CASE STUDIES

Do-It-Yourself Approach as Appropriate Technology for Solar Thermal System: the example of CDF Médina, Dakar (Senegal)

Riccardo Mereu, Tomaso Amati and Irene Bengo

GDEE GLOBAL DIMENSION IN ENGINEERING EDUCATION

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DL B 10735-2015
ISBN 978-84-606-7546-4

Citation: Mereu, R., Amati, T. and Bengo, I. (2015) ' Do-It-Yourself Approach as Appropriate Technology for Solar Thermal System: the example of CDF Médina, Dakar (Senegal)', in *Case studies for developing globally responsible engineers*, GDEE (eds.), Global Dimension in Engineering Education, Barcelona.
Available from: http://gdee.eu/index.php/resources.html

DO-IT-YOURSELF APPROACH AS APPROPRIATE TECHNOLOGY FOR SOLAR THERMAL SYSTEM: THE EXAMPLE OF CDF MÉDINA, DAKAR (SENEGAL)

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1. Introduction

In international projects in Developing Countries activities related to water treatment, energy, ICT, etc. topics often require the introduction or improvement of specific technologies. A large amount of literature and case studies about the characteristics of the technologies to be used is available nowadays and the concept of appropriate technology has been extensively studied and developed in recent years.

The present case study is mainly focused on the application of the do-it-yourself approach to a solar thermal system in Dakar, Senegal. Beyond the technical aspects, the sustainability of the solution from the economic and social point of view is treated including the potential for the development of local enterprise.

1.1. Disciplines covered

The main topics covered by this case study are engineering and cooperation for global development and energy for development. The first topic is specifically related to the do-it-yourself technique as appropriate technology and as potential skill for local enterprise development, the latter one focuses on the use of this technique to provide energy for improving standards of living and local productive activities.

1.2. Learning outcomes

Learning outcomes expected from this case study are:

a) increase knowledge of the appropriate technology and its main characteristics;

b) a better understanding of the economic and social dimensions of a technical project in developing countries.

1.3. Activities

During the class activity students are involved in a preliminary analysis of the solar thermal system in the local context. This activity is mainly developed as a problem to be debated in order to identify involved stakeholders, energy resources and needs, the energy system and related indicators; based on the appropriate technology as defined and the local social context. In this step students should identify a reliable solution for the specific case study but also potentially replicable in the local context.

The homework activity is focused on two different aspects concerning the technical part, including a do-it-yourself approach, for deciding the size of the solar thermal system and the local market analysis for entrepreneurship development. This group work activity includes design and deciding the size of the solar thermal system. The number of solar panels and tank size are defined based on resources and needs identified in the previous activity. Once the system is defined students should find appropriate local materials, decide the layout of the solar panel, and estimate related costs. Furthermore, students have to identify locally available solar power systems and related costs in order to define the potential position of a do-it-yourself solar power system in the local market.

2. Description of the context

2.1. Senegal overview

Senegal is a country in West Africa. Senegal surrounds Gambia on three sides and is bordered on the north by Mauritania, on the east by Mali, on the south by Guinea and Guinea-Bissau and on the west by the North Atlantic Ocean, between Guinea-Bissau and Mauritania. Senegal has a land area of 192,530 km2 with 531 km of coastline. Senegal is mainly a low-lying country, with a semi-desert area in the north and northeast and forests in the southwest. The largest rivers include the Senegal in the north and the Casamance in the southern tropical climate region.

Figure 1 *Senegal map*

The climate in Senegal is typical of African sub-Saharan countries with the warm rainy season from November to May and the dry season from December to April. The average annual temperature in the country is around 29°C, while the coast is slightly cooler (24°C, Dakar). In particular during the dry season minimum temperatures can reach up to 6-10°C.
Senegal is a member of the Economic Community of West African States (ECOWAS). Integrated with the main bodies of the international community, Senegal is also a member of

the African Union (AU) and the Community of Sahel-Saharan States. Senegal remains one of the most stable democracies in Africa and has a long history of participating in international peacekeeping and regional mediation.

The economy is driven by agriculture and that sector is the primary source of employment for the rural areas. The country's key export industries are phosphate mining, fertilizer production, and commercial fishing. The country is also working on iron ore and oil exploration projects. Senegal relies heavily on donor assistance and foreign direct investment (CIA, 2014). The economy continues to suffer from unreliable power supplies and rising costs of living, which has led to public protests and high unemployment and has prompted migrants to flee Senegal in search of better job opportunities in Europe. Some of the principal key economic and social indicators for the country are detailed in Table 1.

Table 1 *Human Development Indicators (2014), (UN, 2014)*

Human Development Index	HDI rank 163 (187 Countries) Index 0.485
Population total (millions)	14.13
Urban (% of population)	43.13
Median age (years)	18.17
Dependency ratio, young age (ages 0-14)	80.53
Life expectancy at birth	63.45
Mean years of schooling	4.45
Expected years of schooling	7.9
Adult literacy rate (% ages 15 and older)	49.7
Primary school dropout rates (% of primary school cohort)	38.63
Gross national income (GNI) per capita (2011 PPP $)	2,169.26
Consumer Price Index	120.1
Domestic food price level index	2.02
Price level volatility index	31.7
Inequality-adjusted HDI (IHDI)	0.326
Gini coefficient	40.3
Population in multidimensional poverty (%)	69.36
Population in severe multidimensional poverty (%)	45.09
Population living below $1.25 a day (%)	29.61
Employment to population ratio	75.5
Share of working poor, below $2 a day (%)	61.1
Primary energy supply, Fossil fuel (% of total)	53.24

2.2. THE CAPITAL DAKAR AND THE MÉDINA AREA

Forty-three per-cent of the Senegalese population live in urban areas, and more than half of the urban population is concentrated in Dakar. Dakar is the capital of country and with its port represents a key trade center not only for the country, but also for the economy of the region.

Médina, the traditional city within Dakar, is a neighborhood populated by poor people composed of various ethnic groups from the area (lébu, toucouleur, soninké, sereer, wolof, peul, mandinka, …) living side by side in an environment rich in tradition in which local craftsmanship is anchored to its origins. Security in the area remains critical in spite of the presence of basic infrastructure (water, telephone, internet, electricity, asphalt roads and public transport, a hospital,…), partly because of unemployment and juvenile distress.

The neighborhood of Médina is characterized by a young population (19% of the population is under 12 years old, 22% are aged between 13 and 21 years, only 23% are more than 35) and families are extended and numerous, consisting of an average of 7 members or more.
In this economically depressed context, 55% of the heads of households are employed, but youth unemployment is much higher, due to the lack of specific training. The economic activities of the Médina are mainly of three kinds:

- Commerce: The main focus of this activity is the marché de ethylene, the most African market of Dakar. The trade is a source of income for many of the local residents, but remains predominantly an informal activity, which does not generate sufficient profits to ensure sustainability or to make investments and develop the business;
- Handicraft: one area in constant development and involving almost all specializations, such as tanners and leather artisans, weavers, dyers, carpenters, tailors, jewelers, craftsmen working metal, wood, wicker...
- Tourism: is mainly another form of trade because it is mainly made up of the Artisan Village, a cooperative of more than 200 dealers (sometimes trades) is geared to tourists and, to a lesser extent, foreign residents.

Some aspects negatively influencing the main economic activities of the Médina are related to the reliability of the energy supply and the support for professional formation.

The energy supply system in the Médina, as well as in other urban and peri-urban areas of Dakar, is characterized by the presence of a public network. The distribution of electricity in the neighbourhood is strongly dependent on the availability of electricity from the main network and national power plant. The presence of a capillary network in the neighbourhood does not guarantee a reliable supply because of regular blackouts during the day and night in all seasons. These blackouts can last from a few hours (2-6) to days (1-2) and are usually not announced causing trouble for both residential and commercial activities. The main causes of the blackouts can be related to the lack of fuel for the power plant at national level or (rarely) specific issues in the national or local network. Another issue related to energy supply is the cost and environmental and health impact of sources used for thermal energy generation. Used mainly for cooking and heating purposes the main sources are wood and gas, unsuitable due to environmental and health issues and with high costs (gas).

From the educational point of view the schools of the Médina are numerous: 6 kindergartens, 25 elementary, 11 secondary, as well as numerous informal schools: Koran, community-based and literacy of children and adults. The main lack of this system is the absence of training schools or technical institutes in the area. This aspect strongly affects the employment opportunities of young people living in a working class neighbourhood, with basically a poor and uncertain future because of the lack in Médina of formative pragmatic and concrete opportunities that will lead, in short order, to a useful qualification for the world of work.

2.3. The 'Centro di Formazione Médina' project

The project, 'Centro di Formazione Médina' (CdF Médina) or Médina Training Centre, is part of the context described in the previous paragraph 'The capital Dakar and the Médina area'.
From the beginning the main objective of the project has been to improve the living, health and economic conditions of the population in the Médina. This has been carried out through scholar education and qualifying training for young people, giving them the opportunity to be involved or to develop sustainable economic activities in the local context and within the community in which they operate.

Specifically the 'CdF Médina' focuses on the education and training of young weavers and it is connected with the fair trade system. The first beneficiaries of the project were the unschooled and unemployed young people of the Médina who received a professional formation tailored to the work opportunities of the context.

The CdF Médina is part of the wider Senegalese textile chain that has witnessed a growing effort to enhance the national product through the promotion of organic cotton and the rediscovery of traditional techniques for weaving and fabric dyeing.

The project started involving qualified partners in fair trade (Karibuny), textile craftsmanship, local nongovernmental organization (Yaakaar G.I.E. and Domû Africa) and ISF-MI for the technological transfer and formation.

The project activities, while not having the specific objective of reducing gender disparity, are based on an accurate analysis of gender relationships and they develop specific strategies:

- the training courses were open to an equal number of men and women;
- teachers commissions were equally distributed in order to provide to the students positive female role models;
- very important is the prospect of working in the craft and trade fair, sectors in which there is usually a fair distribution of gender in terms of quantity (number of employees) but in which women are often relegated to an informal or subordinate position, with lower wages and very few business prospects. The project is scheduled for the active support of the students and most deserving producers with special attention given to girls and women (as well as other vulnerable groups).

In this description some aspects related to the sustainability of the project are not reported and attention is focused on the energy field. It is important to highlight that one of the main constraints identified for the overall sustainability of the Centre was the supply of energy. Indeed, due to its costs and discontinuity, the affordability and reliability of energy is not guaranteed.

The need for electricity and heat provision has been studied in the local context and with the local actors with the aim of determining the kinds of intervention and eventually technology to be used and how to introduce them into the context.

As far as supplying electricity is concerned, the continual and prolonged blackouts in the local electricity grid led to the design of an alternative system able to:

- compensate power shortage from the grid by working “off-grid”;
- limit electricity consumption from the grid by working as a supplementary system “on-grid”.

This need was faced with the design of a hybrid photovoltaic system characterized by the possibility to convert and store energy and to be used as a complementary system when the grid was regularly working and as an off-grid system during blackouts. The most important aspect in this case was to maximize the use of electricity from the photovoltaic system in order to decrease the running costs for the electricity supply and increase the amortization of the photovoltaic plant.

Another important energy requirement for the Center was the supply of thermal energy, i.e. hot water both for domestic use (showers, cooking…) in the b&b of the Center and for textile production (dye fixing).

2.4. Thermal energy needs and Solar Water Heater (SWH) technology

In general, in most of the developing countries hot water supply is not considered a basic need due to their warm climates and Solar Water Heater (SWH) is not considered the ideal technology to enhance the living conditions of the poor population in these contexts (Langniß & Ince 2004). Despite that, hot water is increasingly seen as a fundamental aspect of a modern hygienic and healthy life in contemporary societies (Milton 2007) and, in some cases, has a key role in artisanal productive processes, incentivizing the growth of demand. Furthermore, SWH actually represents a competitive economic alternative in countries with high energy costs and sufficient irradiation, contributing to open up possibilities for sustainable socio-economic development (Sitzmann & Langenbruck 2003). For these reasons, many representatives of the international community believe that the SWH system is one of the most simple yet effective renewable energy technologies, characterized by being often constructed using locally available materials by technicians with no special expertise and skill (Milton 2007).

The hot water requirements can be divided into three main categories: need for domestic hot water at the household level; commercial/services level which includes tourist accommodation (hotels, b&b ...), clinics and hospitals; production/manufacturing level.

In Dakar there has emerged at the household level a fairly high and increasing sensitivity compared to some previous years in respect of hot water needs, especially during the coldest months (January, February, March). Most tourist facilities ensure the use of hot water for their customers. Hot water requirements have been identified also in commercial and productive activities both in urban and rural areas such as laundries, textile and agri-food production.

In Dakar at the household level the domestic hot water needs are still satisfied with the use of the same gas bomb used for cooking. Especially in the more well-off social classes the use of electric boilers is well established (cost of 80-200 liters boiler: 130-190 €).

Even at the commercial and tourist level and in the health clinics the boiler is the most common technology, while the solar thermal systems are beginning to spread. Especially in Dakar on the roofs of some of the hotels and houses in residential neighborhoods several installations of solar thermal systems are present, which after a greater initial investment incur no or almost no costs.

Compared to the first analysis conducted in 2009, in 2013 the solar thermal market in Dakar has seen an increase of retailers and a slight drop in sales prices (about 10%). In Dakar official retailers of solar thermal systems are present and active, guaranteeing in most cases the installation and support that resellers related to the informal market cannot guarantee. In

Dakar you can find all the different configurations of solar thermal systems suitable for different contexts and needs - a thermosyphon and forced circulation; with flat plate collectors, vacuum and heat pipe - but certainly the most common configuration is the thermosyphon circulation with heat pipe collector.

All types of systems are pre-assembled kits imported from abroad (China, in most cases, and Europe). Based on interviews conducted in Dakar, sometimes the installation of an imported kit does not provide the desired results mainly due to lack of know-how that leads to incorrect installation and maintenance.

The prices of commercial solar thermal systems present in Dakar vary considerably depending on the type of plant and retailers. Although it is difficult to calculate a weighted average of the prices at the level of hot water demand as the technical characteristics of the systems are often not present, an average price of about € 1000-1150 can be estimated for solutions adapted to the needs of an average family with the cheapest ones at around € 700-850.

3. Class activity

This activity is mainly focused on a preliminary analysis of the use of solar water heater systems as a solution for hot water supply. Specifically, the technological appropriateness is evaluated for application to CdF Médina and its activities, with potential replication in the local context (Médina, Dakar).

Different aspects have to be analysed in order to identify involved stakeholders, energy needs and resources, the potential energy systems and related indicators based on the appropriate technology, and the local social context.

The first phase of the activity is developed via debate, in a kind of brainstorming, and the professor should stimulate and guide students in the process. Students should try to identify some technical and social characteristics from the context description reported in the previous section and their background:

- direct and indirect beneficiaries and involved stakeholders with their roles;
- stakeholder matrix according to the Logical Framework Approach of the Project Cycle Management (EC, 2004) and related graphic showing power and interest;
- needs of hot water in CdF Médina, and most representative specific needs in the Médina and Dakar;

- main advantages and limits of available resources and technologies for heating water from the point of view of sustainability.

At the end of this phase a list of potential beneficiaries and stakeholders with specific roles, a list of potential needs, and a table indicating advantages and limits of energy systems (resources+technologies) should be defined. Time required for this phase approx. 75'-90' including the introduction to the context reported in the previous section.

Finally, students should define a list of indicators based on social, economic and environmental dimensions and aim to characterize the energy system chosen as a solution. In this way the energy system can be evaluated and compared with other options in terms of its technological appropriateness.

ADDITIONAL INFO ABOUT HOT WATER NEED OF THE CDF MÉDINA

The dye fixing in Cdf Médina, as well as in all other enterprises, is realized by heating the water up to the incipient boiling point. The water is mixed with the "khemé", which allows the agent to dissolve the dye, then added to the color and, finally, the ségéné (fixative). The tissues are then immersed for a few minutes (5 to 15 minutes, depending on the fabric and color) and subsequently rinsed in water and vinegar. The amount of water used for each day of normal production (thus excluding the periods in which they work on the sample for the creation of new collections) is about 150 liters. About half of the water is heated; the rest is used at room temperature for wet tissues before they are colored and to wash them after coloring, to wash pots and pans, bowls and utensils. The 75 liters submitted to heat treatment are used intermittently throughout the day: a first use of hot water, equal to about 40 liters, is used at noon and the remaining at 3pm.

3.1. SOLUTION AND EVALUATION CRITERIA

Direct and indirect beneficiaries and involved stakeholders:

Beneficiaries and stakeholders can be identified at two different levels: people, organizations and Institutions involved in CdF Médina activities and the SWH installation in the Center, and those involved in the potential use of SWH for residential and productive end uses, as reported in Table 2.

Table 2 *List of beneficiaries and stakeholders*

	Beneficiaries	Involved stakeholders
CdF Médina activities and the SWH installation	- young poor people from the Médina - families of selected students and workers - fair trade stakeholders - merchants of the local community (providers and buyers) - artisans and textile entrepreneurs (farmers, spinners, weavers, dyers, tailors...) - local SWH sellers and technicians - CdF Médina workers involved in dying activities - tourist guests of b&bs	- schools of the Médina - Public Institution of the Médina - clothes shops …
SWH for residential and productive end uses	- tourist accommodation business - hospitals and clinics - laundries - textile and food production activities - households - local SWH sellers and technicians	- Public Institutions - oil/gas and wood suppliers - electricity providers - traditional energy supply technologies sellers and technicians …

Direct beneficiaries of the project were originally young people aged between 10 and 16 years old, living in the neighborhood of Médina from different ethnic backgrounds. They usually attended the first years of school and were forced to abandon it before they received appropriate training. In these conditions it is very difficult for them to find a job and they are generally discouraged by their experience at school and, consequently, disappointed by Institutions in general. In a tough working-class context like the Médina it is quite common to be engaged in illegal activities. In general girls and boys are selected from low-income families with lower prospects, especially in terms of employment and the project also tries to maintain a fair gender balance (at least 50 % of female students).

The activities of the Training Centre have external connections and strong links with the surrounding context. These connections lead to the determination of other categories of beneficiaries, specific to individual activities, as reported in Table 2.
The beneficiaries of the research on Senegalese textile traditions and the development of new textile products are all artisans and textile entrepreneurs (farmers, spinners, weavers, dyers, tailors...), especially those involved in fair trade, their families and the communities in which they live and operate.

Some possible main beneficiaries for the use of SWH in the Médina and Dakar have been identified as tourist accommodation businesses, hospitals, clinics, laundries, textile and food production activities and households.

Stakeholder matrix according to the Logical Framework Approach of the Project Cycle Management and related graphic showing power and interest;

Starting from the stakeholders defined in the previous point students should identify, based on the information about the context, the stakeholder interests; their capacity and motivations and the possible project actions as in Table 3 reported below.

Table 3 *Stakeholders matrix*

	Stakeholders	**Interests and how affected by the problems**	**Capacity and motivation to bring about change**	**Possible actions to address stakeholder interests**
CdF Médina activities and the SWH installation	Poor young people and their families from the Médina	Improve their skills Increase their income …	Lack of knowledge, tools and techniques; Strong motivation to increase their income Resistances to accept changes	Training with strong work access relationship; Technical training; Awareness; …
	Fair trade stakeholders	Improve the quantity and the quality of products …	Managerial capacity Resource availability …	Involvement for market access and the employment of the trained students ..
	Artisans and textile entrepreneurs (farmers, spinners, weavers, dyers,	Increase profits Create a strong local chain guarantee	Technical skills Motivation for improvement of the production chain …	Involvement as suppliers or teachers in the school …

	tailors...)	economic sustainability		
	Local SWH sellers and technicians	Image return Increase profits …	Technical skills Motivation to be known in the neighborhood …	Involvement in the activity …
SWH for residential and productive end uses	Commercial/services and production activities requiring hot water (tourist accommodation; hospitals and clinics; laundries; textile and food production…)	Hot water production at low costs; Improve their images/ marketing strategy	Financial resources	SWH awareness / marketing campaign
	Public institutions	Concern about public image Clean technologies interest	Political influence	Involvement Pressure for “green” policies
	Local SWH sellers and technicians	Increase profits	Technical resources	Training for business increase Involvement in maintenance
	Traditional energy supply technologies providers, sellers and technicians	Maintain/increase profits	Financial and technical resources Limited current motivation to change	Involvement in complementary sources use Training for business enlargement

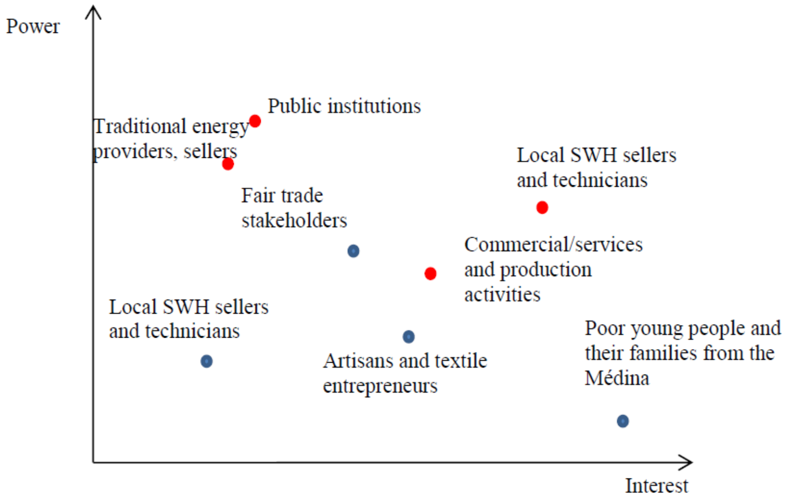


Figure 2 *Stakeholders power and interest*

Needs of hot water in CdF Médina, and most representative specific needs in the Médina and Dakar;

In this analysis of the needs of Médina/Dakar only residential (households), b&b/hotels, and hospital/clinical uses are considered. The use of hot water for productive activities is excluded from this analysis. Some data can be found in the literature to give a rough estimate of these quantities.

Table 4 *List of activities and related hot water needs*

	Activity	Quantity/Temperature
CdF Médina	Tissue dye	75 liters/day, 95°C
Médina-Dakar	Residential use	25-50 liters per person per day (excluding food preparation) @ 40°C. Gleick (1998)
	Tourist accommodation	60-90 liters per guest per day @ avg. 50°C (excluding the presence of pools)
	Hospital/clinic	120-160 liters per person per day @ avg. 50°C

Main advantages and limits of available resources and technologies for heating water from a sustainability point of view.

Table 5 *List of technologies and related advantages and limits*

Resource/Technology	Strength	Limits
Electricity/boiler	- no local pollution - instant availability - high temperatures - simple technology	- strong dependency on network reliability - cost
Gas/stove	- reduced health impact (compared with traditional biomass) - efficiency - high temperatures	- environmental impact - cost - safety (CO emission, explosions…) - imported source
Solar/SWH	- no environmental impact and local pollution - instant availability - no operating costs - strong independency from source providers - possible local technology production - modularity	- source availability - complementary source needed - no high temperature - high capital cost - low energy/surface ratio
Traditional biomass (wood, char…)/stove	- cost - possible self-providing - high temperature - simple technology - local availability of source and know-how	- environmental impact - local pollution (health impact) - average efficiency - time for providing source (especially with self-providing approach)

List of indicators of appropriate technology

In this analysis some indicators are not included related to the poor availability of data without a direct connection with the specific context. Only the main indicators with widespread and internet availability are considered.

Table 6 *List of indicators*

Social	Affordability	Share of household income spent on fuel and electricity
	Safety	Accident fatalities per energy produced by fuel chain
	Accessibility	Share of household time spent on providing fuel

Economic	Supply efficiency	Efficiency of energy conversion
	Prices	End-use energy prices by fuel and by sector
	Imports	Net energy import dependency
Environment	Climate change	GHG emissions from energy production and use per capita and per unit of GDP
	Air quality	Ambient concentrations of air pollutants in urban areas
	Concentrations of pollutants in air	Air pollutant emissions from energy systems

4. Homework activity

Introduction

The requirement of hot water for textile production (dye fixing) and for domestic use (showers, cooking…), led ISF-MI to an analysis of the local context aiming at determining the types of technology to use and how to introduce them properly into the context. Different resources and technologies have been considered and studied in order to evaluate the most appropriate solution to guarantee the satisfaction of the Centre's needs with positive social, economic and environmental impacts.

These requirements led to the designing of a do-it-yourself system of solar heating panels as an alternative to biomass (wood) and gas used in both rural and urban contexts. This solution offers environmental, economic and social advantages over traditional methods, in eliminating the indoor pollution and the cost and inconvenience of obtaining wood and gas. The easily obtainable materials (wood, sheet metal, copper and glass) required to build the panels and the do-it-yourself techniques, which do not require specialized skills, also make the production of panels for the local market a potential activity within the Médina, where traditional local artisans are involved and are the main actors.

Main activity

Based on the introduction the homework activity is focused on two different aspects concerning the technical part, including a do-it-yourself approach, for deciding the size of the solar thermal system and the local market analysis for entrepreneurship development.
Working in groups students should:

- quantify the energy needs in the Center and in the Médina and Dakar for most representative activities;
- quantify the energy resources available in the context and their affordability;
- deciding the size of SWH with a simplified/accurate method based on students' background.

Once the system is defined students should find appropriate local materials, decide the layout of the solar panels, and estimate related costs.
Finally, students have to identify locally available solar thermal systems and their related costs in order to define the potential position of a do-it-yourself solar thermal system in the local market.

ADDITIONAL INFO ABOUT THE SWH

The system defined by ISF-MI is characterized by an open thermosyphon configuration and a glazed flat plate panel, in accordance with the appropriateness criteria, available materials and resources.

4.1. SOLUTION AND EVALUATION CRITERIA

Quantify the energy needs in the Center and in the Médina and Dakar for most representative activities: Starting from the data reported in Table 4 the energy needs can be defined considering a constant heat capacity for the water cL=4186 J/kg°C, density □=1000 kg/m3 and an initial average temperature of the water from the aquifer Taquifer=15°C.

Table 7 *List of activities and related energy needs*

	Activity	Energy [MJ]
CdF Médina	Tissue dye	25.1
Médina-Dakar	Residential use	2.6-5.2
	Tourist accommodation	8.8-13.2
	Hospital/clinic	17.6-23.4

Quantify the energy resources available in the context and their affordability:

Table 8 *List of energy sources and related costs*

Energy sources	Energy	Avg. source cost
Electricity	-	Domestic: 0,18 €/kWh; Enterprises: 0,25€/kWh
Gas	~50 MJ/kg1	0,9€/kg
Solar	6010 Wh/m2/day2	-
Traditional biomass	Wood: 14÷17MJ/kg1 Charcoal: ~30MJ/kg1	Wood: 0,2€/kg; Charcoal: 0,3€/kg

1: Gross Calorific Value – GCV.
2: Yearly average irradiation per day on horizontal plane (JRC-PVGis).

Deciding the size SWH with a simplified/accurate method based on students' background:

The size reported in Table 9 is able to cover 50-70% of needs of the CdF Médina for tissue dying and represents the basic size of SWH for general requirements (coherently with Médina and Dakar consumption, as indicated in Table 4), considering the basic needs for a family composed of 4 members.

Table 9 *SWH size*

Component	Size
Collector	Active surface 2 m2, collector pipes: D=22 mm (1 manifold) and 14 mm (8 secondary vertical).
Tank	Volume: 150-170 l
Hydraulic system	Pipes Diameter: ¾"

Appropriate local materials, layout of the solar panel, and related costs:

In this phase of the project a context analysis was carried out in the field by ISF-MI focusing on the possible craftsmen concerned in the DIY activity and on the materials and skills available locally. Local artisans have been involved and the available materials and skills have been defined.

Table 10 *DIY SWH system construction materials*

Collector			
	Panel Box		
		Wood board	1030x2030x15 mm
		Lateral wood boards	1030x70x15mm (6)
		Glass	1000x2000x4 mm
		Mineral wool	1000x2000x50 mm
		Aluminum L profiles	1000x30x30x2 mm (6)
		Insulating rubber	6000x35mm
		Flattering	3 liters
		Vinyl glue	
		Silicon	
	Absorbent		
		Aluminum sheet	1960x840x2 mm
		Copper tube	22mm x 4,5 m
		Copper tube	14 mm x 1900 (8)
		Welding brass joint	22mm -3/4 F-F (2)
		Black paint	
		Wire	
		Sandpaper	
		Gas bomb and brazing tube	
Accumulator and hydraulic system			
	Accumulator		
		Plastic tank	250 liters
		Floating valve	3/4
		Clapet valve	3/4 (2)
		Tank joints	¾ (3)
		Tank rubber insulator	
	Hydraulic system		

		PEX tube	16mm x 4m
		Male joint for PEX	¾ (4)
		Female joint for PEX	3/4 (2)
Support Structure			
	Cubic wall		1300 x800x 500 mm
		Bricks	
		Concrete	
		Iron frame	

The analysis revealed the presence of good logistics for supplying materials in Dakar, the presence of technical skills (welding, glass production…), but at the same time underlined the need of training for a not yet well known technology. Furthermore, the same training need for the installation and maintenance of a SWH system emerged from the study of the local SWH commercial market that is entirely composed of imported solutions and is still not well developed.

The system is characterized by an open thermosyphon configuration and is composed of a glazed flat plate panel and insulate plastic tank, as reported in Figure 3 and Table 10.

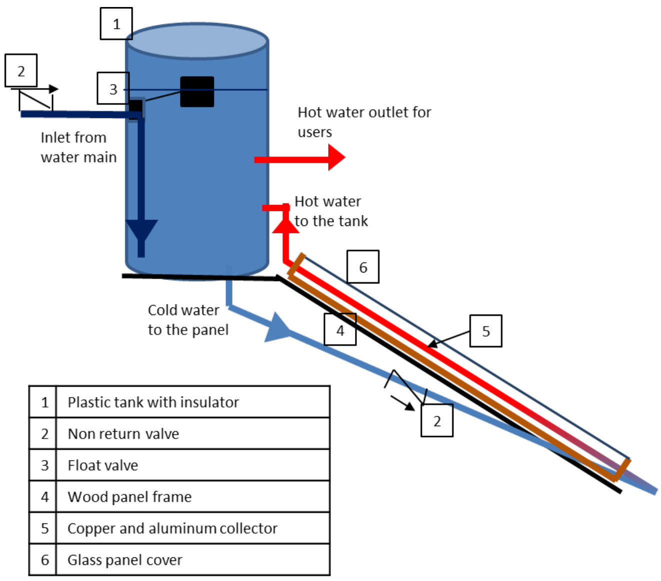


Figure 3 *DIY SWH system scheme*

Table 11 *DIY SWH system cost*

	FCFA	€
Materials		
Collector	165.963	255
Accumulator and Hydraulic system	69.427	107
Support structure	18.865	29
TOT	**254.255**	**391**
Manpower	33.886	52
Indirect costs (supplies, transport, instrumentations) 10%	28.814	44
Industrial Cost	**316.955**	**488**
Profit 20%	63.391	98
VAT 18%	68.462	105
Client price	**448.809**	**690**

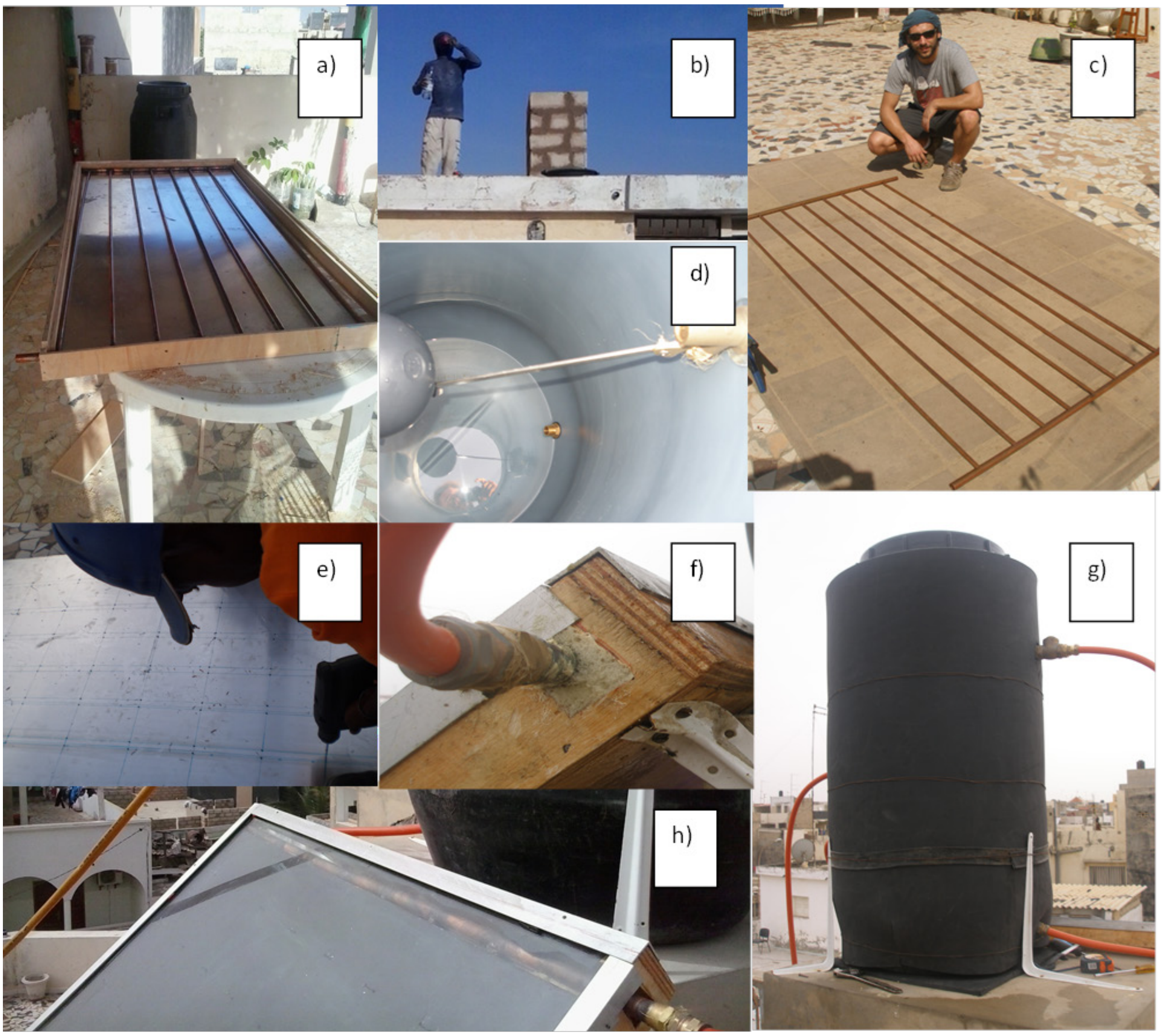
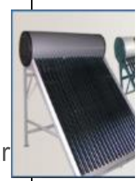


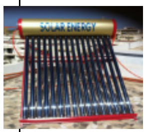
Figure 4 *DIY SWH materials and construction phases*

a) wood box with the absorber and the plastic tank;
b) contruction of the support wall;
c) collector tubes frame;
d) floating valve and outlet joint in the tank. The inlet of the floating valve is completed with a tube up to the bottom of the tank (not present in the photo);
e) alluminum sheet preparation for the contact with the copper tubes frame;
f) close-up of the panel outlet sealed with silicon
g) tank with insulator coat and clapet valve for the inlet of the water main (due to the low pressures of the water main system);
h) collector with rubber (bicycle inner tube) and aluminum L profiles ceiling the panel.

Locally available solar thermal system and related costs in the local market:

Table 12 *Commercial SWH in Dakar*

		Tank Liters	Cost		Notes
			FCFA	€	
Touba Solar Rama Hann Mariste 2 61N, Dakar, Dakar Senegal Tél : +221 77 203 2241 www.toubasolarrama.com	Flat 2m2 (forced circulation)	150	700.000	1.077	Not specified if VAT included or not 
		200	875.000	1.346	
		300	1.300.000	2.000	
	heat pipe 18-20 tubes	150	450.000	692	
		200	650.000	1.000	
		300	735.000	1.131	
SEN TECHNOLOGIES POWER Dakar : 2 Bd de la Libération Tél : 221 33 823 62 14 e-mail sentechpower@live.fr		120	650.000	1.000	system typology Not specified
		150	730.000	1.123	
		200	800.000	1.231	
		240	1.100.000	1.692	
PREMIUM Engineering Ingénierie - Bâtiment - Energies Renouvelables 6 bis, Mermoz Pyrotechnique BP 15155 Dakar - Sénégal Tél : +221 33 820 60 84 email : contact@premium-engineering.com	heat pipe	100-200	678.500	1.044	VAT Included. Supply and installation only in Dakar 
Rayon vert SARL 34, Mermoz Pyrotechnique ancienne piste BP : 11600, Dakar Sénégal Tél. : 33 860 13 04 Email : info@rayon-vert.pro	Vacuum pipe with forced circulation	150	1.795.000	2.762	supply and installation included 
	heat pipe with copper heat exchanger in the tank	150	755.000	1162	25% sales 
		200	813.000	1.251	
		300	897.000	1.380	
	heat pipe galvanized steel	80	305.000	469	Installation with boiler link 200€ more
		150	465.000	715	
		300	680.000	1.046	
	heat pipe alluminum	80	355.750	547	
		150	557.500	858	
		300	759.500	1.168	

	heat pipe with electric resistance 1,5kW	200	1.373.000	2.112	
Solar Energy Senegal Allée Seydou N. TALL Villa 27 B Zone B Dakar SENEGAL Tél : 77 303 35 89	heat pipe midea CFSN0207	150	550.000	846	Installation 185€ more 

From the assessment carried out by ISF-MI comparing costs between DIY and commercial systems, the opportunity for creating a local social business based on SWH production is available.

The final price to the customers of the solar thermal system proposed considering all cost items and a profit for the company of 20% (including installation) is 690 €, with a price about 30-35% lower than the cost of the panels currently on the market in Dakar with similar features. Based on the data collected, the sale price could also be lower than the cheapest commercial solutions (€ 700-850). Considering the scale-up of local production a plausible reduction in material costs can be estimated at approximately 10% of total cost.

Furthermore, the need for technical training of local technicians and commercial actors, in this case would be an integral part of the business idea, if we consider the knowledge transfer for the production of local systems necessary and essential.
The high initial investment for solar thermal systems is actually limiting the diffusion of SWH instead of conventional electric water heaters. Nevertheless, the negligible operating costs makes SWH competitive with other technologies and a policy of deferral of the initial investment could facilitate its introduction in the local market considering a payback time of 3-4 years if compared with electric boiler operating costs.

Considering the positive social effects due to technical training and job creation, the positive impacts related to the use of renewable energy sources and the development of a local supply chain, social enterprises may also require institutional support for its development ensuring their inclusion in government policies and programs for the training of young people and the use and/or for the development of renewable technologies.

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Annex 1: *List of the costs for materials and manpower for the DIY SWH system*

	FCFA	€	Q.ty per panel	€ /panel	Provider
Panel					
Wood Board 15x2500x3000	13.500	20,8	1	20,8	Loc market
Glass 6mm	16.000	24,6	1	24,6	Loc market
Flattering	6.271	9,6	0,5	4,8	Bernabè shop
Aluminum L profiles 30x30x2mm x 6m	8.600	13,2	1	13,2	Bernabè
Mineral Wool 5m2 x 100 cm	26.500	40,8	0,25	10,2	Bernabè
Aluminum sheet .2*1m	42.500	65,4	1	65,4	Bernabè
Copper tube 22mm x5m	28.499	43,8	0,5	21,9	CSS
Copper tube 12mm x5 m	17.699	108,9	3	81,7	CSS
Welding brass joint 22-3/4	1.278	2,0	2	3,9	CSS
Black paint/ vinyl glue /wire	2.900	4,5	0,5	2,2	Loc market
Silicon / paint solvent /sandpaper	4.500	7,0	0,5	3,5	Loc market
Gas for welding/brazing	4.000	6,2	0,5	3,1	Loc market
Tank and Hydraulic system					
Brass floating valve	7.343	14,4	1	11,3	CSS
Floating sphere	1.514	2,3	1	2,3	CSS
Clapet valve	4.500	6,9	2	13,8	CSS
Tank 250 l	22.000	33,8	1	33,8	Sandagà
Tank joints 3/4	2.814	4,3	3	13,0	CSS
Male joint for PEX 3/4	1.335	2,1	4	8,2	CSS
Female joint for PEX 3/4	1.598	2,5	2	4,9	CSS
PEX tube 16x4 meters	648	1,0	4	4,0	CSS
Tank rubber insulator	8.000	12,3	1	12,3	Loc market
Support structure					
Bricks, concrete and iron frame	26.950	41,5	0,7	29,0	Loc market
	Master builder	Assistant			
Manpower	CFA/day	CFA/day	€/day	Workday	€/panel

				/panel	
Bricklayer	3182	1590	7,34	1,5	11,0
Woodworker	3636	1818	8,39	1	8,4
Plumber	5455	1636	10,90	3	32,7

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This project is funded by