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INTEGRATION OF SOLAR THERMAL COLLECTORS ON FACADES: A REVIEW OF INSTITUTIONAL BUILDINGS

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Abstract: **The utilisation of alternative energy in buildings are getting closer to being a basic process in the construction of projects with the need of having sustainable building outlines with energy efficiency and expanding the exploration and utilisation of renewable energy sources in the industry with examples in solar energy, wind energy and geothermal energy. Solar thermal systems have turned into alternatives in the energy efficiency of current buildings, therefore less energy expending buildings, utilising the solar energy as an alternative in process are increasing and this has a tendency to give answers for energy issue which furthermore increase the lifecycle and decrease the upkeep of the buildings in general. Solar thermal systems integration in buildings have increased the performance through utilizing most building components and envelope for the generation of energy or reduction of its use which are the use of mounting solar panels ,integration of PV in windows, facade and roof of buildings. For better understanding, this paper will compare some institutional buildings which use solar collector integrated facades, analyse the methods of application on façade, efficiency of the generation and a critic of the general use of solar collectors integrated facades. The final result of this work will help and encourage designers on specifications and integration techniques and know-how of which method of integration is best suited to be used on their building projects.**

Keywords: **alternative energy, buildings, facade, energy efficiency, integration, solar thermal collectors, sustainable.**

1. INTRODUCTION

The need for sustainability which was caused by the resource consuming life style in our modern community, put us and future generations at great risk and we are given a huge problem to deal with on hand. It is therefore of the highest importance that this problem is addressed effectively and urgently. The use of fossil fuels must be significantly reduced and renewable energy sources implemented on a large scale throughout our communities.

Recently, approximately 80% of the primary energy use in the world is provided by fossil fuels and only about 13% by renewable energy sources. The energy use within the building and service sector accounts for a large share of the total energy use, approximately 40% both in Sweden and in the European Union[1]. This energy demand can be lowered significantly by using improved building construction techniques and a great part of the energy used for space heating and domestic hot water can be supplied by solar thermal energy, which is not only renewable, but also clean in the sense that the conversion phase does not give rise to any green house gas emissions [2].

The solar thermal market has a gigantic potential for development [3]. The solar energy got by the earth amid one hour is more than the aggregate yearly energy request around the world. Clearly we could benefit from sun based energy to a far more prominent degree than what is done today.

The best test has been on the cost of sunlight based warm frameworks which has not been adequately low to make these frameworks promptly accessible. This example is starting to change with rising energy costs, be that as it may, it is not rapidly advancing. Remembering the ultimate objective is the usage of sun powered warm energy, there are a couple ways to deal with dealing with the issue. Enactment is a way, viably sharpened in some European countries. Legislative sponsorship is another route, in which progression is critical.

Although the collectors of today are already highly developed it is also important to continue the development of collectors and system designs in order to improve their efficiency, quality, life expectancy, profitability and many other features [2].

Buildings ought to dependably be composed and worked in an energy productive way. Energy utilized for construction and working the building ought to be minimized. On account of new construction this should be possible through fitting introduction, detached utilization of sun oriented energy and determination of suitable materials. According to [4], suitable materials implies they are delivered or extricated by next to no utilization of energy beyond what many would consider possible.

In old buildings energy utilization can be diminished essentially by protecting the building shell, utilization of windows with better warm execution, trade of warming frameworks and so forth. The rest of the energy request ought to be secured by dynamic frameworks that utilization energy from a renewable source [5]. This renewable source can be dealt with from solar based energy.

Utilisation of solar energy for power and warming is a noiseless and non-dirtying way that requires the least upkeep. Be that as it may, their joining into buildings speaks to a genuine engineering challenge, as to an extraordinary degree, the improvement of heavenly bodies for energy has been portrayed by the desire for energy adequacy and minimal effort, while the compositional angles have been dismissed. Indeed, these frameworks can be coordinated into buildings as a multifunctional component that expands the compositional quality other than giving free energy [17].

Finally, this paper studies the integration in terms of sustainability potential of these systems, the solar thermal collector to be used in different regions in institutional buildings. This research is basically confined to the architectural integration of solar thermal collectors into buildings, both new construction and existing. This review is not considering integration into urban spaces and landscapes rather focused on integrating into buildings on individuality. Different aspects of integration have been explained with relevant examples to make the study illustrative and comprehensive.

2. LITERATURE REVIEW

2.1 Solar thermal collectors:

Solar innovations utilise energy from the sun to warmth water at helpful temperature. This permits supplanting other energy sources, for example, normal gas and power as the method for giving boiling point water to the building. Essentially, sunlight based warm applications change over the short-wave sun based radiation into long-wave warm radiation. This happens in the safeguarded material, which must minimise response and expand transmittance of the sun oriented energy.

Consequently, specific safeguard materials have been produced in dim hues keeping in mind the end goal to expand the changing efficiency. The nature of a gatherer relies on upon the level of efficiency, that is the proportion of the warmth stream to the worldwide radiation episode on the authority [6].

With reference to [7] in her Ph.D proposal have depicted the sun based warm framework as dynamic. Energy when gathered on surfaces improved for warmth accumulation called safeguards which are set on outside of the building conceal and transported by a medium either straightforwardly to the place of utilization or to a capacity to be utilized when required is regularly known as a dynamic framework. As indicated by the medium utilized, dynamic frameworks are principally of two sorts: air authorities and water gatherers.

For this undeniable reasons, a capacity and a legitimate control have an imperative part in the energy arrangement of the building. The sun powered warm frameworks have this assignment to change over sun based energy into warmth and store it which makes it accessible when it is required by the building clients. The warm energy is by and large utilized as a part of the working to warm or to cool indoor spaces and to warm the sterile water.

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2.2 Water based collectors:

The water based collectors are utilised for reconciliation on the envelope and exterior of the buildings and these savvy frameworks are additionally called pressure driven gatherers. They permit simple stockpiling of solar gains and are appropriate both for local boiling point water creation and space warming. Their medium comprises primarily of water accused of glycol in factor rates to abstain from solidifying as indicated by the particular atmosphere. Since water has a decent warm limit, it is able to do great nature of warmth trade both with the safeguard and the capacity.

The sun oriented energy picked up can without much of a stretch be put away in protected water tanks and effectively be utilised. The water powered frameworks can be partitioned into four sorts as evacuated tubes, glazed flat plate collectors, unglazed flat plate collectors and unglazed plastic collectors[9].

2.2.1 Evacuated tubes collectors:

Evacuated-tubes collectors are made out of a few individual glass tubes, each containing a safeguard plate clung to a warmth pipe and suspended in a vacuum. The considerable protection force of vacuum permits working at high temperatures even in cool atmospheres basically because of low warmth misfortune. These frameworks are appropriate for local reason for warming water and spaces furthermore for mechanical applications where high working temperature is required. The adaptability to arrange the internal safeguards freely from the module mounting point in a profitable component of this kind of authority [9].

Fig 1: Evacuated tube collector set

(http://greenbrotherservices.blogspot.com)

Fig 2: Evacuated tubes

(Maria Cristina)

2.2.2 Glazed flat plate collectors:

These are the most widely recognized collectors utilized for local high temp water and space warming. A flat-plat authority comprises essentially of a protected metal box with a glass or plastic cover (the coating) and a dull hued safeguard plate. Sun oriented radiation is consumed by the safeguard plate and exchanged to a liquid that courses through the gatherer in tubes. These collectors warm the flowing liquid to a temperature not exactly the breaking point of water and are most appropriate to applications where the request temperature is 30-70°C and for applications that require warm amid the winter months [9].

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Fig 3. Glazed flat plate (http://www.homepower.com/articles/solar-water-heating/domestic-hot-water/saving-solar-pool-heating)

2.2.3 Unglazed flat plate collectors:

Unglazed flat plate collectors are in fact less perplexing than coated or evacuated collectors. They are made of less layers and can be collected without the requirement for various jointing. These are made out of a particular metal plate which is the safeguard, a water driven circuit warmed up by the safeguard and by a back protection. Instead of the coated collectors, the safeguard is not protected by a covering coating and working temperatures are likewise nearly bring down [11]. A unique kind of unglazed authority called a punctured plate gatherer is utilized to preheat ventilation air for commercial buildings [13].

The absence of the defensive straightforward cover adds to the diminishment of optical misfortunes, however, the immediate presentation of the safeguard to the encompassing air expands the warm misfortunes by radiation and convection, with a noteworthy affect the ability of the safeguard to wind speed, making the unglazed collectors reasonable for effective operation just in low temperatures.

Then again, the minimal effort of unglazed collectors is a preference for financially savvy sun based warm energy applications in this temperature extend, e.g. water preheating for residential or mechanical utilise, water warming of swimming pools, space warming, air warming for modern or rural systems and so on [10].

Fig 4: Unglazed flat plate collectors integrated on the façade (Energie Solaire)

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2.2.4 Unglazed plastic collectors

Collectors of this sort are generally made of dark plastic or elastic that has been balanced out to withstand bright beams, and are not protected. In any case, a huge bit of the heat assimilated is lost, especially when it is blustery and not warm outside. They exchange warm so well to air and from air that they can really catch warm amid the night when it is hot and breezy outside. Because of their low working temperatures they are helpful for swimming pool water warming [11].

Fig 5: Unglazed plastic collectors

(http://www.solarexpert.com)

2.3 Advantages and disadvantages of solar collector types:

There are several advantages and disadvantages to the types of solar thermal collectors mostly depending on temperature, sun intensity, solar incident angle, mode of operation and other factors. The mode of their creation and character slightly influences some operational capabilities of the collectors below is a table showing the operation temperature, efficiency and their typical application areas.

Table 1

Solar Collector Type	**Opertaing Tempeture(^oC)**	**Degree of Effiency(%)**	**Typical application on building**
Evacuated tube solar collectors	70-130	80-85	Domestic hot water, space heating and cooling, industry
Glazed flat plate solar collectors	60-90	65-70	Domestic hot water, space heating and cooling
Unglazed flat plate solar collectors	30-40	40	Domestic hot water, space heating, pool heating, pre-heating

2.3.1 Evacuated tube collectors:

Advantages:

- Different from different sorts of sun powered collectors, evacuated tube collectors still give an additional remarkable outcome in shady days, this is so since they can retain the energy from diffuse radiation on a shady day.
- Wind and lesser temperatures likewise limitedly affect this gatherer because of the great protecting properties around the authority. As the tube is round, the aggregate sum of sun powered radiation striking the authority is moderately consistent.

- The evacuated tube collectors are composed particularly to work at high temperatures and demonstrate their most noteworthy execution at 100°C.
- They are very much adjusted to the warming of modern and business high temp water additionally to the cooling of buildings by recovering refrigeration cycles [16].

Disadvantages:

- Initial cost can be a disadvantage

2.3.2 Glazed flat plate solar collectors:

Advantages:

- These collectors have better energy ratings than the unglazed flat plate collectors at 50°C

Disadvantages:

- Flat plate-collectors are subject to a high heat loss factor (about 2.9 to 5.3 W/m^2).
- These collectors have lower energy ratings at 100°C than the evacuated tube collectors. Thus, they are used for heating domestic water [16].

2.3.3 Unglazed flat plate solar collectors:

Advantages:

- Since these collectors have no coating, a bigger segment of the sun powered energy is ingested.

Disadvantages:

- A vast part of the consumed warmth is lost, especially under blustery and cool climate conditions as these collectors are not protected.
- When subject to a high warmth misfortune the efficiency decreases drastically as the yield temperature increments.
- They deliver high energy appraisals at 35°C, low evaluations at 50°C and typically zero at 100°C. Along these lines, they are for the most part utilized for warming swimming pools [16].

2.4 Advantages and disadvantages with integration in buildings:

From a technical point of view, the facade is also a part of the building envelope which is the separation between the interior and the exterior environments of the building. The facade deals with tasks such as the view, lighting, ventilation, user thermal comfort, some building services and possibly load-bearing [12].

Therefore these are some of the pros and cons of integration on elements of the facade.

2.4.1 Window based:

Advantages:

- When the solar collector component is placed within a cavity of glazing unit it has no reduced life expectancy.
- This regulates the visual relations between inside and outside with the supply of fresh air, daylight and passive solar gains.
- There is high grade of pre-fabrication possible.

Disadvantages:

- This has a low light transmission through solar collector components.
- These have risks in reducing the life expectancy caused by water leakage or thermal breakage and expansion under high temperature [14].

2.4.2 Wall based:

Advantages:

- This is an economical and high efficient solution as an active solar collector in the finishing layer of the external insulation.
- This lessen the climate disturbance of original facade system.
- It also improves the thermal insulation of the building.
- It has the most solar collection area.
- It is simple to arrange.
- Well suited for superimposing in an existing building.
- Pre-fabrication for this is also high.

Disadvantages:

- Solar collector components require to be of high quality, material expansions compatible and installation due to totally external exposure.
- There is more costs for outdoor cleaning and maintenance of facade.
- A risk of condensation and thermal frost within insulation.
- They have a cold bridge and acoustic problems at a penetration hole [14].

2.4.3 Balcony based:

Advantages:

- The optimum overall shading with full room height visions allow an adequate day lighting.
- Energy output independent of orientation and solar angle for the vacuum tube collector.
- Easy cleaning and maintenance.
- They are well suited for superimposing in an existing building.
- Also high grade of pre-fabrication in the system.
- Reduces the cost of shading.

Disadvantages:

- Solar collector component requires high demands in both quality and installation due to totally external exposure for both overall performance and safety aspect.
- Extra support structure is needed to support the balcony [14].

3. CASE STUDIES

This section considers some institutional buildings such as schools and offices with the solar integrated facade, study on the application and other properties. The integration may be Window based, balcony based or wall based, the analysis will also help in choosing the right and optimum technique on these categories of buildings.

3.1 Office Building in Switzerland- Facade system:

In this review the South confronting façade of the Center d'entretien des Routes Nationales (CeRN) in Switzerland, is secured with the Solaire Energie unglazed solar thermal collectors which goes about as a multifunctional material. The North confronting façade of the building is then secured with stainless steel components of a similar geometry however not thermally dynamic.

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The south façade comprises of stainless steel solar collectors. The gatherer comprises of two sheets of stainless steel which are amassed consecutive making their pinnacles and edges moved so as to identify with each other so the liquid can move through the subsequent voids.

This strategy gives a uniform stream of water and warmth exchange which is especially viable since the liquid is in contact with nearly the whole surface of the authority sheet. The authority region is 576 m2 and they are pre-manufactured off-site and amassed nearby. The 576 m2 of thermal solar collectors deliver 288,000 kWh/year [15].

Fig 6: Solar integrated on the Centre d'entretien des Routes Nationales (CeRN) in Switzerland(Rafaella Agathokleous,2014).

3.2 University in Stuttgart, IBK 2 – Window system:

The University of Stuttgart has developed a facade system which uses integrated evacuated tube collectors to generate solar heat at a high temperature and provide semi-transparent light and protection against the sun for indoor areas without impairing the view. This system is particularly suitable for offices and other functional buildings with a large number of windows. It can also be used as an architectural design element for facades enhancing the aesthetic quality.

The superior evacuated tubes are furnished with punctured allegorical mirrors which are coordinated into a unitised façade. The mirror packages the immediate radiation of the sun and part of the diffuse light onto the evacuated tubes in doing as such decreasing solar additions and consequently the related cooling necessity of the working by somewhere around 70 and 90 %. By changing the example and size of the apertures on the mirrors, the interaction between gatherer yield, sun insurance and room lighting can be streamlined or modified. From within the building, the daylight seems decreased, is uniformly conveyed and is not making inconvenience the human eyes [15].

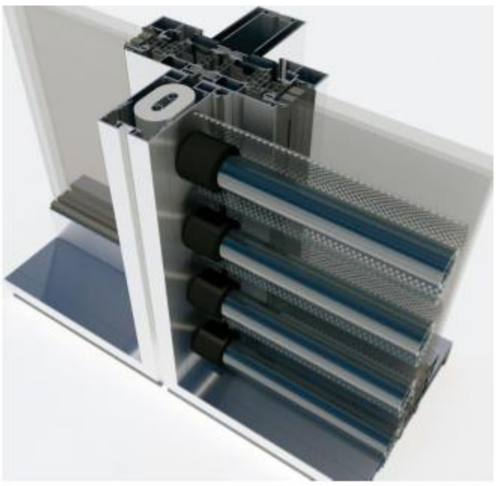

Fig 7: Evacuated tubes and perforated parabolic mirrors developed (Rafaella Agathokleous,2014).

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20 mm thick laminated safety glass cover panel is used to provide the required safety in contrast. Simulations have shown that the choice of glass has a greater influence than the perforation of the reflector mirror on the energy yield of the system.

By utilizing evacuated tubes the framework is secluded and can be introduced on building veneers of various sizes. For compositional, geometric, specialized and visual reasons, the even arrangement – as with sun insurance blinds – has ended up being the most appropriate.

Fig 8: University of Stuttgart integrated façade (Rafaella Agathokleous,2014)

3.3 Environmental Research Station Schneefernerhaus - UFS, Germany - Facade system:

This retrofitting project with building coordinated solar thermal framework is situated at Germany's most astounding mountain from a stone working into an examination station. With including extra thermal protection, 100m2 solar collectors were coordinated in the building exterior too for both Domestic hot water readiness and space warming. The related water based warmth dispersion comprises with floor warming and radiators, while warm pumps and power are set for helper warming. The cost of every authority was € 943 with aggregate solar pick up of 60 000 kWh/year [14].

Fig 9: Environmental Research Station Schneefernerhaus (http://www.schneefernerhaus.de/en/home.html)

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3.4 Hotel Jezerka, Czech Republic – Balcony:

This solar thermal application pays exceptional thought to the level establishment with 236m2 solar collectors in the south-bound galleries for warming faucet water and swimming pools. These collectors were planned as handrails of overhangs not on level rooftops where vertical collectors would be over-burden by wind. The cost of every authority was € 364.8 with aggregate solar pick up of 120 000 kWh/year [14].

Fig 10: Hotel Jezerka, Czech Republic (http://www.legrestour.com/en/ceska-republika/hotel-jezerka-d21)

3.5 Retrofitted Office Building in Ljubljana, Slovenia:

This is a detail composed retrofitting venture with solar thermal framework application. The air warming vacuum tube collectors supplant the balustrade on the fifth floor, while the straightforward solar thermal collectors are joined to the stairwell. Both gatherer ranges confront south, the solar collectors 15° towards east and the air-warming tubes 15° towards west. Both segments are created to be a substitute for the building skin and in addition the thermally enacted assembling arrangement of 100 m2 office space with liquid at temperatures over 35 °C amid the warming season [14].

Fig 11: Office Building in Ljubljana, Slovenia (Zhang X et al. 2015)

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4. FINDINGS AND DISCUSSION

From the first case study, the solar thermal collectors are integrated on the facade facing the south to provide domestic hot water, control light and temperature through the building. This system ensures the provision of domestic hot water throughout the building without reliance on electric supply. The system also provide an aesthetic pleasing facade but the unglazed wall systems are hard to maintain. These systems add additional function to the buildings.

From the second case study, the solar thermal collectors were integrated in the window system which apart from provision of hot water has other qualities of Integrated systems. These qualities are sunlight control and aesthetics. These systems reduce the demand for energy in water and cooling because of its multi-functionality. The systems are harder to maintain because it cannot be easily accessed. The arrangement of the systems makes it easier to install and fabrication is also faster.

From the third case study, the solar collectors were retrofitted this shows the systems can also work in old or existing buildings. These integrated systems provide space heating and thermal insulation as it is located on a high point and temperatures are very low reducing the electricity consumption and footprint of the entire building. Though these systems are fairly high in price, the total benefits and long term cost tends to be lower with the life cycle of the systems.

From the fourth case study, the solar thermal systems were integrated horizontally on the balconies to provide hot water for the hotel users and heat the swimming pool. The handrails also were integrated with these systems. The fabrication degree is higher making the cost higher but provision is high reducing the demand from the grid.

From the fifth case study, the collectors were also retrofitted on the south side of the building using balustrade and stairwell. They provide additional thermal heating to the building, the placement also shows the flexibility of the system on the envelop of the buildings.

From all the case studies, the solar thermal systems serves as an alternative to the conventional building material on facades and also as domestic hot water, space heating and energy generator to the building. There are factors that affects the efficiency of all solar thermal systems in different regions under different conditions. This efficiency depends on the type of collector, tilt and orientation, overheating, shadowing and annual average daily solar radiation.

Solar thermal collectors are oriented based on the location of the building on the hemisphere .Sunlight being the fuel to these systems, output and generation will be more at long sunny days. As such, to make use of the solar energy more effectively the façade integrated with solar collectors is placed more towards where the sunlight duration is more for example in the northern hemisphere south areas will be more effective.

5. CONCLUSION

With these discussions, it is clear that the integration of solar thermal systems in building façade is a very good and efficient alternative to the conventional building material used in façade designs .Not only as building material, the integration of the system have changed the building position from an energy consuming element to the energy generating element. This integration also protect building occupants from outer weather influence, noise and daylight control.

Solar integration in façade may not seem to be highly efficient due to verticality and orientation, but it is more effective in the case of solar balconies and shading devices on façade. The enormous façade gives space for large installations and generation of heat to the building but still roof integration gives more popularity than façade integration.

The similarities between the installation on façade and the conventional facade material system used, this makes the technique of the solar integration on facades not complicated or brand new. The installation of the solar collector system on the façade can be done using the standard glazing system like the structural sealant glazing or using the standard curtain wall system, in the case of shading and balconies it is also quiet similar.

The main advantage of the system is though the initial cost is higher, the systems replace the conventional cladding materials which when installed do not produce any energy and do not have any payback time rather they require additional cost of regular maintenance. Moreover, solar thermal systems gives a pay back to their initial cost of installation after some years. They have a high guarantee value that they work for years without any need for maintenance.

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Furthermore, the integration of solar collectors in building façade gives a wide range of opportunity in terms of the sustainable energy generation and heat generation which is alternative to conventional building materials and also gives a life cycle effectiveness to building efficiency and maintenance.

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