



# High Rise Buildings and Solar Water Heater Installations

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## 1- Introduction

There is a growing demand for the integration of renewable energy into buildings, especially with the new construction law under study in Lebanon that aims to increase the allowed building heights. Of the many renewable energy sources available, solar water heaters (SWH) have the most mature market due to the advanced development of the technology and the financial initiatives available to the consumer. Part of initiative 4 of the NEEAP (National Energy Efficiency Action Plan) is to “prepare a draft law incorporated into building code to enforce the use of solar water heaters in new and existing buildings in 2012” (LCEC, 2012). CEDRO Exchange Issue 8 investigates the available techniques to integrate SWH into high rise buildings (defined here as building with at least 8 floors and more).

## 2- Beirut's Urban Plan

As per Eric Verdeil, researcher at the CNRS (National Council for Scientific Research), Beirut has become a massive agglomeration of concrete structures with random heights and varied setbacks hence casting shadows on neighbouring lower structures (<http://www.worldviewcities.org/beirut/urban.html>). According to the Order of Engineers and Architects' yearly statistics, of the 1,086,382m<sup>2</sup> registered structures in 2012, 83% are residential. It is worth noting that when compared to 2011, 2012 has registered a decrease in construction registration in all regions except for the Bekaa region, and Beirut has registered the highest reduction with 18% (OEA, 2012). Figure 1 shows the most recent map of urbanized area of Beirut (dating back to 2005) available in the Geographical Information System (GIS).

The below map shows an urbanization ratio (ratio of built up space over total Beirut area) of 0.23 in 2005. When referring to the OEA statistics, the 10.6 km<sup>2</sup> that have been licensed and completed between the years of 2006 – 2012 increase the urbanization ratio up to 0.73.

A new construction law is in the works to increase the allowed building heights in order to cater for the congestion some cities are facing, especially for Beirut. Whether this allowance is positive for the urban environment or detrimental or whether the authors support it or not, is outside the scope of this Exchange, however within this Exchange's scope is how the integration of solar hot water systems can occur for apartments within high-rise buildings.

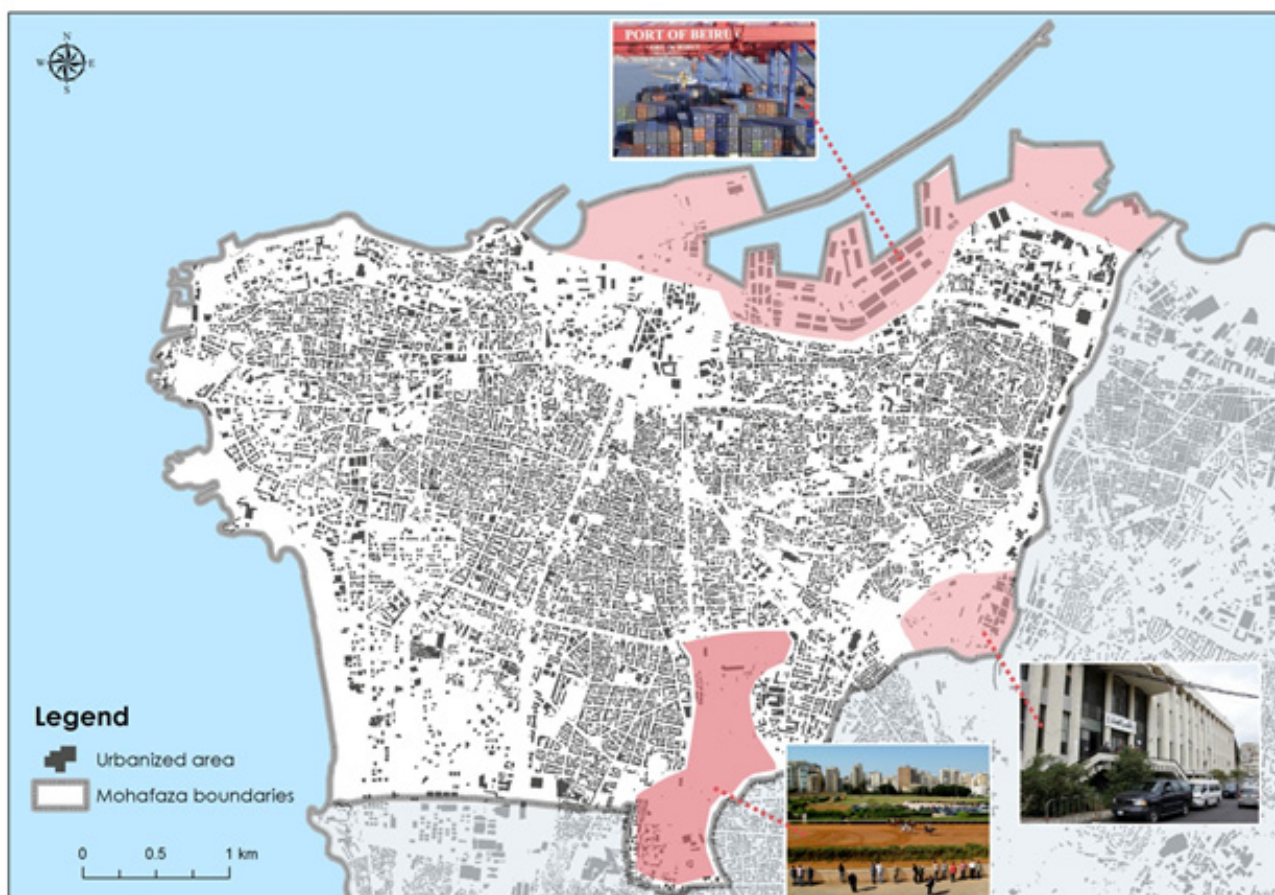


Figure 1: Urbanized Beirut District (source: GIS, 2005)

### 3 – Installations

Installation options for solar hot water systems are presented through a case study of one typical building found in Beirut.

#### A- Case presentation

A sample has been chosen, Beydoun family building in Beirut:

Latitude: 33°53'48.40"N

Longitude: 35°28'53.73"E



Figure 2: Overhead satellite view of Beydoun family building (CEDRO, 2013)

The building is 17m tall and 17m wide; the roof area: 289m<sup>2</sup> (measured outer wall / outer wall) for 12 floors.

Each floor is considered two apartments of 124m<sup>2</sup> each; totaling 24 apartments. The satellite picture of the Beydoun Building shows that the roof is partially used for other utilities.

2m<sup>2</sup> + tank Solar Water Heaters are used installed at 35° tilt for optimal performance.

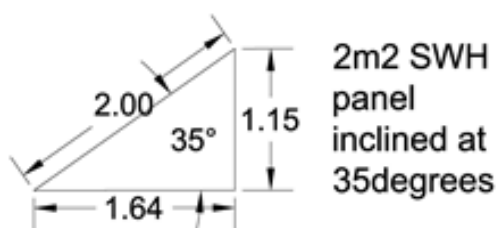


Figure 3: Inclination of SHW panel

#### B- Installation options

##### Decentralized solar water heating system

The common installation over the roof area as per the diagram before has given, as its best arrangement, the schematic shown in figure 4. This schematic was completed assuming the whole roof area is clear for RE usage, i.e., no antennas, satellite, plumbing etc...

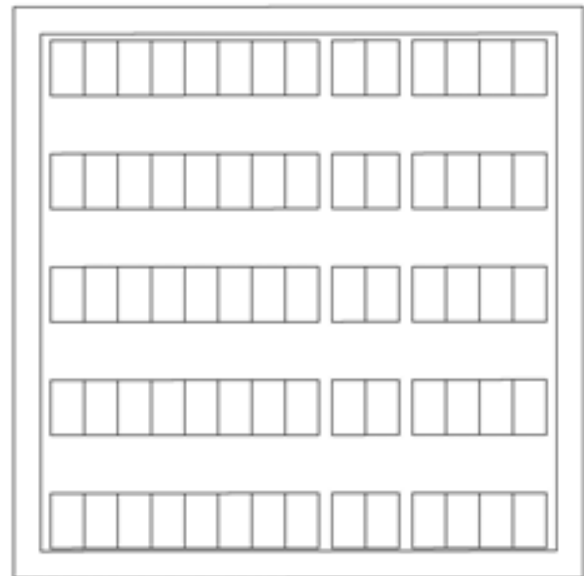


Figure 4: SWH roof distribution (source: Author's own)

The installation has been set as to provide 2 SWH panels (2m<sup>2</sup> each) per flat. The first array of 8 panels will have a meter and will provide hot water for 4 flats. A 1.5h (m) distance is kept between each row of panels as per the rules of installation.

This assembly has allowed the most use of the roof space, with 70 panels installed, hence providing for 35 flats. This does not leave space for the tanks, as the height beneath the panels (inclined at 35°) is not enough. Therefore the tanks would be installed in the flats themselves or in the mezzanine floor, requiring additional piping.

### Centralized solar water heating system

Counting 50l/person, a 4000 liter system requiring 110 m<sup>2</sup> roof spaces and an additional 30 – 40 m for the tank can provide enough water for 80 people.

In the Beydoun building, 24 flats counting on average 5 people, this system would be 20 people short.

This type of installation is commonly referred to as “centralized solar collector” and consists of a common thermal solar collector. Depending on the type of the centralization (6 types available and discussed below), other accessories might be common while some individual.

### Centralized Collector field and backup system

This system consists of installing an individual solar thermal collector with a common water tank and then connected to the hot water plumbing system of each dwelling. Each apartment is billed according to:

- 1- Its area
- 2- Hot water used per month (metered at the dwelling)

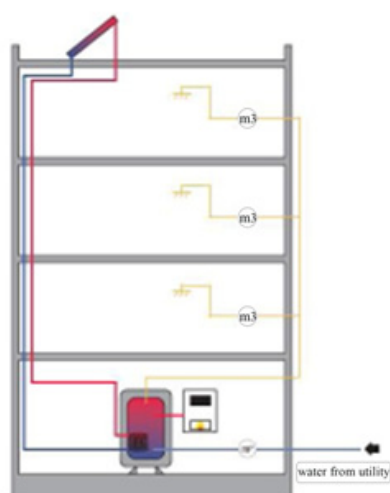


Figure 5: simplified schematic of a centralized collector field and backup system

This centralized collector and backup system was installed in Barcelona, Sarria – Sant Gervasi District, and users were satisfied with

the system as it reduces water waste; when one apartment is not using the heated water, the other is. On the other hand, as it had a common backup system, users were not aware if the hot water is from the solar energy or the backup, annulling the awareness raising efforts.

### Collective solar field and storage with individual backup system

This system consists of installing a common solar thermal collector and water tank; the heated water is then distributed to the dwelling to be further heated in the apartment for use and hence billed for the amount used.

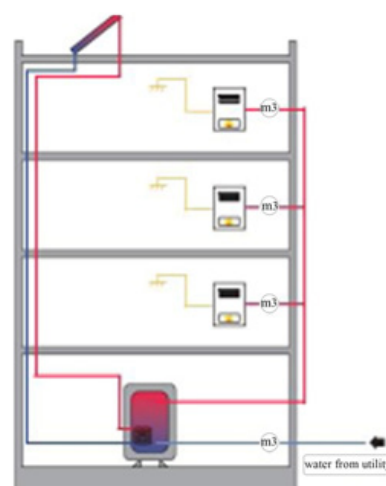


Figure 6: Simplified schematic of a centralized collector field with a common accumulation system and individual backup system

The users are satisfied with the functioning of this system, but have some concerns on how the distribution is balanced per dwelling (E-Nova, L., 2012).

### Collective solar field with individual accumulation and backup system

This system consists of a common solar thermal collector that feeds hot water in individual tanks installed in each apartment. The users are billed for their use.

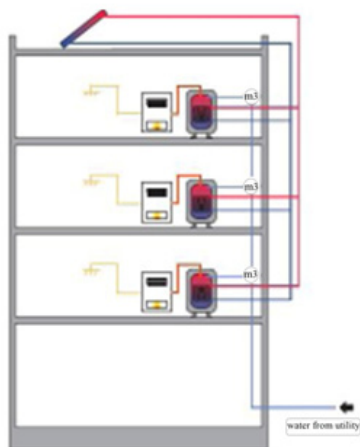


Figure 7: Simplified schematic of a centralized collector field with individual accumulation system and backup system

The users understood this system better as they had a visual of what is heating their water. Moreover, with other centralized systems and in the absence of monitoring systems, it was not clear how the hot water is equally distributed over the apartments. The major negative point was the extra space in the dwellings for the tanks.

#### Centralized systems for DHW and heating

This system functions as a heating plant: hybrid gas and solar thermal. The collective solar thermal collector is connected to the boiler, “when needed, the back-up heating heats up the stand-by volume of the buffer storage to the required set temperature.” Hence, dwellings received hot water in their respective faucets directly (E-Nova, L., 2012).

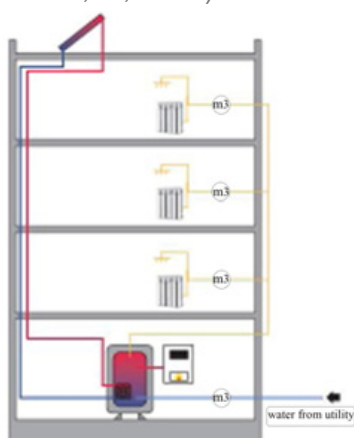


Figure 8: Simplified schematic of centralized Solar Thermal System for DHW and space heating

Same as the first type of centralized system discussed, billing is either done based on apartment area or on hot water consumption measured through water meters.

#### Solar thermal systems with district heating and cooling

This system is a utility owned and grid tied arrangement. Several such examples are available in Austria, Denmark, Germany and Sweden.

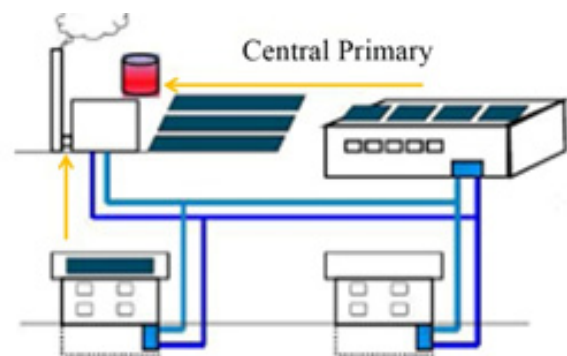


Figure 9: Simplified schematic of a solar thermal system within district heating and cooling

## 4- Building Integration

### A – Background

The construction law in Lebanon is working towards increasing the allowed building heights (storey) within the city to more than 25 storeys. This increase does not entail any amendments to the total roof area, hence bringing forth limitations to any solar based technology installation; a common drawback in China, which has gotten people to investigate alternate ways for solar installations.

### B – Technology

The flat plate water heaters are more suitable for such applications, “in Hong Kong, with warm winters and significant diffuse solar radiation year round, the use of the more common flat plate collector is recommended” (Chow, et al., 2005). Moreover, “the flat plate collectors

are more suitable for pressure system and secondary circulating systems, easier to be installed, and with longer service life and better compatibility to building appearance” (Shi, et al., 2012).

Building integrated solar thermal installations are emerging, giving ways to alternate installation systems: central, central – distributed and distributed hot water system.

Normally, central and central – distributed systems are installed on the roof, which renders enough to cater for the whole building. In case of high density (high rise buildings catering for elevated number of residents), distributed systems are implemented, which are basically installing solar technology on the balconies and the walls, provided that they have the proper orientation (east – west axis) and less than 40% shading.



Figure 10: SWH integration into building facade (source: Shi et al., 2012)

## C – Accessories

The integration of SWH onto building fabrics (façade, balconies, shading elements, etc...) does not entirely solve the problem for the lower floors, as the solar absorption might be affected by neighboring buildings and vegetation. Some technical enhancements can be applied to help in such cases, depending on the technology used (flat plate / evacuated tubes) “such as increasing the area of collectors, adding the number of evacuated tubes, installing reflector plate additionally to increase heat collecting efficiency, and so on.” (Shi, et al., 2012)

## D – Legislation

It is worth mentioning that in the Shanghai code for urban planning and design, for

example, “the distance between buildings must be designed to ensure no less than one hour sunshine time for each bedroom of residential buildings on the winter solstice. As for buildings using solar water heater, the distance between them should be designed to meet the demand that the building envelope upon which the solar collector is installed can get no less than four hours sunshine duration in order for preferable performance of solar collectors” (Shi, et al., 2012).

## 5 – Roof installation

A third building integration option was provided: roof structure. This consists of creating a metallic structure on the roof raising the level on which the panels will be installed. Below is a proposed arrangement for the Beydoun building especially that it is a 12 storey construction.



Figure 11: Roof structure SWH installation

A pitched roof is created with the metallic structure with 35° inclination; this arrangement has allowed the reduction of the minimum space between rows since the panels are installed right on the structure, and thus no shadowing would be created onto the following panel. The space under the structure (5.4 m high) is enough to install a few water tanks. This implementation has been applied in “Keserwan Public Hospital”, one of the UNDP-CEDRO projects.



**Figure 12: Keserwan Public Hospital - SWH roof structure installation (source: Cedro)**

This arrangement allows 52 panels to be installed per side (total 104), hence providing hot water for 52 apartments. In the case of the Beydoun Buildings stated above (24 apartments), this installation provides its needs and more. But for the sky scrapers (above 25 floors) trending in Beirut, this installation would leave certain apartments without solar water heating.

## 5- Alternative solar thermal technology

Another technology could be used for heating water: solar thermodynamics panels which can be installed on facades or balconies regardless of their orientation.



**Figure 13: Solar thermodynamics panel**

The panel absorbs the heat from its surrounding environment as long as the temperature is above 5°C, and energy is taken to the heat exchanger through piping (maximum 10m long) to heat the water. Hot water can be heated at night, hence constitutes half cycle time compared to traditional solar heaters that can only heat during the day (and only if the proper meteorological conditions are met).

This system is composed of a water tank (installed vertically), a compressor and the thermodynamic panel (metallic as shown in figure 13) rendering a very robust system as its exposed parts (metallic plate) are less prone to breaking.

Mr. Emile Azar, General Manager at METACS, explained that such a system is most commonly used in applications requiring 60°C water, such as floor heating, fan – coil units, swimming pool heating and clean hot water for everyday use. Heating the water up to 55°C, not only reduces the overheating problems faced in the summer with traditional SWH, but also rids the system from any calcification or legionella problems, hence reducing any maintenance cost. In fact the only maintenance required is the replacements of an anode probe that protects the tank and equipment, within 3-5 years, at minimal cost.

Since it works on heat and not on solar radiation like conventional SWHs, the system is operational throughout the year especially in Beirut. In the absence of heat, a 350W resistance is available to draw electricity from the conventional grid power. Typically, a 250 liter system costs up to 3500\$ (Metacs, 2013). Mr. Azar emphasizes that solar thermodynamics is highly recommended for installation in underground parking. The heat generated by cars in parking spaces can be utilized to heat the water while cooling down the space.

This system was installed 3 years ago in an apartment in Achrafieh, Beirut. The apartment owner has explained that installing a regular SWH system was not possible due to roof access and permissions, and it was after 2 years of trying that she came across the solar thermodynamics system. The system as

shown in the picture below (figure 14) is fixed on the interior part of the balcony cladding, hence blending perfectly with the architectural outlook of the building. The gas going through the plate (R134A) boils at 20°C; in other words, the plate will have a 20°C temperature, which means that in the hot summer weather the plate will be “cool”, making it safe for children and adults, however when the system is operational and gas flows through the plate, some condensation occurs, requiring proper draining. For the past three years, the residents of the apartment (4 people) have relied entirely on the system for their hot water needs which have not required any maintenance or even routine checks.



Figure 14: solar thermodynamics installation

Based on Lab tests completed on a 300 L tank, it takes about 5 hours to heat the complete water tank to around 55°C in the summer season, and around 7-8 hours in winter due to lower ambient temperature, and cooler water temperature entering tank. Those numbers are slightly less for a 250 L system.

## 6- Specialists inputs

A survey by Probst and Roecker has been completed in Europe targeting “170 European architects and other building professionals” investigating the most accepted architectural integration for solar thermal technology (Probst & Roecker, 2007).

The most acceptable architectural element to use is the façade and more specifically the balconies. Flat plate can fit onto the external side of the parapet of the balcony serving as both external finishing and solar collector.

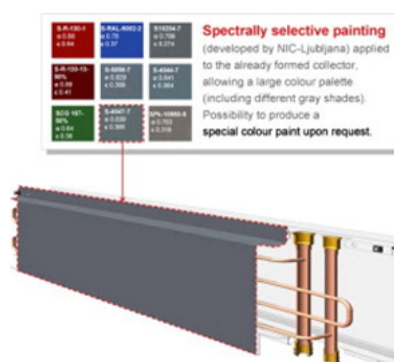
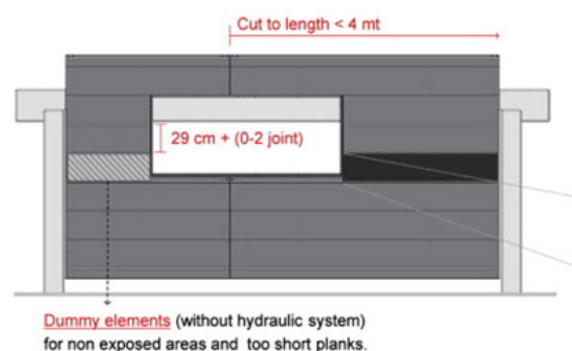


Figure 15: Balcony SWH integration (source: Probst & Roecker, 2007)

Another installation is the solar wall, which is applying the solar collector onto an exposed masonry wall.



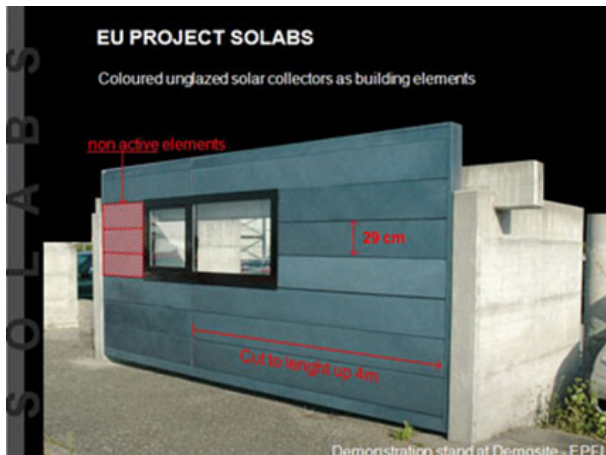


Figure 16: Exposed wall SWH integration (source: Probst & Roecker, 2007)

The SOLABS project (2003-2006) had, as a target, to extend the use of solar thermal collectors into the building construction.

In order to encourage building integration, colored absorbers have been introduced; those function in the same way as their more efficient black colored counter parts, but give the architects a small sense of a fashionable installation (Chow, et al., 2005). Although a wide range of rated examples of building integrated thermal solar use the conventional black colored plates (Probst & Roecker, 2007).

In reference to the Lebanese market, Mr. Aram Yeretzian, LGBC president, and Ziad Haddad, LGBC board member, have explained that in new construction, mainly high rise building lacking roof space, two options are available:

- The installation of a common collector for the building with distributed storage tanks for each apartment. Hot water would be equally distributed to the available apartments using a smart controller.
- A raised structure could be installed above the available roof services, providing enough space for both. This could be applied to the centralized solar collector or for individual ones.

## 7- Incentives

From a financial perspective, the UK government has put forth a scheme to encourage entrepreneurs and residents to produce electricity from renewable sources – the feed in tariff. In March 2011, the UK has announced that it is launching a Renewable Heat Incentive (RHI), the first in the world to remunerate heat produced from renewable sources. This incentive includes: heat pumps (air and ground), biomass boilers and solar thermal technologies.

The RHI is implemented over 2 phases: the non-domestic sector that became effective in March 2011 and remunerates the system's owner at a set rate for every KWhth produced and phase 2, the implementation in the domestic sector that starts in March 2014. This incentive applies for renewable heating sources (air and ground source heat pumps, biomass boilers and solar thermal technologies) and is for a period of seven years. In a press release on 12 July 2013 by the Department of Energy and Climate Change, (DECC) solar thermal remuneration, to be paid on a quarterly basis, has been set at minimum 19.2 p/kWhth, if the solar technology meets the following requirements:

- The owner has to be the beneficiary
- The solar installation is less than 200KWhth and consists of flat plates or evacuated tubes
- The installation was completed and commissioned before 15 July 2009
- The installation was not completed through grants or public funding
- The installation was brand new at commissioning
- The installation has an MCS (Microgeneration Certification Scheme) certification at time of commissioning
- The installation utilizes liquid or steam as final output
- The installation's output is utilized for at least one of the following: space heating, water heating or heat used in a process within a household

The value of 19.2 p/kWhth is not final, as

further studies are ongoing and the final tariff will be announced in autumn. This tariff has been set so that it reflects the expected cost fluctuations over the next 20 years; the support is designed to end after 20 years, though the remunerations would be completed on quarterly basis over 7 years. Only liquid filled flat plate and evacuated tubes with capacity less than 200 KWth are eligible for the RHI scheme. As for PVT technologies, a separate metering system will be installed to monitor the heat output. No specific details are provided as to how the monitoring and remuneration would be assessed.

As per the Department of Energy and Climate Change (DECC) “the deeming figure for solar thermal will be the estimated contribution of the solar thermal system to the property’s hot water demand (in kWh) that is calculated as part of the installation process and shown on the Microgeneration Certification Scheme (MCS) certificate”. In order to ensure that all declared systems are properly functioning, an annual self declaration system to Office of Gas and Electricity Market (Ofgem) confirming the system’s status (properly functioning, broken down, etc...) based on the maintenance of care as per the manufacturer’s instructions will be put forth.

Heat incentives are brought forth in Netherlands and Italy amongst other places; in the Netherlands, the compensation will be retrieved from the extra taxes imposed on fossil fuel, while in Italy it will come to replace the currently offered tax credit.

## 8- Other solar technologies

These solutions have definitely solved the shortness in space for solar thermal integration, but with its entire use of all available spaces, both on the roof and on the building envelope, this has left no space for the solar electric installations.

Recent studies have been investigating the Photovoltaic / thermal (PV/T) technology. These have started from the fact that “small portion of the heat is sunk into the cells which results in a reduction in their efficiency” (Anderson, et al., 2008). In other words, if one can extract the heat “sunken” into the cell, the PV panel’s efficiency

would increase, increasing its market along the way. A small cooling process is implemented to rid the cells from the excessive temperatures. Results from theoretical studies have shown that 60 – 80% efficiency can be reached from PV/T collectors.

Instead of dumping this heat back into the environment, it could be used as source for solar thermal applications. In situations where roof area is limited, PV/T is considered as a cost effective solution.

SolarWall is a supplier that has installed several PV/T systems in Canada; the system utilizes the solar thermal energy for heating. Such a system has been installed in the University of Concordia, a LEED certified building. From preliminary data monitoring, the system has registered a 5% improvement in the heating season over the traditional installation (Solarwall, 2013).

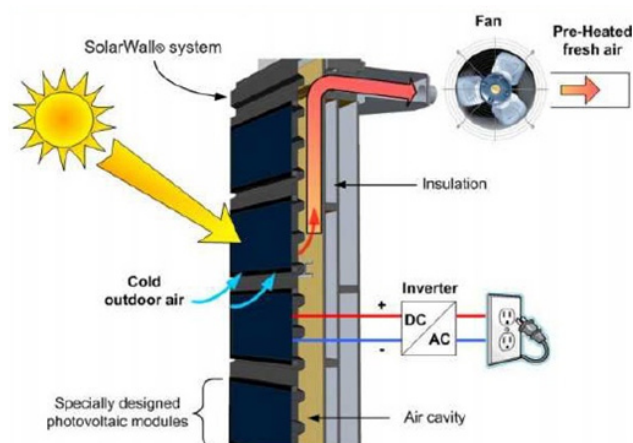


Figure 17: PV/T system installed at the John Molson School of Business - University of Concordia

A recent simulation has shown that the building integration of PV-T increase the electricity production by 8% to 15% in warm climates (Matuska, T. 2012).

## Conclusion

The Lebanese government is committed to 12% energy production from renewable sources by the year 2020; while the Lebanese construction law is looking to increase the allowable building height. This Exchange has tackled the restriction of possible roof spaces for SHW systems in the

capital Beirut and in other cities in Lebanon. Examining SWH installations, several solutions are being implemented, from raised roof structure to envelope integrated. From an architectural point of view, studies completed in Europe showed that balcony cladding installation are the most visually acceptable. Such implementations in the Lebanese market face more obstacles especially in the terms of efficiency due to the limited solar incidence on building facades in highly urbanized spaces such as Beirut.

Installing a large common system is enough for 52 apartment buildings, but opens room for the cost sharing arguments amongst the users. Decentralization through installation of individual water tanks provides a suitable solution that is preferred by users as it provides the interface with the system, hence raising awareness and prompting better management.

Other technologies also exist that can have dual output, solar thermodynamics. The latter would absorb the heat in habitable spaces such as balconies, hairdressers' salon, underground parking, to heat the water. Such system can be installed on balconies or any other space with heat, which makes it highly convenient for installations with space restrictions.

In the case of Lebanon and Beirut in particular, solar thermodynamics is a solution that provides the resident's hot water needs, and leaves space for other solar renewable energy installations.

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