Energy 75 (2014) 508–512

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

# Characteristics of energy-efficient swimming facilities – A case study

Wolfgang Kampel [a,*], Bjørn Aas [a], Amund Bruland [b]

[a] *SIAT - Centre for Sport Facilities and Technology, Department for Civil and Transport Engineering, Faculty of Engineering Science and Technology, Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

[b] *Department for Civil and Transport Engineering, Faculty of Engineering Science and Technology, Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

A R T I C L E  I N F O

*Article history:*
Received 8 April 2014
Received in revised form
31 July 2014
Accepted 2 August 2014
Available online 22 August 2014

*Keywords:*
Energy efficient
Swimming facilities
Swimming pools
Savings
Energy
Pools

A B S T R A C T

The European Union has introduced a directive with the aim to reduce primary energy production. With 40% of energy consumption connected to buildings there is a particular need of understanding the energy consumption profile and determine measures to achieve the agreed targets. Swimming facilities is a building category with particularly high energy consumption. The aim of this paper is to identify energy-efficient facilities and do an in-depth analysis to be able to determine their characteristics and further to describe how they achieve this low energy consumption. In order to find the most energy-efficient facilities, questionnaires were sent to all Norwegian swimming facilities. The results were screened and a follow up questionnaire, making a deeper analysis possible, was sent to the facilities with the lowest energy-use. The in-depth analysis showed that the facilities with the lowest energy consumption use heat exchangers and heat pumps to recover energy from the outgoing water and air. The energy is then used to warm up incoming air, pool water and tap water. However, it can be seen that even the best swimming facilities have room for improvement.



## 1. Introduction

In Europe, there is an overall target of energy savings in primary energy production of 20% within 2020 [1]. Around 40% of energy consumption is related to buildings [2] and there is a considerable need of action in order to reach the mentioned targets. Within the building sector, sports facilities may be described as high-level energy consumers [3], where swimming pools and ice rinks are on top [4]. This paper describes a case study on Norwegian swimming pools.

In order to meet the requirements of different user groups there is a considerable variety of swimming facilities in Norway. While a little shallow pool is enough for pupils to learn swimming, the features of the largest facilities (leisure pool facilities) are completely different. Their offer often includes a pool of international size, a pool with artificial waves, a diving platform, different water attractions and relaxation areas like a restaurant, spa or sauna. Opening hours reflect the variety of size where small school pools are open for 20 h per week and the largest facilities for up to 80–90 h per week for.

These different concepts result in different building envelopes, HVAC (heat, ventilation and air-conditioning) systems and water treatment systems [5] which is expected to lead to equal variation in energy-use. Some data about energy-use in swimming facilities are published [4–10] but little is stated on why facilities achieve low energy consumption. Further, several papers deal with specific subjects related to the water and energy aspects of swimming facilities, like evaporation [11–13], heat pumps [14–18] and building envelope [19].

The publications about evaporation from Shah [11,13] focus almost exclusively on the calculation while Asdrubali [12] included a chapter about energy consumption. However, no solutions or suggestions are given.

The publications concerning heat pumps [14–18] conclude that this investment leads to savings in energy consumption. Sun et al. [16] calculated the payback period to be 1.1 year for a pool in Shanghai when investing in using a ventilation system with a heat pump dehumidifier. Additionally, it must be mentioned that investment in energy saving measures is closely related to the price structure for energy in each country, in particular price differences in electric and thermal energy [20].

* Corresponding author. Tel.: +47 45134270; fax: +47 73597021.
*E-mail addresses:* wolfgang.kampel@ntnu.no (W. Kampel), bjorn.aas@ntnu.no (B. Aas), amund.bruland@ntnu.no (A. Bruland).

http://dx.doi.org/10.1016/j.energy.2014.08.007
0360-5442/

Trianti-Stourna et al. [5] state that the energy-use for swimming facilities in Mediterranean climate is about 4300 kWh/m$^2$ water surface (WS) and up to 5200 kWh/m$^2$ WS for buildings in the continental European zone. There is no indication about where these numbers originate from. The authors suggest architectural and electromechanical interventions to improve the energy-efficiency of swimming facilities.

A Finnish publication [6] deals with one swimming facility in Finland calculating the energy-use to be 2784 kWh/m$^2$ WS per year. This number is much lower than the one presented by Trianti-Stourna et al. [5] but it represents only one swimming facility on a theoretical basis.

Data from Germany [7] and Norway [8] include swimming facilities from the whole country and show a large spread in energy-use. The papers include only statistics and no more information about what makes the difference between swimming facilities with high and low energy consumption.

In a publication by Swedish public authorities [4] the numbers are presented in kWh/m$^2$ useable area (UA) and it is not stated from where these numbers originate. The only known fact is that no multi-purpose facilities are included. The publication reports the distribution of energy to the different subsystems but there is no distinction between the swimming facilities with high and low energy consumption.

British authorities [9] distinguish between “typical practice” and “good practice” without defining criteria for the categories.

The study published by Kampel et al. [8] divides the facilities in groups based on their WS and analysed their final annual energy consumption (FAEC). Considerable variations were found within the groups leading to the research question for this paper. How can the most energy-efficient swimming facilities be described? What makes the difference between facilities with high and low energy consumption?

## 2. Methods

A questionnaire was used to collect data from Norwegian swimming facilities. In total, more than 250 data sets (one data set is defined as the FAEC for one year for one swimming facility) were collected where a bit more than a third (37%) could not be used due to inaccuracy, missing data or the lack of energy measuring devices at the facilities. The questionnaire was processed by senior staff at the facilities.

The swimming facilities were divided into three categories. The buildings in category one are characterized by containing one pool. The second category includes facilities with two or three pools. Typically, a sports pool and a therapy pool that is slightly warmer. The third category consists of the biggest swimming facilities with several pools and water attractions. These categories differ slightly from the ones used by Kampel et al. [21] and the Danish Technological Institute [10]. The central change is the shift of facilities with a sports pool of 25 m × 12.5 m (WS of 312.5 m$^2$) from the second to the first category.

The term WS used in the article is equal to the pool surface area. The attractions are not included, but an overview can be found in Table 2.

The facilities were evaluated concerning their energy consumption and a follow up questionnaire was sent to those using the lowest amount of energy in each category to learn more about their characteristics. As benchmark for energy consumption kWh/m$^2$ WS/opening hour was used as suggested by Kampel et al. [21]. In the analysis, delivered energy [22] is studied while primary energy is not discussed. The whole questionnaire with all included questions can be found in the Appendix A. Further information was collected by personal communication with plant representatives.

The original intention was to investigate three pools in each category, which was not possible under the given circumstances. The authors met the greatest challenges concerning swimming facilities in category one as this building type is often combined with other sports halls or facilities and have no separate measuring devices installed. In general, some of the swimming facilities, which seemed to show good energy performance, turned out to be not so energy-efficient after a deeper analysis, and had to be excluded. Another reason to exclude answers was a general lack of understanding of the energy systems by plant operators, leading to inaccurate responses.

Climate correction was applied, as the FAEC of the different swimming facilities is dependent on the location and annual climate variations. Referring to Enova [23], 40% of the FAEC in swimming facilities are influenced by the climate and needs to be adjusted. All data was corrected, using the Oslo climate of 2010 (degree-days of Oslo in 2010) as reference, with the following formula [24]:

**Table 1**
Overview over the collected data for all swimming facilities.

| | Category 1 | | Category 2 | | Category 3 | |
|---|---|---|---|---|---|---|
| | Facility 1 | Facility 2 | Facility 3 | Facility 4 | Facility 5 | Facility 6 |
| Building year | 1966 | 1969 | 1995 | 1982 | 2008 | 2007 |
| Annual opening hours | 1404 | 2904 | 3682 | 3294 | 4328 | 4114 |
| Annual visitors | 55,000 | 44,700 | 100,000 | 130,000 | 365,000 | 210,000 |
| Air temperature [°C] | 30 | 32 | 28 | 30–33 | 31 | 31 |
| Water temperature [°C] | 27.5 | 28–32 | 28.5 | 29.6 | 28 | 28.9 |
| Humidity [%] | 55 | 55 | 55 | 55 | 55–60 | 60 |
| WS [m$^2$] | 281 | 312.5 | 548.5 | 637.5 | 1467 | 1170 |
| Water consumption [m$^3$] | 3563 | 6500 | 13,278 | 11,817 | 48,418 | 16,250 |
| Water consumption per person [l] | 65 | 145 | 133 | 91 | 133 | 77 |
| FAEC [kWh/m$^2$ WS/hour opened] | 2.93 | 1.40 | 0.86 | 0.78 | 0.89 | 0.47 |
| Automatic water quality control | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Water quality within regulations | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Heat pump for filter cleansing (pool refill) | | | | ✓ | | ✓ |
| Heat exchanger for grey water (showers) | ✓ | | ✓ | | | |
| Heat pump for grey water (showers) | | | | ✓ | ✓ | ✓ |
| Heat exchanger in HVAC | ✓ | | | | | |
| Heat pump in HVAC | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Energy from HVAC distributed to air | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Energy from HVAC distributed to pool water | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Energy from HVAC distributed to tap water | | ✓ | | ✓ | | ✓ |