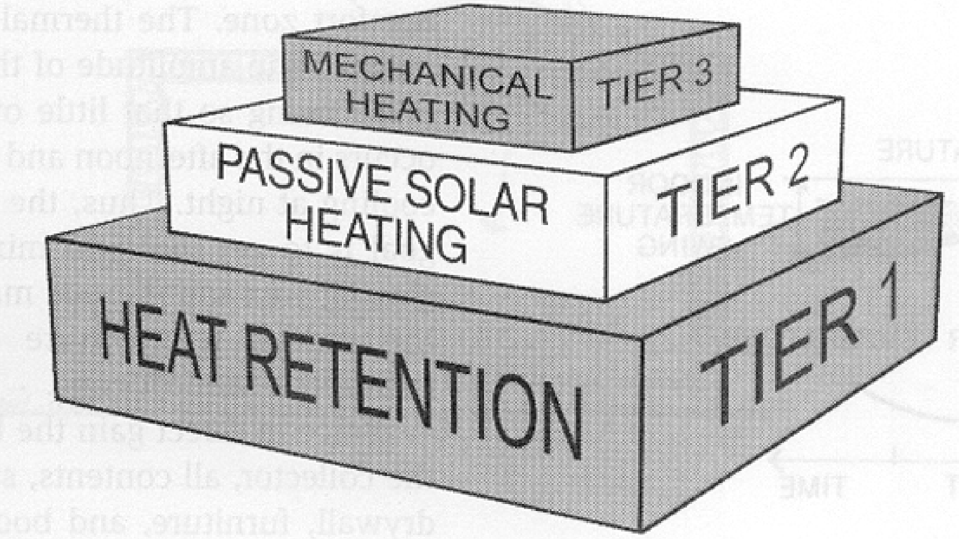
Renewables:

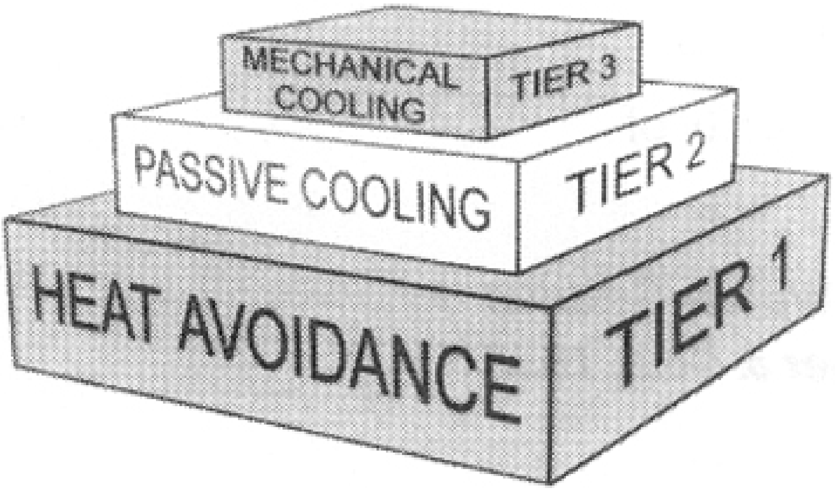
Supplementing the Natural with Active Systems

Photovoltaics, wind, geothermal,
radiant floor heating, solar thermal

Passive vs Active Systems



Heating Mode



Cooling Mode

Seeking well integrated solutions

Renewables

Renewable energy sources, such as

- solar to generate electricity and hot water, as well as
- wind, to generate electricity,
- geothermal, to create heating,

are increasingly being looked to as a means of reducing reliance on NON renewable energy sources such as fossil fuels of all types.

Renewables:

Renewables have the advantage of being in

- INFINITE in supply,
- FREE (ie. Sun and wind).

What is difficult at present is the cost of the means required to convert both solar and wind to something “more useful” to the built environment.

As a result, these systems are only implemented where conditions are IDEAL, as a way to increase efficiency and reduce costs.

Systems we are going to look at:

Photovoltaic Systems: standard and BIPV (building integrated photovoltaics)

Solar thermal: concentrating units that use the sun

Wind energy: single turbines or wind farms

Geothermal: using the temperature of the ground beneath the building to preheat or pre-cool

Radiant Floor Heating systems: mostly because they are a natural extension of the principles of geothermal heat transfer.

PV systems

Photovoltaic Systems:

The Science of Photovoltaics

Photovoltaic science is the science of turning energy produced from the sun into electricity. Edmond Becquerel discovered the concept known as the photovoltaic effect in 1839. However, the first positive/negative (p/n) junction solar cell was not created until 1954 at Bell Labs.

Definition

Photovoltaics are solid-state semiconductor devices that convert light directly into electricity.

They are usually made of silicon with traces of other elements and are first cousins to transistors, LEDs and other electronic devices.

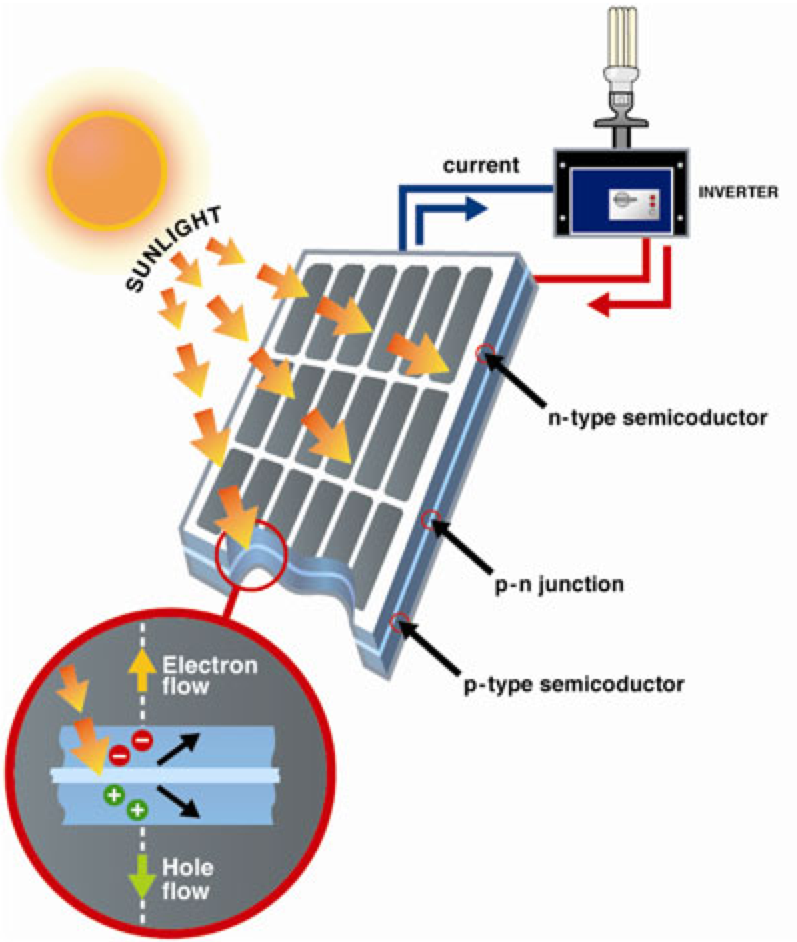
Solar basics:

Solar cells are converters.

They take the energy from sunlight and convert that energy into another form of energy, electricity.

The conversion of sunlight into electricity is made possible with the special properties of semi-conducting materials.

How the PV cell works



Sunlight Converted

- At the atomic level, light is made of a stream of pure energy particles, called "photons."
- This pure energy flows from the sun and shines on the solar cell. The photons actually penetrate into the silicon and randomly strike silicon atoms.
- When a photon strikes a silicon atom, it ionizes the atom, giving all its energy to an outer electron and allowing the outer electron to break free of the atom.
- The photon disappears from the universe and all its energy is now in the form of electron movement energy. It is the movement of electrons with energy that we call "electric current.”

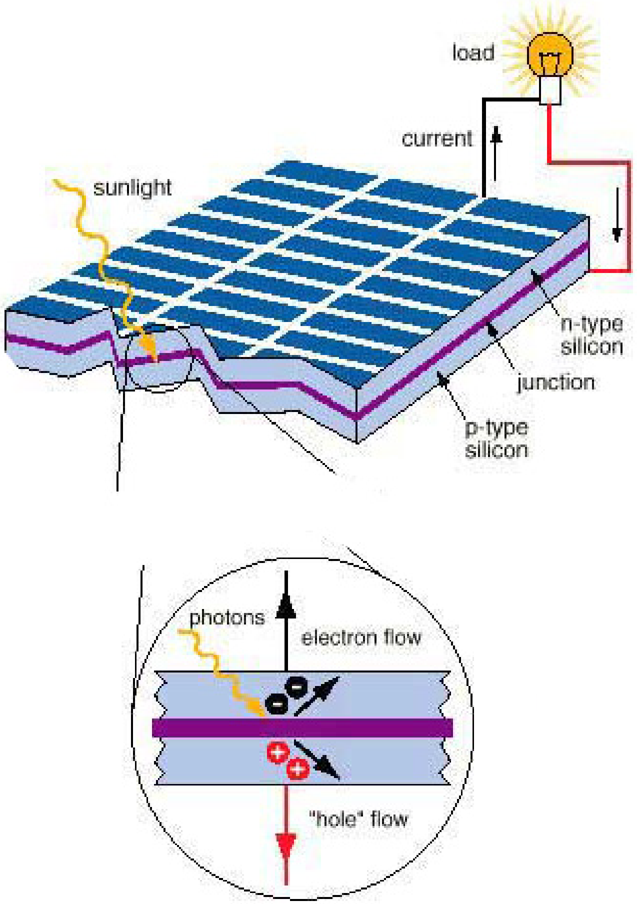
Sunlight to Electricity

A typical solar cell consists of:

- a glass cover to seal the cell,
- an anti-reflective layer to maximize incoming sunlight,
- a front and back contact or electrode, and
- the semiconductor layers where the electrons begin and complete their voyages.

The electric current stimulated by sunlight is collected on the front electrode and travels through a circuit back to the solar cell via the back electrode.

Semi-conductors:



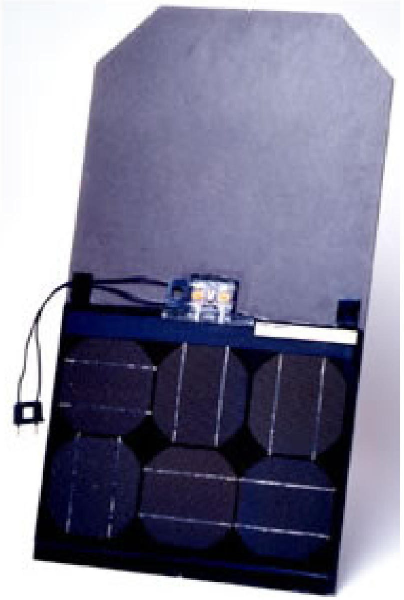
Most solar cells are made from silicon, the 14th element. Silicon is a "semi-conductor" or a "semi-metal," and has properties of both a metal and an insulator.

Atoms in a metal have loosely bound electrons that easily flow when electrical pressure is applied, whereas atoms in an insulator have tightly bound electrons that cannot flow when electric voltage is applied.

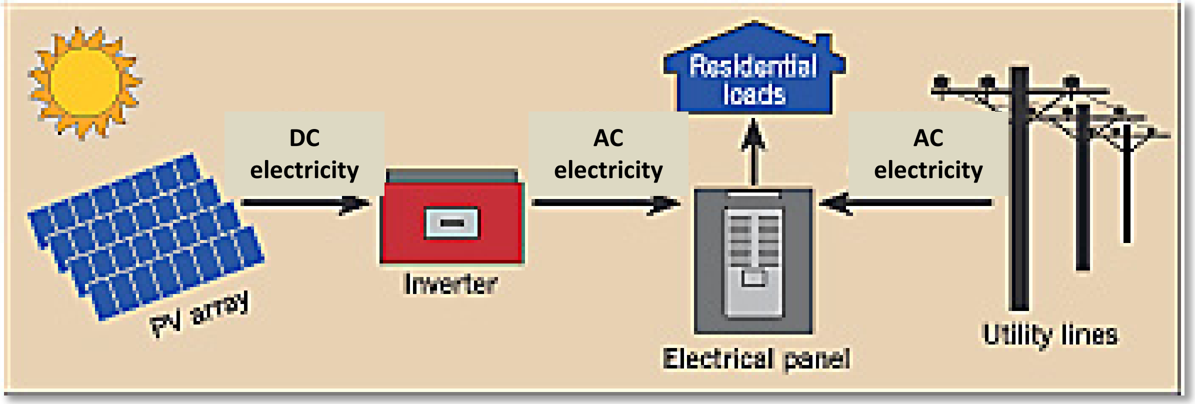
Atoms in a semi conducting material bind their electrons tighter than metals, but they may be manipulated to have conductive properties.

Inverters

Each of the modules must be wired and connected to the next, to eventually transfer the electrical charge to the inverter. In most cases this is done via thin, flat wires that run through the cells. In the spheral solar application, the silicon balls are embedded into a metal mesh sheet, and this acts to carry the electrical charge.

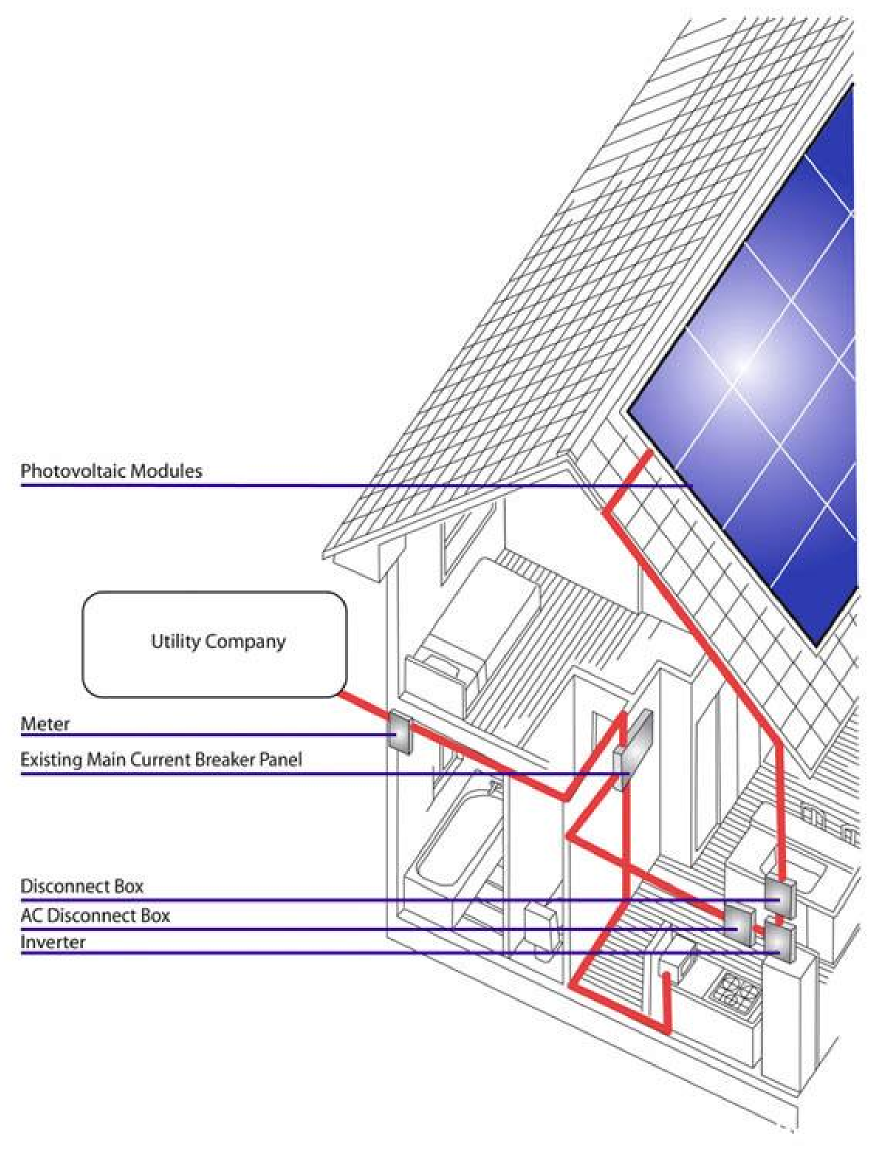


Inverters come in various sizes/types and result in some power loss via the process.



Typical residential system:

Need to include a place for and access to the panels.

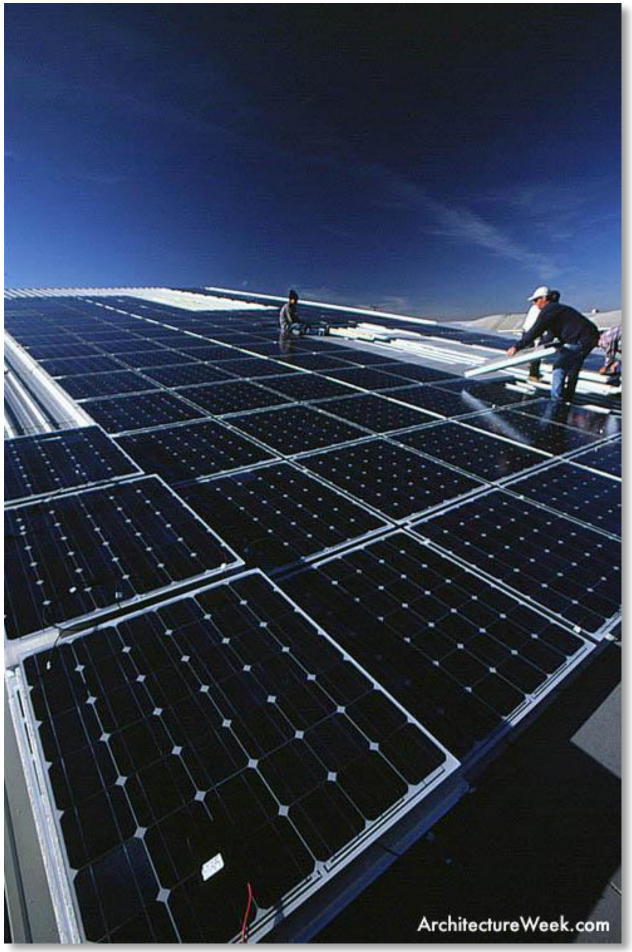


Types of silicon cells:

An individual solar cell can vary in size from 1cm to 15cm and produce between 1 and 2 watts.

Main types on the market are crystalline and thin film. New addition being the “spheral solar” variety. These use tiny balls of silicon embedded into a metal sheet, rather than crystal type silicon.

Cells are combined into modules, and modules into arrays. Arrays are ganged on a surface to provide the amount of power required.


ArchitectureWeek.com

Crystalline silicon:

Mono crystalline cells: are made from very pure mono-crystalline silicon. This type of silicon has a single and continuous crystal lattice structure with almost no defects.

High efficiency (15%).

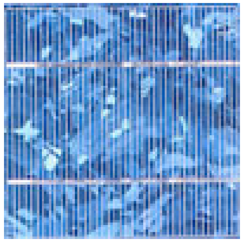
Energy intensive manufacturing process.

Expensive.

Mono-crystalline cells tend to be flat black or deep blue in color.

mono

mono



poly

Crystalline silicon:

Poly- or multi-crystalline cells: are produced using numerous grains of mono-crystalline silicon and have a more irregular surface. In the manufacturing process the silicon is cast into ingots which are rectangular/square in shape. These are cut into very thin wafers and assembled into complete cells. They can also grow this on a substrate.

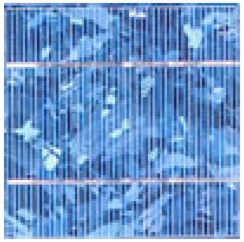
Less efficient (12%).

Less expensive.

Polycrystalline cells have a mottled (like galvanized steel), cobalt blue appearance.

mono

mono



poly

Photovoltaic modules of varying sizes.

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Thin film silicon:

Thin film cells can be amorphous silicon, copper-indium-diselenide (CIS) and cadmium-telluride (CdTe) cells.

Composed of silicon atoms arranged in a thin amorphous matrix rather than a crystalline structure. Amorphous silicon absorbs light more effectively than crystalline and the product is much thinner. Cheaper to produce, but with efficiencies around 6%. These modules have a charcoal grey or bronze color and look like low-E coating or fretting when used on vision glass. Other colors are available but, the cost will be higher.

Comparison of efficiencies:

Cell type	Typical output
Mono-crystalline $$$	12-15%
Poly-crystalline $$	11-14%
Amorphous silicon $	6-8%
Cadmium telluride $	7-10%
CIS Copper indium diselenide $	8-12%

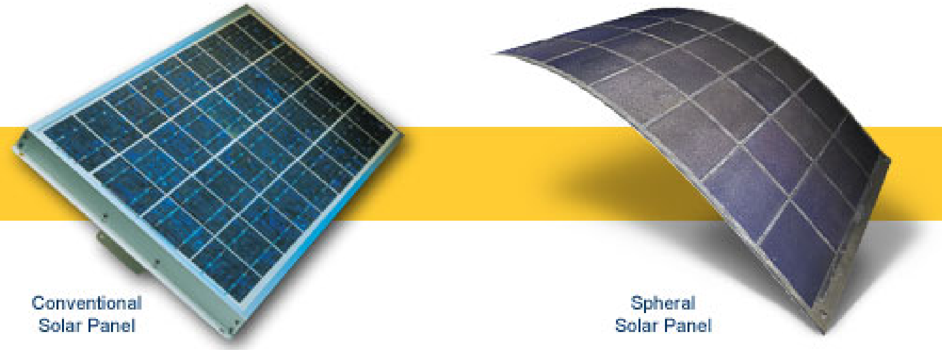
Important to track expense vs. efficiency…

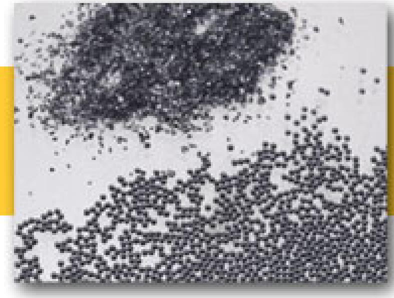
Environmental issues:

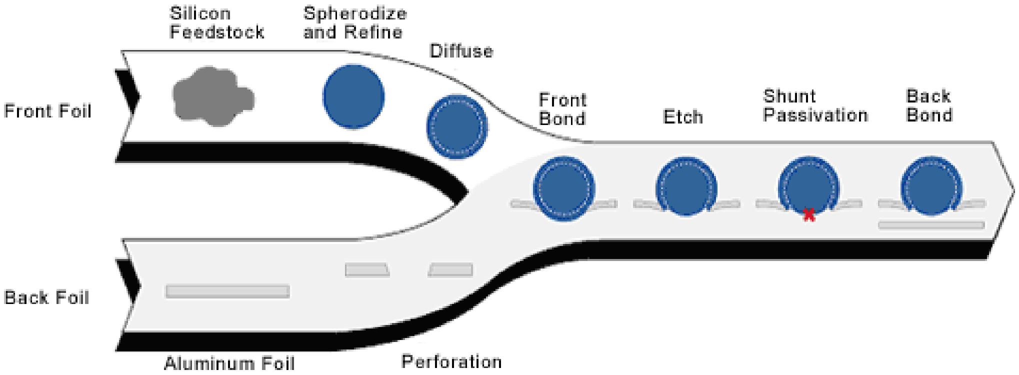
	Crystalline silicon	Amorphous silicon	Cadmium telluride	Copper indium diselinide
manufacture	Oil-based slurry in slicing silicon wafers	No adverse environmental effects	Cadmium is a known carcinogen	Little known about health effects
	Carbon tetrafluoride (a potent GHG) used for edge trimming; Lead (heavy metal) used to solder cell electrical connections	Very little semi-conductor material used	Deposition method is greatest variable: electrodeposition: 90% efficient; spraying: 5% efficient	
End of life	Cells have been salvaged and reused in new modules	No adverse environmental effects	High rates of recovery for all semiconductor materials	

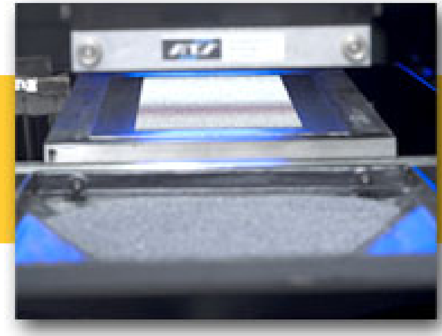
There are environmental costs associated with both the manufacturing and disposal of PV when it has outlived its usefulness.

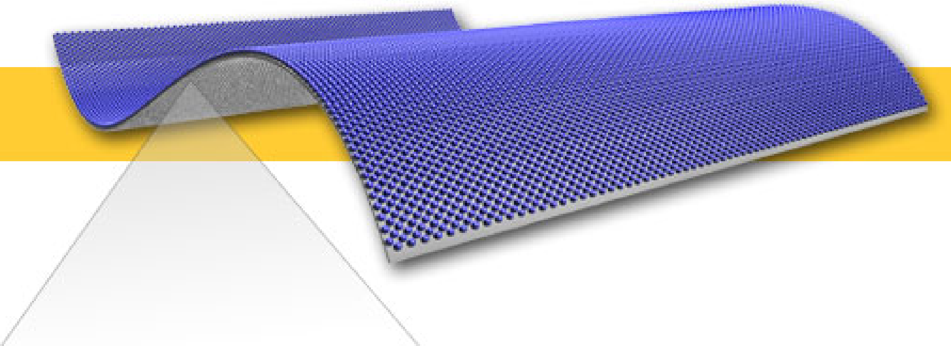
Spheral solar technologies:











The metal backing material carries the charge.

Temperature:

Photovoltaics produce heat as a by-product of the process by which sunlight is changed to electricity. They must be installed so that they are vented, as overheating will decrease their efficiency.

Photovoltaics actually work better in cold weather situations. This makes Canada a good climate for their use.

Temperature:

Contrary to most peoples' intuition, photovoltaics actually generate more power at lower temperatures with other factors being equal.

This is because photovoltaics are electronic devices and generate electricity from light, not heat. Like most electronic devices, photovoltaics operate more efficiently at cooler temperature.

In temperate climates, photovoltaics will generate less energy in the winter than in the summer, but this is due to the shorter days, lower sun angles and greater cloud cover, not the cooler temperatures.

Rain and snow

Roof mounted PV arrays can be covered with snow in the winter. If the array is covered, it will not work.

In snowy climates, **sloped arrays are preferred** to flat installations as theoretically the sun will penetrate the snow, heat the dark PV layer, melt the base of the snow and it will slide off of the panel. It is important to prevent such snow from piling up at the base of the array, or sliding uncontrolled onto passers by below the installation.

Sometimes it is necessary to shovel the array. Care must be taken not to damage it.

Rain will not adversely affect a PV array system since during periods of rainfall the solar irradiance is already low.

Snow must either naturally slide off or be cleaned off.

Dirt and pollution:

Any factor that reduces light transmittance to the PV surface will reduce the output of the system.

If dirt is allowed to accumulate (more likely in urban areas), the output can be reduced by 2% to 6+%.

The higher value occurs if the slope of the array is less than 30 degrees.

This PV array in Abu Dhabi at Masdar City is covered in dust – a huge problem in a country with sand/dust, humidity and no fresh water!

Dirt and pollution:

The occasional heavy rainstorm is usually sufficient to clean the array.

If PV is installed on a wall surface, rain can keep it clean if the array is exposed to such. Otherwise, the surface can be cleaned in the same way as window systems would be.

Dirt and pollution:

Much research is going into nano technology to create self cleaning PV.

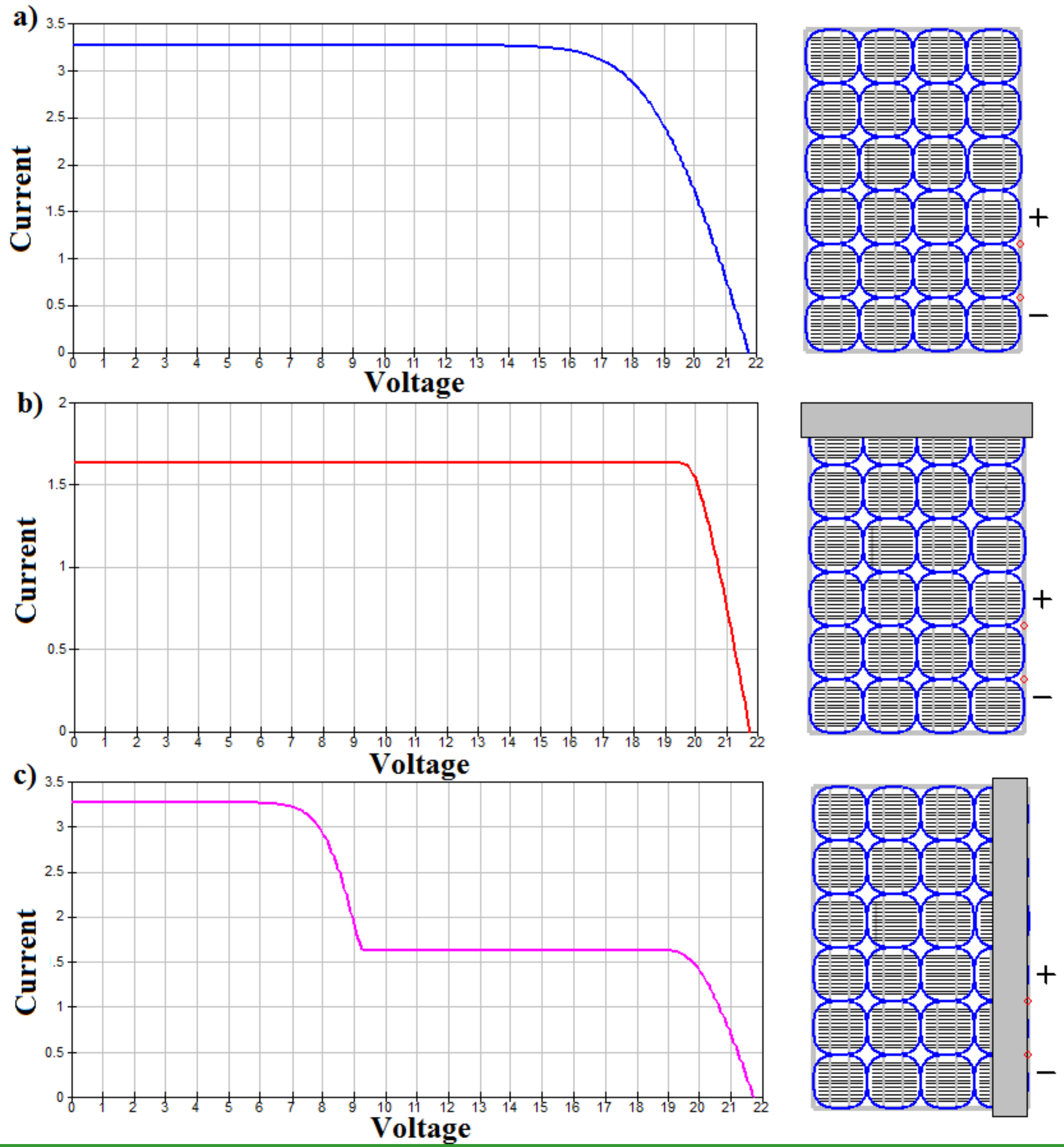
Shading:

AVOID SHADING THE PANEL. The shaded area will not reduce the output proportionally to the area shaded -- loss is much higher. Within a chain of modules the output will be that of the weakest (shaded) module. If shade cannot be avoided at certain times, be sure to gang the affected modules together on the same circuit, leaving the sunny modules to fully function.

This education building at IslandWood near Seattle, Washington is designed to prevent shadows from the nearby trees from shading its PV.

Shading:

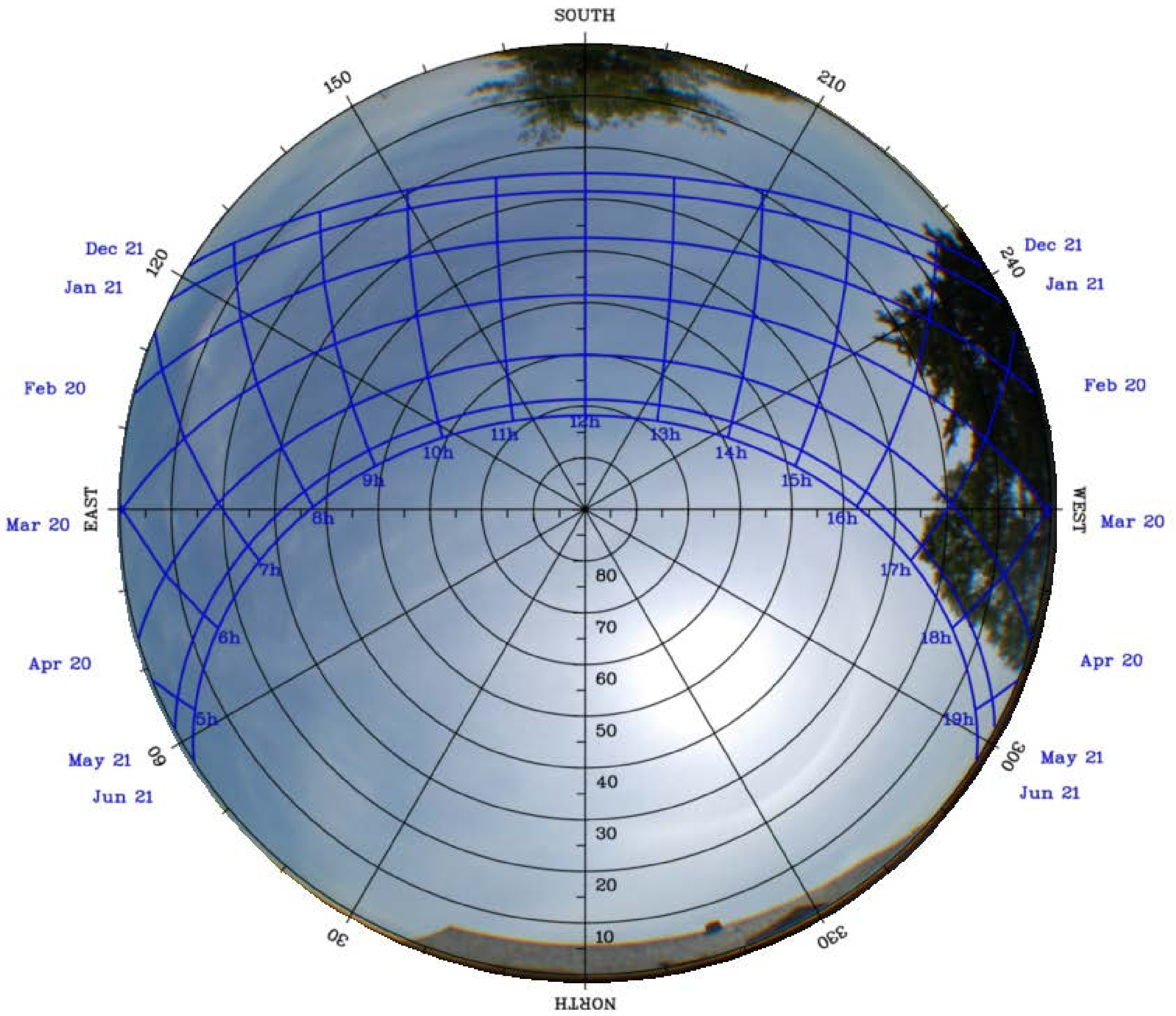
Effects of shading different portions of the array.



Shading:

It is essential to provide unobstructed access to sunlight to optimize efficiency.

Use Sky Dome to prevent Shading:



Orientation:

Due south is ideal but deviations up to 45 degrees only result in a 10% loss of power.

As a rule, BIPV installations are best when oriented south and tilted at an angle of 15 degrees higher than the site latitude; ie.

The further north you go, the more vertical the panel as the sun angles are low in the sky and the system performs better when the rays strike at a right angle (less reflectance).

The Aldo Leopold Center is able to be designed to maximize its orientation efficiency for its PV due to its rural site.

Variation of solar irradiance (%):

tilt	west	75	60	45	30	15	south	15	30	45	60	75	east
10°	83	85	86	87	88	89	90	89	88	87	86	85	83
20°	82	84	87	88	91	92	93	92	91	88	87	84	82
30°	79	83	87	91	95	96	96	96	95	91	87	83	79
40°	73	81	86	90	92	98	100	98	92	90	86	81	73
50°		78	83	87	91	95	96	95	91	87	83	78	
60°			80	82	84	90	91	90	84	82	80		
70°				78	81	84	85	84	81	78			
80°						75	77	75					
90°							72						

Variation of solar irradiance with orientation and tilt for 52° N
**this must be measured for the precise latitude in question.

PV versus BIPV??

BIPV stands for “building integrated photovoltaic” systems.

These use PV, except attempt for a more “architectural integration” of the PV into the roof, wall, glazing and shading systems.

Integration aims to reverse the trend to think of PV as an “add-on” (and usually pretty ugly) system, and ensure that it works as part of the building envelope system.

This works with sustainable notions of having building elements “do” more than one thing. Roofs can easily accommodate another use -- by adding electrical production. The same with curtain walls, skylights, etc.

Generally costing 3X the flat type that are roof mounted.

This is NOT Building INTEGRATED Photovoltaics!

This is not totally, but better, integrated.

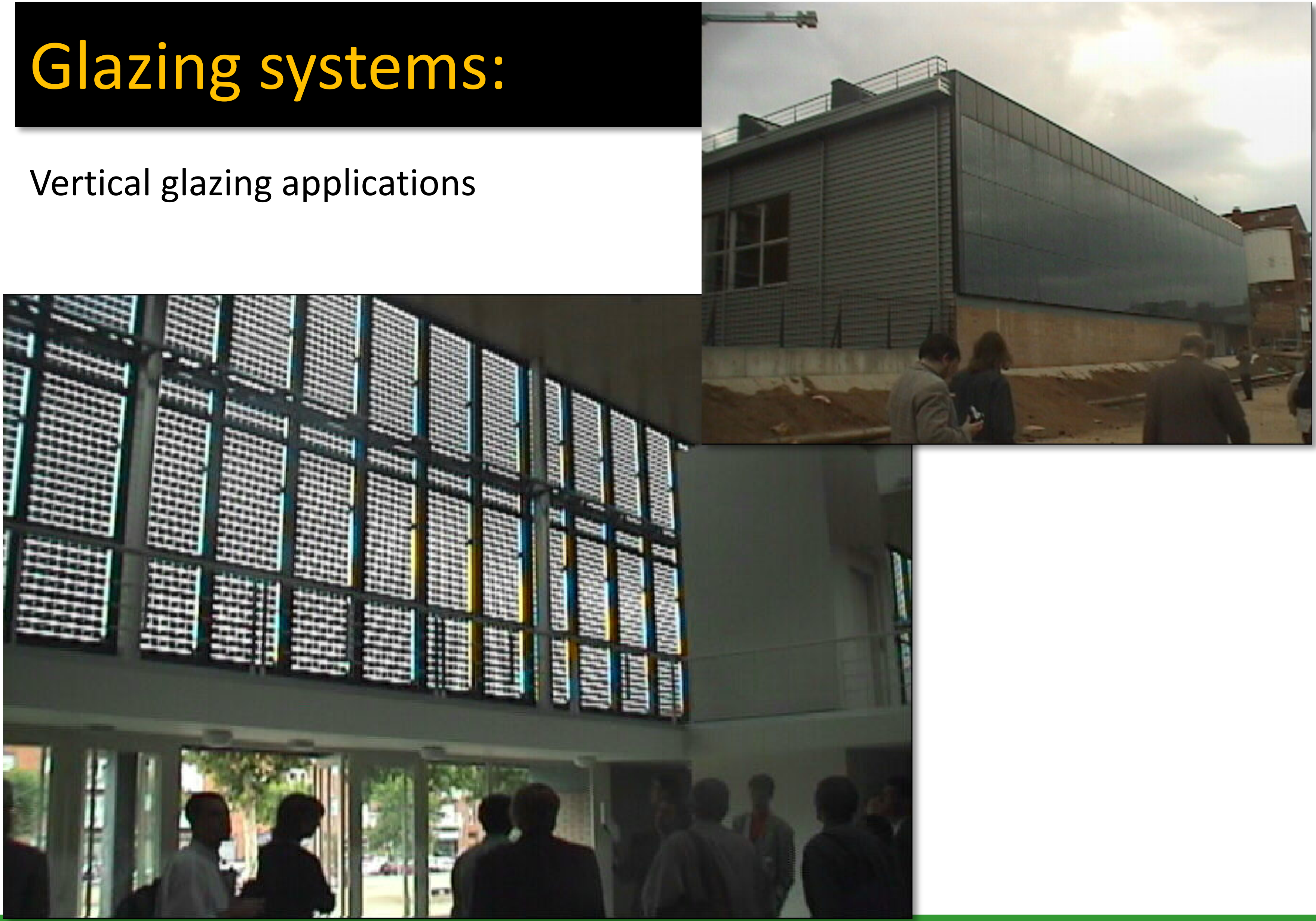
This roofing IS being integrated into the flat roof system:

BIPV: wall systems

The PV on the Calgary Child Centre is used simultaneously as shading devices for the windows.

Glazing systems:

Vertical glazing applications

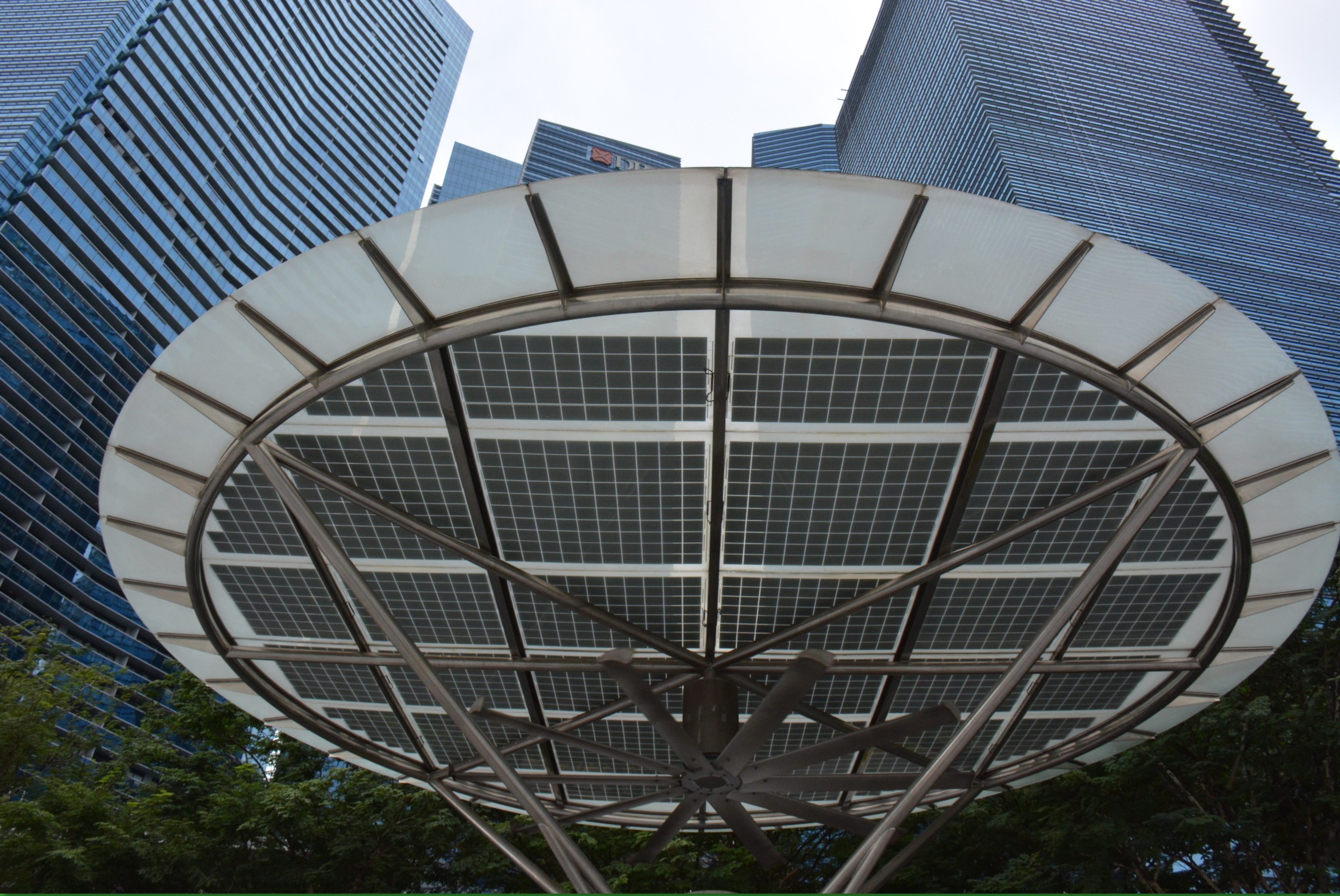


When thin films are incorporated into curtain wall glazing, they can act as a shading device as well.

Eden Project

The Core Building by Grimshaw Architects

Shading Structure, Singapore



Integrated sloped roofs:

Sloped roofs

Balcony railings:

Balcony -- walls

Skylights:

When using thin film in the glazed panels of skylights, the growing practice is to use pitched skylights, have daylight enter from the north side and use the south facing slope for PV.

Skylights:

This also cuts down on excess heat gain into the space, while allowing some south light to enter.

Skylights:

National Works Building, Vancouver, LEED Gold

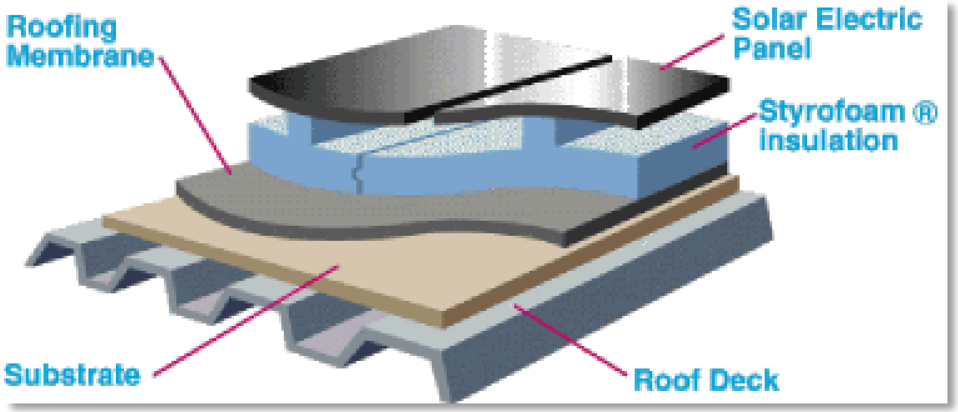
PV roof shingles:

Thin crystalline products have been made into shingles that are run in series and can be installed in lieu of standard shingles.

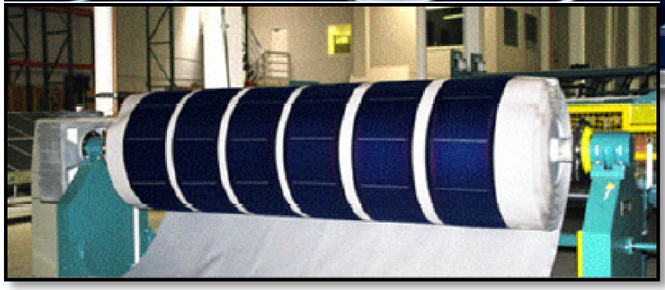
PV Flat roof systems:

PV modules are currently being manufactured as the "top layer" of roofing membranes. The membranes are installed as "normal" (adhered, mechanically fastened, etc.). These applications are more common in snow free climates where snow build-up will not eliminate solar rays for many months of the year.

standard



integrated



www.solarintegrated.com

BedZED, Hackbridge – near London, UK

Thin PV integrated into the glazing at BedZED

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Thin PV integrated into the glazing at Lillis School of Business, U of Oregon

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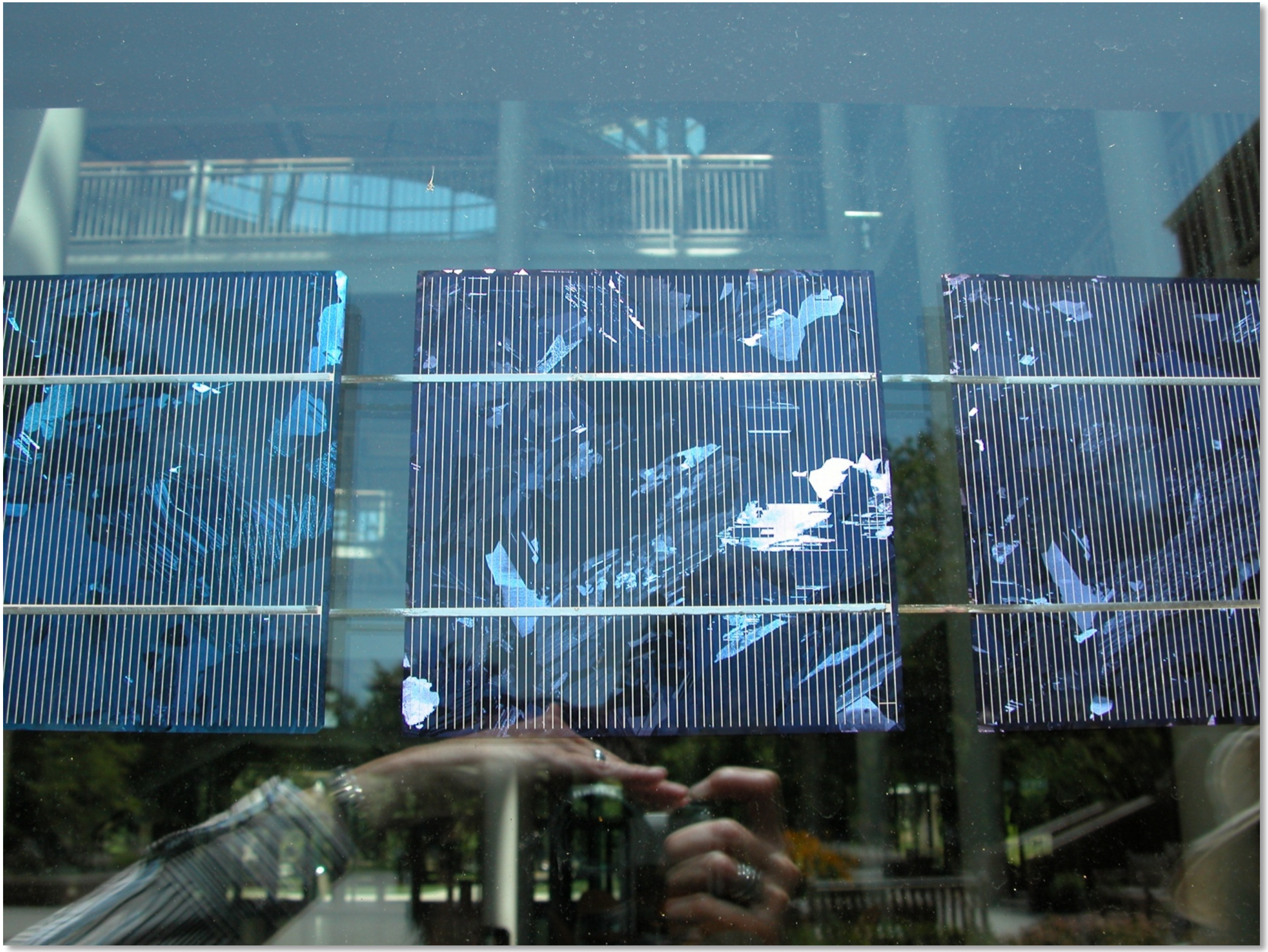


Thin PV integrated into the glazing at Lillis School of Business, U of Oregon

North House – Ontario/BC

The following 2009 Solar Decathlon houses showcase PV. Ours integrated it into the vertical faces of the south, east and west elevations. Our solar hot water array was on the roof – so relegated as it was not as good looking.

Germany

This pavilion took first place in the Solar Decathlon largely due to its PV array and production of electricity.

The PV is attached as shingles. For visual interest, other materials are attached in the same way for a pattern.

Cornell

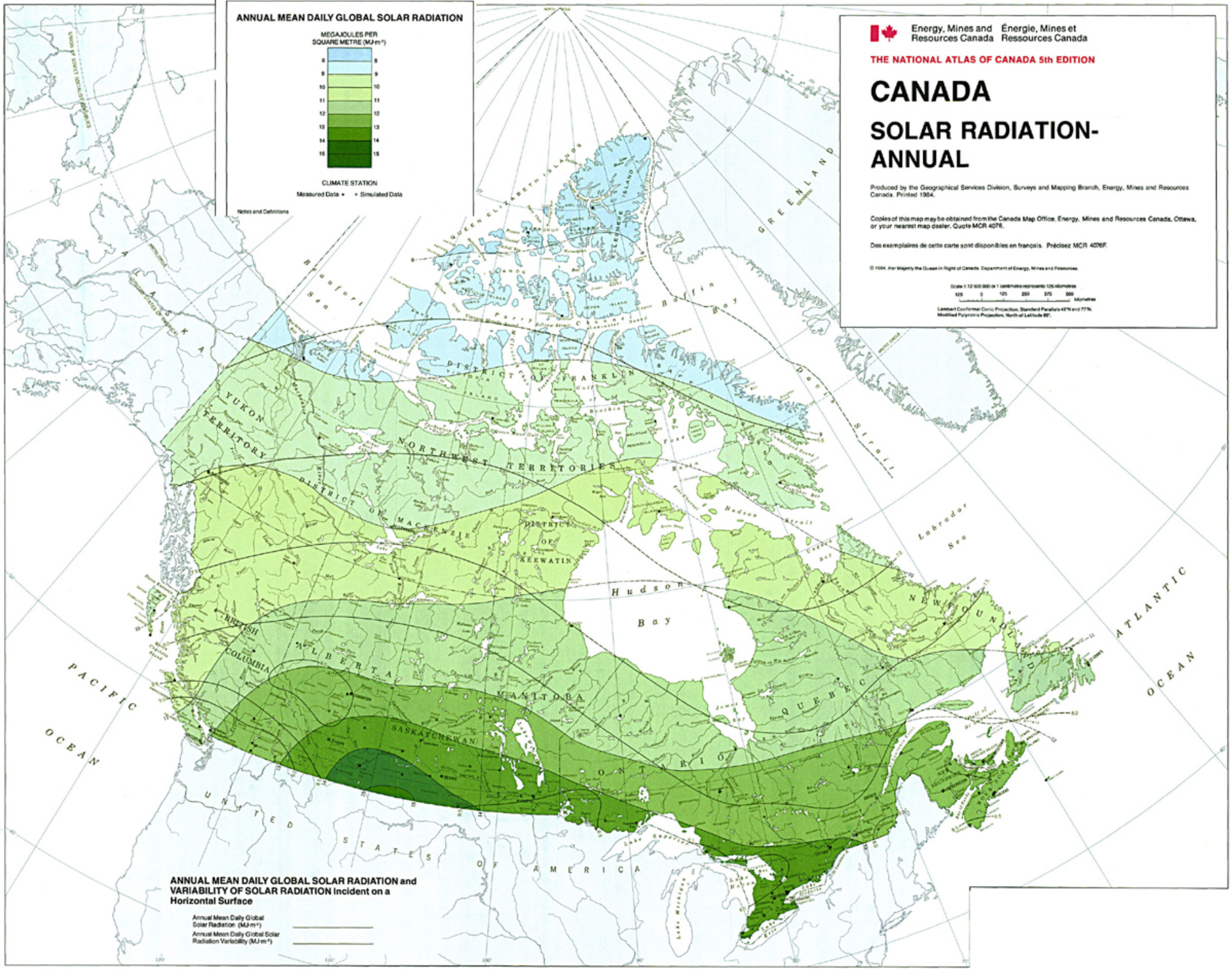
The PV is firmly mounted on the roof but could be set to track the sun.
The wall installation is evacuated tubes for solar hot water.

Illinois

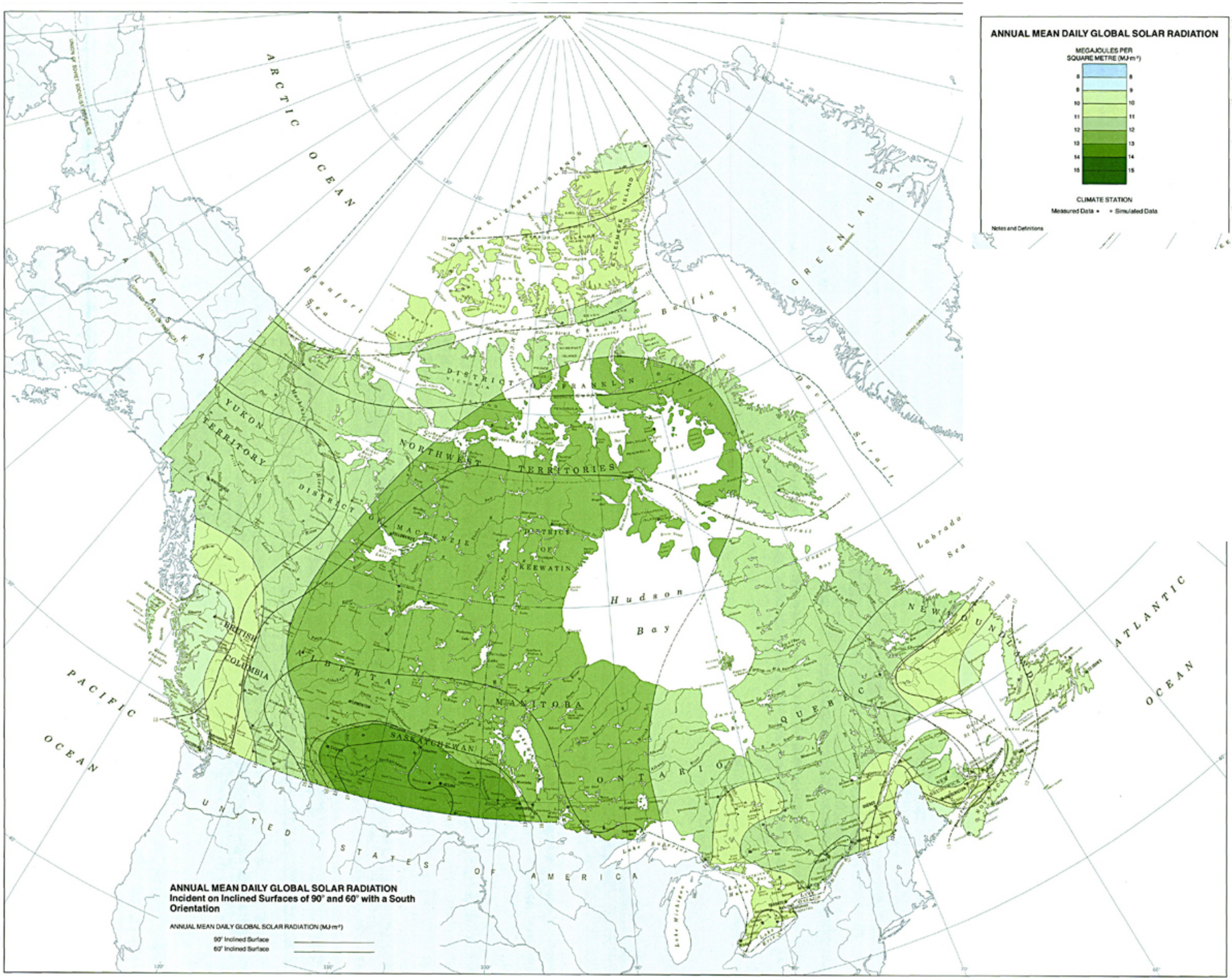
PV covers the entire south face of the roof to maximize potential and also to create a more integrated “look” to the installation.

Louisiana

PV is roof mounted and faces the rear of the house. PV does not work well if it overheats so space is left around it for ventilation.



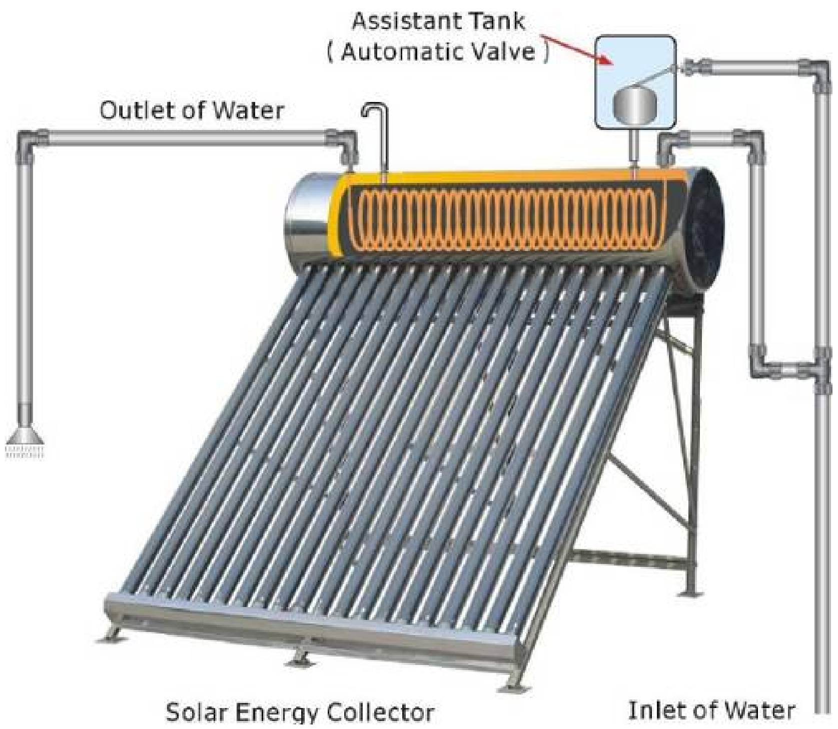
Site suitability: annual solar radiation on a horizontal surface

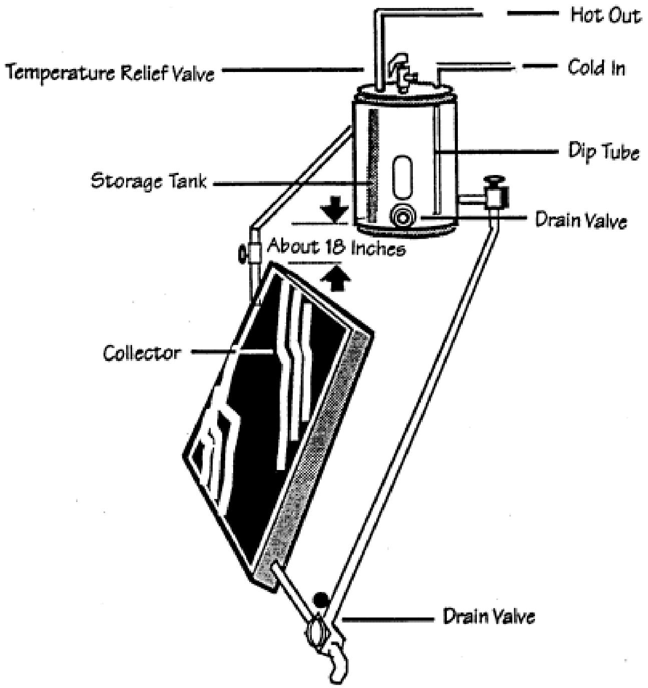


- Site suitability: annual solar radiation on an inclined surface

Solar Hot Water
And
Solar Thermal

Solar hot water:



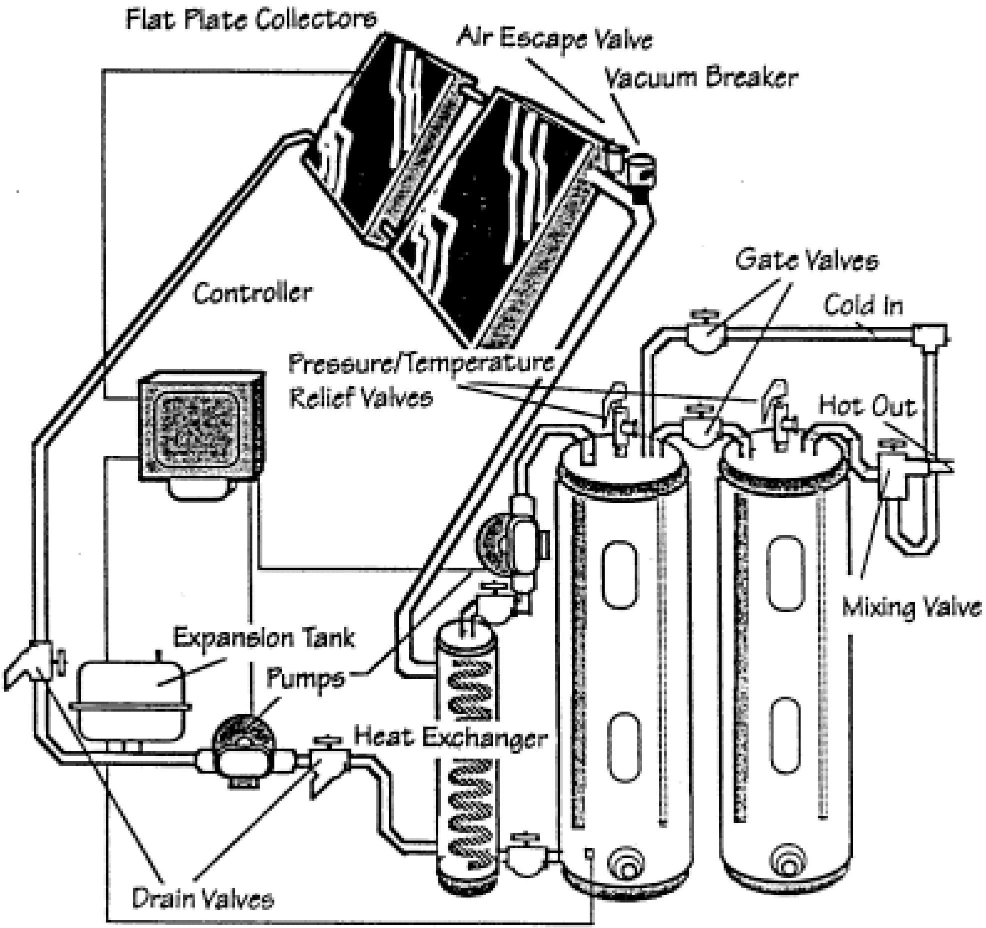


Solar hot water systems use the sun's energy to heat water for a variety of industrial and business uses.

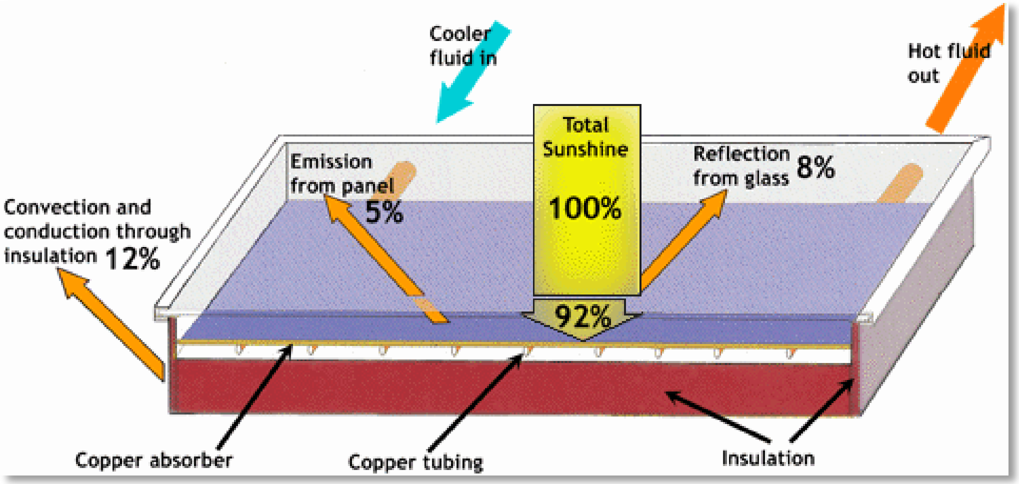
Sunlight passing through glass or plastic glazing strikes a light absorbing material. The material converts the sunlight into heat, which is prevented from escaping by the glazing.

Solar hot water systems:

The most common types of solar collectors used in solar water heaters are flat plate and evacuated tube collectors. A flat plate collector consists of a shallow rectangular box with a transparent glass or plastic window covering a flat black plate. The black plate is attached to a series of tubes through which water or some other transfer fluid passes. An evacuated tube collector consists of several individual glass tubes, each containing a black metal pipe. The transfer fluid flows through these pipes. The space between the pipe and the glass tube is evacuated, in other words, the air is removed.



Flat plate collectors:



Allow one square metre of collector for every 45-50 litres of hot water to be stored.

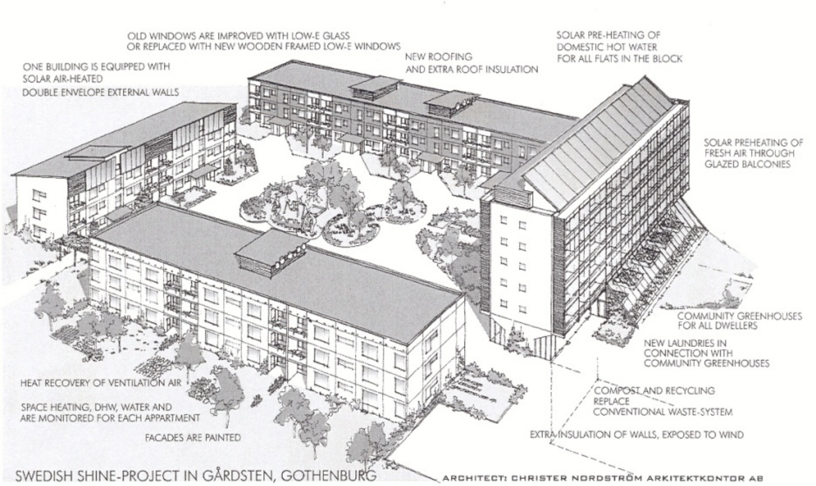
Working towards a NET ZERO WATER status will make it more likely to be able to supply all of the hot water needs with a solar system.

Typical daily hot water usage

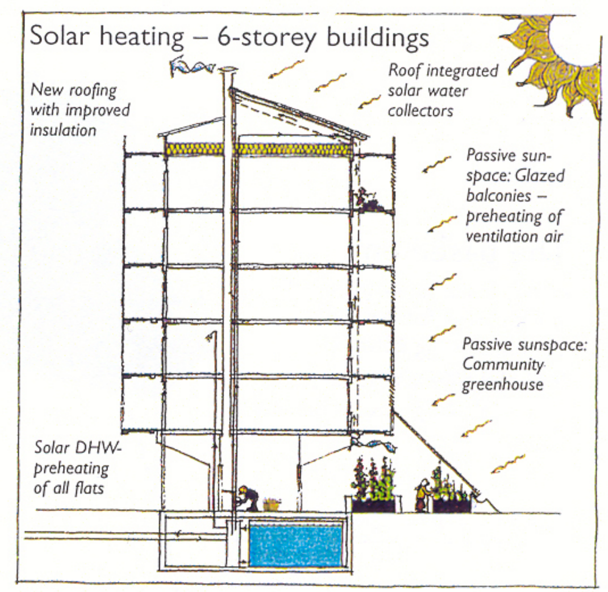
Appliance	*Volume (litres)*
standard sized bath	60
corner bath	120
shower / power shower	15-60
washing machine	50
kitchen sink	15
bathroom washbasin	5

Flat plate collectors:

Flat plate collectors:

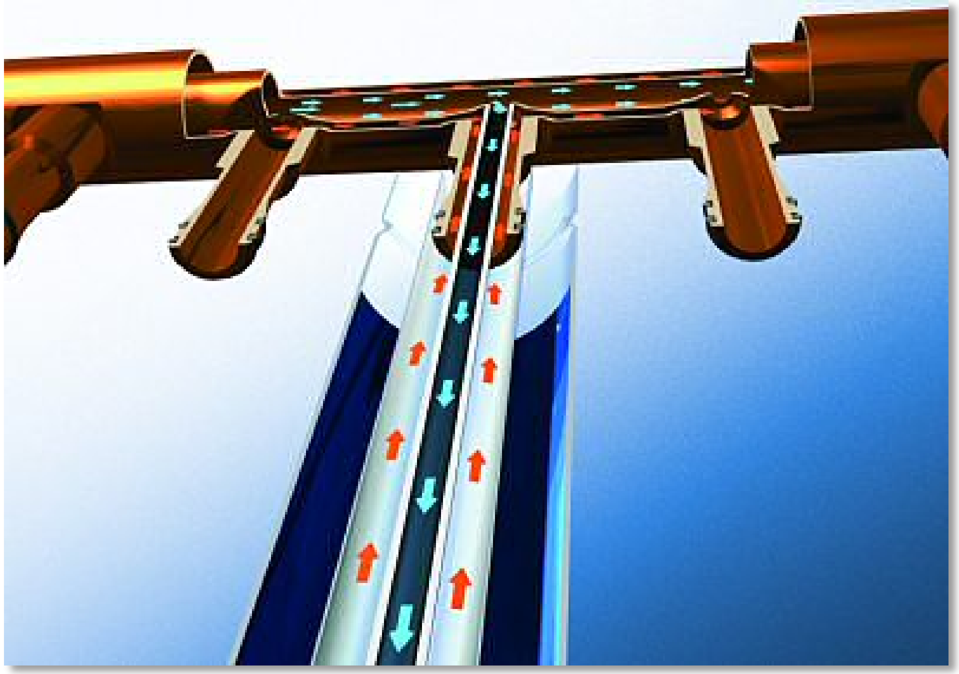


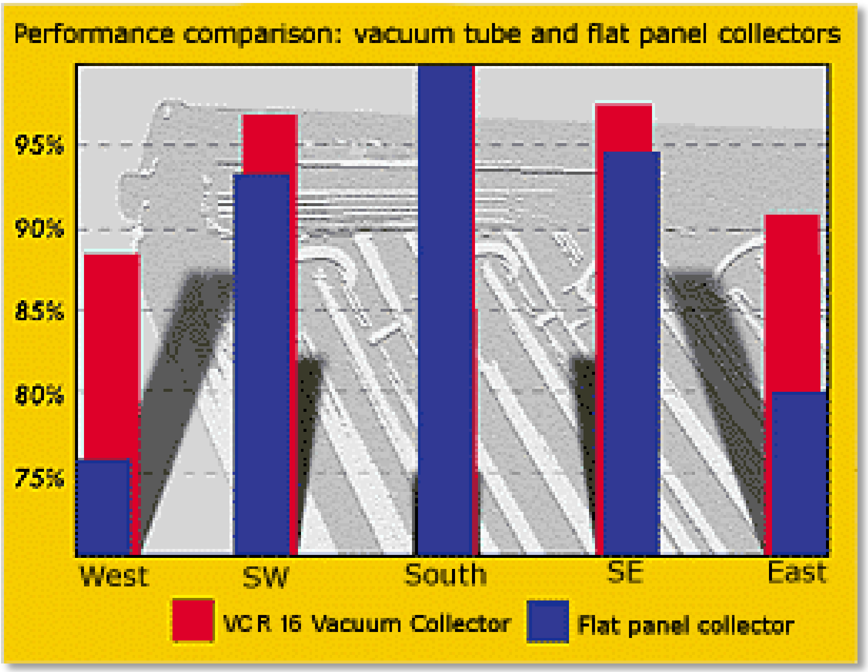
Top: birdview of one of three similar blocks describing the solar- and sustainabletechologies.

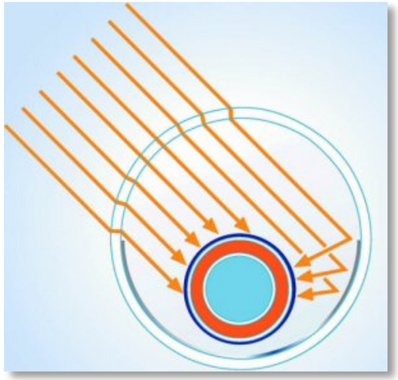


Vacuum tube collectors:

The vacuum tube collector uses a series of glass tubes that act like thermos bottles. The glass allows the light through, which heats up the fluid inside the inner tube. The vacuum between the layers of glass prevents that heat from escaping back to the atmosphere on cold days.







On warm, sunny days, the performance of the vacuum collector is equal to that of the flat collector. But it will increasingly outperform the flat collector as the outside temperature decreases or light levels are reduced.

PV

White Rock Operations Centre, Surrey, BC

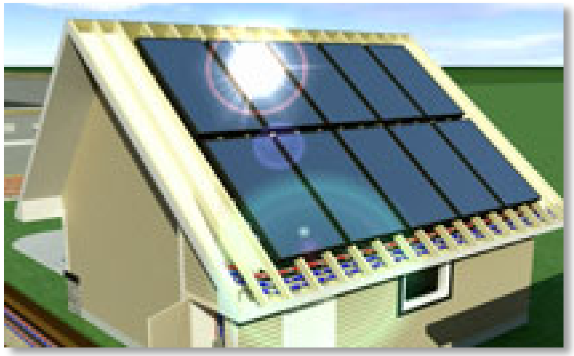
Vacuum tube collectors

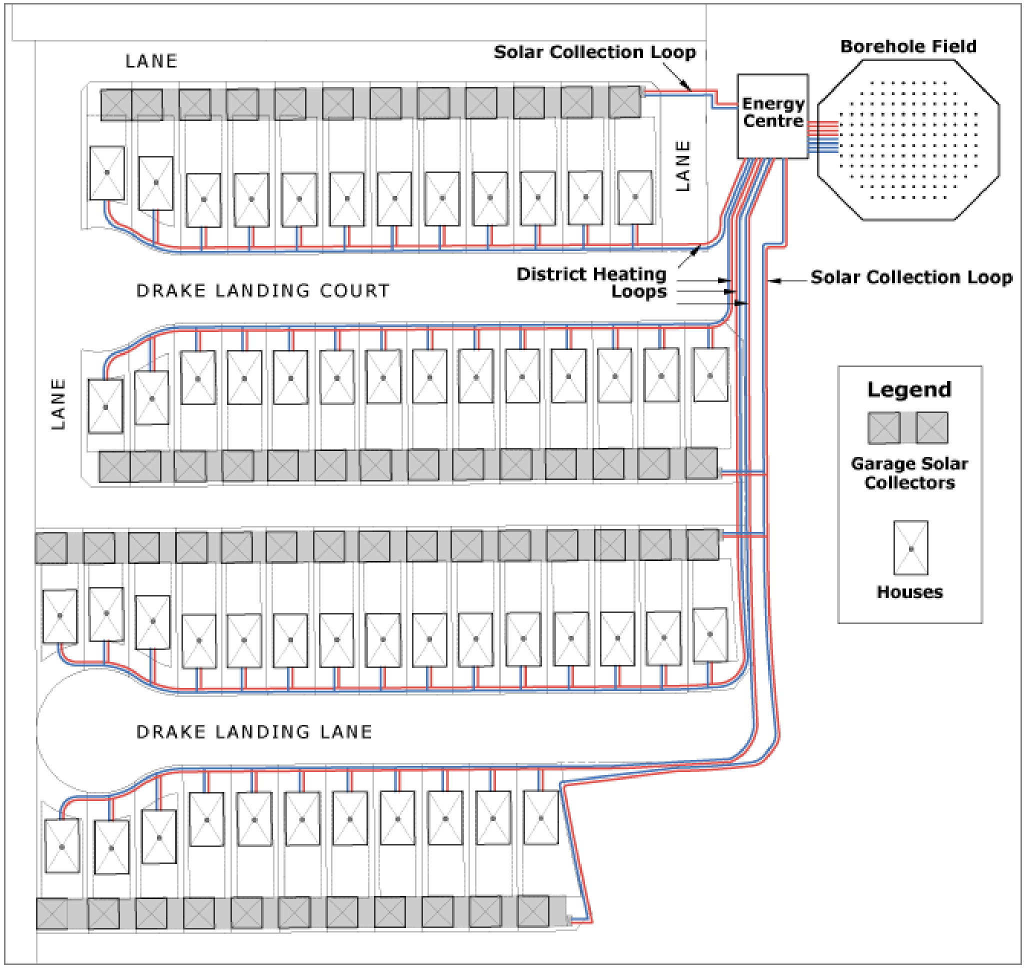
Evacuated tube system at Benny Farm Housing in Montreal.

Drake Landing Solar Community

http://www.dlsc.ca

Solar thermal panels along the garages of Drake Landing that feed into the heating system for the houses.





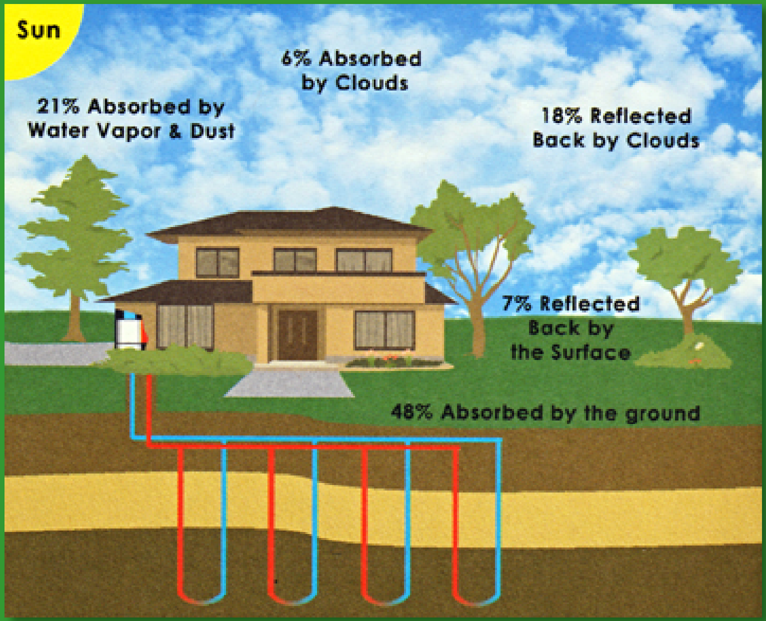
Drake Landing

An antifreeze solution - a mixture of water and non-toxic glycol - is pumped through the solar collectors and heated whenever the sun is out. The 800 collectors are connected via an underground, insulated pipe that carries the heated solution to the community's Energy Centre. Once there, the heated solution passes through a heat exchanger, where the heat is transferred to the water in the short-term storage tanks. While the flow rate through the collectors is constant, the flow rate on the water side of the heat exchanger is automatically adjustable, allowing the control system to set a desired temperature rise.

Drake Landing – Flat Plate collectors

The houses also have flat plate collectors for domestic hot water heating.

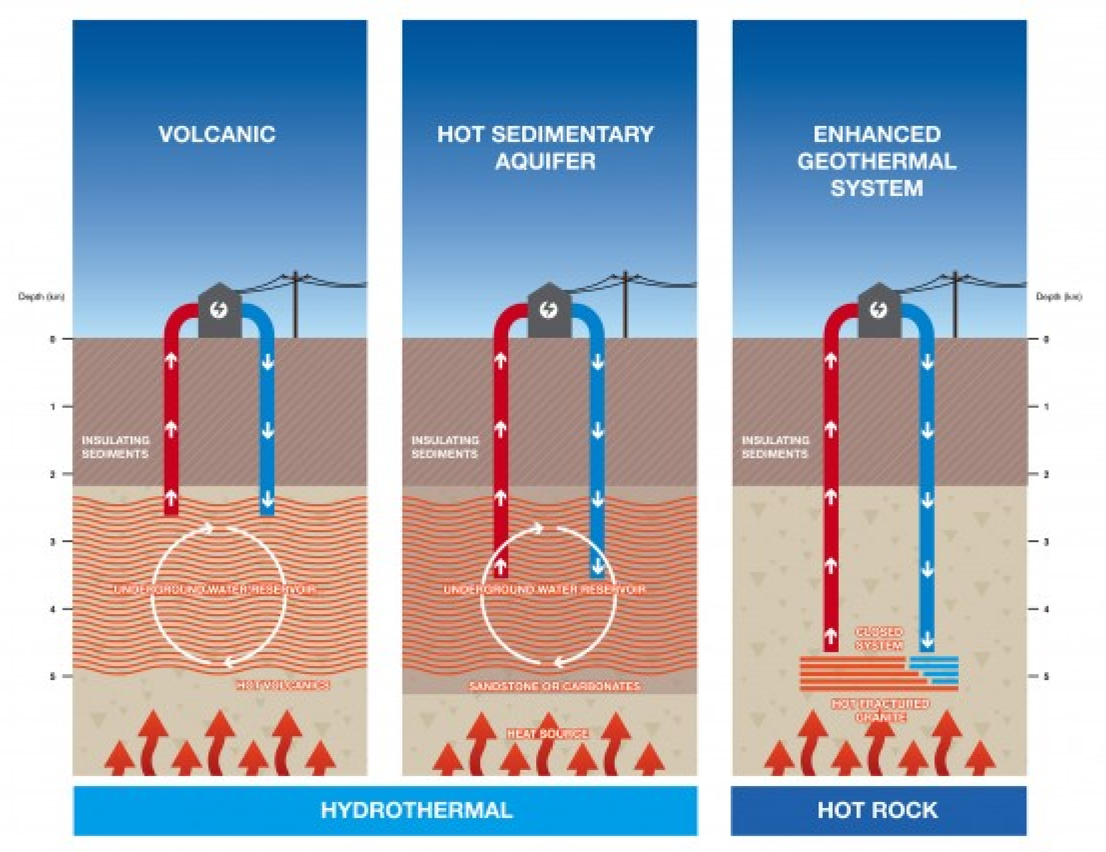
Geothermal Systems



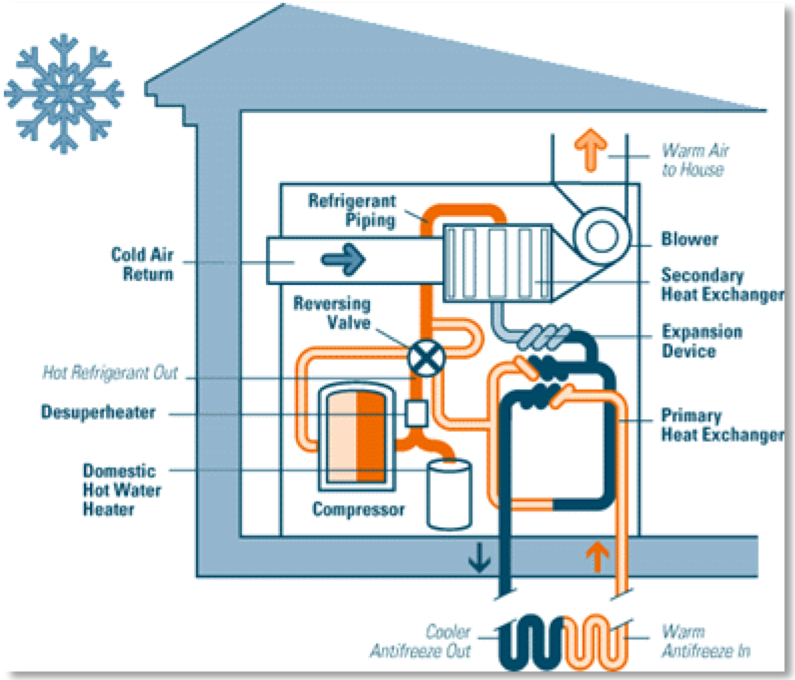
Geothermal components

The characteristics of geothermal systems vary widely, but three components are essential:

- a subsurface heat source
- fluid to transport the heat
- faults, fractures or permeability within sub-surface rocks that allow the heated fluid to flow from the heat source to the surface



Geothermal Systems: Earth Energy Systems



A ground-source heat pump uses the earth or ground water or both as the sources of heat in the winter, and as the "sink" for heat removed from the home in the summer.

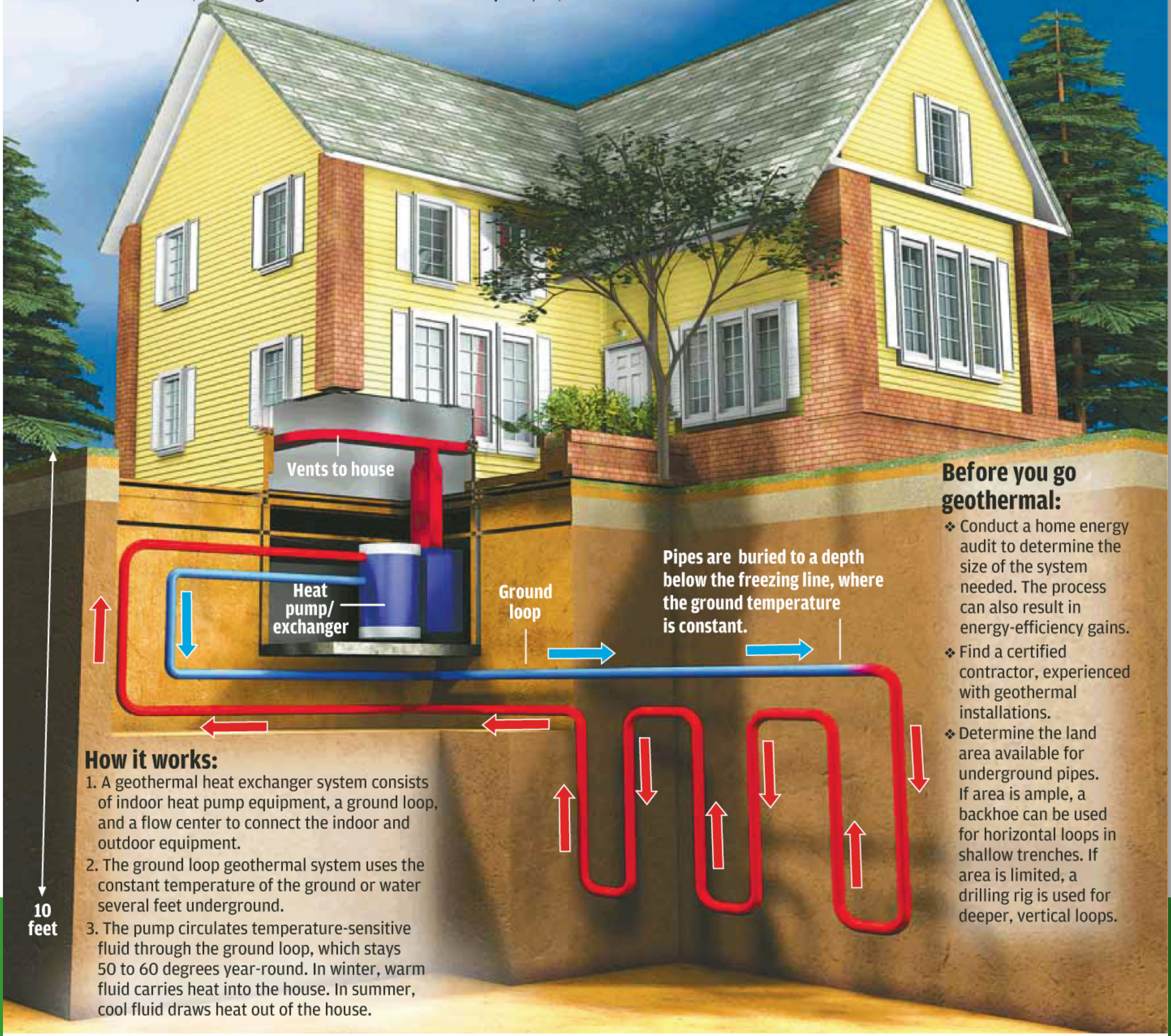
For this reason, ground-source heat pump systems have come to be known as earth-energy systems (EESs).

Heat is removed from the earth through a liquid, such as ground water or an antifreeze solution, upgraded by the heat pump, and transferred to indoor air.

During summer months, the process is reversed: heat is extracted from indoor air and transferred to the earth through the ground water or antifreeze solution. A direct-expansion (DX) earth-energy system uses refrigerant in the ground-heat exchanger, instead of an antifreeze solution.

Tapping the underground

Geothermal heat pumps use stable ground temperatures for home heating and cooling. According to the EPA, the geothermal systems can save 40 percent to 70 percent on home-heating and 20 percent to 50 percent on home-cooling costs over conventional systems, although installation costs can be up to $12,000.



Pipes are buried to a depth below the freezing line, where the ground temperature is constant.

How it works:

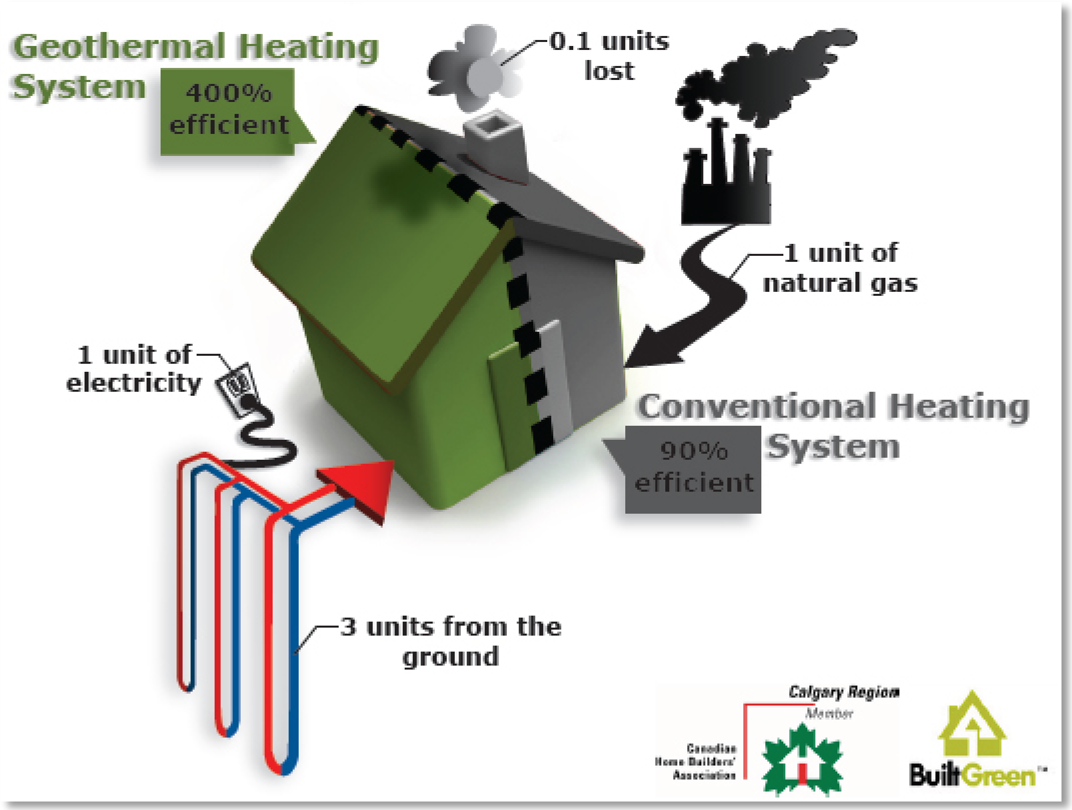
1. A geothermal heat exchanger system consists of indoor heat pump equipment, a ground loop, and a flow center to connect the indoor and outdoor equipment.
2. The ground loop geothermal system uses the constant temperature of the ground or water several feet underground.
3. The pump circulates temperature-sensitive fluid through the ground loop, which stays 50 to 60 degrees year-round. In winter, warm fluid carries heat into the house. In summer, cool fluid draws heat out of the house.

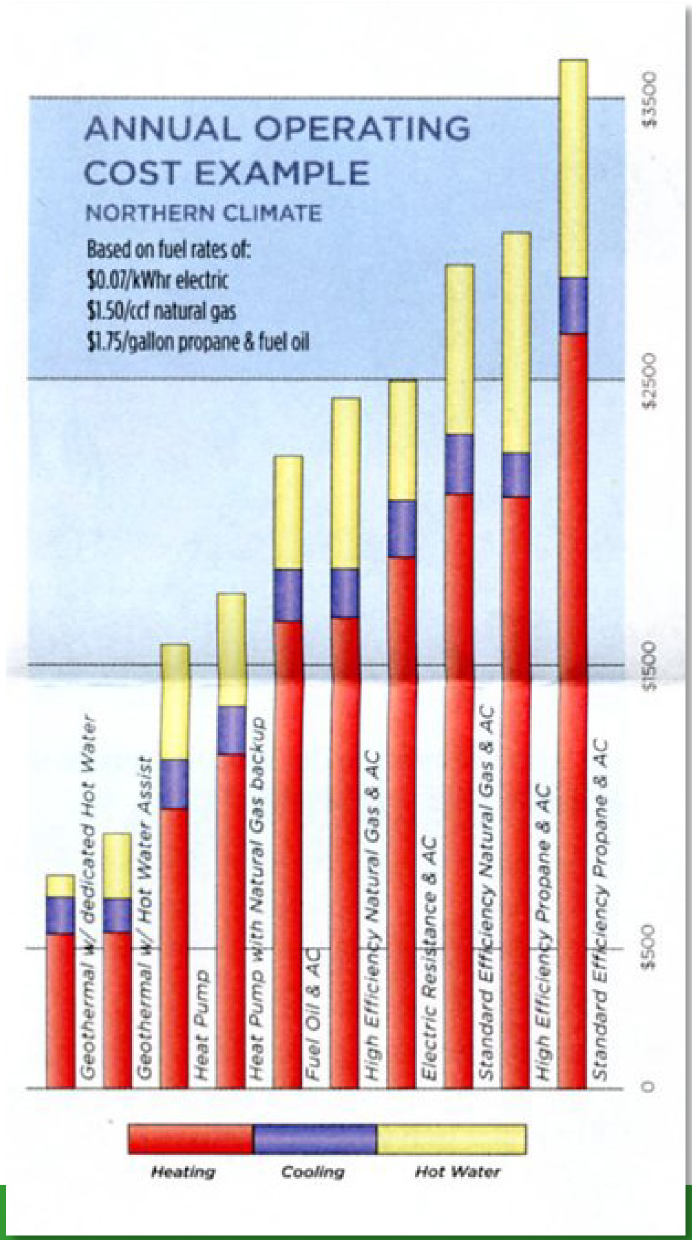
Before you go geothermal:

- Conduct a home energy audit to determine the size of the system needed. The process can also result in energy-efficiency gains.
- Find a certified contractor, experienced with geothermal installations.
- Determine the land area available for underground pipes. If area is ample, a backhoe can be used for horizontal loops in shallow trenches. If area is limited, a drilling rig is used for deeper, vertical loops.

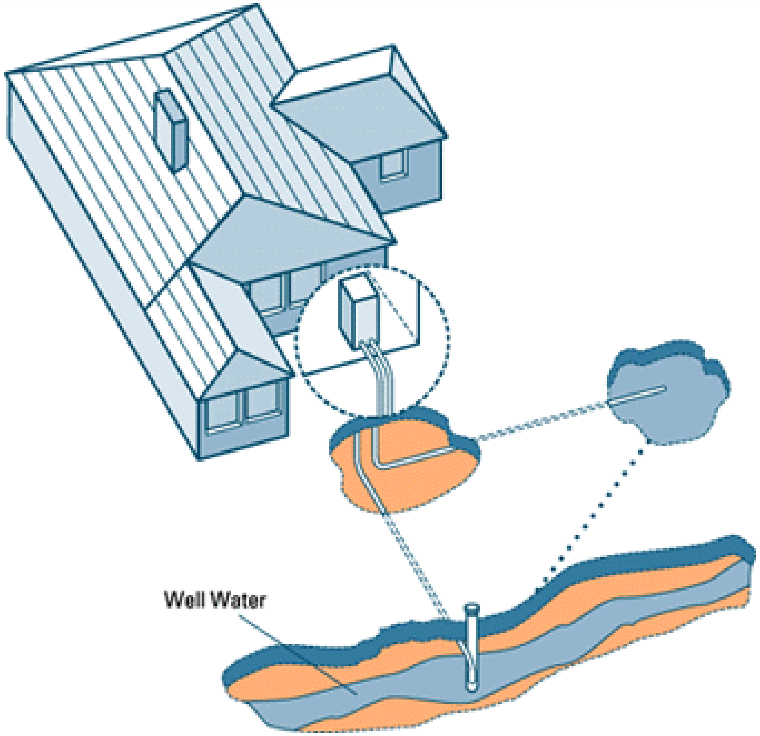
Sources: Delta-Montrose Electric Association, About.com

JONATHAN MORENO/THE DENVER POST


Geothermal Heating System
400% efficient
0.1 units lost
1 unit of natural gas
1 unit of electricity
Conventional Heating System
90% efficient
3 units from the ground
Calgary Region
Member
Canadian Home Builders' Association
BuiltGreen


ANNUAL OPERATING COST EXAMPLE
NORTHERN CLIMATE
Based on fuel rates of:
$0.07/kWhr electric
$1.50/ccf natural gas
$1.75/gallon propane & fuel oil
Geothermal w/ dedicated Hot Water
Geothermal w/ Hot Water Assist
Heat Pump
Heat Pump with Natural Gas backup
Fuel Oil & AC
High Efficiency Natural Gas & AC
Electric Resistance & AC
Standard Efficiency Natural Gas & AC
High Efficiency Propane & AC
Standard Efficiency Propane & AC
0
$500
$1500
$2500
$3500
Heating
Cooling
Hot Water

Open Systems:

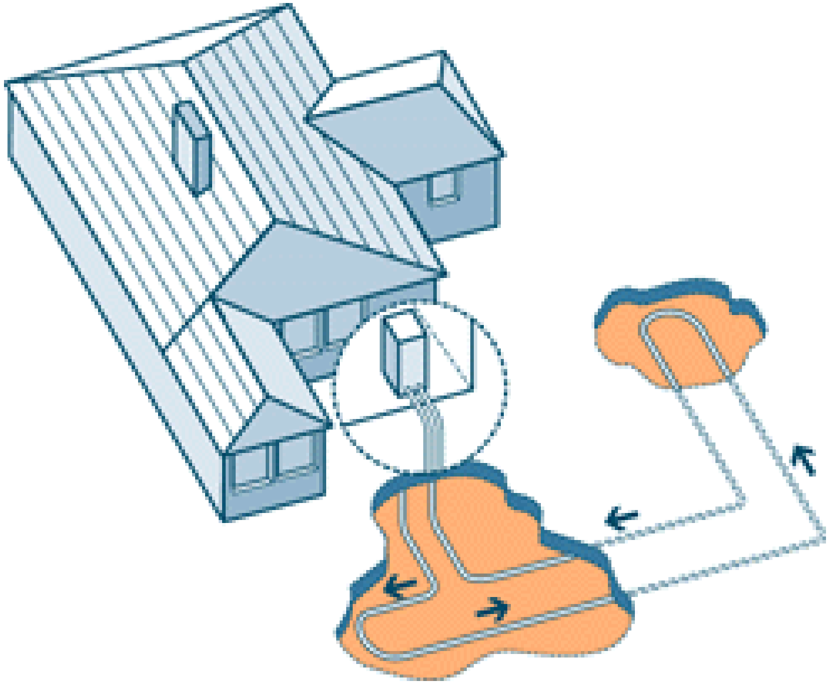


As noted, an open system uses ground water from a conventional well as a heat source. The ground water is pumped into the heat pump unit, where heat is extracted. Then, the "used" water is released in a stream, pond, ditch, drainage tile, river, or lake. This process is often referred to as the "open discharge" method. (This may not be acceptable in your area. Check with local authorities.)

Poor water quality can cause serious problems in open systems. You should not use water from a spring, pond, river, or lake as a source for your heat pump system unless it has been proven to be free of excessive particles and organic matter, and warm enough throughout the year (typically over 5° C) to avoid freeze-up of the heat exchanger.

Open System Using Ground Water from a Well

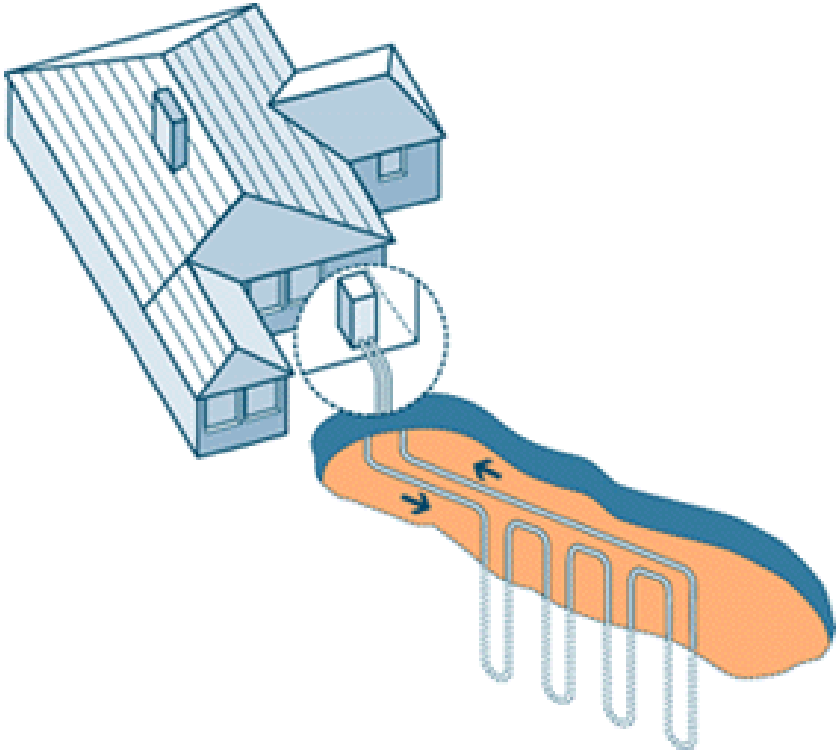
Closed Systems:



Closed-Loop, Single Layer Horizontal Configuration

A closed-loop system draws heat from the ground itself, using a continuous loop of special buried plastic pipe. Copper tubing is used in the case of DX systems. The pipe is connected to the indoor heat pump to form a sealed underground loop through which an antifreeze solution or refrigerant is circulated. While an open system drains water from a well, a closed-loop system re-circulates its heat transfer solution in pressurized pipe.

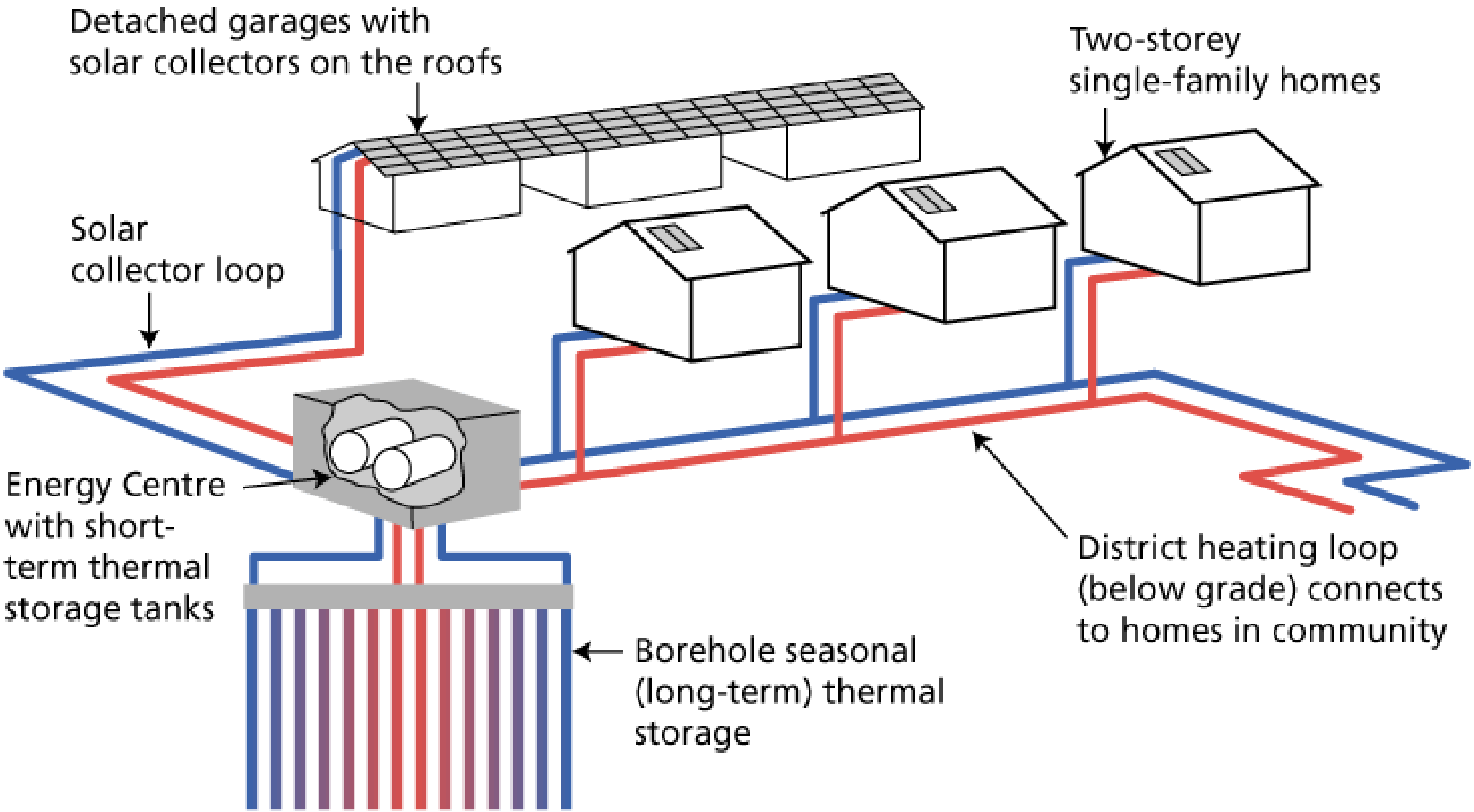
Closed Systems:



Closed-Loop, Single U-bend Vertical Configuration

All piping for antifreeze solution systems must be at least series 100 polyethylene or polybutylene with thermally fused joints (as opposed to barbed fittings, clamps, or glued joints), to ensure leak-free connections for the life of the piping. Properly installed, these pipes will last anywhere from 25 to 75 years. They are unaffected by chemicals found in soil and have good heat-conducting properties. The antifreeze solution must be acceptable to local environmental officials. DX systems use a refrigeration-grade copper tubing.


KOMATSU



Detached garages with solar collectors on the roofs

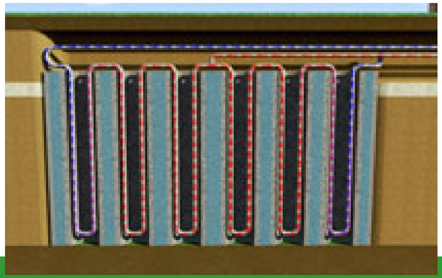
Two-storey single-family homes

Solar collector loop

Energy Centre with short-term thermal storage tanks

District heating loop (below grade) connects to homes in community

Borehole seasonal (long-term) thermal storage

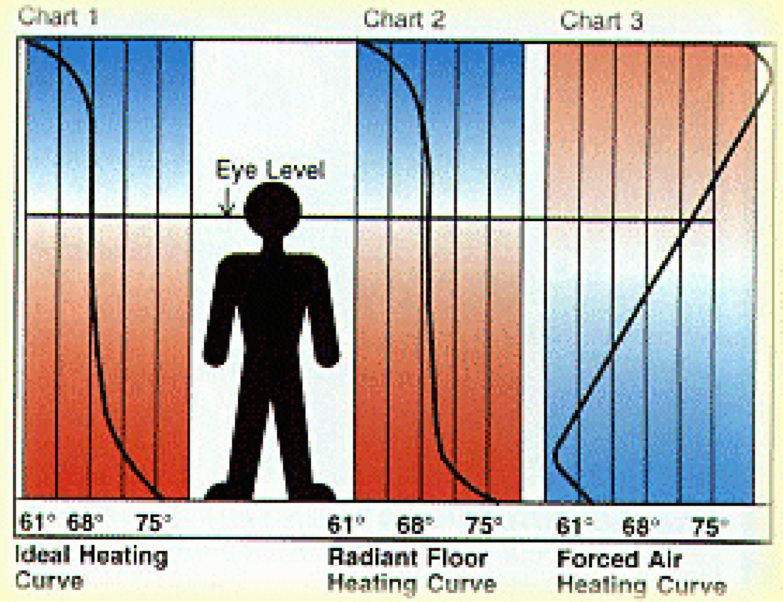


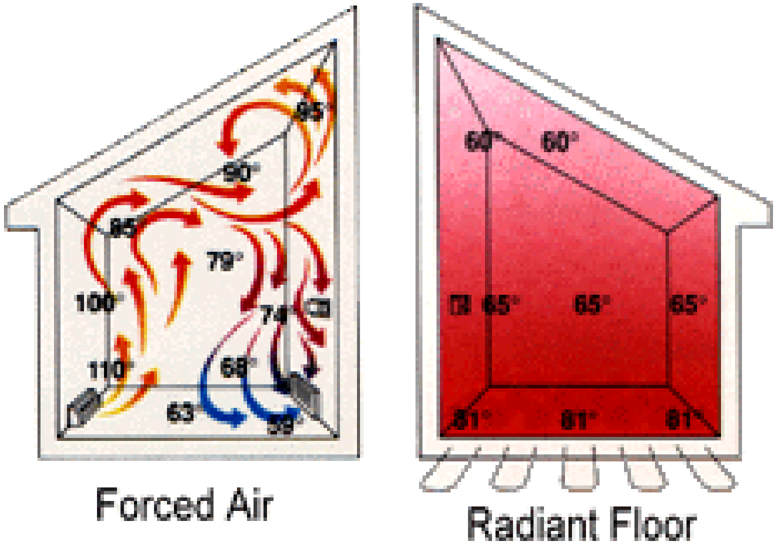
http://www.dlsc.ca

Drake Landing Solar Community

Distribution - Radiant Heating:

A home that requires a cooling system will typically have a separate system installed to provide the cooling. The reason is straightforward: heating is ideally delivered from the ground up.



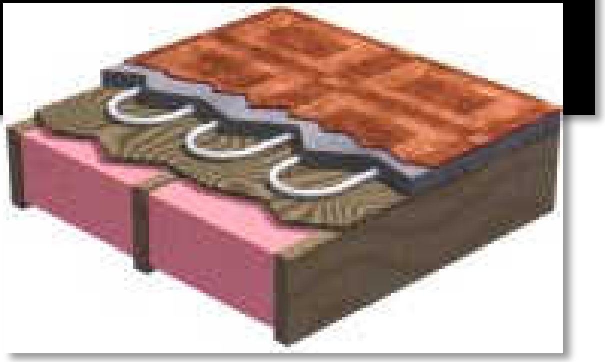


Radiant floor heating produces room temperatures very close to ideal: 75° at floor level, declining to 68° at eye level, then to 61° at the ceiling.

Look into radiant

...and what do you see?

Radiant Floor Heating:



COMPONENTS OF A RADIANT FLOOR HEATING SYSTEM
(FOR HYDRONIC SYSTEMS)

Here are the components required for a radiant floor heating system:

* Heating Source – this can be electricity, solar, natural gas, propane, oil, wood, or any other heating source.
* Boiler – houses the water to be heated
* Pump – to circulate the water through tubing located under the floor.
* Tubing – the water will circulate in tubing running beneath the floor in the concrete, under wood floors, or on a sub floor of wood, precast concrete, or slab-on-grade concrete.

Step 1: The tubing is installed to the sub-floor of the home...

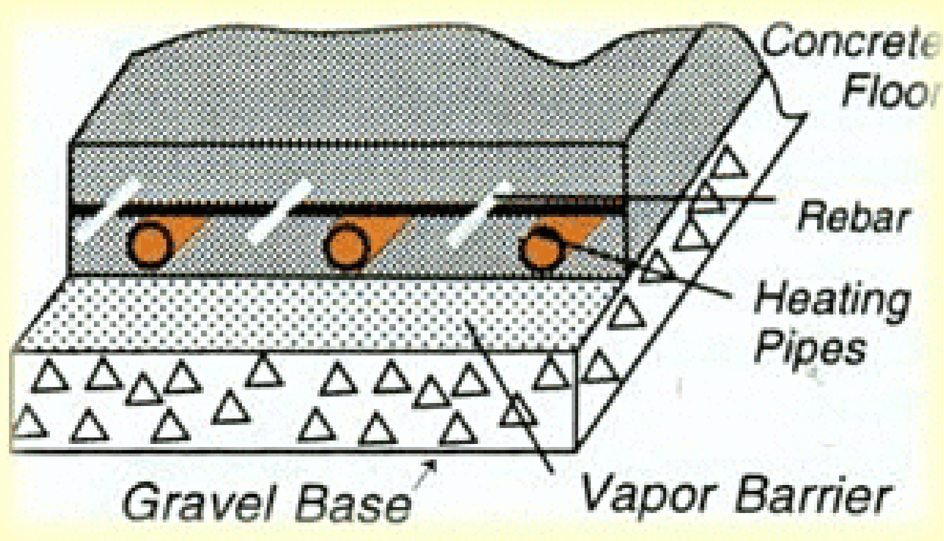
Step 2: The first layer of liquified gypsum covers the tubing...

Step 3: The 2nd layer of liquified gypsum is 'floated' over the 1st layer...

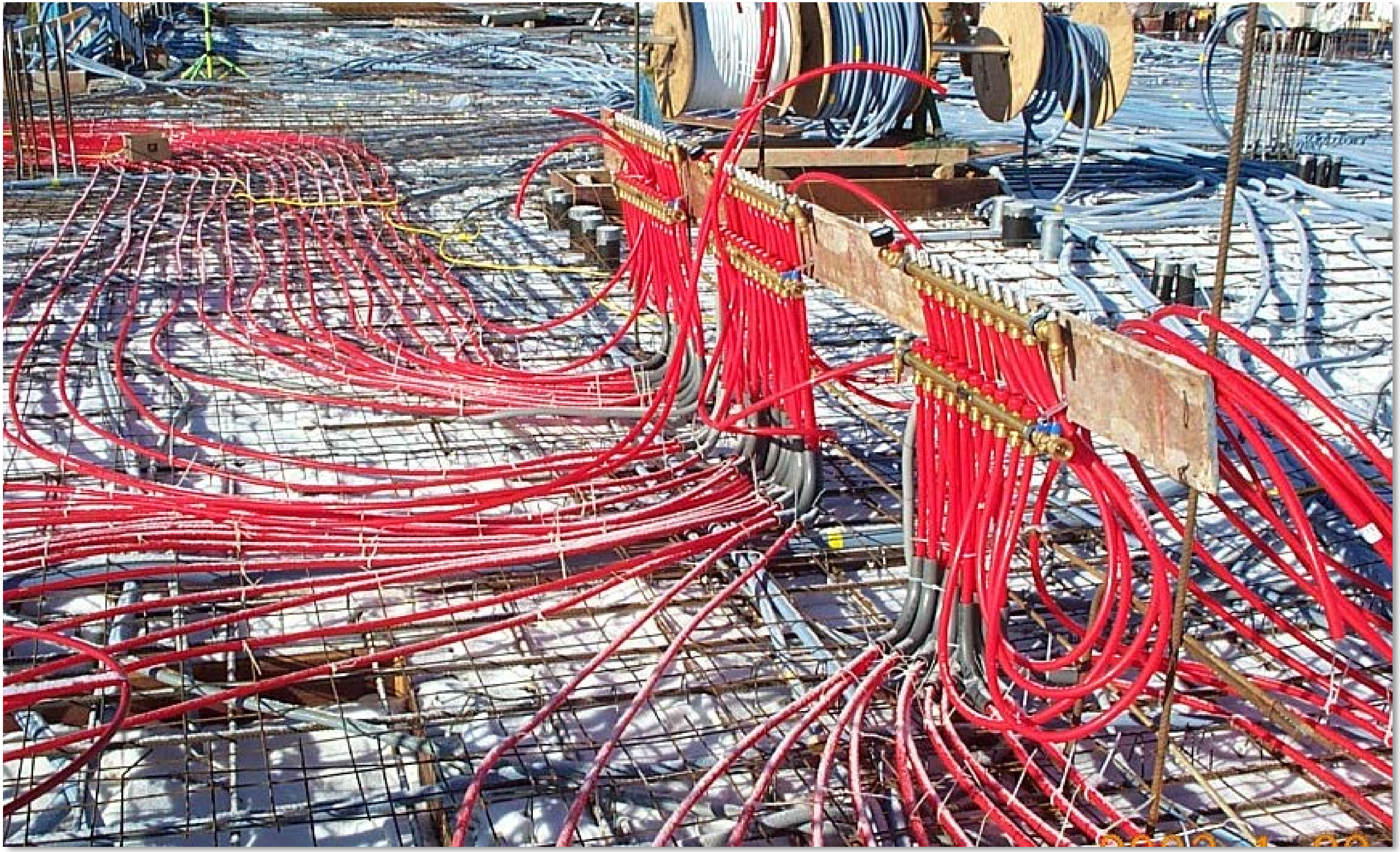
Step 4:The gypsum surface is smoothed to a glass-like finish & left to dry...

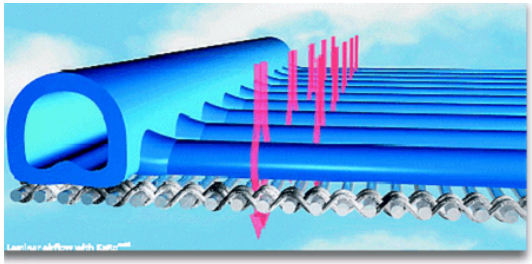
Installation in Concrete

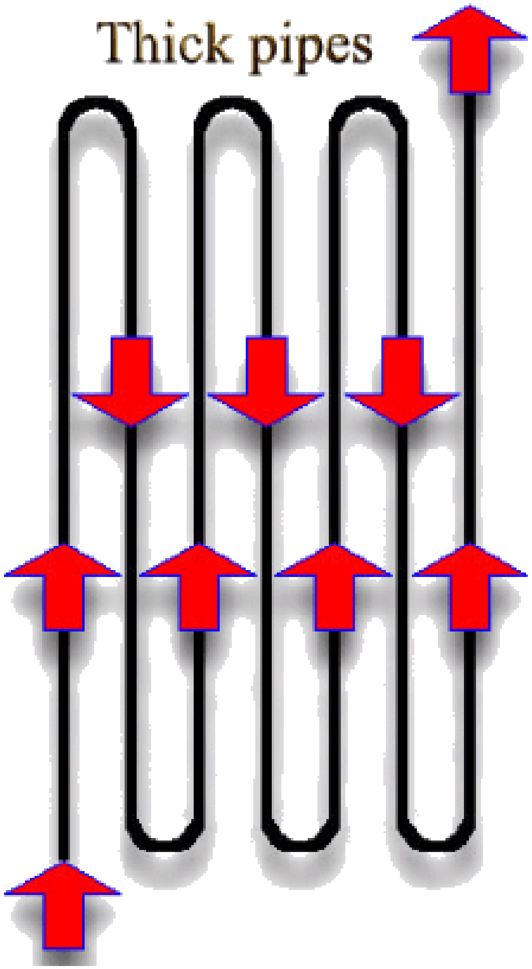
Many radiant floor heating projects are in slab-on-grade concrete. Tubing is installed in the slab. Temperature-controlled water then circulates though the tubing in the slabs: this process turns the slab into a radiant panel.

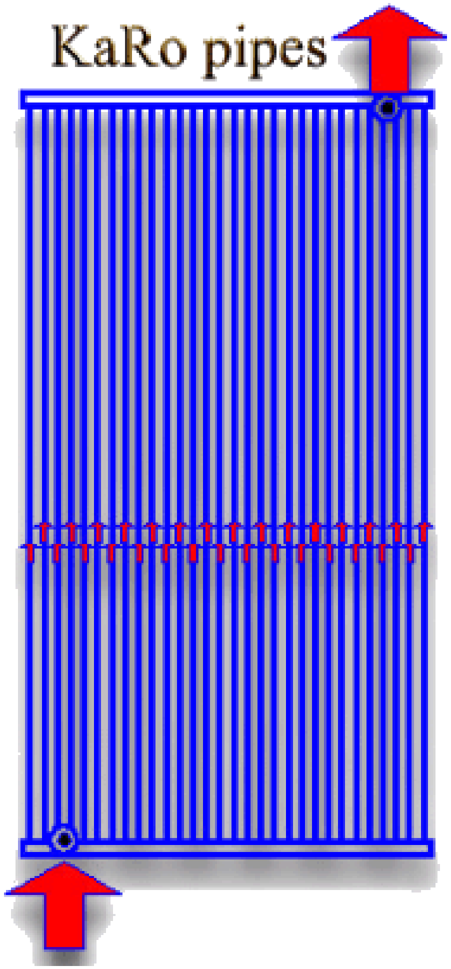


Concrete presents the greatest thermal mass of any of the radiant floor heating methods, which can be a tremendous benefit in rooms or buildings with high ceilings.

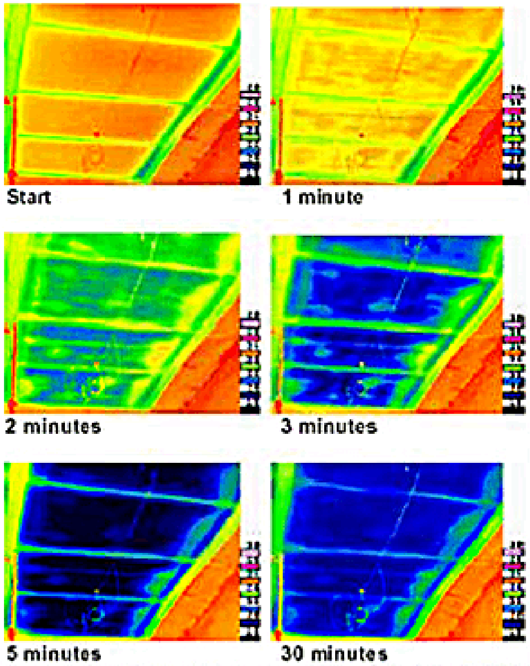


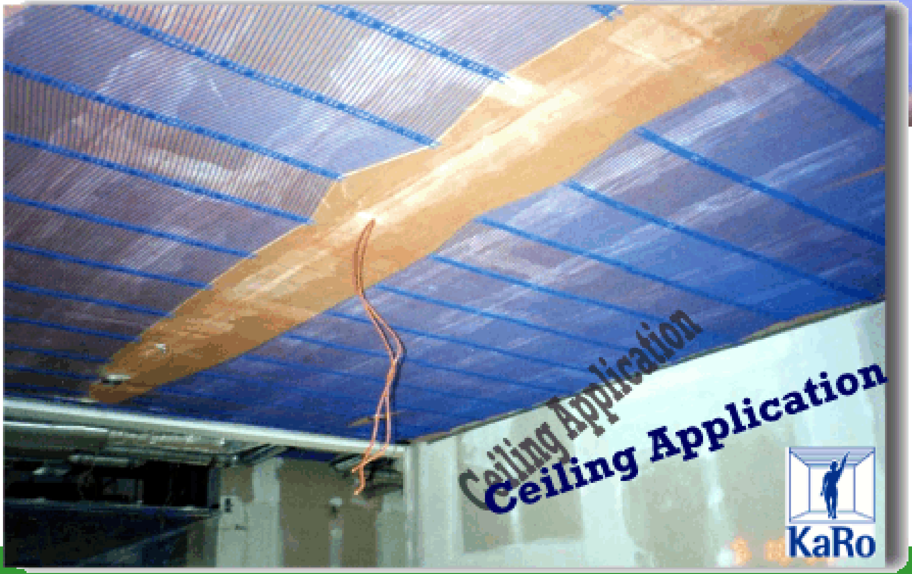






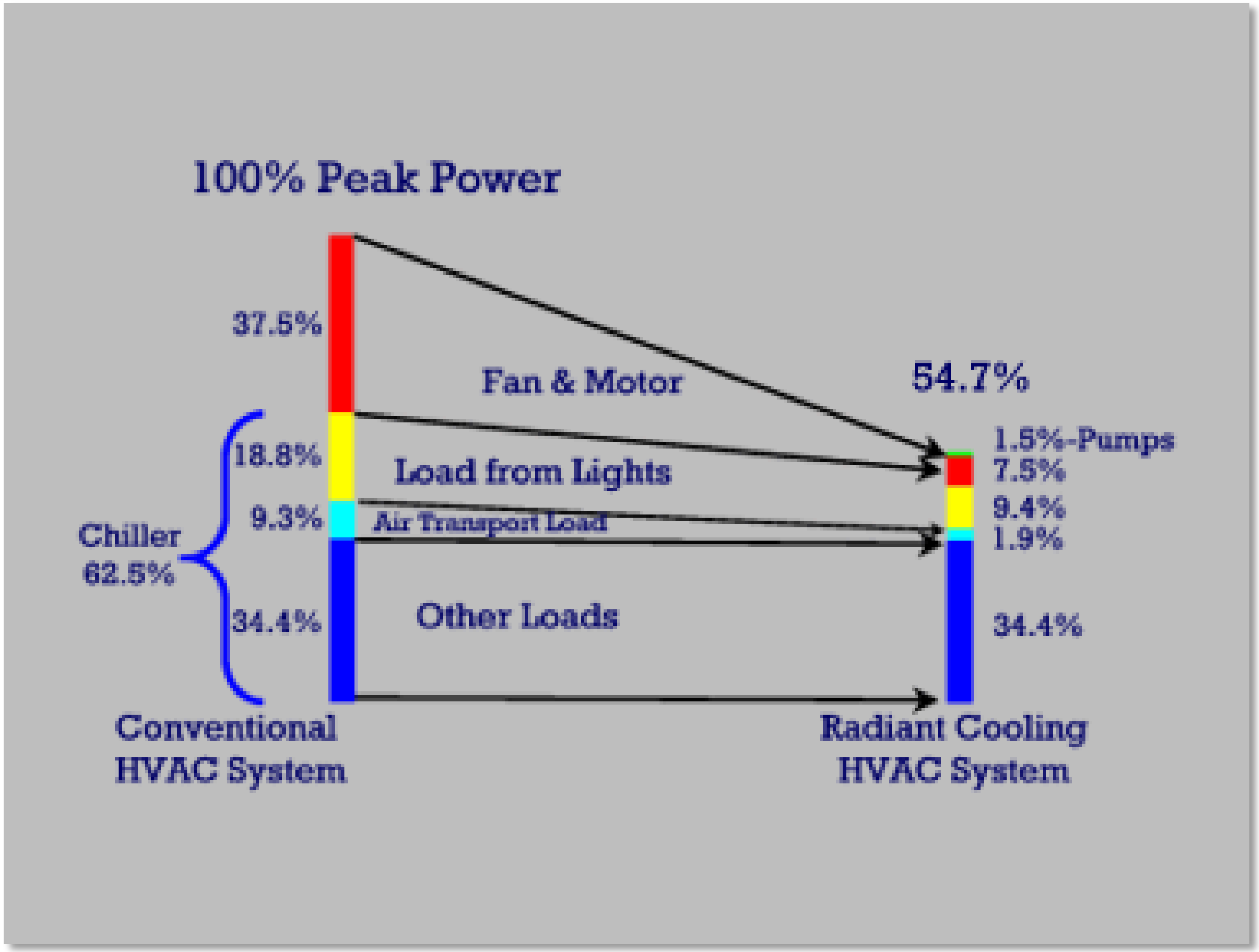
Capillary tube radiant systems


Start
1 minute
2 minutes
3 minutes
5 minutes
30 minutes


Ceiling Application
Ceiling Application
KaRo


KaRo

Radiant Delivery Heating & Cooling:

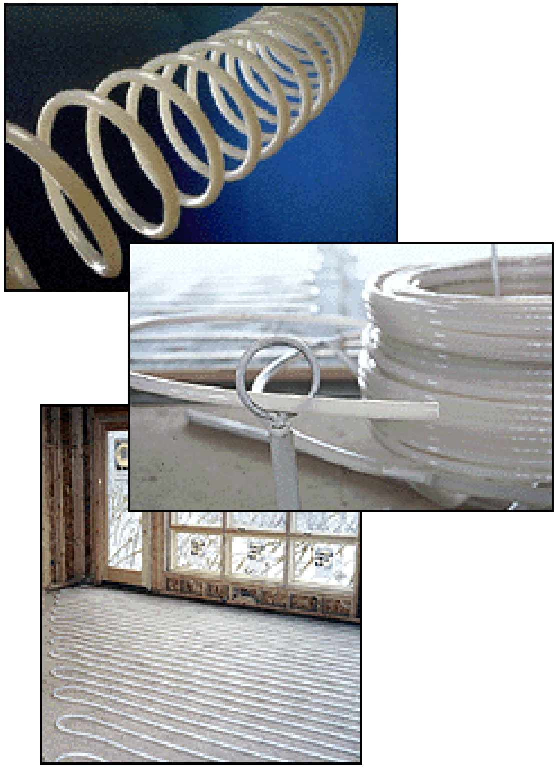



Buderus

Although ceramic tile is the most common floor covering for radiant floor heating, almost any floor covering can be used. However, some perform better than others. Common floor coverings like vinyl and linoleum sheet goods, carpeting, wood or bare concrete is often specified. However, it is wise to always remember that anything that can insulate the floor also reduces or slows the heat entering the space from the floor system. This in turn increases fuel consumption.

Most radiant floor references also recommend using laminated wood flooring instead of solid wood. This reduces the possibility of the wood shrinking and cracking from the drying effects of the heat.

FLOOR COVERING CAN = THERMAL MASS!



Older radiant floor systems used either copper or steel tubing embedded in the concrete floors. Unless the builder coated the tubing with a protective compound, a chemical reaction between the metal and the concrete often led to corrosion of the tubing, and to eventual leaks.

Major manufacturers of hydronic radiant floor systems now use cross-linked polyethylene (PEX) or rubber tubing with an oxygen diffusion barrier. These materials have proven themselves to be more reliable than the older choices in tubing. Fluid additives also help protect the system from corrosion.

types of tubing