are improved because of financial incentives

Colored Entries have Paybacks < 10 yrs

With Financial Incentives

State	INSTALLATION	SDHW electric	SDHW gas	In Pool gas	Out Pool gas	PV-grid electric	TSC gas	Daylight electric
AK		9.0	58.8			27.8		6.0
AK		11.6	17.4	7.1	28.1	36.0	7.7	9.4
AK		8.3				25.9		6.0
AK		8.9	64.4			27.6		6.0
AL		8.5	11.3	4.7	18.6	26.3	5.1	6.9
AL		7.5	15.9	6.6	26.1	23.3	7.2	6.1
AL		12.5	15.1	6.3	24.8	38.8	6.8	10.1
AL		10.6	15.3	6.4	25.1	32.8	6.9	8.6
AR		6.7	20.6	8.4	33.1	20.8	9.1	5.4
AZ		5.1	12.3	4.9	7.7	15.7	7.1	4.6
AZ		6.0	14.2	5.6	8.9	18.6	8.2	5.4
AZ		6.6	11.5	4.5	7.2	20.4	6.6	6.0
CA		14.3	13.6	7.7	13.8	33.0	6.7	12.0
CA		4.1	13.9	7.9	14.1	9.5	6.8	3.5
CA		5.7	10.0	4.0	12.2	13.1	5.9	5.2
CA		3.4	14.2	7.0	7.1	7.8	21.1	2.9
CA		4.3	12.7	6.3	6.4	9.9	19.0	3.7
CA		9.4	19.0	10.8	19.3	21.9	9.3	8.0
CA		4.6	26.2	14.5	36.6	10.7	12.6	3.9
CA		3.3				7.6		2.8
CA		7.7	12.5	7.1	12.7	17.8	6.1	6.5
CA		4.5	14.4	7.6	7.6	10.5	4.5	3.9
CN		5.8	13.1	7.6	11.9	17.9	3.1	4.5
CO		12.2				37.7		10.7
CO		10.8	14.7	8.5	15.2	33.6	3.1	9.5
CO		12.6	25.0	14.5	25.8	39.1	5.3	11.1
CO		11.7	18.5	10.7	19.1	36.2	3.9	10.3
CO		11.4	20.4	11.8	21.1	35.3	4.4	10.0
DC		8.5	13.5	8.2	12.9	26.5	3.3	6.8
DE		7.6	16.2	9.8	15.4	23.5	4.0	5.9
DE		11.3	19.0	11.5	18.1	34.9	4.7	8.8
FL		9.5	14.2	4.8	8.4	29.4	19.6	7.6
FL		12.6	17.2	6.9	27.2	39.3	7.5	10.1
FL		9.7	24.4	8.4	14.5	30.1	33.8	7.8
FL		6.9				21.3		5.5
FL		11.3	16.7	7.0	27.5	35.1	7.6	9.1
FL		7.9	13.4	4.7	8.1	24.5	18.9	6.4
FL		9.5	13.7	4.7	8.1	29.6	19.0	7.7
FL		12.3	17.0	6.8	26.8	38.1	7.4	9.8
GA		10.2	14.3	6.0	23.4	31.6	6.5	8.3
GA		8.7	14.3	6.0	23.5	26.9	6.5	7.0
GA		10.3	15.2	6.3	25.0	32.1	6.9	8.3
GA		12.2	19.7	8.2	32.3	37.9	8.9	9.9
HI		2.9				8.9		3.8
HI		2.4				7.4		3.1
IA		10.6	14.4	7.5	25.2	32.8	3.7	8.6
ID		9.3	12.0	6.3	11.3	28.8	2.3	7.7
ID		11.6	20.4	10.8	19.1	35.9	4.0	9.7
IL		7.2	14.8	11.0	17.3	21.4	3.6	7.0
IN		12.3	27.3	16.6	26.0	38.2	11.2	9.6
IN		13.0	17.5	10.6	16.7	40.4	7.2	10.2
KS		10.4	20.1	10.6	35.7	32.2	5.2	8.4
KS		9.7	22.3	12.5	42.1	30.3	6.2	8.1
KY		14.2	16.7	10.1	15.9	43.9	6.8	11.1
LA		13.0	16.8	7.0	27.6	40.4	7.6	10.6
LA		6.6	18.4	6.1	10.5	20.5	8.2	5.2
MA		5.4	18.9	13.7	21.5	16.7	4.6	5.2
MA		4.3	15.7	11.3	17.8	13.2	3.8	4.1
MA		5.5	11.8	8.5	13.4	17.0	2.9	5.3
MA		7.9	17.3	12.2	19.2	24.4	4.1	7.4
MD		10.5	15.9	9.7	15.1	32.8	3.9	8.4
MD		7.4	19.9	12.1	18.9	22.9	4.9	5.9
ME		5.0				15.7		4.1
MI		10.6	32.3	17.9	28.1	33.0	7.2	7.9
MI		7.4	24.4	13.5	21.2	23.1	5.5	5.6
MN		10.1	17.3	10.5	16.4	31.3	4.2	8.1
MN		11.3	25.4	15.4	24.1	35.2	6.2	9.1
MO		10.6	11.4	6.0	20.3	32.9	3.9	8.6
MO		13.5	21.7	11.4	38.6	41.8	5.7	10.9

70 Air Force Bases

Without Financial Incentives

State	INSTALLATION	SDHW electric	SDHW gas	In Pool gas	Out Pool gas	PV-grid electric	TSC gas	Daylight electric
AK		16.3	106.8			50.6		6.0
AK		21.1	31.7	7.1	28.1	65.5	14.1	9.4
AK		15.1				47.0		6.0
AK		16.2	117.1			50.2		6.0
AL		15.4	20.6	4.7	18.6	47.9	9.3	6.9
AL		13.7	28.9	6.6	26.1	42.4	13.1	6.1
AL		22.7	27.4	6.3	24.8	70.5	12.4	10.1
AL		19.2	27.8	6.4	25.1	59.6	12.6	8.6
AR		12.2	37.4	8.4	33.1	37.8	16.6	5.4
AZ		9.2	22.3	4.9	7.7	28.5	12.9	4.6
AZ		10.9	25.8	5.6	8.9	33.7	14.9	5.4
AZ		12.0	20.9	4.5	7.2	37.2	12.0	6.0
CA		25.9	24.8	7.7	13.8	80.5	12.1	12.0
CA		7.5	25.3	7.9	14.1	23.2	12.4	3.5
CA		10.3	18.2	4.0	12.2	32.0	10.7	5.2
CA		6.1	25.7	7.0	7.1	19.0	38.4	2.9
CA		7.8	23.2	6.3	6.4	24.1	34.6	3.7
CA		17.2	34.6	10.8	19.3	53.3	16.9	8.0
CA		8.4	47.6	14.5	36.6	26.2	22.8	3.9
CA		6.0				18.5		2.8
CA		14.0	22.7	7.1	12.7	43.5	11.1	6.5
CA		8.2	26.2	7.6	7.6	25.5	8.2	3.9
CN		10.5	23.9	7.6	11.9	32.5	5.6	4.5
CO		22.1				68.6		10.7
CO		19.7	26.8	8.5	15.2	61.2	5.7	9.5
CO		22.9	45.5	14.5	25.8	71.1	9.7	11.1
CO		21.2	33.7	10.7	19.1	65.9	7.2	10.3
CO		20.7	37.2	11.8	21.1	64.3	7.9	10.0
DC		15.5	24.6	8.2	12.9	48.2	6.0	6.8
DE		13.7	29.4	9.8	15.4	42.7	7.2	5.9
DE		20.5	34.6	11.5	18.1	63.5	8.5	8.8
FL		17.2	25.8	4.8	8.4	53.4	35.7	7.6
FL		23.0	31.3	6.9	27.2	71.4	13.6	10.1
FL		17.6	44.4	8.4	14.5	54.7	61.5	7.8
FL		12.5				38.8		5.5
FL		20.6	30.4	7.0	27.5	63.9	13.8	9.1
FL		14.3	24.4	4.7	8.1	44.5	34.4	6.4
FL		17.4	24.9	4.7	8.1	53.9	34.5	7.7
FL		22.3	30.9	6.8	26.8	69.3	13.4	9.8
GA		18.5	25.9	6.0	23.4	57.4	11.7	8.3
GA		15.8	26.0	6.0	23.5	49.0	11.8	7.0
GA		18.8	27.6	6.3	25.0	58.3	12.5	8.3
GA		22.2	35.8	8.2	32.3	69.0	16.2	9.9
HI		8.3				25.9		8.8
HI		6.9				21.5		3.1
IA		19.2	26.2	7.5	25.2	59.6	6.7	8.6
ID		16.9	21.8	6.3	11.3	52.3	4.2	7.7
ID		21.0	37.1	10.8	19.1	65.3	7.2	9.7
IL		16.0	33.0	11.0	17.3	49.7	8.1	7.0
IN		22.4	49.7	16.6	26.0	69.4	20.3	9.6
IN		23.7	31.9	10.6	16.7	73.5	13.0	10.2
KS		18.8	36.5	10.6	35.7	58.5	9.5	8.4
KS		17.7	40.5	12.5	42.1	55.0	11.2	8.1
KY		25.7	30.4	10.1	15.9	79.9	12.4	11.1
LA		23.6	30.5	7.0	27.6	73.4	13.8	10.6
LA		12.0	33.5	6.1	10.5	37.2	14.9	5.2
MA		11.7	41.2	13.7	21.5	36.2	10.1	5.2
MA		9.3	34.0	11.3	17.8	28.8	8.3	4.1
MA		11.9	25.6	8.5	13.4	36.9	6.3	5.3
MA		17.1	37.5	12.2	19.2	53.2	9.0	7.4
MD		19.2	29.0	9.7	15.1	59.5	7.1	8.4
MD		13.4	36.2	12.1	18.9	41.7	8.9	5.9
ME		9.2				28.5		4.1
MI		19.3	58.7	17.9	28.1	60.1	13.1	7.9
MI		13.5	44.3	13.5	21.2	42.0	9.9	5.6
MN		18.3	31.4	10.5	16.4	57.0	7.7	8.1
MN		20.6	46.1	15.4	24.1	64.0	11.3	9.1
MO		19.2	20.8	6.0	20.3	59.8	5.4	8.6
MO		24.5	39.4	11.4	38.6	76.0	10.3	10.9

Business Case Analysis (BCA)

- FATE-2P/DoD financial model
  - Developed by Princeton Economic Research, Inc., NREL, and PNNL
- Contacted the 31 bases for detailed information
- Analyzed private and Government ownership
- Private based on Internal Rate of Return (IRR)
- Government based on Savings to Investment Ratio (SIR)

Example BCA Results

Base	State	Project	Annual Energy Saved	Energy Cost	Capital Cost ($K)	Annual O&M ($K)	IRR (%)	SIR
1	CA	Olympic Indoor Pool	5950 MBtu	$7.00 MBtu	192	1.8	32	3.0
2	CA	Daylight 5 Warehouses	412 MWh	$0.106 kWh	245	2.5	22	6.7
3	CA	PV Grid 1 MW	2295 MWh	$0.15 kWh	7000	12	15	1.1
4	NV	Daylight 22 Hangars	2700 MWh	$0.090 kWh	1421	7.1	24	2.2
5	CO	Solar Wall on 40 bldgs	24000 MBtu	$4.80 MBtu	880	4.4	42	1.8
6	HI	Hot Water 400 homes	760 MWh	$0.107 kWh	665	8.1	27	1.4

General Conclusions

- Nearly all military bases have potential for one or more economically viable solar projects
- Most viable applications are daylighting and solar wall
  - For economic daylighting, electricity price should > 8 cents
  - Most economic apps for solar wall are in north-central US
    - Long heating season and good sun
- Many applications to solar heat *indoor* Olympic pools
- Some applications for solar domestic hot water
  - Especially when solar saves electricity
- Photovoltaics --
  - Reliable, elegant, and still relatively expensive
  - Viable with incentives and high electric rates; e.g. CA & HI

Next Steps

- Sandia is currently visiting several bases to better define specific projects
- Obtain DoD commitment to build new solar projects
- Determine financing methods for bases and projects
  - Traditional government ownership with increased funding
  - Private ownership
    - Sell solar energy (not equipment) to military
    - Super-ESPC or UESC approaches could be used
    - However, lower solar-energy prices might be achieved through a direct-buy approach between military and solar companies
      - Eliminate “middle men” and get full use of financial incentives
      - Military creates a “critical mass” of solar projects to make the direct-buy approach feasible
      - Commit to multi-year plan