Energy Consumption of a Public Swimming Bath

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Abstract: Swimming baths are popular sports and recreation facilities. The high energy consumption in swimming baths presents a great challenge for energy conservation in both new construction and renovation. This paper presents a study where the energy consumption of a Finnish recently built public swimming bath was calculated and analyzed. The annual heating energy consumption of the studied swimming bath was 396 kWh/gross-floor-m^2 and the annual electric energy consumption was 240 kWh. The heating of water accounted for 56 percent of the heating energy. The major part of the electric energy was consumed by the sauna stoves and the wet steam bath (31 %), and heating pumps and water elements (30 %). The calculations were also sensitivity-tested. The calculations were most sensitive to changes in the use of the facility.

INTRODUCTION

Swimming baths are popular sports and recreation facilities. They have a great impact to the public health. The gore of the swimming bath facilities is the main pool area, but in addition they need dressing and locker rooms, shower rooms, lavatories, storage rooms, and mechanical rooms. Usually swimming baths consists also gym, medical booms, meeting rooms, and cafeteria.

Acording to Trianti-Sourna *et al*. [1], for Mediterranean type climates the average annual total energy consumption per water pool surface area is about 4,300 kWh/m^2, and for the continental European zone it can be as high as 5,200 kWh/m^2. The high energy consumption in swimming baths presents a geat challenge for energy conservation in both new construction and renovation.

This study is part of a broader concluded research project including the energy flows and environmental impacts of sports facilities of different types during their life cycle. The subject of this substudy [2] is a swimming bath: its operational energy consumption and the resulting environmental burdens, and the most effective ways of affecting them.

MATERIALS AND METHODOLOGY

The research method was computational. It proceeded as follows:

- A swimming bath was selected and its properties and use determined.
- The operational energy and water consumption of the bath was calculated.
- The energy flows and environmental burdens due to operational energy consumption over 50 years were calculated.
- The sensitivity of the calculations was tested.

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The subject of calculations was a recently built Finnish public swimming bath in Kirkkonummi. Kirkkonummi is situated in Greater Helsinki area.

The facility consists of following functional sections:

- Main pool hall (1,140 m^2)
- Locker rooms, shower rooms, and saunas (312 m^2)
- VIP saunas (80 m^2)
- Gym and massage (218 m^2)
- Cafeteria (101 m^2)
- Storages (483 m^2)
- Other programmed spaces (248 m^2)
- Lobby, corridors, and stairs (245 m^2)
- Technical space for swimming pool equipment (272 m^2)
- Ventilation plant room (403 m^2)
- Other technical rooms (32 m^2)
- Total (3,535 m^2)

The cross-floor area of the building is 4,120 m^2 and the building volume is 20,100 m^3.

The facility has three swimming pools and a children's wading pool. The main pool (pool area 360 m^2) in the high section is 25-metres long and has six lanes. It also has a 3-metre diving platform and a springboard as well as a spectator seating area with capacity for 100. The high section also houses a multipurpose pool (pool area 120 m^2) which has a counter-current area and a raindrop fountain – a 42-metre water slide also descends into it.

On the other side of the pool area is a warm-water pool space with a pool for rehabilitation (pool area 100 m^2) that has six massaging showers and a handicapped lift. The space can also be separated from the rest of the facility.

The average temperature of the high section is +28°C and that of the warm-water pool space +30°C. Pool temperatures

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are 26°C – 33°C. Relative humidity of the facility is maintained around 50 %.

The facility has seven saunas, four of which are available to the general public: two are in constant use and two are used for a few hours in the evenings when the number of bathers is at its highest. There is also a Turkish-type wet steam bath for both men and women in the washing area. The facility also has two VIP saunas that can be rented. There is also a cafe, an exercise and fitness room, a multipurpose space, and a conference room. A private massage service also operates in the complex.

It was estimated that bathers pay 150,000 visits to the facility annually. In the calculations the facility was considered to operate for 48 weeks per year and 87 hours per week.

Ozonation, precipitation with open sand filters, and chlorination were chosen as the water treatment method for the exercise and multipurpose swimming pools. The water of warm pools is treated by precipitation using open filters – activated carbon powder is injected if necessary. The carbon powder is intended to make removal of dissolved organic matter more effective as well as to remove trihalomethane from the water. Water treatment of the pools is automated meaning that all pools have, for instance, automatic chlorine and pH feed and regulation. Pool water is disinfected with chlorine.

The fresh air volume of the pool area is dimensioned according to drying need and required temperature of overall air volume. Fresh and exhaust air flows are dimensioned so that the exhaust air flow from the hall exceeds the fresh air flow into it. Pool area ventilation is implemented by supply and exhaust air equipment in the basement and air circulation equipment. The supply and exhaust air equipment include filtration, heat recovery, and pre-heating of supply air. The flow of supply air is regulated according to the need to remove moisture. Supply air is blown into the pool area mainly from under windows. During the night, the air circulation equipment functions as the primary dehumidifying apparatus. Heat from pool area exhaust air is recovered by a glass tube heat exchanger. The exhaust and supply air flows are completely separated from each other in the heat exchanger which means that it does not transfer moisture or the detrimental substances of the exhaust air into supply air. The efficiency of the device is 40–50 %.

RESULTS

Components of Swimming Bath's Energy Consumption

The swimming bath's operational energy consumption consists of heating energy and electrical energy. Table **1** shows the computed heating energy need of Kirkkonummi swimming bath while Table **2** shows its computed need of electrical energy. Table **3** gives the computed water consumption.

Table 2. Computed Annual Electrical Energy Need of Swimming Bath per Gross Floor Area and per Square-Metre of Pool (Kirkkonummi Swimming Bath)

	kWh/Gross-Floor-m^2	kWh/Pool-m^2	%
Lightning	25	178	11
Air-ventilation	65	454	27
Pumps	71	503	30
Sauna stoves	74	519	31
Other equipments	5	37	2
TOTAL	240	1691	100

Comparison of Calculated Consumption Data with Empirical Material

The calculated energy (heating energy, electrical energy) and water consumption figures concerning the subject of the study were compared with the actual measured consumption figures for swimming baths of different ages involved in the VTT swimming bath energy consumption monitoring project (VTT, Kulu project, Swimming bath energy consumption monitoring project. The empirical material was received from Hannu Komulainen in 2001, see Figs. **1, 2** and **3**).

Table 1. Computed Annual Heating Energy Need of Swimming Bath per Gross Floor Area and per Square-Metre of Pool (Kirkkonummi Swimming Bath)

	kWh/Gross-Floor-m^2	kWh/Pool-m^2	%
Envelope	47	332	10
Ground slap	9	65	2
Air-ventilation of swimming hall	74	517	15
Air-ventilation of other spaces	59	416	12
Air-leak	24	170	5
Warming of pool water	143	1007	30
Warming of shower and tap water	123	862	26
Total	479	3369	100
Free energy	-83	-585	-17
TOTAL	396	2784	83

Table 3. Computed Annual Water Need of Swimming Bath per Gross Floor Area and per Square-Metre of Pool (Kirkkonummi Swimming Bath)

	m^3/Gross-Floor-m^2	m^3/Pool-m^2	%
Evaporation of pools	0.9	6.1	19
Be carried by swimmers	0.4	2.6	8
Refilling of pools	0.1	0.8	2
Cleaning of filters	1.1	7.7	24
Cleaning	0.7	4.9	15
Showers	1.5	10.2	32
Cafeteria	0.0	0.0	0
TOTAL	4.6	32	100

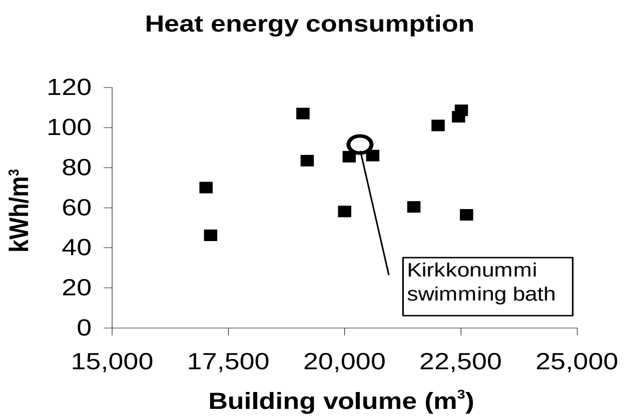


Fig. (1). Comparison of the calculated annual heat consumption (kWh per building volume-m^3) of Kirkkonummi swimming bath (marked with ring) to empirical consumption of swimming baths involved in the VTT swimming bath energy consumption monitoring project.

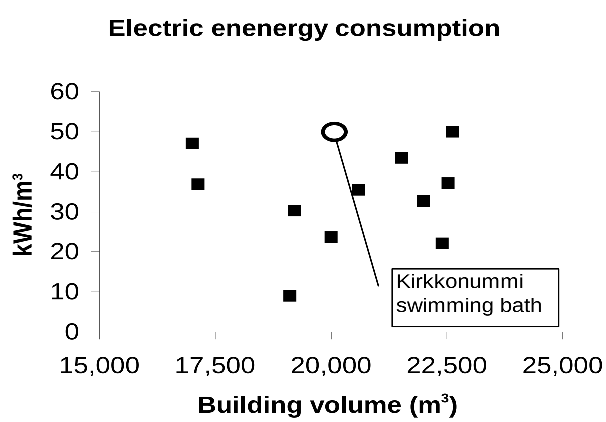


Fig. (2). Comparison of the calculated annual electric energy consumption (kWh per building volume-m^3) of Kirkkonummi swimming bath (marked with ring) to empirical consumption of swimming baths involved in the VTT swimming bath energy consumption monitoring project.

The comparison revealed that the calculated energy and water need of Kirkkonummi swimming bath is larger than the average energy and water consumption of the swimming baths involved in the VTT monitoring project.

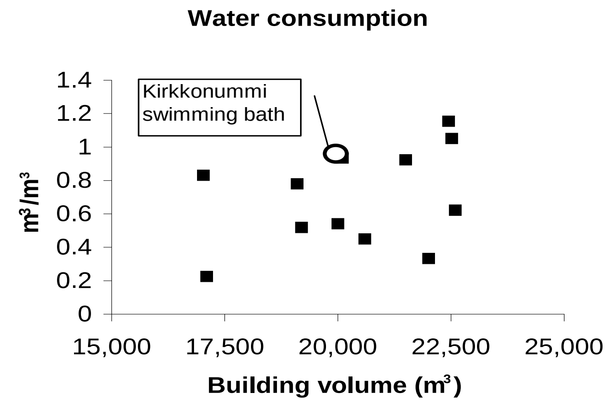


Fig. (3). Comparison of the calculated annual water consumption (water-m^3 per building volume-m^3) of Kirkkonummi swimming bath (marked with ring) to empirical consumption of swimming baths involved in the VTT swimming bath energy consumption monitoring project.

The swimming bath's electrical energy and water need is greatly affected by the activity within.

Presently, the trend is to build swimming-oriented leisure centres with pool space for different functions. A warm-water pool in a swimming bath increases heating energy need while water elements, such as massaging showers, also consume extra energy. Kirkkonummi swimming bath can be considered to be on a level with recreational spas.

Environmental Impacts

The operational energy consumption of a swimming bath results in a nearly 4-fold environmental burden per gross-floor-area compared, for instance, to an apartment block [3] or a training ice hall [4]. In the case of the two latter, operational energy consumption causes over 90 percent of the environmental burden of their life cycle. It can be assumed that operational energy consumption is even more marked in the case of a swimming bath. Therefore, this study is confined only to environmental burdens due to operational energy consumption.

The operational primary energy consumption of the swimming bath under study over 50 years is 193 GJ/gross floor area (m^2). The calculated climate-heating effect of the bath, again, is 11.2 tons/gross floor area (m^2), the acidification effect 0.021 tons/gross floor area (m^2), and the ethane equivalent 0.29 kg/gross floor area (m^2).

The 1998 average district heat and electricity production figures for Finland were used in the calculations where the energy flow from transmitting heating energy into a building is 5.0 MJ/kWh and that from electrical power 7.2 MJ/kWh. The used environmental impact of heating energy with district heat was 400 gCO_2 equiv/kWh for climate-warming emissions, 0.71 gSO_2 equiv/kWh for acidifying emissions, and 0.0083 gethane equiv/kWh for emissions producing oxidants. The used environmental impact of electrical power was 220 gCO_2 equiv/kWh for climate-warming emissions, 0.39 gSO_2 equiv/kWh for acidifying emissions, and 0.004 gethane equiv/kWh for emissions producing oxidants [3].

Sensitivity Analyses

A sensitivity analysis of the calculations was done. The design solution and the mode of use of the bath was varied.

The difference is presented as a percentage of the basic calculation.

Sensitivity to design solutions was tested:

- By varying the thermal insulation capacity of the swimming bath shell;
- By varying the design air volume of the ventilation unit, and
- The efficiency of heat recovery.

All examined changes in studied design solutions had a quite small impact on the energy flow and environmental impacts of the operational energy consumption of the swimming bath (-4 %…+3 %).

Sensitivity of calculations to modes of bath use was tested by

- Pool water exchange;
- Change in indoor temperature;
- Changes in pool water temperature, and
- Change in use of swimming bath.

A two-degree rise in pool water temperature clearly increased the energy flow and environmental impacts (+6 % … +8 %) due to operational energy consumption of the swimming bath. Lowering of pool water temperature by two degrees reduced the impacts clearly (-5 %…-7 %). An increase/decrease in the number of annual visitors also clearly affected energy flow and environmental impacts. Halving of the pool water exchange interval had hardly any effect (Table **5**).

CONCLUSIONS

It is desirable from the viewpoint of the environmental impacts of the swimming bath over its life that is does not consume an unreasonable amount of energy. Its energy consumption can be affected by decisions made already at the construction design phase. An energy- and environment-efficient swimming bath requires that pool and other spaces are dimensioned according to needs and requirements of the activities conducted there. Special attention should be paid to the number of multipurpose pools with warmer than normal water built including jacuzzi functions which use a lot of energy.

The dimensioning of pool area ventilation should be well thought out. It should be sufficient, for instance, to prevent moisture damage, but, on the other hand, overdimensioning results in high energy consumption and a significant environmental burden.

It pays to equip the pool area ventilation apparatus with heat recovery, but with a type that does not return exhaust air moisture back to the bath. Investment in appropriate regulation of ventilation is worthwhile.

The recommendations can be applied to both new construction and renovation. Those responsible for operation and maintenance should see to it that the operating time and efficiency of ventilation equipment is adjusted in accordance with spaces and their use. Attention is to be given especially to the indoor temperature of the swimming bath and temperature of pool waters.

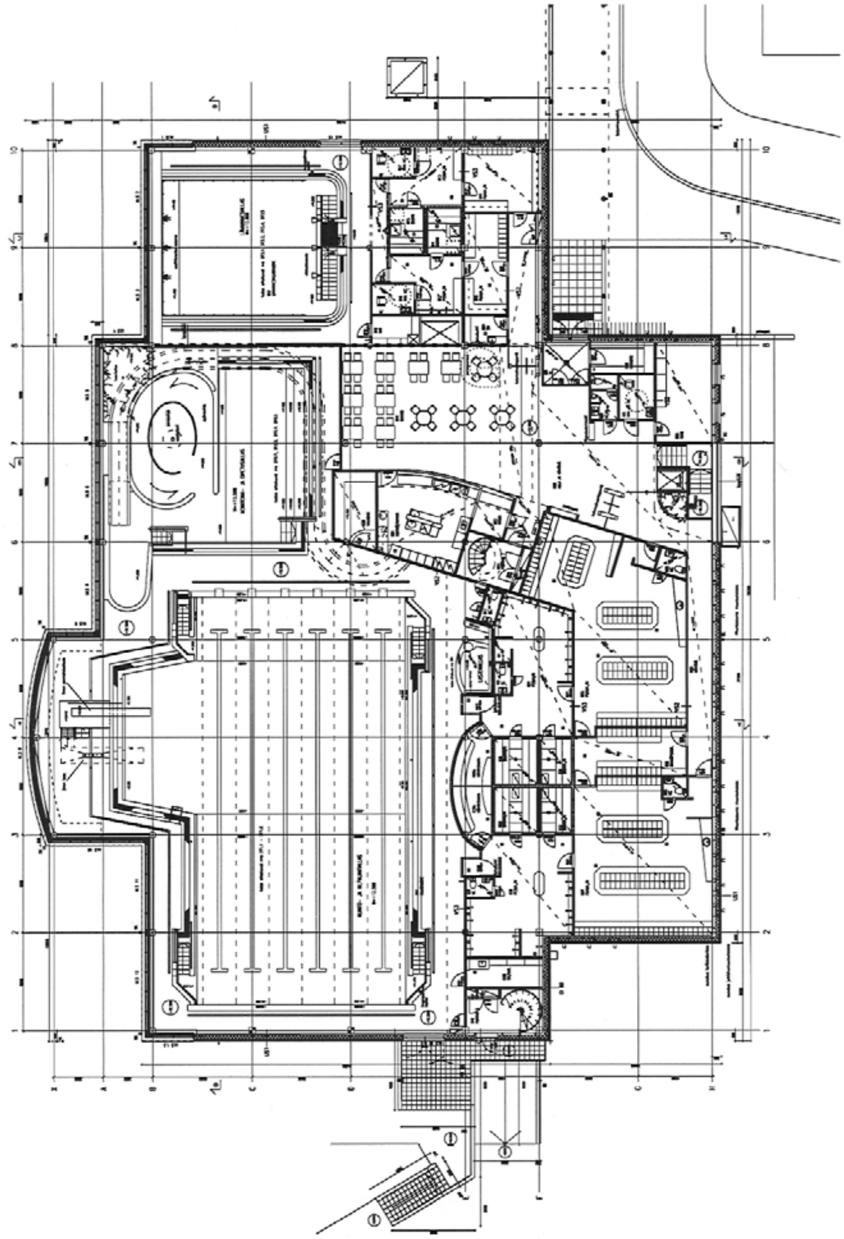
This study looked into the environmental burdens due to the operational energy consumption of a swimming bath. A subject of a further study might be a side by side examina-

Table 4. Sensitivity of Environmental Impacts of Operational Energy Consumption of the Swimming Bath to Design Solutions (Kirkkonummi Swimming Bath)

	Energy	CO_2 eqv.	SO_2 eqv.	Ethene eqv.
Envelope's heat insulation +40%	-3%	-4%	-4%	-4%
Swimming hall's air-ventilation +17%	2%	3%	3%	3%
Swimming hall's air-ventilation recuperation efficiency 0.45->0.55	-2%	-3%	-3%	-3%
Swimming hall's air-ventilation recuperation efficiency 0.45->0.35	2%	3%	3%	3%

Table 5. Sensitivity of Environmental Impacts of Operational Energy Consumption of the Swimming Bath to Mode of Use (Kirkkonummi Swimming Bath)

	Energy	CO_2 eqv.	SO_2 eqv.	Ethene eqv.
Empty and refill of pools +100%	0%	0%	0%	0%
Increase indoor temperature + 2 degree	-3%	-4%	-4%	-4%
Decrease indoor temperature - 2 degree	3%	4%	3%	3%
Increase pool's water temperature + 2 degree	6%	8%	8%	8%
Decrease pool's water temperature - 2 degree	-5%	-7%	-7%	-7%
Increase the attendance +13%	4%	6%	6%	6%
Decrease the attendance -13%	-4%	-6%	-6%	-6%



tion of environmental burdens and life-cycle costs. It would also be interesting to broaden the approach by including the environmental burdens due to the activity conducted in the bath.

APPENDIX

Ground floor of Kirkkonummi swimming bath.

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