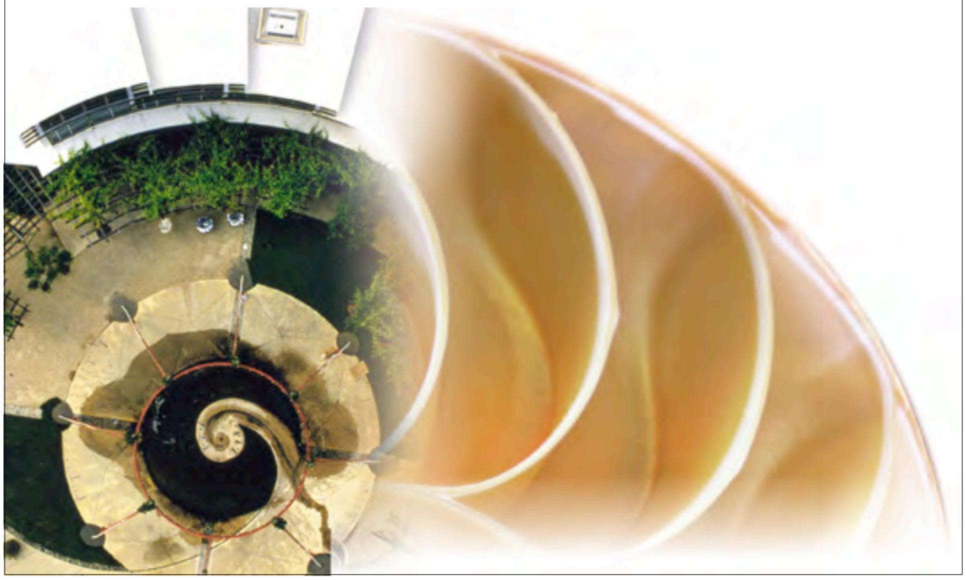
Direct Gain, PV and Solar Thermal

ARCH 331/431 Spring 2008
Lecture 15



announcements 5/20/08

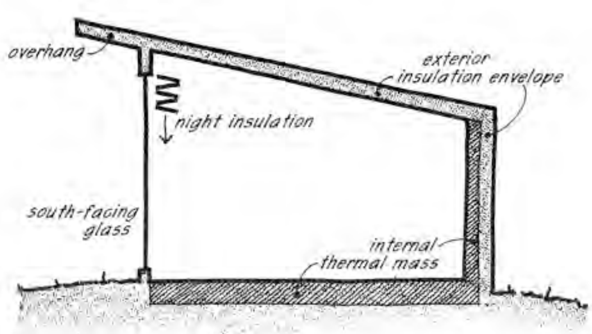
Assignment 4: Shading Model Studies

DUE THIS NEXT WEEK

Assignment 5 will be presented and available on Thursday

Trust Pharmacy
Grants, New Mexico

Direct Gain



Solar Savings Fraction

(Fig. 8.8 MEEB 10th)

70 - 25 = 45 units

45/70 = 64%

SSF = 64

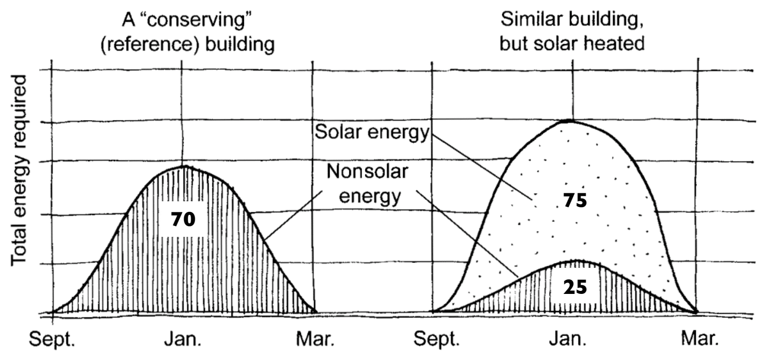
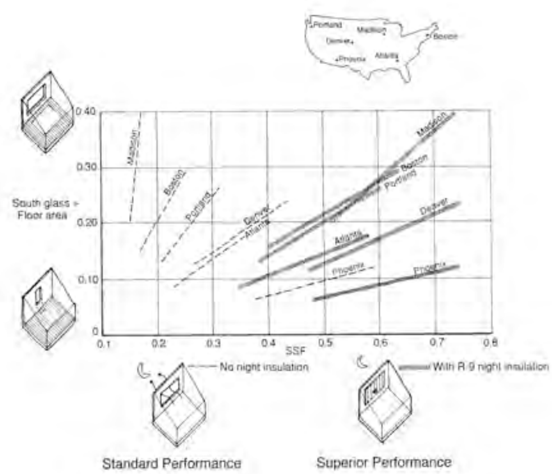


Fig. 8.9 MEEB 10th



Location	Area of Solar Glazing as a Ratio of Floor Area		Approximate SSF Values			
			Standard Performance		Superior Performance	
	Low	High	Low	High	Low	High
Denver, Colorado	12%	23%	27	43	47	74

TABLE F.1 Design Guidelines for Passive Solar Glazing Area *(Continued)*

	Area of Solar Glazing[a] as Ratio of Floor Area		Approximate SSF Values: Standard Performance[b]		Approximate SSF Values: Superior Performance[c]	
Location	**Low**	**High**	**Low**	**High**	**Low**	**High**
Norfolk, Virginia	0.09	0.19	23	38	37	62
Richmond, Virginia	0.11	0.22	21	34	37	61
Roanoke, Virginia	0.11	0.23	21	34	37	61
Olympia, Washington	0.12	0.23	20	29	38	59
Seattle-Tacoma, Washington	0.11	0.22	21	30	39	59
Spokane, Washington	0.20	0.39	20	24	48	68
Yakima, Washington	0.18	0.36	24	31	49	70
Charleston, West Virginia	0.13	0.25	16	24	32	54
Huntington, West Virginia	0.13	0.25	17	27	34	57
Eau Claire, Wisconsin	0.25	0.50	—	NR —	53	75
Green Bay, Wisconsin	0.23	0.46	—	NR —	53	75
La Crosse, Wisconsin	0.21	0.43	—	NR —	52	75
Madison, Wisconsin	0.20	0.40	15	17	51	74
Milwaukee, Wisconsin	0.18	0.35	15	18	48	71
Casper, Wyoming	0.13	0.26	27	39	53	78
Cheyenne, Wyoming	0.11	0.21	25	39	47	74
Rock Springs, Wyoming	0.14	0.28	26	38	54	79
Sheridan, Wyoming	0.16	0.31	22	30	52	75
CANADA						
Edmonton, Alberta	0.25	0.50	—	NR —	54	72
Suffield, Alberta	0.25	0.50	28	30	67	85
Nanaimo, British Columbia	0.13	0.26	26	35	45	66
Vancouver, British Columbia	0.13	0.26	20	28	40	60
Winnipeg, Manitoba	0.25	0.50	—	NR —	54	74
Dartmouth, Nova Scotia	0.14	0.28	17	24	45	70
Moosonee, Ontario	0.25	0.50	—	NR —	48	67
Ottawa, Ontario	0.25	0.50	—	NR —	59	80
Toronto, Ontario	0.18	0.36	17	23	44	68
Normandin, Quebec	0.25	0.50	—	NR —	54	74

Source: Adapted from J. D. Balcomb et al. (1980). *Passive Solar Design Handbook*, Vol. 2 (Passive Solar Design Analysis), U.S. Department of Energy, Washington, DC.

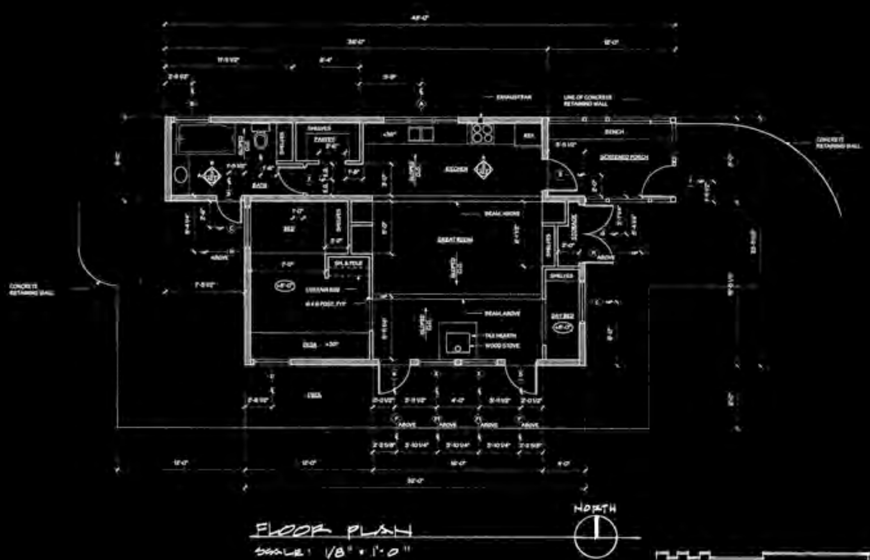
NR = not recommended.

[a]Due south–facing openings are assumed.

[b]Double-glazed, clear glass (approximately equal to window 3, Table E.15).

[c]Either movable window insulation of R-9, in place from 5:30 P.M. to 7:30 A.M., solar time, or superwindows with an overall U-factor near 0.30 (approximately equal to windows 7 or 12, Table E.15).

Example: A Small House in Seattle



Example: A Small House in Seattle

Determine:
- South Glazing Area to maximize Solar Savings Fraction (“collector area”)
- Appropriate amount of Thermal Mass (4” brick) as a function of “collector area”

Enclosed Area = **800 square feet**

UA_{ref} = **180 BTU/hr °F**

UA_{ref}* = **143 BTU/hr °F** (*without south glass)

HDD = **5500** (heating degree days, Appendix B)

TABLE F.1 Design Guidelines for Passive Solar Glazing Area *(Continued)*

Location	Area of Solar Glazing[a] as Ratio of Floor Area		Approximate SSF Values: Standard Performance[b]		Approximate SSF Values: Superior Performance[c]	
	Low	High	Low	High	Low	High
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Source: Adapted from J. D. Balcomb et al. (1980). *Passive Solar Design Handbook,* Vol. 2 (Passive Solar Design Analysis), U.S. Department of Energy, Washington, DC.

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[a] Due south–facing openings are assumed.

[b] Double-glazed, clear glass (approximately equal to window 3, Table E.15).

[c] Either movable window insulation of R-9, in place from 5:30 P.M. to 7:30 A.M., solar time, or superwindows with an overall U-factor near 0.30 (approximately equal to windows 7 or 12, Table E.15).

A small house in Seattle (cont.)

Determine:
- South Glazing Area to maximize Solar Savings Fraction ("collector area")
- Appropriate amount of Thermal Mass (4" brick) as a function of "collector area"

South Glass: @ 22% south glass, SSF = 30
without night insulation

@ 22% south glass, SSF = **59** ←
with night insulation (R-9)

800 sf x 22% = **176 sf** "collector area"
(south glass)

Direct Gain

Thermal Mass Requirements

TABLE F.2 Design Guidelines for Passive Solar Thermal Mass

Expected Solar Savings Fraction (SSF), %	*Thermal Storage by Weight/Collector Area* — *Water* lb/ft²	kg/m²	*Masonry* lb/ft²	kg/m²	*Recommended Effective[a] Thermal Storage Area Per Unit Area of Solar Collection Area* — *Water Surface Area[b]* / Collector Surface Area	*Masonry Surface Area[c]* / Collector Surface Area
10	6	29	30	147	0.1	0.7
20	12	59	60	293	0.2	1.5
30	18	88	90	440	0.3	2.2
40	24	117	120	586	0.4	2.9
50	30	147	150	733	0.5	3.7
60	36	176	180	879	0.6	4.4
70	42	205	210	1026	0.7	5.1
80	48	234	240	1172	0.8	5.9
90	54	264	270	1319	0.9	6.6

59 → (between 50 and 60) ← 4.3

Source: Adapted from J. D. Balcomb et al. (1980). *Passive Solar Design Handbook*, Vol. 2 (Passive Solar Design Analysis), U.S. Department of Energy, Washington, DC.

[a] Effective area is that area exposed at some point to direct sun during a clear winter day.

[b] For a water container 12 in. (300 mm) thick.

[c] For a 4-in. (100-mm)-thick brick, density 123 lb/ft³ (1970 kg/m³).

A small house in Seattle (cont.)

Determine:
- South Glazing Area to maximize Solar Savings Fraction ("collector area")
- Appropriate amount of Thermal Mass (4" brick) as a function of "collector area"

Thermal Mass: For a SSF = 59, the Masonry Surface Area: *4.3 sf mass for each square foot of collector area*

176 sf "collector area" (south glass)

4.3 x **176** sf = **757 sf** masonry

A small house in Seattle (cont.)

Conclusion:

176 sf "collector area" (south glass)

757 sf masonry (4" brick)

SSF = 59 with night insulation (R-9)

This is only accurate if the building passes the "thermal fingerprint" test: it must have a tight, well insulated envelope, as measure by its UA_{ref}

Convert UA_{ref} *to the "overall heat loss coefficient"*

1. Calculate the Overall Heat Loss Coefficient (convert UA_{ref})

(UA_{ref} x 24 hr) / (total heated floor area)

without south-facing glass

Enclosed Area = 800 square feet

UA_{ref} = 180 BTU/hr °F

UA_{ref}* = 143 BTU/hr °F (*without south glass)

HDD = 5122 (heating degree days, Appendix B, pg. 1496)

Overall Heat Loss Coefficient:

(143 BTU/hr °F x 24hr) / 800 ft^2 = **4.3 BTU/DDF ft^2**

TABLE 8.3 Overall Heat Loss Criteria for Solar Guidelines

Maximum Overall Heat Loss

Annual Heating Degree Days (Base 65°F)	(Base 18°C)	Btu/DDF ft²: Conventional Buildings	Btu/DDF ft²: Passively Solar-Heated Buildings, Excluding Solar Wall[a]	W/DDK m²: Conventional Buildings	W/DDK m²: Passively Solar-Heated Buildings, Excluding Solar Wall[a]
Less than 1000	Less than 556	9	7.6	51	43
1000–3000	556–1667	8	6.6	45	37
3000–5000	1667–2778	7	5.6	40	32
5000–7000	2778–3889	6	4.6	34	26
Over 7000	Over 3889	5	3.6	28	20

Source: Balcomb et al. (1980). SI conversions approximated by the author.

[a]The guidelines in Table F.1 assume a solar building that meets this criterion.

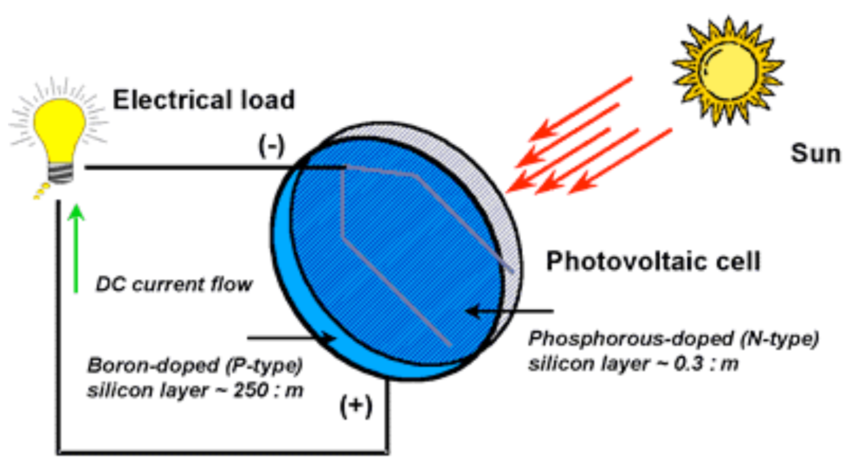
HDD 5122

(5122 heating degree days)

Overall Heat Loss Coefficient: 4.3 < 4.6 √

Photovoltaics

Solar Electricity



Photovoltaics Sites

National Renewable Energy Laboratory (NREL)

National Center for Photovoltaics
www.nrel.gov/pv/

Follow links to:

- ***PV Watts*** PV WATTS calculates electrical energy produced by a grid-connected photovoltaic (PV) system (also linked in Blackboard)
- ***Solar America Initiative*** Federal program of incentives to promote use of renewable energy
- ***Information Resources*** Technical papers, conferences and information on PV

Cost & Value of PV in 4 U.S. Cities

CITY	ARRAY PEAK OUTPUT **kW**	ANNUAL ENERGY PRODUCTION **kWh**	COST OF ELECTRICITY **cents/Watt**	VALUE OF ENERGY **dollars**	% Household Energy Provided (3192 kWh/yr*)	PAYBACK TIME ($9.00/W ~ $18,000**) **years**
Santa Maria, CA	2	3147	12.5	$393.38	99%	45.8
Albuquerque, NM	2	3363	8.7	$292.58	105%	61.5
Seattle, WA	2	1940	6.4	$124.16	61%	145.0
Minneapolis, MN	2	2571	7.9	$203.11	81%	88.6

**3192 kWh was the average annual electricity usage for Rob's household (4 people) in San Luis Obispo.*

***At an estimated installed cost of a $9.00 per Watt, a 2 kW system in Seattle would cost $18,000. Federal, State and Municipal incentives can reduce this capital cost.*

Note:

The installed cost of a grid-integrated system (no batteries) is estimated to be $8.00 to $10.00 per Watt.

PV Watts
Solar Electricity Calculator

http://rredc.nrel.gov/solar/codes_algs/PVWATTS/

Comparison of 4 PV Panels

	PANEL	OUTPUT	PANEL SIZE		PRICE/PANEL	COST/AREA	OUTPUT/AREA	AREA REQUIRED*	PANEL COST
		Watts	DIMENSIONS **inches**	AREA **SF**	**dollars**	**dollars**	**Watt/SF**	**SF**	**dollars**
1	BP SX 75TU Polycrystal	75	22" X 47"	8	$367.50	$45.94	9.4	213	$9,922.50
2	BP 275 Monocrystal	75	22" X 47"	8	$316.00	$39.50	9.4	213	$8,532.00
3	Unisolar US64 Amorphous - panel	64	30"x 54"	11.25	$274.00	$24.36	5.7	352	$8,768.00
4	Unisolar PVL64 Amorphous - sheet	64	112" x 15.5"	12	$352.50	$29.38	5.3	375	$11,280.00

*Area required to provide 2,000 Watts (2 kW) peak power

**Cost of panels for a 2,000 Watt (2 kW) system

3. Unisolar Amorphous - panel

1. BP Polycrystal

2. BP Monocrystal

4. Unisolar Amorphous - sheet

Sunpower
High Efficiency PV panels

http://www.sunpowercorp.com/

Building Energy Use Targets
CBECS 2003 • Architecture 2030

http://www.architecture2030.org

Site EUI Targets - Conversion
1 kBTU = .293 kWh

eg.:
College/University Bldg: 60 kBTU/sf year

60 kBTU/sf year x .293 kWh/kBTU = 17.58 kWh/sf year
63% is electric = 10.55 kWh/sf year

Solar Thermal

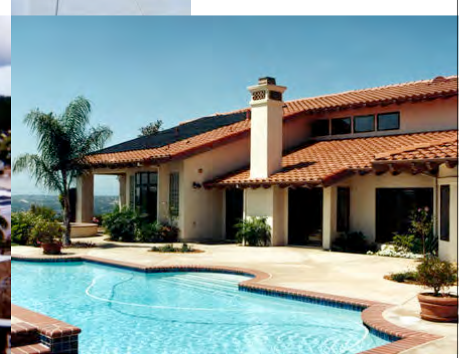
Solar Heated Water and Air

Solar Hot Water

Solar Hot Air

Solar Thermal

Swimming Pool Heating



Adam Lewis Center for
Environmental Studies

Oberlin College, OH

58.6 kW PV array

Building Integrated PV

- Building Skin Integration
- Shade Structures
- Window Shading Devices

Lillis Business Complex • University of Oregon

crystalline pv cells integrated in glass façade

Ekoviikki PV Building Project • Finland

24 kW of crystalline PV cells in the balcony glazing

Building Integrated PV

Home
Oxford, England

Fetzer Vineyards
Hopland,California

The Williams Building

Boston, MA

Thin Film Photovoltaics

SUNSLATE

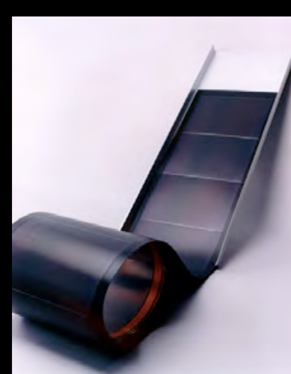
- 480 PV Tiles
- 5.8 kW
- Grid-integrated

Solar Shingles

- 70 PV Shingles
- 1.2 kW
- Grid-integrated

Thin Film Photovoltaics

Uni-Solar flexible PV with self-adhesive back applied to a metal standing-seam roof.




Uni-Solar Thin-Film PV
Flexible PV with self-adhesive back applied to metal deck on Sim Van der Ryn's houseboat in Sausalito, CA