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ACTIVATE APPLICATION OF SOLAR WATER HEATING IN RESIDENTIAL BUILDINGS - CAIRO-EGYPT

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ABSTRACT

Solar thermal has been proposed as a solution to lower the dependency on fossil fuel sources. The solar atlas issued in 1991, indicates that Egypt is on the Sun Belt countries. Solar water heaters can be a cost-effective way to provide hot water in the homes. It is possible to make full use of external parts of the solar energy that building can use, and to realize external harmony of landscape building. A field study showing the current use situation of solar water heaters based on previous application programs that applied the use of solar water heaters for residential blocks of flats build by Egyptian government during the late 70th and early 80s. The research proposed Participation and Funding Management for future residential projects in Cairo, goal ling to achieve sustainable urban development and Streamline overlaps and interconnections between various parties involved in the project. The research is an attempt to maximize the use of solar energy as a non-conventional energy resource for residential buildings in the field of solar water heating in Cairo, Egypt.

Keywords: solar energy, solar water heating, non-conventional energy, residential buildings, Cairo- Egypt.

Abbreviations

SWH: Solar water heaters

1. INTRODUCTION

Energy gives a vital contribution in development of human life. Energy resources are naturally available in various forms and are utilized by human being since ancient times. Energy needs increases with development, and with ever growing population. Industrial revolution results in many revolutionary changes in technology. The demand of energy sources like oil and coal increased dramatically during last decade, Their primary resource is fossil fuel which is of exhaustible nature and going to deplete one day causing despite its burning causes global environmental damages like greenhouse effect, water and air pollution etc... The extreme use such fossil depending resources leads to its un-availability for future generations. The international trend is increasing towards replacing the fossil fuel as a primary source for energy by non-conventional resources such as wind, sun, water, biomass etc. which are more environment-friendly and sustainable (renewable).

Solar thermal has been proposed as a solution to lower the dependency on fossil fuel sources, (Solar Thermal Application in Egypt, and others, 2009). The solar atlas issued in 1991, indicates that Egypt as on of the Sun Belt countries, Figure- 1 and 2), is endowed with high intensity of direct solar radiation ranging between 2000 - 3200 kWh/m2/year from north to south,(Energy Research Center, 2006). The sunshine duration ranges between 9- 11 hours with few cloudy days all over the year, Table-1, (S. M. Robaa, 2006). Despite the excellent conditions, Egypt is still considered as a pre-matured market for solar thermal applications either for power generation or heating processes. However, RE has got more political attention recently, and a strategic decision has been taken by the government having the target to supply 20% of the electricity in 2020 from renewable energy sources, (ERC, 2006).

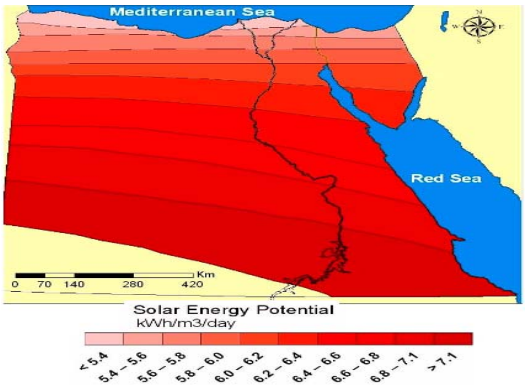


Figure-1. Solar energy potentials in Egypt .Source: ERC, 2006, P 31.

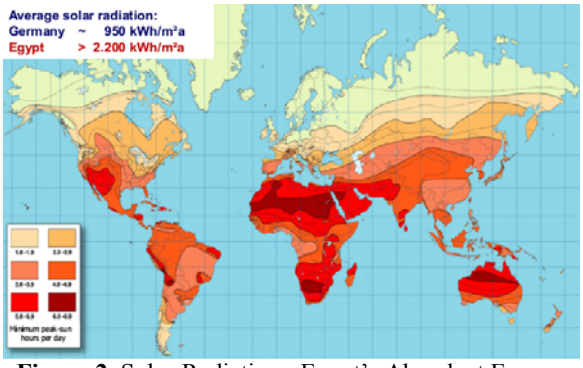


Figure-2. Solar-Radiation - Egypt's Abundant Energy Resource. Source: WernerB. Koldehoff, 2012.

Table-1. The monthly, seasonal and annual mean number of days of the sky-cover occurrence (clear sky, C = 0 octas, partially cloudy sky, C = 1–5 octas and cloudy sky, C = 6-8 octas) over Cairo (1992-2003)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Clear sky	22	21	26	28	29	30	31	31	30	29	26	25	27
Cloudy sky	2	1	0	0	0	0	0	0	0	0	0	1	0
Partial cloud sky	7	6	5	2	2	0	0	0	0	2	4	5	3

Season	Winter	Spring	Summer	Autumn
Clear sky	23	28	31	28
Cloudy sky	1	0	0	0
Partial cloud sky	6	3	0	2

Source: S. M. ROBAA, 2006.

Out of all non-conventional sources of energy, solar energy is available in abundance. With its best use, electric energy can be generated and can be used for the different sectors. As building sector is the one in which maximum (22%) of energy is used, Figure-3. Proper channeling of non-conventional solar energy resource leads to energy conservation.

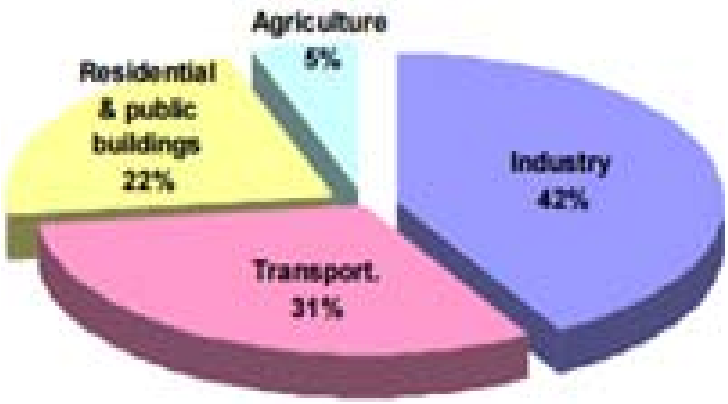


Figure-3. Energy consumption by sector (2005) .Source: Alexandra Hilbig, 2009.

The first straight forward application which reduces the consumption of the traditional energy (electricity, oil, LPG) is the use of Solar Water Heaters (SWH).If the need for hot water in residential areas would be satisfied 100% by solar energy (Kalogirou, 2009), 4.5 Million tons of CO2 equivalent GHG emissions could be saved each year in Egypt resulting from direct and indirect fuel consumption. (Solar Thermal Application in Egypt and others, 2009).

There are many ways to use Solar energy including heating a house, providing electricity, or desalination of seawater, besides in architectural applications, Figure-4. Solar energy is widely available today, because the sun will always shine on the Earth. We only need the right instruments to capture the sun's rays and convert those rays into energy. Also a need must exist for solar energy to be stored for future use, (Arjun Basnet, 2012).

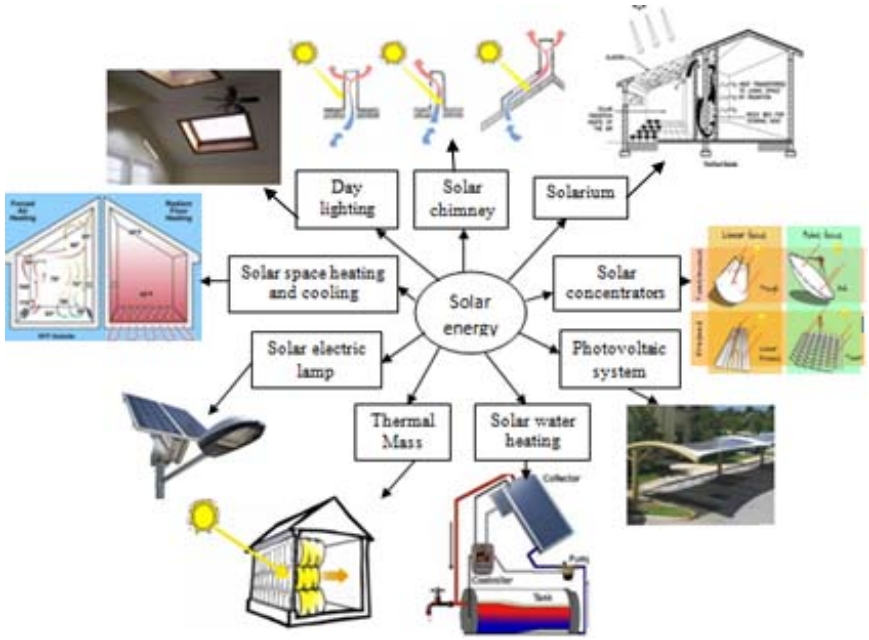


Figure-4. Implementation of solar techniques in buildings.

Using solar energy for heating water became a wide-spread technology and is applied in many countries around the world, but still has a big potential for expansion, (Dixon, J.A. and P.B. Sherman, 1990), Figure-5. On the other hand, the reliance of customers in SWH technology in Egypt waned because of the short service life of solar water heaters installed systems due to poor quality of the material as well as the provided installation and maintenance services, (The Ministry of Electricity and Renewable Energy, 2012), Table-2.

Recently there are many barriers for SWH market development in Egypt such as Political, Financial, Social, Economic, (Figure-6).

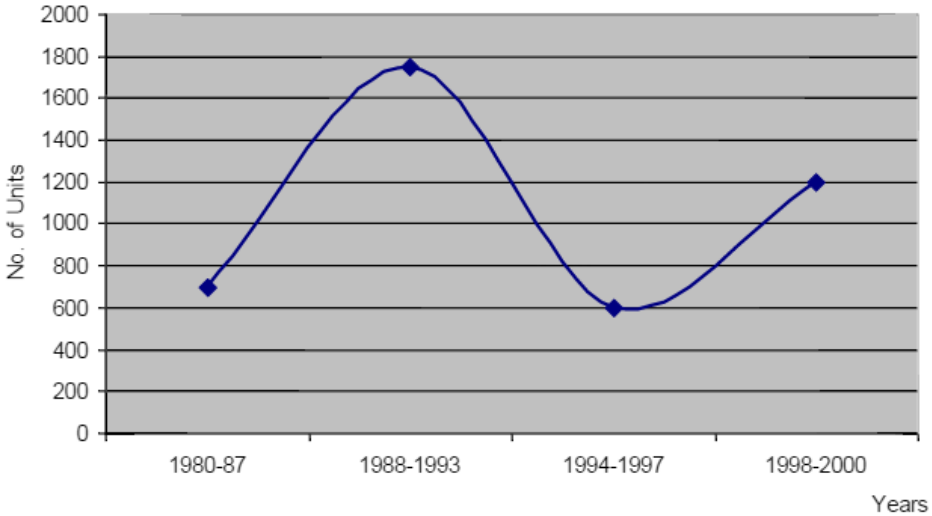


Figure-5. Annual sales of solar water heaters in Egypt 1980-2000.
Source: El-Salmawy, 2005.p. 22

Table-2. Local manufacturing of solar water heaters in Egypt depends mostly on imported materials resulting in increase of its market price.

Materials	Local	Imported
glass	tempered	High transmission
Absorber plate	Copper sheet and tubes stainless steel	Copper tubes soldered plate Absorber
coating	Locally available paints	Selective coatings
frame	Anodized aluminum	
insulation	Locally available materials foam and polyurethane	
tank	Galvanized steel with magnesium anode or stainless steel	
piping	polypropylene	

Source: Alexandra Hilbig, 2009.

Table-2 56% of raw materials or system components are imported, 33% are partially imported and only 11% are completely locally produced.

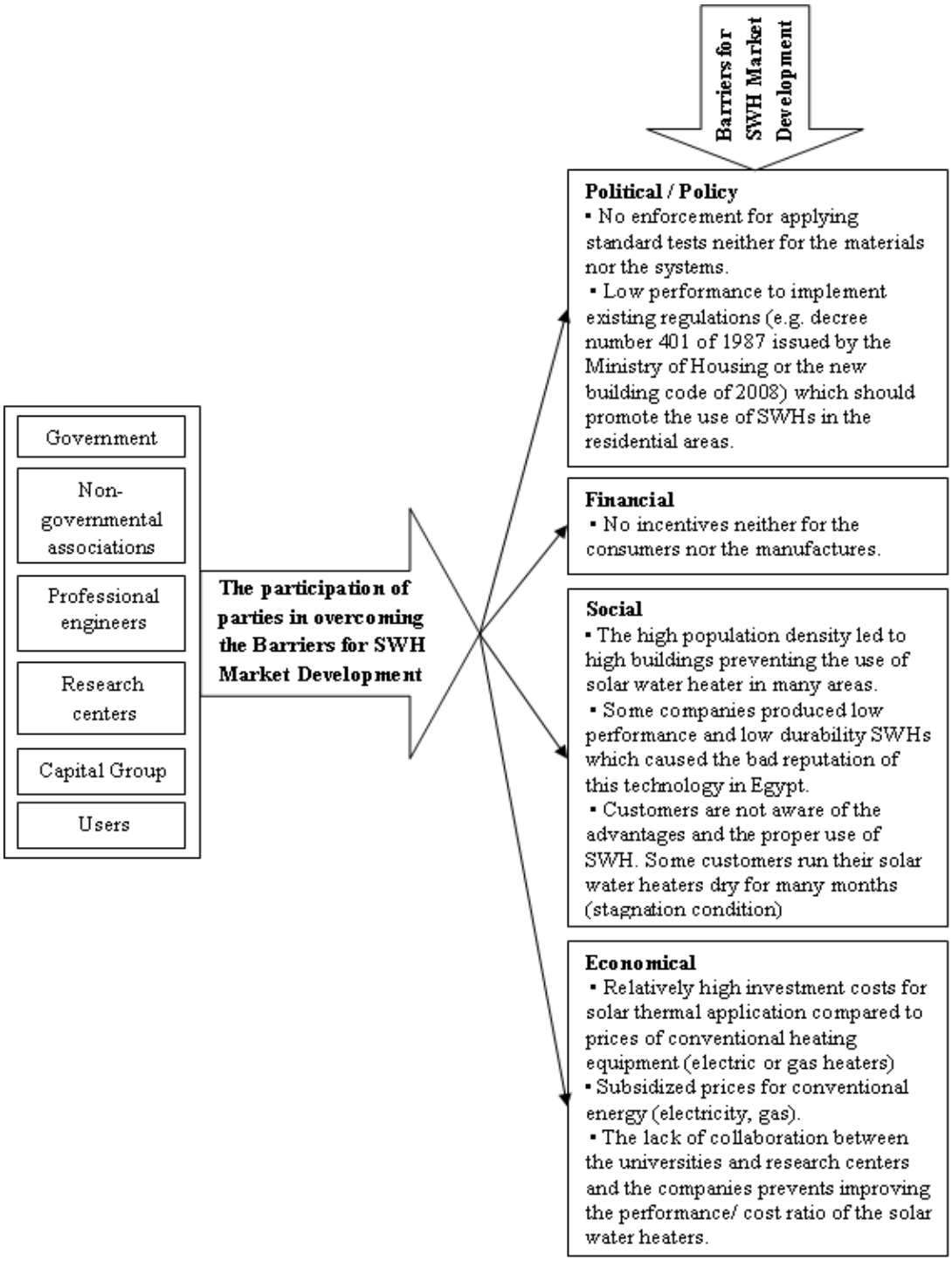


Figure-6. Complementary roles to remove the Barriers for SWH Market Development Resource: the researches.

Programs that promote the application of Solar water heater technology in Egypt therefore have to tackle the quality issue under the given legal and economic circumstances, aiming at the definition of minimum quality or performance standards of system components as well as related services for installation and maintenance. This could contribute to stabilize the existing jobs in this sector and create new ones in the future. Stimulated by well targeted awareness campaigns and client oriented credit schemes to ease the purchase of this technology, the sales and installation rates could be significantly increased in the future, having a positive effect on the reduction of greenhouse gas emissions and lower the constantly growing energy demand, Figure-7.

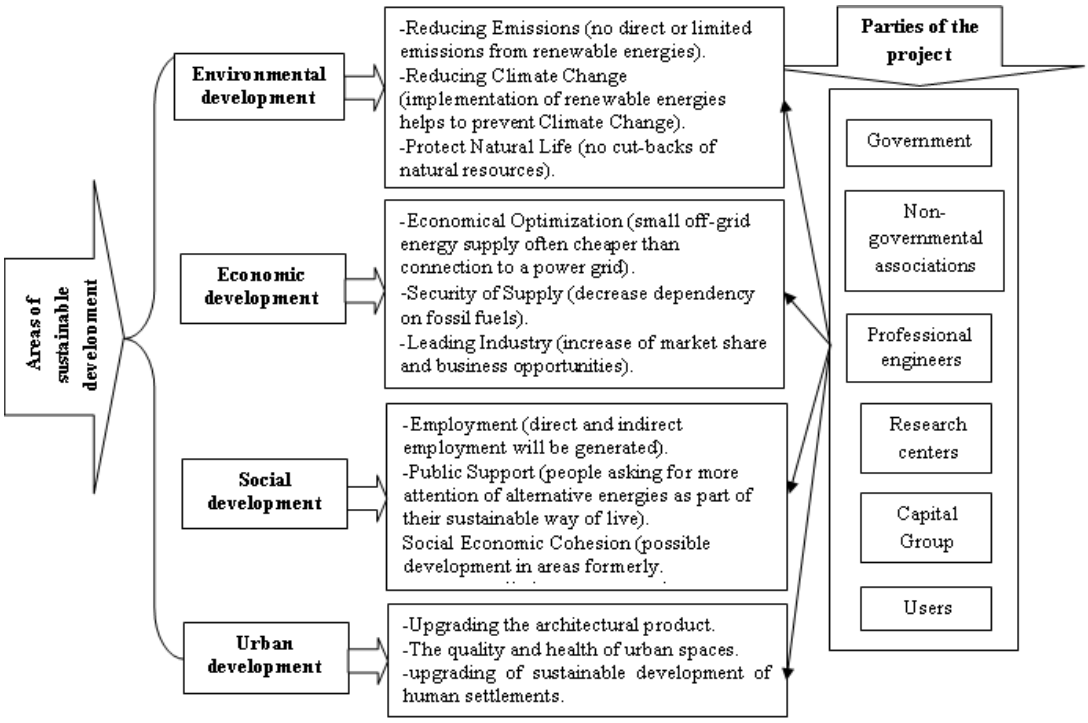


Figure-7. Influence of using SWH in the fields of sustainable development.
Source: the researchers

2. SOLAR WATER HEATING

Solar water heaters can be a cost-effective way to provide hot water in the homes,(Diakoulaki, D. and others, 2001) Instead of relying on gas that is more expensive and could cause death if inhaled, one can save money with free power that only the sun can provide, Table-3.

Table-3. Taking water heating systems using fuel economic comparison.

sort	Natural gas	electricity	Solar energy + electricity
Heat value	8470 Kcal/m^2	860 Kcal/KWh	4.5 KWh/d
Efficiency	88%	100%	100%
Fuel expense	1.04	2.15	0.43
The percentage of running expense	242%	500%	100%
Initial investment	1000	2000	4000
Service life	5 a	15 a	15 a
Equipment cost	0.55	0.37	0.73
Day running expense	1.43	2.52	1.16
Year expense	522	920	423
Total cost contrast	123%	217%	100%

Source: Yibing Xue, Jie Zhang, 2013.

Solar water heaters come complete with storage tanks and solar collectors. In order to use a solar water heater one must have a well-insulated storage tank. These storage tanks have an outlet and inlet connected to and from the collector. If one happen to have a two-tank storage system, the solar water heater will preheat the water before it goes into the regular water heater. No matter what solar water heating system you use, there will always be a backup system you will need to deal with. This is to provide hot water on cloudy days and when demand for hot water rises. Each solar water heating system carries certain parts that make it do its job. These

parts include the heat exchanger and heat-transfer fluid. The heat exchanger takes the solar energy that was absorbed by the solar collectors, and transfers it to whatever is used to heat the water. Heat-transfer fluids work by carrying heat through solar collectors and a heat exchanger to heat storage tanks, Table-4.

Table-4. Solar water heating technique. Source: Harry Husted, 2007.

Solar Water Heating		
the types of thecollector	**Flat-plate collector:** There are two types of flat-plate collectors. One is a glazed flat-plate collector that is insulated and waterproof. It also contains a dark absorber plate under a glass cover. The other type is an unglazed flat-pate collector. This has a dark absorber that is made of metal or polymer, but without a cover.	
	Integral collector-storage system (ICS): This system contains one or more black tanks or tubes in an insulated and glazed box. It works by cold water going through the solar collector first, where it is preheated. Then to a storage tank where it is used.	
	Evacuated-tube solar collector: This collector features parallel rows of transparent glass tubes, with a glass outer tube, and a metal absorber tube that is attached to a fin.	
solar water heater systems	**active**	**Direct circulation systems:** The pumps circulate household water through the collectors and into the home.
		Indirect circulation systems: The pumps circulate non-freezing, heat-transfer fluid through collectors and a heat exchanger. This allows the water to get heated then it flows into the home, Figure-8.
	passive	**Integral collector-storage passive system:** This system works best in areas where the temperature rarely hits the freezing point.
		Thermosyphon system: This system works by water flowing through when warm water rises as cooler water sinks. A collector must be installed below the storage tank, so the warm water will rise into the tank,(Kalogirou, S., 2009), Figure-9
designs of heat exchangers	**Coil-in-tank:** This heat exchanger uses a coil of tubing that is inside the storage tank.	
	Shell-and-tube: This heat exchanger is separate from the storage tank. it contains two fluid loops that are separate from each other, but are contained in a case or shell. When the fluid flows, the tubes are directly opposite each other when it goes through the heat exchanger. This way the most heat possible gets transferred.	
	Tube-in-tube: This type of heat exchanger is actually very efficient, for the tubes of water and heat-transfer fluid are in direct thermal contact with each other.	
The types of heat-transfer fluids	**Air:** This is the most obvious one and is also common. Air is used because it will not freeze or boil, plus it is not corrosive. The only negative to it is that it can leak out of pipes, ducts, or whatever a little hole may be.	
	Water: Water is also another form that is used being it is nontoxic and inexpensive. Water is very easy to pump. The only problem with water is that it can boil and freeze. Plus, it can corrode pipes and ducks.	
	Glycol/water mixtures: Glycol and other water mixture are sometimes used. You may find such mixtures as 50 or 60/40. You may even find ethylene and propylene glycol being used. This is antifreeze. Ethylene glycol is very toxic and should only be used in a double-walled, closed-loop system. Because if it leaked out into the water supply, it could cause major problems.	
	Hydrocarbon oils: These oils have a high viscosity and lower specific heat than water. A downside to using this fluid is it requires more energy to pump. But on the plus side the fluid is cheap.	
	Freon: Freon is used in refrigerators, air conditioners, and heat pumps. They do have a low boiling point and a high heat capacity. Because of this, only a small amount of refrigerant is needed to transfer a large amount of heat efficiently. These units work by heat being absorbed when the Freon boils in the solar collector. Heat is released when the gas condenses to a liquid in the heat exchanger.	
	Silicone: Silicone is good to use in solar water heating systems because it has a low freezing point and very high boiling point. The downside to silicone is it requires more energy to pump, and can leak easily.	
Things to consider	The costs, location, Size, local building codes, zoning ordinances, and any other rules, and maintenance.	

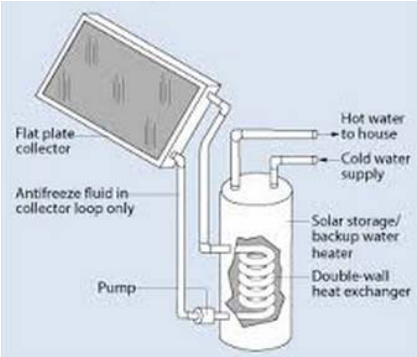


Figure-8. Indirect circulation systems.

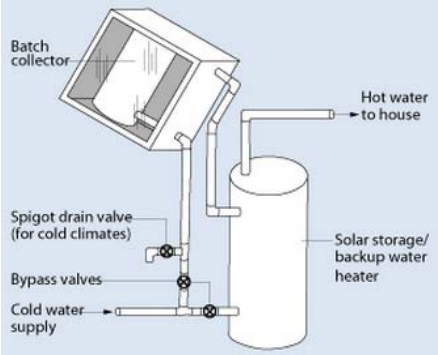


Figure-9. Thermosyphon system
Source: Harry Husted, 2007.

3. Solar water heating in residential buildings

Solar hot water equipment is not a long time in domestic applications, the combination of solar equipment and residential is still at primary stage. Currently, people tend to value only the functionality of the solar hot water equipment, to the neglect of other aspects of the problem. As messy mercy on the roof, different size specifications, the disorder of the pipeline, the metal component caused by light reflection, resulting in a strong visual pollution, affecting the building aesthetics and building facades, sometimes improperly installed and may even cause potential safety problems such as water heaters fall wounding roof broken, housing leaking. In order to solve this problem, it is to make full use of external parts of the solar energy that building can use, and to realize external harmony of landscape building, (Pranita Pranjale and Deepali K.Hejiib, 2013). Specifically speaking there are four meanings:

a) Making full use of the sunny part of the building (such as the sunny slope, roof and so on) to install solar equipment;
b) Joining with community planning, architectural design, equipment installation and acceptance, and saving the cost of solar equipment;
c) Combining solar energy systems and building organically, to make them harmony in appearance;
d) When design, solar component can be used as architectural component and bear some building functions.

3.1. Combined with the Wall

The buildings south facade good illumination condition. Take advantage of the window sill wall design of the solar collector and the wall of the south facade combination. The essence of the flat-plate collector as part of the facade wall, solar equipment at the same time meets their also fulfil certain structural and architectural features. The solar collector wall from outside to inside by translucent insulation coating, photo thermal conversion layer , wall support and thermal conductivity layer, collector tube, foam insulation layer, interior wall supporting layer, interior wall smear layer section composition. When the sun along an angle of incident to the wall, the press effective projected cross-section to obtain the effective light energy through the transparent insulation coating, incident to the light-heat conversion layer, the photo-thermal conversion layer is completely or selectively converted into heat. In this design, the solar collector to become a part of the wall, it should be so that the solar collector device has a certain strength, and to satisfy the wall insulation and aesthetics, Figure-10.

Figure-10. Student apartment block in Germany, the façade is covered with evacuated solar tubes .Source: Lex Bosselaar, and others, 2004.

3.2. Combined with the Roof

Building roof without cover and a wide range of contact with the sun, so it easy to the lighting and solar collector of solar hot water equipment. Solar collector roof close of flat roofs typically use overlay, with sloping roofs mosaic; same time to reduce the roof weight, solar collector alternative building insulation and insulation and can completely replace or partially replace the roof overburden, doing so can reduce costs and improve efficiency, Figure-11.

Figure-11. The fully integrated solar roof. this solution is suitable for smaller apartment buildings. Source: Lex Bosselaar, and others, 2004.

3.3. Combined with Balcony

For high-rise building, the floor area can't meet the building all the installation of solar equipment, so people began to consider the use of the balcony, as well as the sunny side of the wall and other parts. But to do so would affect the aesthetics of the building facade and artistic effect. For this case, we can take household-type system, each household can solar collector device installed on the balcony the outer wall, the tube can be horizontally arranged in order to add the horizontal lines of the building, rich facade effect. Also in the south instead of railing use layout contiguous solar collector from bottom to top, as in the south facade, to provide centralized hot water sup-ply in the whole building, Figure-12.

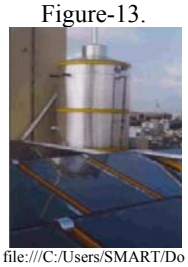
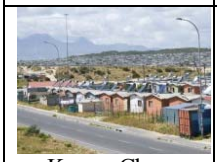
Figure-12. On the railing of a house. Source: http://mnre.gov.in/file-manager/UserFiles/Photogalary_swh.pdf

4. INTERNATIONAL AND LOCAL SOLAR WATER HEATERS PROJECTS

4.1 international solar water heaters projects

There are some international solar water heaters projects, Table-5 we can obtain some results and lessons learned from them.

Table-5. International solar water heaters projects.

project	results	lessons learned
The Hotel Golden Tower in Chennai, Tamil Nadu, India, Figure-13.  file:///C:/Users/SMART/Downloads/SWH08-C.pdf	-The hotel has 70 guest rooms and requires hot water 24 hours a day, 7 days a week. A solar water heating (SWH) system was installed at the hotel and has enabled it to drastically reduce its potential electricity consumption. - The system proved to be very satisfactory from environmental, aesthetic and technical points of view, Figure-13.	• Solar water heating can be very attractive financially when compared to electric resistance water heaters in areas where the cost of electricity is high. • Where SWH systems replace or augment electric water heaters, they can serve as a good demand side management and load shaving option for electric utilities. •India's Ministry of Non-Conventional Energy Sources (MNES), operating through the Indian Renewable Energy Development Agency (IREDA) and other public sector organizations, provides soft loans to domestic and institutional solar hot water systems, which makes the investment more attractive.
 Kuyasa Clean Development Project, South Africa, Figure-14. Source : (Growing Inclusive Markets. 2010)	-The Kuyasa project -All 2 309 households of the original Kuyasa housing project were beneficiaries of these installations. -Project reduces carbon emissions. -Reducing costs, improving living conditions, Figure-14.	-Government should also look to facilitate opportunities for public-private deliberation, collaboration and standard-setting, so that opportunities for private sector participation can be identified and barriers addressed. - Training for employment of local residents. - Employment creation: Solar water heaters contribute to sustainable improvement of livelihoods and have the potential to create jobs in South Africa while directly alleviating poverty. -Involvement of local residents in projects in general.

4.2 local solar water heaters projects

Lessons learned from previous solar water heaters projects in Egypt, Table-6,

Table-6. Solar water heater project in Egypt. Source: Solar Energy for Heating Water in Urban/Peri-Urban Areas, Egypt.http://www.solarthermalworld.org/sites/gstec/files/SGP_Egypt3.pdf.

Local solar water heaters project (domestic)		
project description	In most of poor communities especially in agricultural areas in Egypt, water is normally heatedusing agricultural residues in a kanoun (a small wood burning furnace). The Kanoun produces smoke and is generally unsafe. In more well-off communities, electricor gas water heaters are used, but there may be shortages ofgas cylinders, or electricity costs might be high. Three solar water heater projects took place in poor villages and neighborhoods surrounding El Menia, a city in Upper Egypt.These projects introduced the use of solar energy to heat water, and raised awareness about climate change and the effects of pollution produced by traditional methods of heating water.	
Implementation	The projects installed solar water heaters in poor neighborhoods of El Menia, and also carried out training and education programs for community members regarding the installation and maintenance of solar heaters and how the use of solar water heaters is related to solving global and local environmental problems.	
Benefits	**Environmental**	**Global:** The use of solar energy to heat water for household use reduces or eliminates the need to use agricultural waste or other traditional fuels to heat the water, thereby reducing greenhouse gas emissions
		Local: The reduced use of agricultural waste and/or wood for heating water reduces the amount of smoke released into the air, thereby improving the local air quality.
	Livelihood	**Health:** Improved access to hot water can help improve sanitation, and therefore lead to health benefits. Reduced smoke inhalation due to the reduced burning of agricultural waste to heat water is another health benefit.
		Cost savings: it is estimated that solar water heaters of 150-liter capacity save a household 10-15 Egyptian pounds every month.
		Employment: The project implemented most recently involved training three local young people to install, maintain and repair solar water heaters. The training should help these young people earn an income doing this work.
Partners	Local governments, the private sector, companies manufacturing solar water heaters, residents of poor areas in and around the city of El Menia.	
Barrier Removal	**Technical**	Since the projects have trained local community members to better understand, operate, install and repair solar water heaters, technical barriers to their use in this region have been reduced.
	Financial	Community members contributed part of the costs of the water heaters, which increased project ownership and allowed more water heaters to be installed. In addition, the projects partnered with nongovernmental organizations entities and local governments to improve the quality of the technology used and to sustain the effort.
	Information/ awareness	These projects have placed great emphasis on raising awareness, educating hundreds of people about the connection between renewable energy use and global and local environmental problems. The importance of public awareness in promoting renewable energy use is another of the lessons learned from these projects.

A field study showing the current use situation of solar water heaters based on previous application programs that applied the use of solar water heaters on residential block of flats build by the government during the 80s. There are the results according to screening questionnaire, Figure-15, 16, 17, 18.

Figure-15. Blocks of flats provided by solar water heaters that were build during the 80s.

Figure-16. Lack of solar water heaters maintenance – lead to inefficient Water heating.

Figure-17. Dusty weather is one of the major problems that lower the efficiency of solar water heaters. Source: the researchers.

Figure-18. Many non operating solar water heaters due to its replacement with electric of natural gas water heaters. Source: the researchers.

The field study (year 2015) for the Solar water heaters program applied during the 80s shows that future application programs have to convince the residential users who had faced problems from solar water heaters installed previous programs by the benefits of using new ones, Figure (19, 20 and 21).

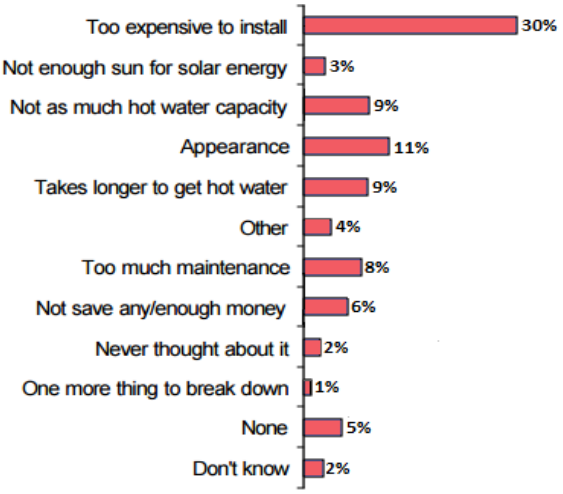


Figure-19. Perceived disadvantages of solar (total respondents: 300) .Source: the researchers.

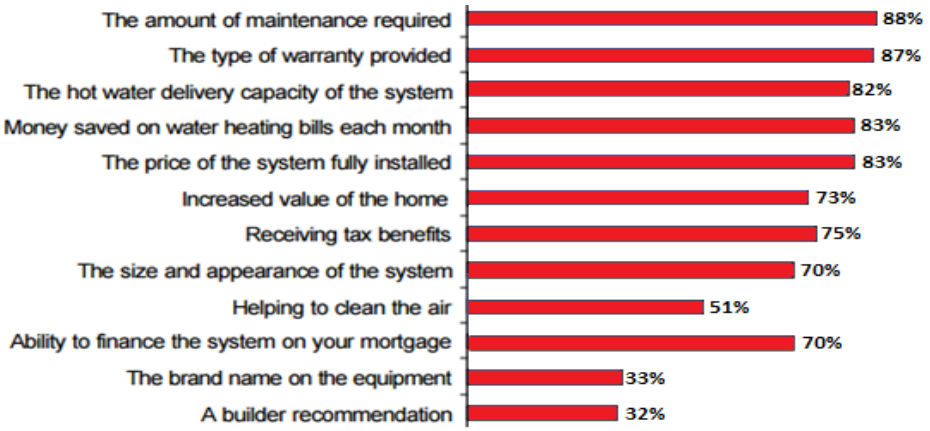


Figure-20. Importance of purchase decision factors %rating very important -4 or 5 (total respondents: 300). Source: the researchers

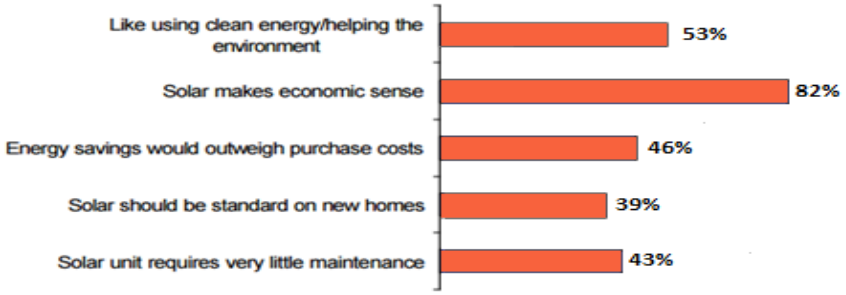


Figure-21. Agreement with attitudinal statements %rating very important -4 or 5 (total respondents: 300). Source: the researchers.

It found that solar water heaters offered the largest potential savings, with solar water-heater owners saving as much as 50% to 85% annually on their utility bills over the cost of electric water heating, (Mohamed A. Abdrabo, and Moataz Soliman, 2008). A total area of Solar water heaters in Egypt is about 750 thousand m2 (The Ministry of Electricity and Renewable Energy, 2013).

-The market study (year 2015) showed that the economic viability of SWH in Egypt cannot in financial or economic terms compete with conventional electrical or gas water heaters, Table-7.

Table-7. Types of heaters and their capacity and prices. The prices of the SWH are depending on the capacity and specifications.

Hs	Electric heater			Gas heater			Solar heater							
Company	Universal	Olympic electric	Fresh	Universal	Tornado	White whale	Natural flow system				Vacuum tubes system			
Capacity	50 L	50 L	50 L	10 L	10 L	10 L	180 L	360 L	500 L	750 L	165L	200L	245L	300L
Price	EGP 550	EGP525	EGP425	EGP 735	EGP 775	EGP 760	EGP4000	EGP9000	EGP12000	EGP15000	EGP9600	EGP11616	EGP13068	EGP16236

Source: the researchers

5. THE PROPOSED METHOD

The proposed method shows Management of Participation and Funding Management for project to achieve sustainable urban development, and Streamline overlaps and interconnections between the parties involved in the project, Figure 22 and 23.

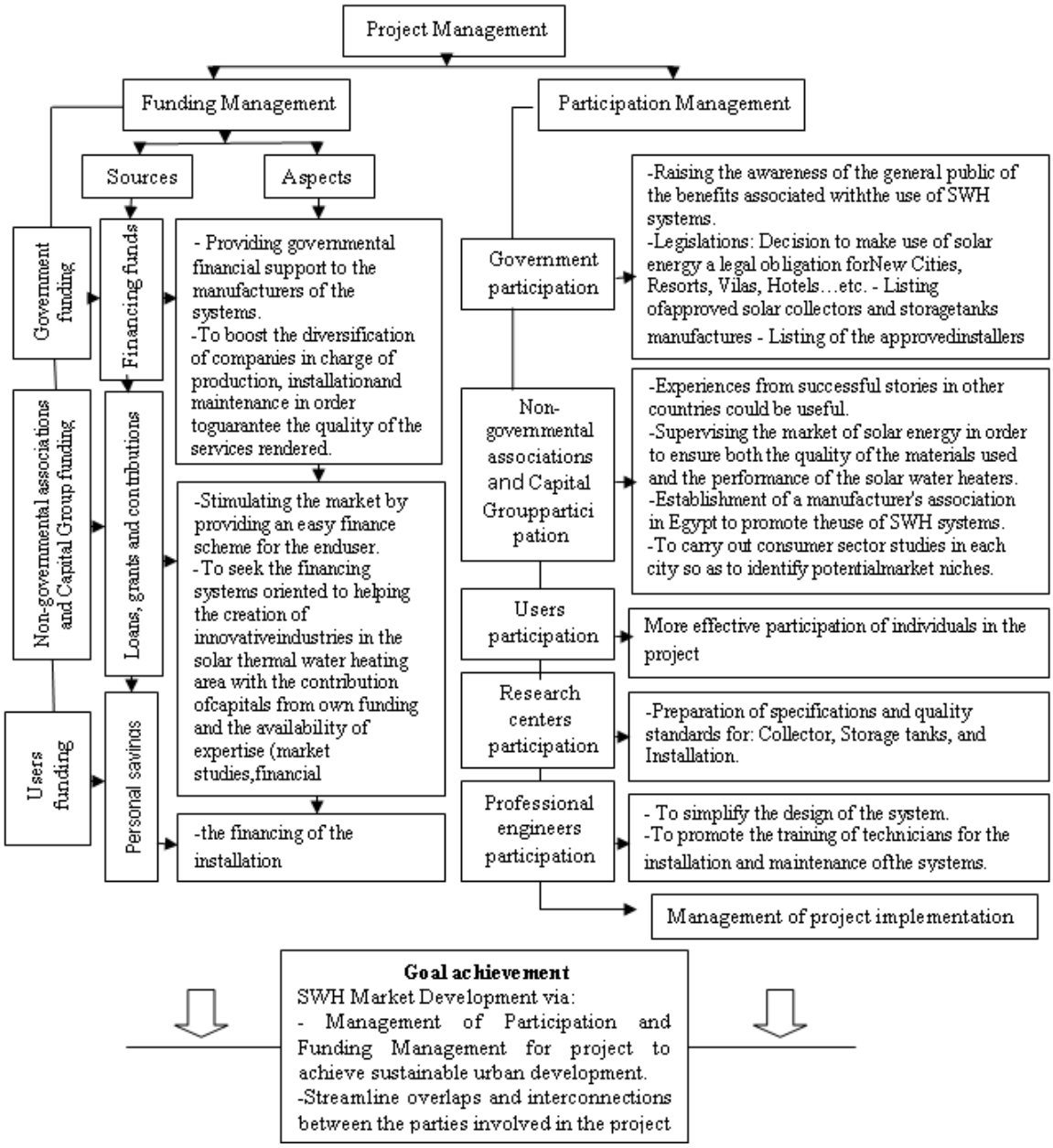


Figure-22. The proposed method. Source: the researchers.

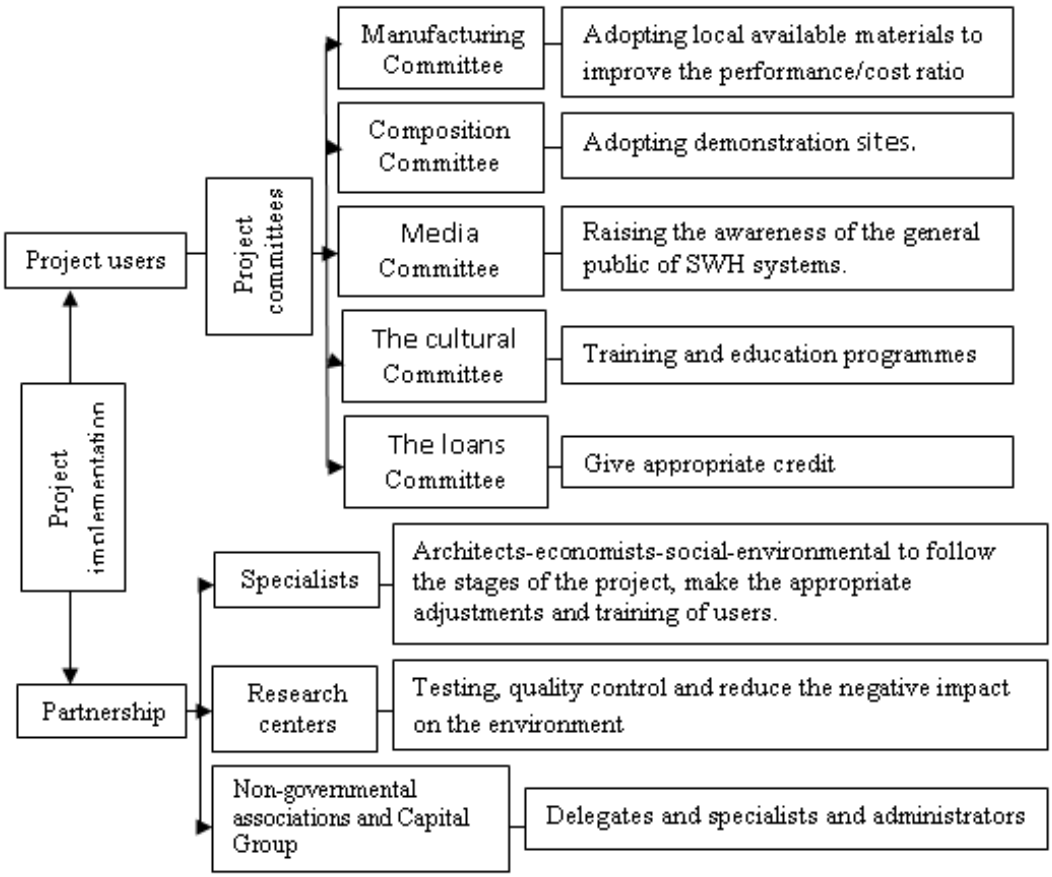


Figure-23. Project implementation. Source: the researchers.

6. RESULTS

Energy efficiency means using less energy to produce the same amount of services or outputs. The rapid growth of energy use raised concern over problems of supply worldwide. Exhausting the energy resources and causing severe environmental impacts such as depletion of the ozone layer, global warming and climate change. In developed countries, especially in Egypt contribution from residential buildings to energy consumption has steadily increased to 22% of the total energy consumption. Efficient use of energy will play an essential role in minimizing energy usage and associated emissions released into the atmosphere.

Solar technology in Egypt faces several issues and challenges:

- Lack of policy framework.
- Expensive solar technology.
- Lack of expertise.
- Lack of public interest and awareness.
- Insufficient funding.
- Combination of solar equipment and residential design is still at primary stage.

Solar water heaters have many advantages such as fuel savings, environmental benefits in addition that it does not require much maintenance, and a long payback period. It is important to put road map to solve the challenges: Legislation and policy, Funding from the Private Sector, Tax relief or rebates, Skilled and knowledgeable manpower, making full use of external parts of the solar energy that building can use, and to realize external harmony of landscape building.

7. CONCLUSIONS

Solar technology as an energy efficient approach in buildings is generally considered to be beneficial and would result in a cleaner environment in the long term.

Egypt, despite its high solar potentials, is considered a premature market for solar applications as the market analysis of SWH in Egypt had indicated that both of the demand and supply forces suffer from a wide range of issues and restricted by a number of factors. The role of the government, society, and the majority of researchers in the continuous efforts of the solar and building integrated design will gradually improve, achieve energy saving and Eco win.

A policy framework has to be developed for promoting the use of solar water heater in Egypt; such a road map may include the following measures:

- Creating the governmental commitment to solar energy (awareness, publicity, stimulating the market, and adopting demonstrations).
- Establishing and supporting testing facilities at national Institutions as well as developing and enforcing a set of specifications and quality standards for collectors, storage tanks and installation.
- Supporting research and development of solar technologies in order to adopt local available materials to be used for these technologies, increase efficiency and durability, promote simplicity ,reduce production costs, and allow for incorporating SWH systems when designing new buildings
- Establishing and supporting a SWH manufactures' association.
- Promoting market demand for SWH through raising awareness of the general public on the benefits associated with SWH
- Develop a framework of incentives to support SWH manufacturing and potential consumers.

It is recommended to design prefabricated building elements which can easily integrate and generate electricity within residential building. By using readily available solar electric generating elements like louvers, windows, balcony railings, walls etc., we can make the future safe for the energy use.

During the whole process of architectural design, serviceability and adaptability to buildings should be taken into account seriously in the application of solar energy technology, which means comprehensive consideration of needed materials, system styles, color application and assembling/disassembling performance of solar energy system. These aspects have great influence on building facade design.

Funding from private organizations can be a huge influence in the country's advancement of solar technology and its use as well as the progress towards sustainable development. Tax relief and rebates will attract more public awareness and instill interest in energy-saving techniques in daily life.

REFERENCES

Alexandra Hilbig. 2009. Short compendium on solar thermal applications and the solar water heaters industry in the Middle East. Solar Thermal Application in Egypt, Jordan, Lebanon, Palestinian Territories and Syria: Technical Aspects, Framework Conditions and Private Sector Needs. Cairo, 23rd - 25th March.

Arjun Basnet. 2012. Architectural Integration of Photovoltaic and Solar Thermal Collector Systems into buildings, Master's Thesis in Sustainable Architecture. Trondheim,https://www.ntnu.no/wiki/download/attachments/48431699/Master-Basnet.pdf?version=1&modificationDate=1339765553175

Diakoulaki, D.; A. Zervos; J. Sarafidis and S. Mirasgedis. 2001, Cost benefit analysis for solar water heating systems, Energy Conversion and Management, vol. 42.

Dixon J.A. and P.B. Sherman. 1990. Economics of Protected Areas: A New Look at Benefits and Costs, Earthscan, London, U.K.

El Salmawy, H., Sept. 2005. Report on Financing Mechanism for Solar Water Heaters and Energy Efficiency in Tourism Sector at the Red Sea, Mediterranean Renewable Energy Progarmme, and UNEP RISO Centre, Denmark.

Energy Research Center (ERC), December, 2006, Renewable Energy Sector in Egypt (Tender IMC/PS_217), Final Report, Volume (I). file:///C:/Users/SMART/Downloads/RE%20in%20Egypt%20Report%202006.pdf.

Growing Inclusive Markets. 2010. Case Study: Kuyasa CDM Project: Renewable energy efficient technology for the poor, United Nations Development Programme.http://www.growinginclusivemarkets.org/media/cases/SouthAfrica_Kuyasa_2010.pdf.

Harry Husted, Solar Energy and Its Use Today, 2007. http:///creatingwords.com/work/ghostwriting/solar/SolarEnergyandItsUseToday.pdf.

Kalogirou, S., 2009, Thermal Performance, Economic and environmental life cycle analysis of thermosiphon water heaters, Solar Energy. Vol. 83.

Keith Robertson and Andreas Athienitis, Solar Energy for Buildings, Canada Mortgage and Housing Corporation,https://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/OAA_En_aug10.pdf.

Lex Bosselaar *et al*. 2004. Integration of solar water heating into residential buildings, International practice and perspectives in China: moving towards closer integration with the housing industry. http://www.aee-intec.at/0uploads/dateien254.pdf.

Mohamed A. Abdrabo, and Moataz Soliman. 2008. Economic assessment of solar water heaters potentials in Egypt, Journal of Commercial and Management Studies, No. 4, October 2008, PP. 3-18http://www.researchgate.net/publication/236865654_Economic_assessment_of_solar_water_heaters_potentials_in_Egypt.

Pranita Pranjale and Deepali K.Hejiib, 2013, Non Conventional Sources of Energy- Applications of Solar Energy in Architectural Buildings, International Journal of Computer Applications (0975 – 8887), International conference on Green Computing and Technology.

S. M. Robaa. 2006. A study of solar radiation climate at Cairo urban area, Egypt and its environs. International Journal of Climatology, Int. J. Climatol. 26: 1913-

1928.http://onlinelibrary.wiley.com/doi/10.1002/joc.1349/pdf.

Solar Thermal Application in Egypt, Jordan, Lebanon, Palestinian Territories, Syria and Tunisia: Technical Aspects, Framework Conditions and Private Sector Needs, Cairo 23rd - 25th March, 2009,Workshop report.

The Office of Standards for Engineering Design and Construction of Anhui Province. Technical Standards for the Integration of the Use of Solar Energy and Architecture. DB34854-2008.

The Ministry of Electricity and Renewable Energy, annual report 2012-2013, http://www.nrea.gov.eg/annual2012-2013.pdf).

Werner B. Koldehoff, Solar Energy Focus on Solar Thermal, Conference on "Green Energy" Cairo, Egypt-2012-01-22.

Yibing Xue, Jie Zhang. 2013. Solar Hot System and Design of Buildings, International Journal of Clean Coal and Energy, 2, 13-15.

Appendix (1)

SOLAR WATER HEATING STUDY (SCREENING QUESTIONNAIRE)
September, 2015 -Cairo -Egypt

1-What is the age of this home?

Less than one year old	One to two years old	Two to five years old	Six to ten years old	Over ten years old

2-Which of the following most accurately describes the manner in which the water in your home is heated?

Natural gas	Electricity	Gas & solar combined	Electricity and solar combined

3-From what sources have you heard anything about solar water heaters?

Builder	Have seen them on homes	Friend	Books magazines	Internet	Direct mail piece	Advertising	Home shows	Other	Don't know

4-What do you think the disadvantages of using solar energy to help heat the water in your home would be?

Units do not look good on homes/appearance
Too much maintenance
One more piece of equipment to break down
Not as much hot water capacity
Takes longer to get hot water
Too expensive to install
Not save any / enough money
Never thought about it
Other (Specify)
None
Don't know

5-The solar energy industry has developed solar water heating systems for homes that look just like a skylight and can be easily installed on a home while it is being built. These systems require very little maintenance, and provide a large amount of the household hot water needs year around. If you had been aware of this type of solar water heating system when your house was being built, how much more per month would you have been willing to spend on your mortgage payment to have the system installed?

I would not want solar	Zero / none	Not sure / don't know

10-50pounds per month	50-100 pounds per month	100-150 pounds per month	More than 150 pounds per month

6-If you knew that the savings on your monthly utility bill would completely offset the additional cost of the system on your monthly mortgage payment, meaning your out-of-pocket expenses would be zero, how likely would you be to have the system installed? Would you be.

Extremely likely	*Somewhat likely*	*Might or might not*	*Somewhat unlikely*	*Extremely unlikely*

7-Using a scale of one to five, where a one means "not at all important" and a five means "very important," how important would each of the following things be in your decision to purchase a solar water heating system for your home if you had been interested in one?

start	Not important				Very Important
	1	2	3	4	5
The price of the system fully installed					
The amount of maintenance required					
Helping to clean the air					
A builder recommendation					
Receiving tax benefits					
The size and appearance of the system					
Money saved on water heating bills each month					
The hot water delivery capacity of the system					
Ability to finance the system on your mortgage					
The brand name on the equipment					
The type of warranty provided					
Increased value of the home					

8-Now let's use a scale of one to five again, only now a one means “completely disagree” and a five means “completely agree,” how much do you agree or disagree with each of the following statements?

start	Disagree				Agree
	1	2	3	4	5
A solar water heating unit would make economic sense.					
A solar water heating unit would require very little maintenance.					
I like the idea of using clean energy and helping the environment					
The savings on my monthly energy bills would outweigh the cost of purchasing the solar unit					
Solar water heating systems should be offered as standard equipment on all new homes being built					