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ScienceDirect

Energy Procedia 83 (2015) 525 – 532

Energy Procedia

7th International Conference on Sustainability in Energy and Buildings

'Hybrid Transitions: Combining Biomass and Solar Energy for Water Heating in Public Bathhouses'.

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Abstract

This paper presents and evaluates initiatives taken in Morocco to reduce wood consumption, improve energy efficiency and reduce deforestation due to the operation of hammams (Turkish baths). First, the paper examines the vernacular energy systems used in heritage hammams and their lessons of sustainability. Second, it presents the problems associated with the new hammam furnaces and how they replicate vernacular systems. Third, the various initiatives for more energy efficient systems are presented. These include hybrid solar/biomass hammam systems. The paper evaluates the opportunities for addressing local and global concerns over deforestation and CO_2 emissions and discusses various difficulties and challenges.

Peer-review under responsibility of KES International

Keywords: public baths; Morocco; Energy efficiency; water heating systems; biomass; solar energy, hybrid systems, energy transition

1. Introduction

The paper comprises nine sections. It begins with an introduction to the hammam, or Turkish bath, and examines its role in North African society. The section following that presents a general discussion of the energy requirements

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Peer-review under responsibility of KES International
doi:10.1016/j.egypro.2015.12.172

of a hammam. Sections four and five present energy performance studies of a hammam and introduce an improved hammam boiler which has greater efficiency than the traditional one. Section six details some experiments carried out on a functioning hammam to see how solar power can be combined with biomass boilers. The conclusion follows a discussion of the results.

2. The Hammam

Public bathhouses in Islamic cities, known as hammams but also widely known as Turkish baths, are one of the very few building types that have sustained a tradition from the Roman times to the 21st Century. Reminiscent of the small Roman baths known as balnea, they were introduced in large numbers in all cities of the Islamic world as they facilitate bodily cleanliness and wellbeing as well as the accomplishment of major body ablutions necessary before the act of praying. In Morocco, heritage public bathhouses are the latest contemporary examples of this Roman tradition and they continue to operate in the urban historic centers well into the 21St Century. The location of hammams in cities is historically linked to the availability of springs, wells and underground water distribution systems. As such, water was freely available for many centuries until the traditional system of water distribution was made redundant and replaced by modern metered municipal water distribution system. Hammams are a key facility that is planned and built in the each new residential neighbourhood and are usually within walking distance of a mosque.

Unlike other North African and Middle Eastern countries where the hammam practice is disappearing, a weekly visit to the hammam is still a strong tradition in Morocco and is a living heritage sustained through many centuries. Studies conducted by the author on the heritage hammams of Fes and Marrakech [1.2] have revealed that the institution is still strong as it continues to provide a key affordable urban facility for hygiene, health and well-being for the urban population living in heritage centres. However, interviews conducted with hammam managers as part of various research projects conducted between 2004 and 2012 [1;2;3] revealed that ongoing increasing costs of water and fuel are making these centuries' old facilities vulnerable to irreversible closure and decay. A study conducted by the project REMMEE on the usage of hammams in Marrakech has revealed that clients use the hammam on a weekly basis and consume between 170 and 260 litres of water [4]. Furthermore, hammam managers complained that their clients expect to consume as much hot water as they wish, thus increasing the already high running costs associated with water heating and consumption. Many hammams are in urgent need of a rehabilitation project to improve their efficiency [5].

Rapid urbanisation and urban expansion in Morocco has seen a large increase in the number of newly built hammams. Indeed, housing regulations prescribe the insertion of a hammam along with a mosque in any new housing neighbourhood [6]. However, there is no definite and clear estimate of the total number of hammams currently operating in the whole of Morocco. Various sources present different numbers for operating hammams which vary between 6,000 and 10,000 hammams that still operate using the traditional heating system [6]. A number of studies conducted on the energy consumption of hammams [2, 3, 6, 7] indicate clearly that, on average, a hammam consumes between one to two tonnes of wood per day for both space and water heating. On average, a tonne of wood costs 650 Moroccan Dirhams (about 60 Euros) so the daily cost of fuel is 1,300 Moroccan Dirhams (about 120 Euro) [6]. Some organic rubbish was also used in the hammam furnaces which acted, for many centuries, as a neighbourhood recycling centre for organic waste. The collective impact of all the hammams in Morocco burning wood is significant and leads to deforestation. Indeed, it has been estimated that 30,000 hectares of forest is disappearing on a yearly basis [6] .A number of initiatives have been carried out since the 1990's to address the environmental problems associated with the hammam furnaces and their daily operation.

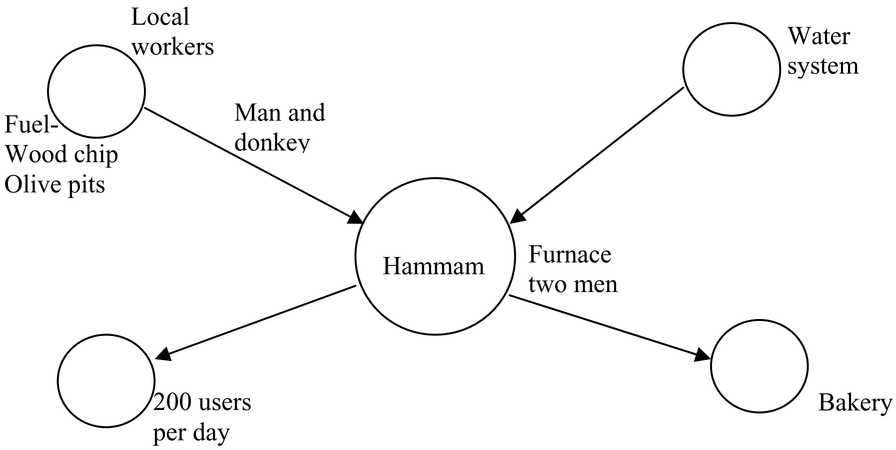

Figure 1 – Interplay of resources for hammams

3. Hammam energy consumption

In 2008 a multidisciplinary study of hammam Seffarine [3,8], a 14th century bathhouse located in the spiritual heart of the medina of Fez, clearly indicated that hammam operation has weekly and seasonal fluctuations in the number of clients; the high season being winter and the low season being the summer. During the hot season (May – August) the average number of bathers varied from 35 to 45 a day. During the cold season (November – February), this average reaches 150 to 200 bathers a day. The fasting month of Ramadan is also characterised by a sharp decrease in the number of bathers and is the time when the yearly maintenance of the hammam furnace and bathing spaces is carried out. September, October, March and April are considered as middle periods. Additionally the hammam operates at its full capacity before major religious celebration and during Thursdays and Fridays before Friday's noon prayer.

The seasonal and weekly fluctuation in the number of clients requires regular adjustments to the operation of the furnace. A traditional practice consists of knocking on the wall of the hammam hot room, which is adjacent to the furnace, to indicate to the boiler attendant to increase hot water when the hammam is working at its full capacity. The hammam boiler attendants work continuous eight hour shifts during which the furnace is manually fed with fuel. The hot ashes of a traditional hammam furnace were re-used by the furnace attendant to slow cook for the hammam neighbourhood some dishes such as the Tanjia Marrakechia, a vegetable stew cooked in a clay pot placed under the hot ashes. The cold ashes were subsequently reused as a puzzolanic additive to lime for the preparation of waterproof renders and plasters for the hammam walls and roof.

As such, the traditional hammam furnace operated a circular economy: recycling by-products from local small industries and organic refuse from the neighbourhood; provided a centralised water heating and distribution system for the neighbourhood residents; recycled heat from the ashes as a slow cook oven and recycled the cold ashes in the regular maintenance of the hammam structure. In addition, the hammam furnace created low income employment for two furnace attendants working in shifts, one person for donkey transport and delivery of fuel to the hammam, and additional income to wood workshops and olive presses by recycling their by-products. There is a nuisance factor from the hammam furnace to the neighbourhood in the form of air pollution from the hammam chimneys.

In view of the amount of fuel required per day (1-2 tonnes) by a hammam, work has been carried out on in 2000 redesigning the furnace to make it more efficient. An ultra-efficient boiler developed by the German Agency for Technical Cooperation in collaboration with the French Agency for Development and the Centre for Renewable Energy on Morocco (CDER) is claimed to reduce fuel wood consumption by up to 80% compared to existing hammam boilers. Since fuel wood is expensive relative to the cost of the boiler, the pay-back time for the investment was estimated at 10 months (the cost of the improved furnace being 982,000 Moroccan Dirhams). The estimated economy on biomass consumption was at 166 tonnes per year per hammam. i.e. a cost of 106,240 Dhs/year, bearing in mind that a ton of wood for the furnace costs 640 Dhs. [6]. With this return on investment, it might be thought that demand would be high. However, hammam owners expressed scepticism over the new technology and, as already successful businessmen, the owners had little incentive to upset a profitable business model. The initial plan was to implement this improved furnace in 1,000 hammams in Casablanca, 40 in other Moroccan cities and 30 in rural areas [7] . However, the high initial investment cost and scepticism have acted as a major deterrent to most hammam managers.

Figure 2 Delivery of wood shavings
Photo by Dr Magda Sibley

Figure 3 The traditional furnace area in hammam Deb Marrakech.
Photo by Dr Magda Sibley

4. Hammam energy performance studies

Before going on to compare furnace performance, a base-line of measurements relating to the "standard" heating system will be given. Information regarding the current energy performance of the hammam buildings was collected by Nigel Mortimer and Garry Jenkins [3.2]. It was based on on-site energy surveys, interviews with the staff, and readings from electricity and water meters. Regarding water and space heating system (boiler, storage tank and pipe work for water heating, and hypocaust and chimneys for space heating) additional information regarding temperatures of the furnace walls, flue gas emerging from the hypocaust vents, and supply water was collected. Given the uncertainty associated with the short-term nature of such surveys, as well as the limited reliability of metering information, the collected energy use data provides order of magnitude information rather than precise values [3, 2].

Collected data regarding energy use suggests that the water heating constitutes approximately three quarters of the total thermal energy use in a hammam. It was calculated that the thermal efficiency of the water heating systems is 22%. Reduction of water usage, together with more efficient water heating systems, should thus be the primary target of thermal retrofit measures, given the considerable energy saving potential involved. Additionally, flue gases from the furnace are used for space heating by means of hypocaust systems. It was estimated that the thermal efficiency of this space heating system is 68%. Parametric simulation studies suggest that the space heating demand of hammams could be reduced via addition of thermal insulation. Better insulated roof constructions, for instance, could reduce space heating demand by the order of 20%. It has been estimated that an average size hammam consumes 30 m^3 of water per day and a total of 1,500 kg of wood of which 300 kg is for under floor and space heating and 1,200kg for water heating. The potential of renewable (primarily solar) energy to cover – at least partially – the hammams' energy demands must be further explored in the future (see later in this paper). Despite challenges associated with the urban context and complex roof geometries of most hammams, the potential contribution of renewable energy is considerable, specifically given the relative abundance of solar radiation in the Mediterranean countries [3, 2].

5. The improved furnace

To date, only a limited number of hammam owners have installed the improved furnace developed by the Centre for the Development of Renewable Energies (CDER, now ADEREE) in Marrakech [7]. The aim of the development was to reduce wood consumption in the hammam furnaces, therefore reducing costs, deforestation and air pollution. Commercial outlets have been opened for it across the Moroccan territory. A discussion with Mrs. Khedija Kadiri, the owner of a traditional hammam in Rabat who has installed the improved furnace system, revealed that although the initial investment and installation costs are high, the improved furnace has contributed to a significant reduction of 60% of fuel consumption in her hammam (recorded interview with Mrs Kadiri in Fez, March 2011). There were, however, some issues with calcium deposits in the boiler and the fact that the intensity of the heating could not be regulated according to the owner of hammam al Karam in Marrakech. This illustrates that the transition to more efficient energy systems is rather slow and difficult as the traditional system of hammam furnace continue to operate in almost all the traditional hammams of the Moroccan medinas such as Fez and Marrakech until today - 15 years after the introduction of the improved furnace.

Figure 4 The improved furnace at hammam al Karam, Marrakech (Photo taken in January 2015 by Dr Magda Sibley)

6. The hybrid solar/biomass system

A hybrid system has been used to retrofit the furnace and heating system of Hammam al Karam in Marrakech. In addition to the improved furnace the owner of the hammam has installed on the roof of the hammam 105 sqm of solar panels for pre-heating the water before it enters the boiler and bio-mass boilers. The requirement for hot water is 30 m^3 per day. The results are summarised in table 1. The first set of columns relates to the baseline – the use of a traditional furnace to provide for water heating, under floor heating (UFH) and space heating. As can be seen the wood consumption is 1,500 kg and this equates to 2,700 kg of CO_2. This is per day. Use of a 105 m^2 solar thermal panel to preheat the water prior to heating by the furnace contributes 72 kW of heat for an investment of 500,000 Dh. The total power generated, including the traditional boiler, is 272 kW. Use of the solar panel reduces the wood requirement by 500 kg which equates to a saving of 900 kg of CO_2. The pay-back time is estimated as 4 years.

Table 1 Comparison of various hammam parameters and their variation with different sustainability options
Source: Adapted from Benhaim and Khaldoun (2014) [9]

	Base		Phase 1			Phase 2			Phase 3			
System	Water	UFH + room	Pre-heat	Water	UFH + room	Pre-heat	Water	UFH + room	Pre-heat	Water + UFH + room		
Heating	Trad	Trad	Solar	Trad	Trad	Solar	Bio	Trad	Solar	Bio 1	Bio 2	Bio 3
Power (kW)	200		72	200		72	115	200	72	115	69	46
Total (kW)	200		272			387			302			
Wood (kg)	1,200	300		700	300			500				
Olive pit (kg)							300			250	150	100
Total (kg)	1,500		1,000			800-			500			
CO_2 (kg)	2,700		1,800			1,440			900			
Reduction in consump. (kg)			500			700			1,000			
Reduction in CO_2 (kg)			900			1,260			1,800			
Investment (Dhs)			500k			500k	200k		500k	600k		
Fuel cost (Dhs/day)	1,050		700			560			350			
Fuel saving (Dhs/day)			350			490			700			
RoI (years)			4			5			6			

The third set of columns shows what happens when a bio-mass boiler is used to heat the water that is still pre-heated by the solar panels. This time the olive pit fed boiler contributes 115 kW to the total power output. The traditional boiler is still in use for the under floor and space heating. There is a considerable saving in fuel and CO_2 generated. The final set of columns shows what happens when the furnace is replaced by three biomass boilers still with the solar thermal panels. The total power output is 50% higher than the traditional boiler and this is achieved with a one ton reduction in fuel. This is clearly a significant advance but it does come at a cost of 1,000,000 Dh and a pay-back time of 6 years. It remains to be seen if the hammam owners can be persuaded to adopt this system.

7. Discussion

Hammams can be regarded as district heating systems but not in the way we traditionally think of them. Instead of the heat being distributed amongst families, the families come to the hammam. This convergence of neighbourhood residents offers opportunities of social interactions which have been lost in contemporary housing projects. As well as the users, the hammam plays an important role in the community at large. The 1-2 tons of wood per day provide jobs for workers which would otherwise be lost. The hammam provides an important focus and it needs to be saved.

The current heating system is very inefficient and some simple measures could result in lower fuel consumption. Insulation of the hot-water pipes would save fuel as would the insulation of the boiler. However care should be taken when imposing “Western” solutions as there is usually a vernacular ecosystem of a circular economy that offsets some of the exiting energy inefficiencies. Such as recycling and using the waste heat for cooking, etc. Of the possible solutions, the one that uses solar pre-heating and three biomass boilers is the optimum solution. It is not just a case of moving the problem from wood shavings and deforestation to olive pits and hence a lack of olives. The pits are the product of olive oil production and that has been going on for centuries. Swapping the wood shavings for olive pits is more sustainable and increased demand will provide local employment.

Increasing the size of the solar collectors is an option. However roof space is limited and this places a limit on the solar panel size. It is possible to use a photovoltaic/thermal combined panel which would generate hot water and electricity in one unit. This is a possibility and would be useful to power the electric lights in the hammam. Such panels are rather expensive at present and might not be considered for use. As already said, the optimum solution appears to be the solar thermal panels and three biomass boilers.

Initial installation costs should be subsidised by the habous authority (who own most of the hammams) in order to safeguard this hammam living tradition and its associated historic structures. Without their intervention, hammams will close due to increased cost of fuel and water. The habous need to create more incentives for hammam managers to continue the running of this very much needed traditional institution that has promoted health and well-being of the urban poor and others for many centuries. Also, we need to look back at the original methods of heating and getting water. It might be possible to get water from a well with solar p.v. providing the power for the pump. The burning of other by-products might help with the fuel costs. All of these things need to be considered if the hammams of Morocco are to be saved.

8. Conclusion

This paper has discussed the energy usage of hammams in Morocco. Figures relating to energy consumption on a traditional hammam have been given. The implementation of an improved energy efficient furnace has been examined along with the difficulties of adopting at large scale despite its fuel savings and short term returns on investment. This was due to skepticism among hammam owners making a transition from the vernacular system almost impossible, particularly for the heritage hammams where a circular economy applies. Following on from this, a solution using three biomass boilers and a solar thermal panel was installed and monitored in a new neighbourhood hammam in Marrakech. . The biomass boilers operated with olive pits rather than wood. The return on investment was quite high at 6 years.

In all cases. The Ministry of Habous in collaboration with the Ministry of Renewable Energies and the Ministry of Housing could join resources and efforts to act together as a catalyst for the energy transition of the public hammam institution in Morocco by subsidizing the installation of hybrid systems. The positive environmental, social and economic impacts on the low income populations would exceed by far the initial monetary investments.

9. Acknowledgements

The authors would like thank the Arts and Humanities Research Council (AHRC) for the funding allocated to survey the hammams of Marrakech in 2009, the EU funding for the HAMMAM project, Mr El Mehdi Khaldoun owner of hammam, Mr ElMehdi Khadoun and Michael Benhaim for the provision of the data for hammam al Karam in Marrakech, Mrs Khadija Kadiri, hammam manager in Rabat and member of the Moroccan hammam managers association.

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