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Solar Energy

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Solar Photovoltaic (PV) Cells

- A solar cell is a photo-diode which is made from semi-conductor grade silicon (but below spec for semiconductor man. process)
- Generates electricity (direct current) when exposed to sunlight
- Not hot water
- Three types:
  - Mono-crystalline
  - Poly-crystalline
  - Amorphous

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Mono-crystalline Solar Cells

- The silicon is melted and crystals formed through a seeding process
- Crystals are large – up to 12cm diameter
- Sliced into wafers 0.2 – 0.4mm thick
- Metal grids are attached front and back to conduct the electricity
- Cells are mounted on an acetate base with a glass panel on top to provide protection and waterproofing
- About 20% efficient

(ie converts 20%
of the suns energy
falling onto the cell
into electricity)

BP Solar mono-crystalline solar panels. 2,100W total

Poly-crystalline Solar Cells

- Made of many tiny silicon crystals pieced together
- The small crystals are inexpensive to make but lose efficiency because the boundaries between the crystals impede the flow of electricity
- Similar overall efficiency and cost characteristics as mono-crystalline cells

Kyocera poly-crystalline solar panels

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Amorphous (thin-film) Solar Cells

- Gaseous silicon is condensed onto a substrate to make extremely thin (0.3 micron) solar cells
- Crystals are arranged randomly hence the term “amorphous”
- Uses very little silicon
- Low embodied energy
- Flexible and semi-transparent
- Tolerant of shade and heat
- But amorphous structure is not efficient and so efficiency typically 12% overall

(which means the arrays are larger than crystalline arrays of a similar power output)

A typical amorphous solar panel

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Comparison of solar cells

Type	Advantages	Disadvantages
Crystalline	• Compact	• Requires full sun - stops working in partial shade • Loses efficiency in hot weather (loses 0.5%/degree over 25^{O}C)
Amorphous (thin film)	• Continues working in partial shade • Maintains efficiency in hot weather • Flexible and light • Semi-transparent • Uses less energy to make and to mount on a building	• Less compact – requires more space

Typical solar panels

- Solar cells are joined together in a matrix to form panels

- Size of the individual panels is typically 1,600mm x 800mm for crystalline and 1,000mm x 1,000mm for amorphous thin-film

- Panels are grouped into arrays to give the required power output
- **For nominal 1,000W (1kW) output:**
  - Crystalline (6 panels) = 3.2m x 2.5m
  - Thin film (16 panels) = 4.0m x 4.0m

- The dc output voltage is usually converted into 240V ac to power household appliances by an **inverter.**

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24 Kaneka thin film solar panels giving 1.4kW

9 BP Solar mono-crystalline panels giving 1.6kW

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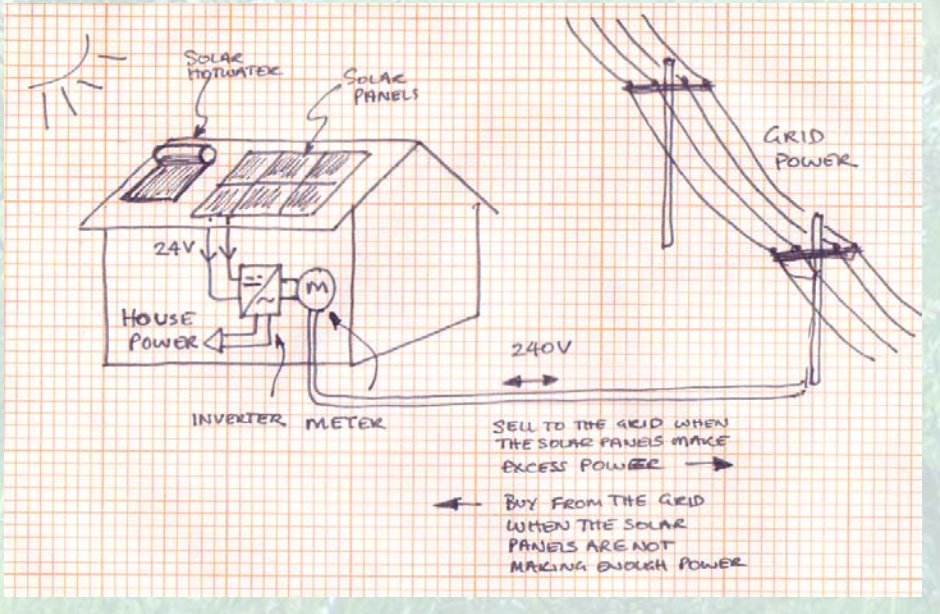
Grid-connected or standalone?

Grid-connected

- Solar panels connected to the grid through the inverter and an import-export meter
- Export power during the day when its sunny and import power at night
- Goes off if the grid power goes off
- Optional batteries provide limited standalone capacity



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Standalone

- Standalone systems use batteries to supply power at night and during overcast weather
- Larger more costly systems
- Usually only in remote areas

Solar panels - 2kW crystalline cells

Inverter and battery charger

Battery bank

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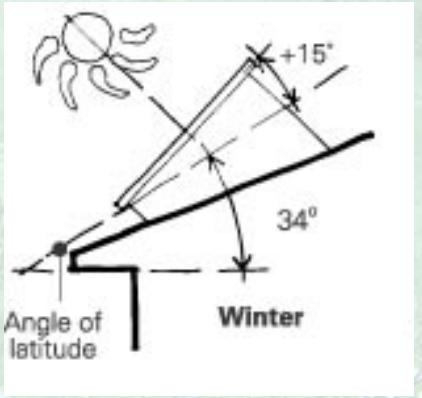
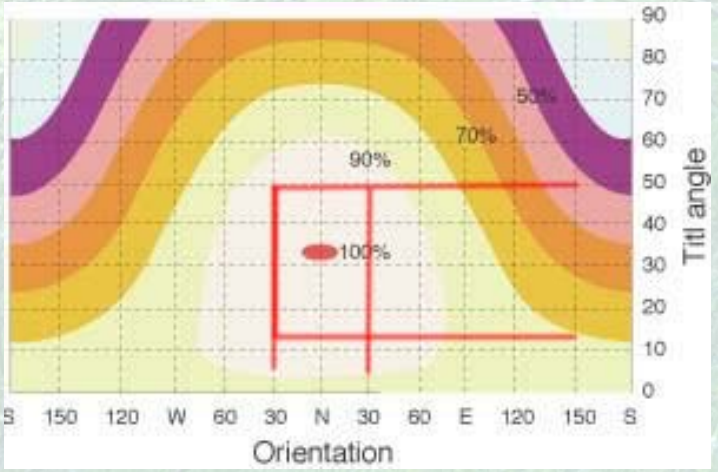
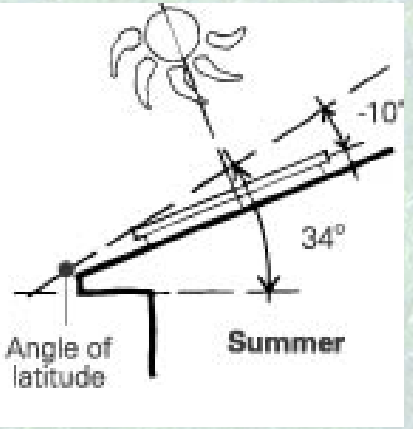
Orientation of solar panels

- Solar panels are tilted so that they face the sun
- Ideally face north but +/- 30^{o} from north OK
- Ideally in full sun from 9:00am – 3:00pm in midwinter
- In winter in Sydney – “angled at latitude + 15^{o}” = 49^{o}
- Summer – angled at “latitude - 10^{o}” = 24^{o}
- Best output for grid-connected system is 24^{o}







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How solar panels are mounted

- Mounted on tilted frames
- On frames above the roof or awning
- Integral to the building structure (BiPV)

1kW thin film cells in partial shade at Limeburners Creek

BiPV being installed

1kW BiPV (plus solar hotwater) at Newington

2kW crystalline cells

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How much power do solar panels make?

- Output is effected by temperature, sun angle and shading
- Partial shade causes crystalline panels to switch off
- Thin film panels continue to work in partial shade

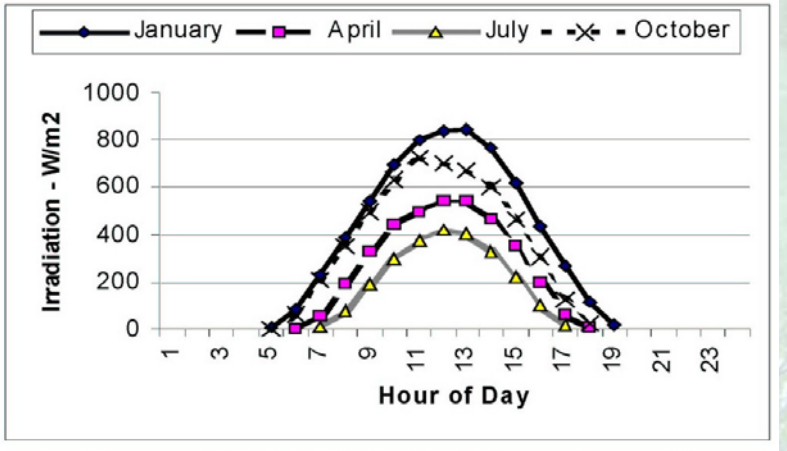

Figure 3.3 Average Hourly Solar Distributions for Summer, Winter and Spring

- Solar array output is measured in peak power (kWp)
- Energy = power x time (kWh)
- A 1kW array, in full sun, in Sydney, will produce on average **1,400kWh** of electrical energy per year

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Power that a house uses

▪ Houses and people's life styles are all different and effect energy usage. For instance, for a family of 4 in a 200m^2 house:

House	Electricity use (kWh pa)
• With electric hotwater, cooking and ducted air-conditioning	>20,000
• With gas cooking and heating and gas or solar hot water	~7,500
• With gas cooking and heating and gas or solar hot water • Energy efficient house and appliances	~4,000
• With gas cooking and heating and gas or solar hot water • Energy efficient house and appliances • Energy conscious lifestyle	<2,000

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Appliance	Power rating (W)	Number	Hours on each day (on average)	Electricity use (kWh pa)
Fridge		2	24 (cycles on/off)	1,200
Lights	2,000 total	54	0.5 – 8	1,200
Computers	200	2	6	880
Oven (electric, gas cooktop)	2,400	1	0.75	660
Jug, toaster, microwave	1,000 – 2,000		0.5	600
Washing machine			6 wash per week	450
Fish tank (heater and filter)	200	1	24 (cycles on/off)	440
Swimming pool (pump)	750	1	3 in summer	400
Air-conditioning	1,200 – 2,500	3	Occasionally	400
Equipment on standby	5	8	24	350
Dishwasher			1 wash per day	250
Heat lights (bathrooms etc)	650 – 1,300	3	0.5 in winter	220
TVs etc	150	2	2	220
Electric fan heaters	1,200	1	1 in winter	220
Total				**7,490**

Cookies house in the gully - cool in summer, cold in winter. Gas heating and hot water

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Solar panel costs (for a typical 1kW system)

- Panels, inverter and installation = $14,500 - $15,500
- Less government rebate ($8-00/W) = $8,000
- Less Renewable Energy Certificates (REC) = $500
- **Net cost = $6,000 - $7,000**

- Notes:
  - Government rebate only available to householders
  - RECs are sold to energy retailers to help meet their mandatory renewable energy (MRE) targets if they are not selling sufficient renewable energy. The solar panel provider generally deducts the REC from the cost of the PV system and sells them to the energy company on your behalf

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How long for solar panels to pay for themselves?

- Embodied energy is paid back in 3 – 4 years (including, inverters, support frames and installation labour)

- Financial payback takes longer:
- 1kW system with net cost $6,000

Pays back 1,400kWh pa @ 19c/kWh = $266 (4.4% return)

The value of money is ~2.1% net, therefore pays for itself in about 24 years

- If buyback rates increase as in Germany (SA Gov pursuing this), the equation gets much better – 40c/kWh pays itself in 12 years

- Statement of values, rather than a financial investment decision

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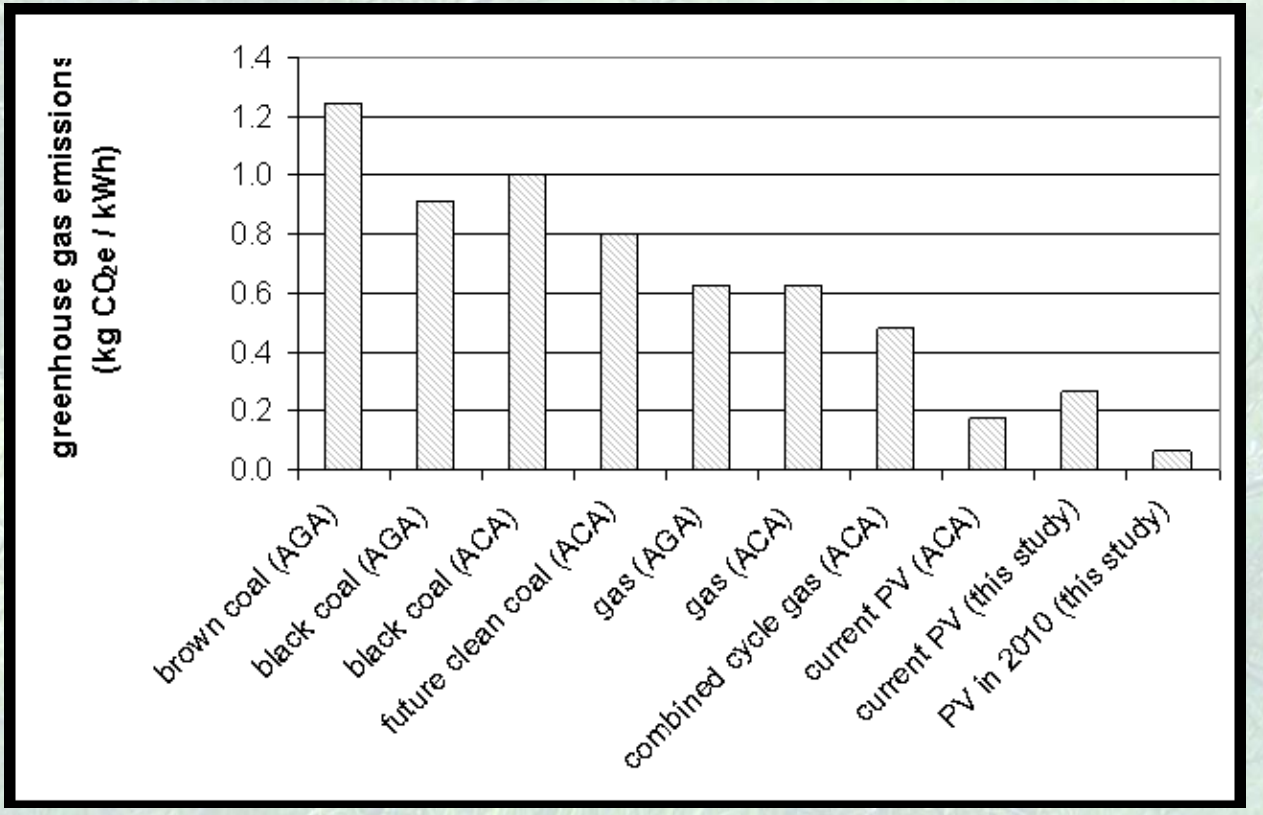

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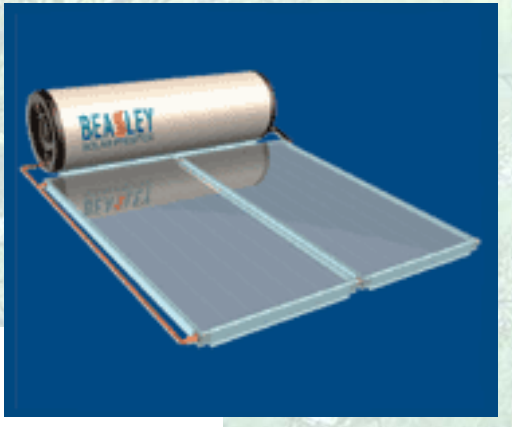
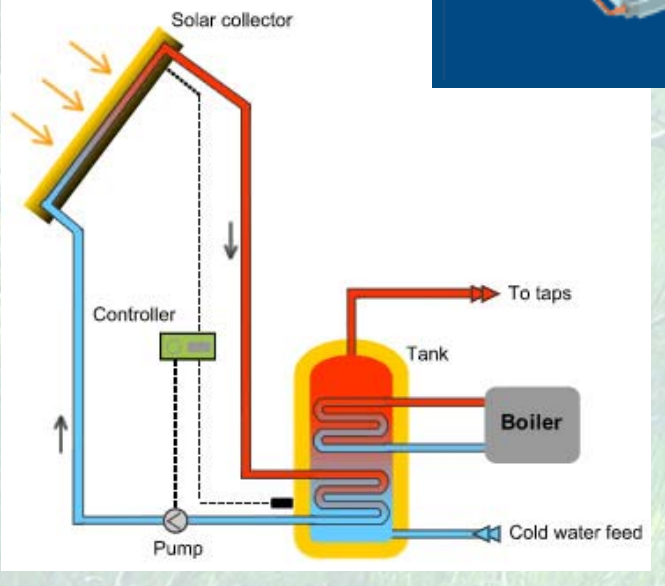
Solar Hotwater

- Plate collector
- Combined tank
- Separate tank





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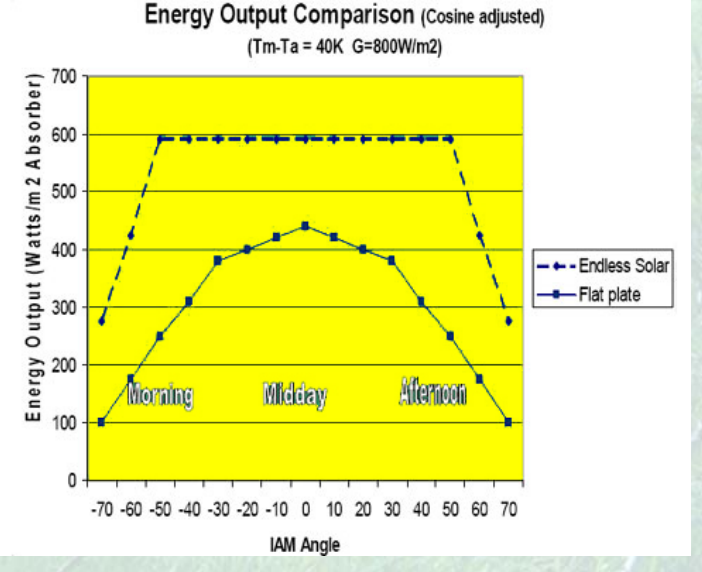
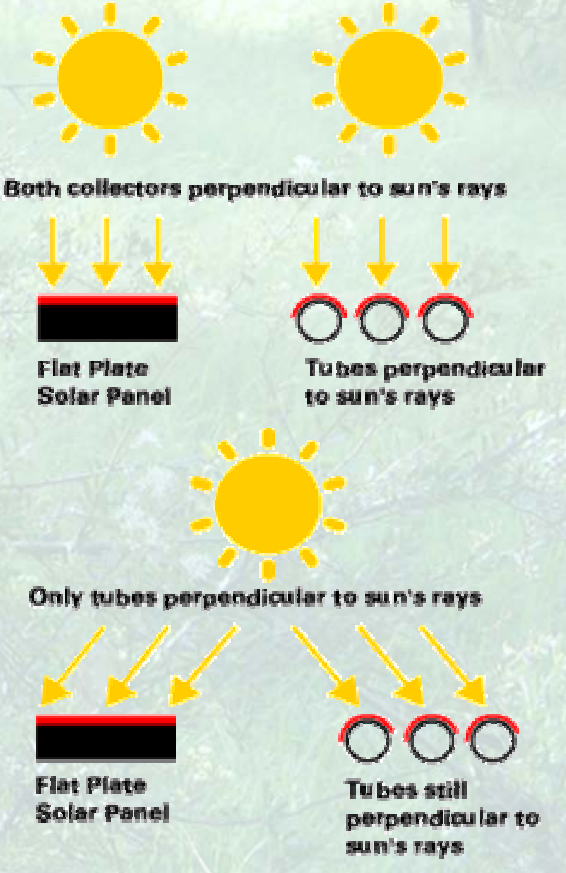
- Evacuated tube solar hot water heater





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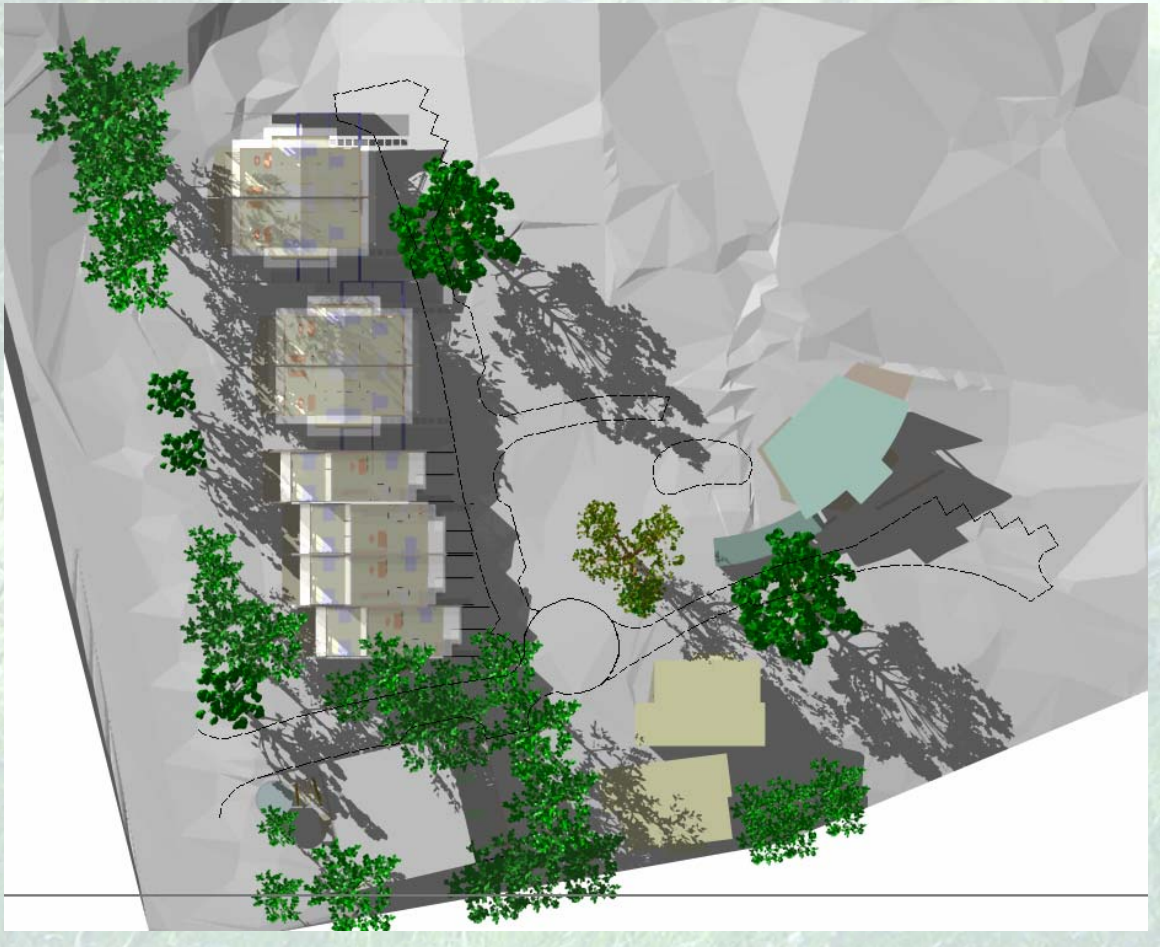

June 21, 9:00am

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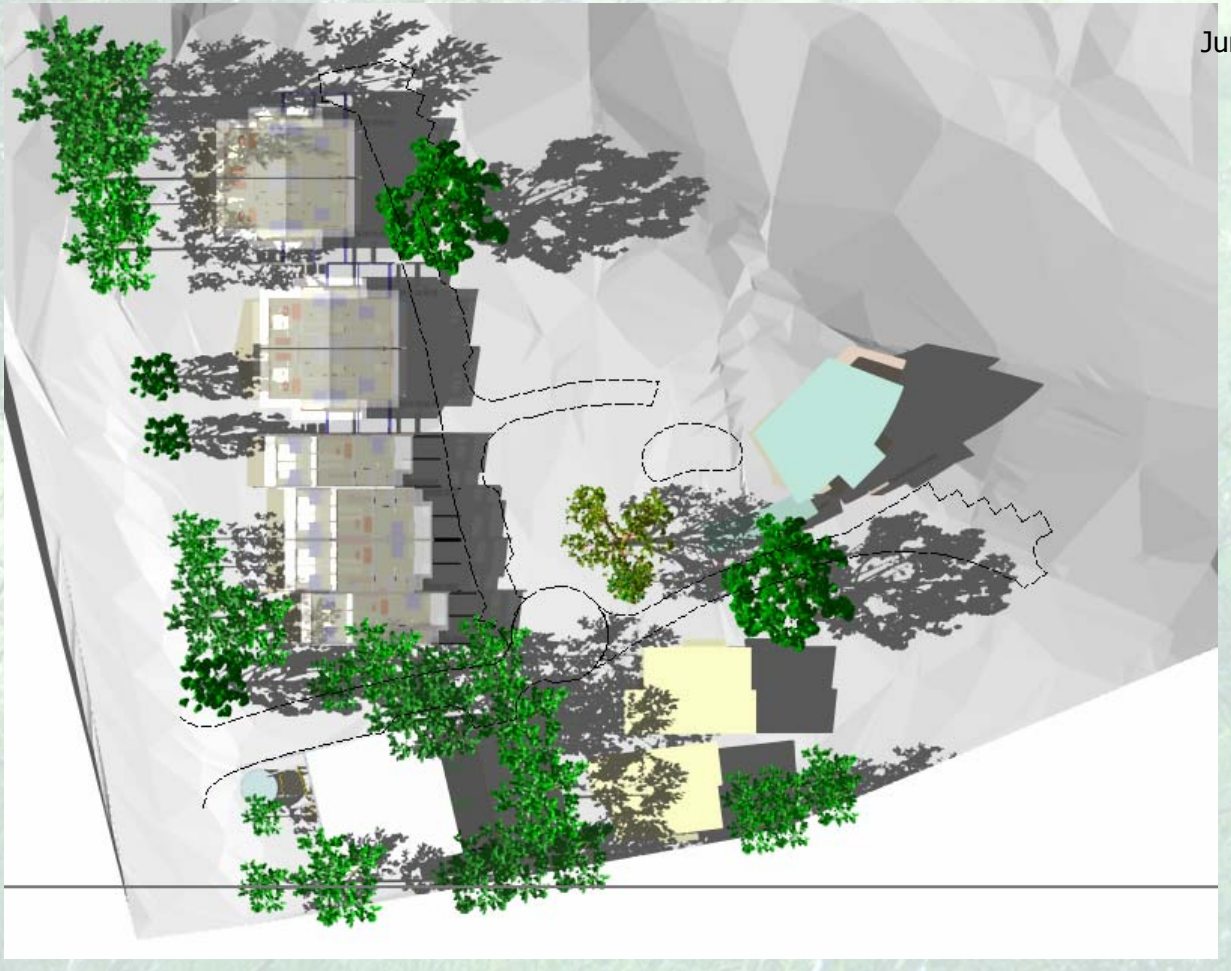

June 21, 12:00am

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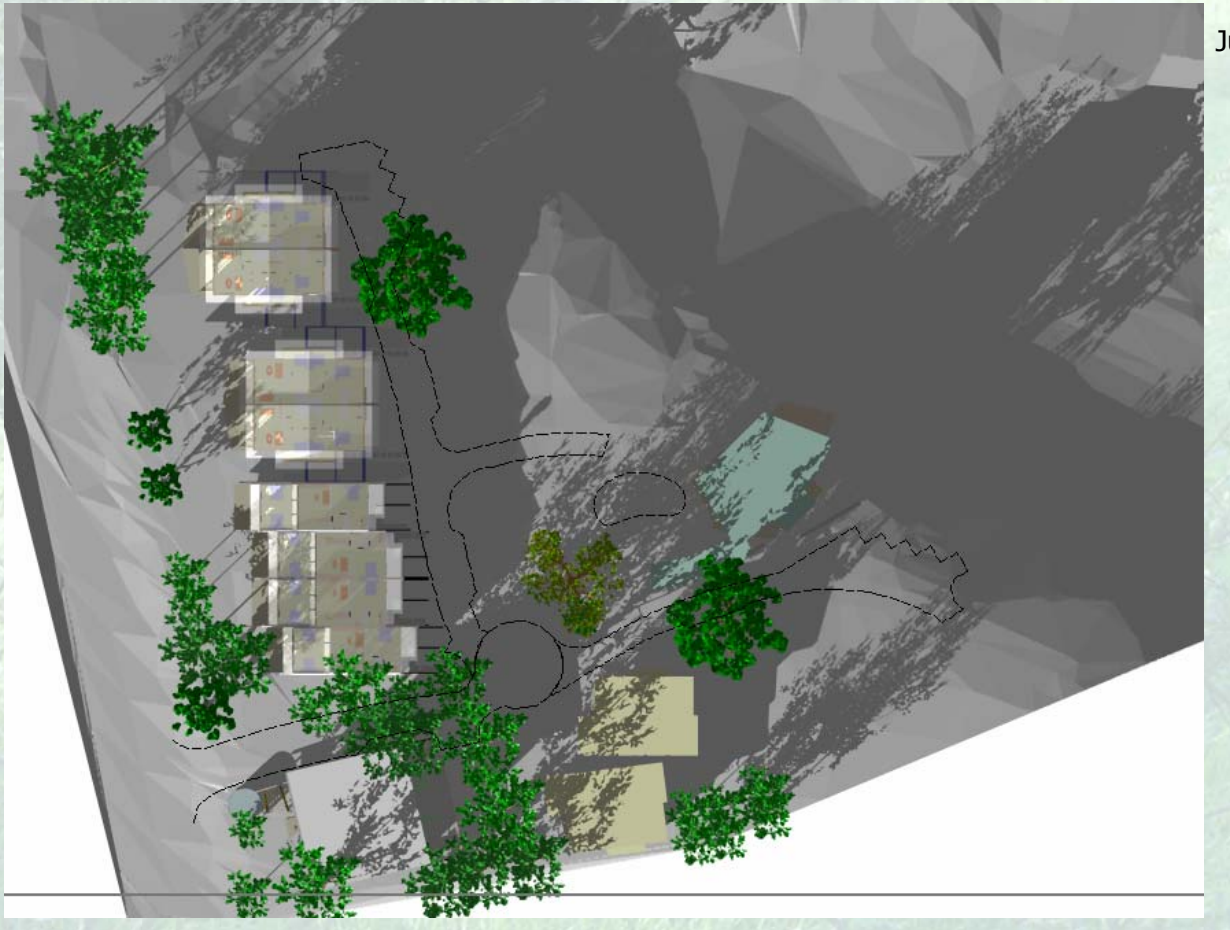

June 21, 3:00pm