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1.0- What device ?

If the building designer has the idea that some form of solar device could be installed on the project being designed, the first question he faces is what type of device could be considered. Electric power generation is out of the question at present, unless the situation is exceptional, i.e. if there is no public electricity supply available and the demand is only in the order of a few hundred watts.

Thermal utilisation is feasible in most situations. The first choice is whether the building should be designed as a collector, or some specific collector device should be installed. The former (i.e. the 'passive system') is definitely useful, but its success will very much depend on the user's correct actions at the appropriate times. This should be ensured by a clear set of instructions. It will rarely give the same performance as an 'active system' would, and certainly not the same degree of control. The strongest argument in its favour is its simplicity and relatively low cost.

With the second alternative the choice is between flat plate or focusing devices. The latter can only be considered if the climate is predominantly sunny. Even then the cost of the concentrator and the tracking system required will only be justified if there is a demand for temperatures near to or exceeding the boiling point. The use of flat plate collectors is on the other hand feasible even where the skies are predominantly overcast.

2.0- Is it feasible?

Technically, the collection of solar energy is possible in any situation on the earth. Feasibility is largely a question of point of view. The lowest efficiency system, with only a minimal contribution is an improvement and may be taken as feasible from the point of view of resource conservation. The speculative investor may not consider the most excellent system as feasible, even if it would pay for itself in five years. The average house owner may set the criterion of feasibility in terms of 10 or 15 years amortisation. Government agencies should (but rarely do) take a longer term view and consider a 20 or 25 year 'pay-back period' as satisfying their feasibility criteria.

Thus, before a feasibility study is started, the criteria (thus the standpoint) of the client should be clarified.

In the next step climatic factors may be considered. As a generalised rule it may be accepted that focusing devices are feasible if the annual total number of sunshine hours in the given location exceeds 2500 (i.e. about 6.8 hours/day average). This information is readily available from meteorological publications.

In a similarly generalised form it can be suggested that the feasibility of flat plate collectors is not governed by sunshine duration. Their use may be feasible where the annual total amount of radiation, measured on a horizontal plane exceeds 800 kWh/m² (or approximately 2880 MJ/m² or 68800 cal/m²).

A general world and UK data are indicated in Figure 2.1 and Figure 2.2 respectively.

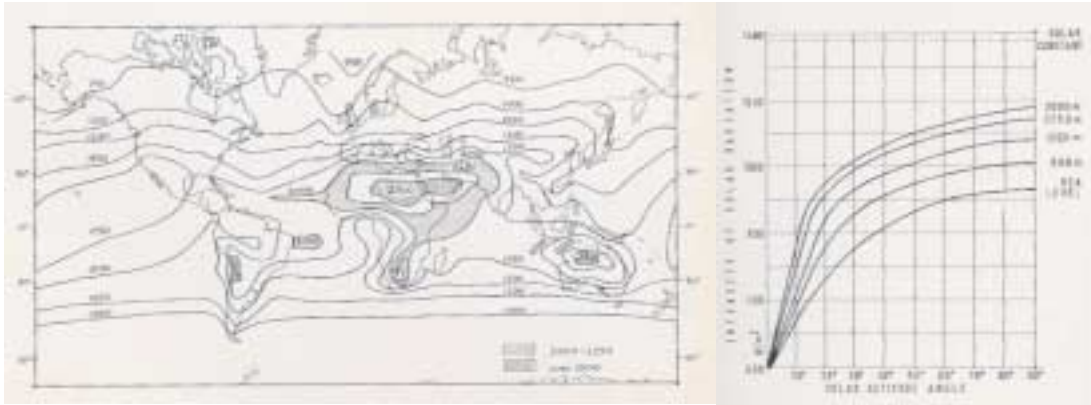


Figure 2.1 – Global Radiation Levels

Monthly amounts of solar radiation at Kew (nr London)

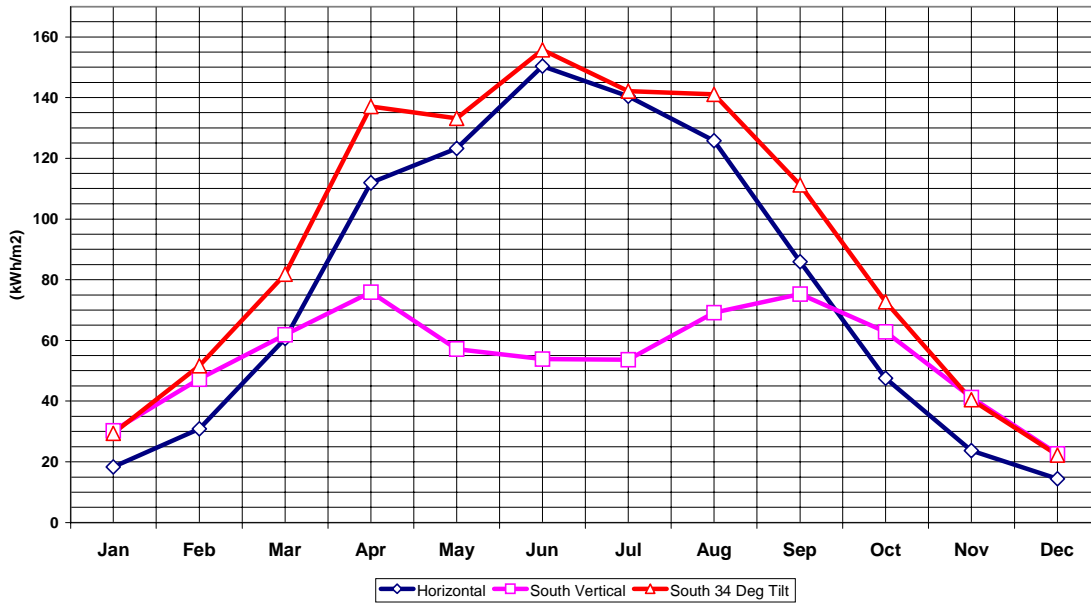


Table 2.2 – Average UK Radiation levels.

This information should be obtainable, if not from publications, from the nearest meteorological office. This statement is based on a comparison of the expected heat collection with the cost of the collector.

As a rough guidance it can be assumed that an optimally tilted collector will receive about 1.5 times as much radiation as the horizontal and that a well designed system will achieve a 40% average efficiency; thus the heat collected will be annual horizontal total x 0.6 (as 1.5 x 0.4 = 0.6)

With the 800 kWh/m2 annual total we can expect 480 kWh/m2 heat collection. How much of this will actually be utilised depends on the system and the energy use pattern. If we assume a utilisation rate of 0.5, every m2 collector can save average 240 kWh of heat, which would otherwise have to be supplied by conventional sources.

If the cost of such heat is, say 1 p/kWh and the collector cost is £24/m², we have achieved a figure of merit (FM)

$$\text{FM} = \frac{240 \times \text{£}0.01 \times 10 \text{ years}}{\text{£}24} = 1$$

If the figure of merit of 1 is accepted as the criterion of feasibility, one side of the equation is the 10-year fuel saving, the other side is the collector cost. Thus the criterion can be re-phrased to say that the system will be feasible if the collector cost does not exceed the 10 year fuel saving, i.e. (annual total horizontal radiation x 0.3 x unit heat cost x 10) >= collector unit cost.

As a rule of thumb, 1.0 kWh/m² combined diffusion and direct radiation can be assumed for Western Europe and up to 60 ~ 75% of this energy can be recovered depending on collector and system type.

This energy can be used to supplement the heating loads during winter months but the most common applications for the solar collectors in the Western Europe still remains in hot water production.

The following hot water consumption can be used as an initial design guide to size the collector area, water consumption and water storage volume based on average 10 °C city main water intake;

Application	Consumption	Collector Area	Storage Vessel	Cost Min.
	Lt./per person	(m ²)	(lt.)	(£)
Low Demand	35 ~ 50	0.85	44	169 ~ 542
Medium Demand	50 ~ 70	1.19	61	237 ~ 759
High Demand	70 ~ 115	1.95	101	389 ~ 1246
Hotels (Bath only)	115 ~ 170	2.88	149	576 ~ 1842
Hotels (Bath & Shower)	170 ~ 260	4.40	228	881 ~ 2818

3.0- What system ?

The choice is between air and water systems, which can only be decided in conjunction with the consideration of storage medium. Air systems lend themselves for use with crushed rock or gravel heat stores. If the storage medium is to be water, then the use of water for collection fluid is preferable.

Both systems can be good, both have certain advantages and disadvantages. With air systems there is no freezing problem and no corrosion risk. However the collector, the ductwork and the storage will all be bulkier than with a water system. Air systems can normally be competitive in cost only if the building is designed around the system.

Water systems offer a greater flexibility in design and in operation and a higher degree of accuracy in controls. They can be readily coupled with conventional central heating and hot water systems. Provisions must be made to avoid the risk of freezing and corrosion. Any leakage of water may damage the fabric of the building—a risk, which does not exist with air systems.

If the purposes of collection include air conditioning, i.e. the operation of an absorption cooler, refrigeration heat pump then water is the only medium (or some other liquid) that can be used in the collection circuit.

Some of the typical designs are highlighted in Figure 3.1

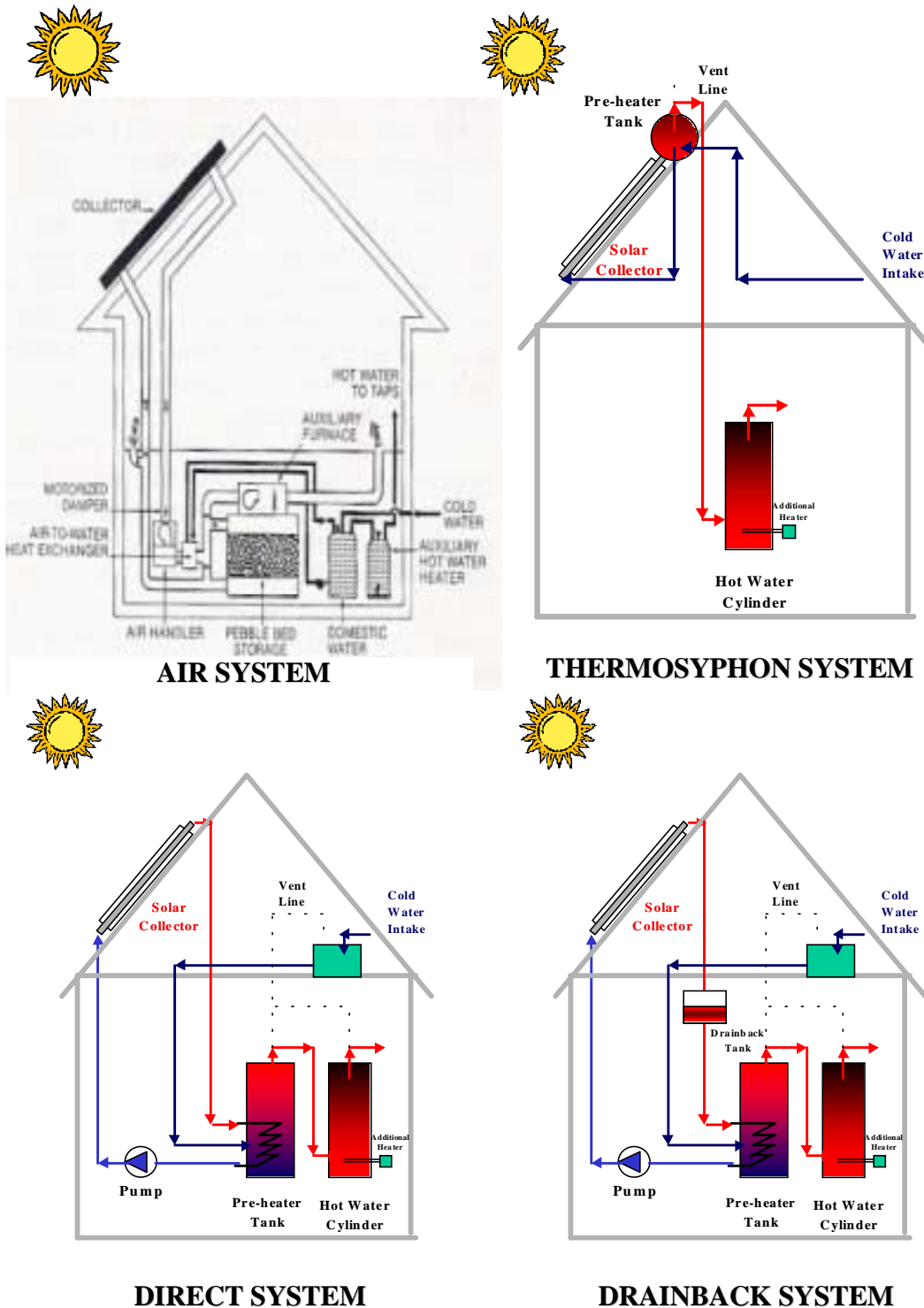


Figure 3.1- Typical Solar System Concepts

4.0- What size collector?

A small collector will work usefully all-year-round, thus the capital investment is better utilised, but it will contribute very little in winter.

A simple rule-of-thumb is to use a collector of about half of the floor area. This may be followed in the sketch-design stage. When the design of the building has been completed, its thermal characteristics have been defined in terms of the specific heat loss rate and/or hot water consumption rates when the unit cost of the actual collector is known, a quick optimisation exercise can be carried out. The base data for this should include monthly total radiation values and the number of degree-days in each month.

It must however be realised that both methods are based on certain efficiency assumptions and that complete reliability could only be achieved by a full system simulation, in which the efficiency figure is produced as a conclusion and not used as a starting point.

This however requires the use of fairly sophisticated computer programs, and therefore it may be argued that unless the designer has access to some research group and can obtain such a computer analysis, there is not much point in carrying out an optimisation exercise, which is unlikely to be much more reliable than the rule of thumb quoted above.

Some of the most commonly used collector types are illustrated in Figure 8.1.

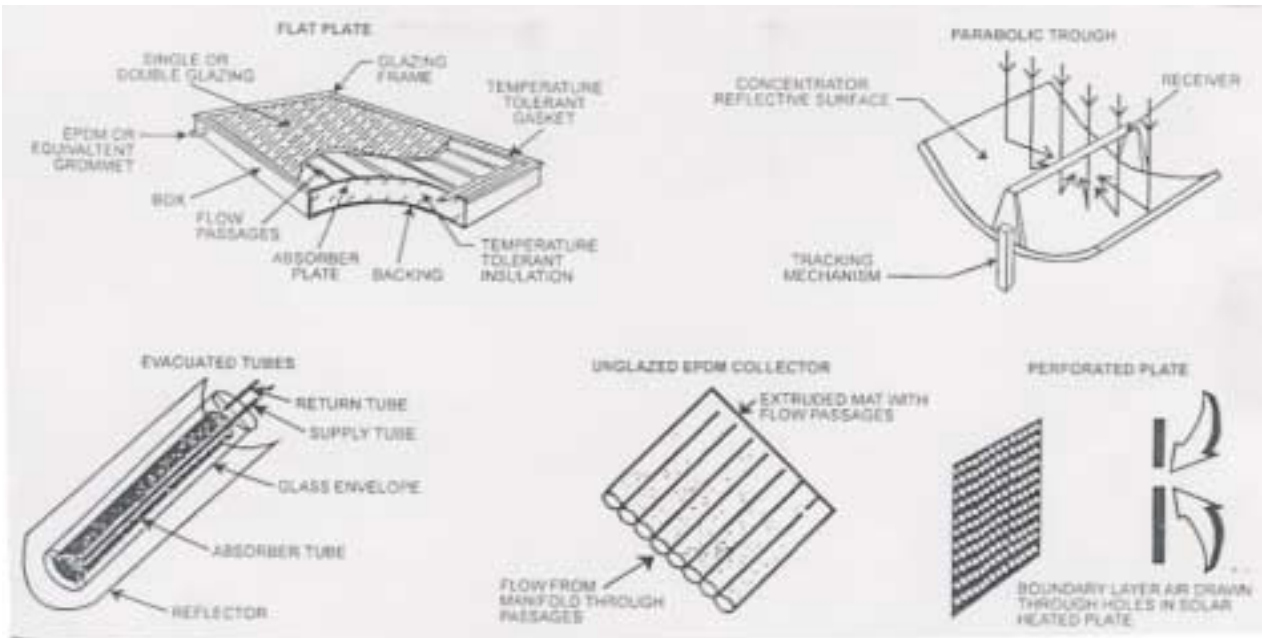


Figure 8.1- Commonly used collector types

5.0- What collector position ?

The collector should obviously face the noon sun (south on the Northern Hemisphere and north on the Southern Hemisphere)-or nearly so.

Regarding tilt, the simple rule-of-thumb suggests an angle equal to the geographical latitude. A precise definition of the optimum tilt is possible if hourly data of diffuse and direct radiation (separately) is available and is used in a computer program.

This type of optimisation will show that there is a fair degree of tolerance. When e.g. the optimum is 34°, practically any tilt between 30° and 70° will be acceptable. Thus the architect has a considerable freedom.

He may opt for a slightly inclined solar wall or for a solar roof, depending on his design concept influenced by factors other than solar. The exact tilt may then be determined by constructional detail considerations or by the availability of components.

6.0- What size storage ?

The widely accepted rule-of-thumb suggests that for every m² collector area one should have a water storage volume of anything between 50 and 100 litres (or the equivalent in other forms of heat storage, giving a capacity of 58-116 Wh/DegC) .

The lesser volume will be more fully utilised, but by reaching a higher temperature more rapidly, it will result in a reduced collection efficiency. The larger volume may not be fully utilised, but would ensure a cooler temperature fluid returning to the collector, thus the collection efficiency would be increased.

The choice will depend on the desired collection temperature. If higher temperatures (around 50°C) are necessary, a smaller storage will be advisable. If lower temperatures (30-35°C) can be made use of, a larger storage will give better service.

Thermal properties of the building may also influence the choice. A massive, high thermal capacity building fabric can take over some of the storage function, thus the storage tank can be smaller. With a lightweight building, however well insulated, a larger storage tank may be necessary, even beyond the above quoted range, up to about 150 litres/m².

Finally, the climate pattern has a significant bearing on the desirable storage volume. Where there is a smooth transition from a cold winter to a hot summer, but there is not much day-to-day change, the storage capacity need not be more than a day's heat requirement. However, in a climate such as that of Britain, where there is no great difference between summer and winter, but almost the whole range of annual changes may occur within days, a larger storage is fully justified.

There is no point however in having a storage of more than 4 or 5 days' heat requirement, unless one decides to attempt an inter-seasonal storage. This would have to be larger by at least two orders of magnitude (e.g. 200 m³ as against 2 m³). The feasibility of this is yet to be proved.

7.0- What auxiliary heat supply ?

Some auxiliary heat source is necessary, not just as a stand-by unit to be relied on in case of inclement weather, but as part of the normally operating system. Only in very favourable climates can the solar heat source be relied on exclusively in normal operation.

It is suggested that in less sunny climates the solar source should normally be used as a preheater only, with the auxiliary heat source acting as a topping-up device. During favourable periods this topping up may not be necessary.

The choice of the actual heat source will very much depend on local factors. It may be chosen on the basis of conventionally applied criteria. It may be an ordinary gas fired boiler (if gas supply is available), an oil fired or solid fuel boiler (if storage facilities can be provided), or, failing these, it may even be electricity. If however off-peak electricity is used, the above suggestion will not be applicable. Then the heating element will have to be located in the storage tank and there is no possibility for a flow-through type topping-up arrangement.

8.0- What emitters ?

The distribution system and the heat emitters may be any of the conventionally used types. The aim of the designer should be to make use of the lowest possible water (or air) temperature compatible with the heat delivery requirements. This would imply that either large surface radiant panels (e.g. floor or ceiling) or convectors with an increased heat transfer surface and air volume delivery will have to be used.

9.0- What controls ?

Where the designer (or someone intimately involved) is to be the user of an installation, manual controls may give a satisfactory operation. In all other cases at least the collection circuit should be controlled automatically. This can take three forms

1) time-switch

2) solar switch

3) differential control

(A thermosyphon system would be self-regulating, but this would require an elevated tank, which is practicable only with small-scale water heater units.)

Time Switch is a rather crude device that would start the circulating pump a few hours after sunrise and switch off around sunset. It would ignore any weather variation. It would not only be wasteful in pumping power, but might in fact dissipate the heat already in store.

Solar Switch may be a photoelectric device or a thermopile, which would trigger off a switch when the radiation intensity reaches a pre-set level and switch off when it drops below this level.

A variant of this is the use of a solar cell array not just as a triggering device, but as the actual source of pumping power. Both these methods of control would follow weather variations, but would still ignore the state of the system, the temperature of the heat store

Differential Control is the most sophisticated. It would use two sensors and a differential controller. A temperature sensor (a thermistor or a thermocouple) would be installed at the top of the collector plate near the flow outlet, another one at the bottom of the storage, near the return outlet.

The differential controller would switch on when the reading of the first sensor exceeds that of the second one by a pre-set limit and switch off when the bottom temperature reaches the flow temperature

Controls of the distribution circuit can be quite simple and the operation may be satisfactory with manual controls. If however a topping-up arrangement is adopted, a manual control may be used to bring on the emitter (the circulating pump and the convector fan), but the phase selection should be made automatic.

Two sensors are to be used, one at the top of the storage and another in the return pipe past the fan-convactor. When the first gives a high reading, the boiler is shut off. When it drops below a pre-set level, the burner is switched on. It acts as a simple thermostat. When however its reading drops below the reading of the second one, the differential controller will operate a motorised valve and the tank will be switched out of the circulation.

The manual switch operating the emitter may also be replaced by a time switch, by a room thermostat or by a combination of both. With all these controls the adjustability of settings is essential to allow for 'tuning' of the system during the commissioning period.

10.0- Developments

There is a tremendous scope for innovations both in system design and in constructional detailing. The field has not nearly been fully explored. The principle of such attempts should be to collect heat at the lowest useable temperature, and literally squeeze out every degree of temperature from the transfer fluid before it is allowed back into the collector.

Many designers got carried away in such attempts and produced overcomplicated systems. As in any design work, the product may go through a stage when it is highly complicated, but the most successful products will have matured into an elegant simplicity.

In constructional design, development is possible in several areas. The design of new emitters is not exactly an architectural task, but there is an opportunity of integrating them with the building fabric (e.g. floor or ceiling). The storage vessel could definitely be made to be part of the building, possibly even in a structural role

The greatest scope is offered by the development of new collector types, not only efficient in operation, but also full-fledged building components. The metal parts carrying the thermal fluid could be shaped to act as structural members and span over longer distances. The insulating backing could be made to provide e.g. a ceiling finish. Producing cheap collectors is one way of improving the economics of solar heating, but producing multi-purpose elements, thus obtaining savings in building is an equally valid approach.

A simple solar heat pump, which has an average, COP of 4 ~ 6 may offer ideal opportunity to combine cooling and heating applications. The saving from conventional air conditioning machinery can easily pay the cost for a very cost effective solar energy solution. A typical Solar Heat Pump design is illustrated in Figure 10.1 and this design can be cost effectively applied for both domestic and commercial applications whereby a combine cooling and heating load exists.

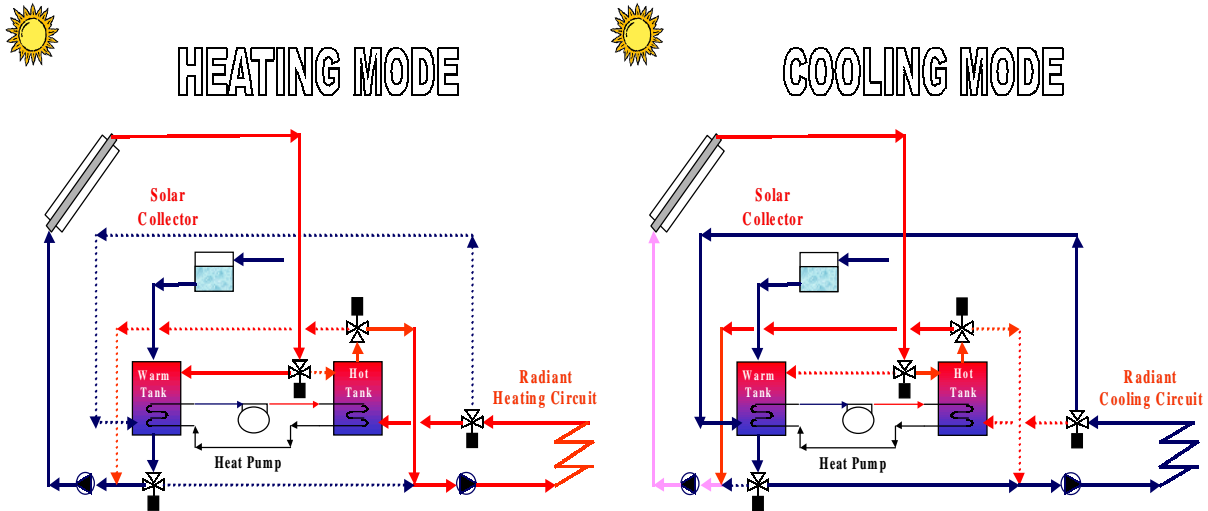


Figure 10.1 – Solar Heat Pump Applications

Eutectic PCM Thermal Energy Storage for positive temperatures offers to fill the time gap between the energy availability and energy usage for an optimum economical utilisation of solar energy.

The latent heat of PCM solutions offers significant water / air storage volume reduction in the order of 1/10 as the steady temperature operation can be achieved via their Latent Heat Capacity against the pure Sensible Heat Capacity of conventional storage systems.

A list of commercially available PlusICE PCM solutions is included in Table 10.1.

	Temperature		Density		Heat of Fusion		Latent Heat	
	(C)	(F)	(kg/m ³)	(lb/ft ³)	(Kj/kg)	(Btu/lb)	(MJ/m ³)	(Btu/ft ³)
A4	4	39.2	766	47.8	227	98	174	4665
E8	8	46.4	1473	92	140	60	206	5529
A8	8	46.4	773	48	220	95	170	4559
E10	10	50	1519	95	140	60	213	5701
E13	13	23.4	1780	111	140	60	249	6681
E15	15	59	1778	111	141	61	251	6721
A15	15	59	780	49	231	99	180	4831
E18	18	64.4	1490	93	150	64	224	5992
E21	21	68.9	1480	92	150	64	222	5952
E24	24	75.2	1704	106	167	72	285	7629
E27	27	80.6	1562	97	191	82	298	7999
A28	28	82.4	789	49	245	105	193	5183
E30	30	86	1374	86	200	86	275	7367
E32	32	89.6	1460	91	186	80	272	7281
E48	48	118.4	1670	104	201	86	336	8999
E58	58	136.4	1280	80	226	97	289	7756
E89	89	192.2	1550	97	163	70	253	6774
E117	117	242.6	1450	90	169	73	245	6570

A - Alkine / Aliphatic Based Solution E - Eutectic Based Solution

Table 10.1 – PlusICE Eutectic Solutions