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Energy-use in Norwegian swimming halls

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ABSTRACT

Norway has about 850 swimming facilities with an average age of 37 years. A questionnaire issued to facility operators gave, in total, about 100 answers, and the received datasets were analyzed and verified. This article contains data from a selection of 41 Norwegian swimming facilities. The final annual energy consumption (FAEC) was collected from the years 1998–2011, and all of the datasets collected were recalculated to match the Oslo climate in 2010, to make them comparable. The data shows a wide variation in FAEC. The findings are compared with corresponding Danish data, which shows a lower FAEC. Relying on the collected data and the assumptions made in this article, the potential reduction of the FAEC in Norwegian swimming pools is estimated to be around 28%.

1. Introduction

Compared to its population size, Norway possesses a large number of public swimming pools. About 850 pools [1], varying from small school pools to facilities for therapeutic use, sports and leisure are owned and operated by the municipalities. Sources of revenue are normally limited to ticket sales and other means of income, such as cafeterias, private events, etc., and a pool facility is usually heavily dependent on subsidies from the owner, in order to keep it operational. Unlike other building categories, sports facilities are designed in order to meet the requirements of dedicated sports activities, with complex technical support systems, e.g., water systems in pools, cooling systems in ice rinks, and advanced HVAC systems. A sports facility can therefore be better described as a processing plant, rather than just as a building. In light of this, other standardized measurements are required to describe the energy efficiency of sports facilities. The consumption of both water and energy may be indicators to describe this deviation from other building categories. Generally, the energy costs of sports facilities represent about 30% of the overall operating costs [2]; when evaluating swimming pools, the share of the energy costs increases even more. The major energy consumers are the heating of water (pool and showers), ventilation, room heating, light systems and the operation of pumps.

The swimming pool facilities in Norway are, on average, 37 years old [1] (Fig. 1), which means that the construction and technology used is not up to date. About 350 pools had a major refurbishment which was done approximately 11 years ago [1]. Eliminating the 50 swimming halls built between 1990 and 2010 means that about 450 swimming facilities are currently operating with outdated technology. Taking into account Norway's steadily growing requirement for energy efficiency in the building sector for the last 20 years, there is a strong need to understand the energy systems in sports facilities in general, and in swimming pools in particular. To be able to improve energy efficiency, and make use of this presumed large potential energy savings, it is necessary to determine the actual usage of energy and compare it with new energy efficient swimming facilities.

The average swimming hall in Norway contains of a pool size of 12.5 m × 8 m with wardrobe and showers. Thermal energy is provided from different sources like district heating, oil fueled boilers or electricity. Electricity powers lighting, pumps and rotating equipment. In the early years, the typical HVAC system comprised of an air inlet system (blower, heater and filter) and an air outtake system (blower only). Normally no other heating system was installed, as airborne energy was the preferred solution. Thus, no energy recovery (except a partly use of return air), but the indoor climate appeared to be good, as dehumidification was made by use of heated outdoor air, and the pool room normally had negative pressure related to ambience. After 1973 and the oil crisis, awareness of energy recovery rose, and the first generation of integrated packages with heat recovery unit and heat pump was introduced. New and rehabilitated facilities are nowadays

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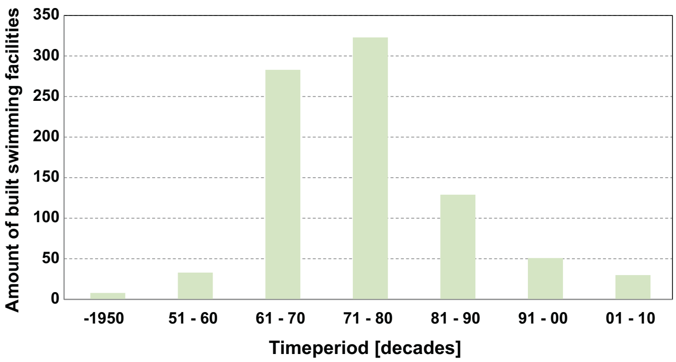

Fig. 1. The number of swimming facilities built in 10 year periods.

equipped with advanced HVAC systems including heat pumps which allows for energy recovery to air, pool water and tap water.

An analysis of the energy-efficiency in over 850 swimming facilities is nearly impossible, and requires a very detailed analysis. The approach taken in this project was to identify the FAEC, and compare it with the FAEC of the most efficient Norwegian facilities, as well as with data from a comparable country. It was an important task to decide which key number to use. The common standard in Norway, for all types of buildings, is to use the FAEC per square meter of usable area (kWh/m^2 ua) [3], but it may be questionable how useful this is for sports facilities, and especially swimming halls. The varying sizes of entrance areas, locker rooms and showers, as well as, e.g., a cantina, are all disrupting factors that affect this standardized number. The variations in the room climates in different zones of the facility may make the key number inaccurate.

Another option may be to use the water surface (ws) as the reference size (kWh/m^2 ws), as a substantial part of the energy used in swimming facilities is related to the water area (heating of water, evaporation, pumps, etc.). The Danish Technological Institute [4] has selected this key number as well. A diagram describing the energy consumed in swimming facilities can be found in a book from Sintef Byggforsk [5]. The annual energy consumption in 27 swimming pools for one year is shown, using kWh/m^2 ua as the measurement unit. This diagram can also be found in the work from Øen [6] who added a curve for the FAEC in kWh/m^2 ws to the curve using kWh/m^2 ua (Fig. 2) to compare them. There is a substantial difference between these two key numbers. This study uses kWh/m^2 ws, making a comparison to the energy data from the Danish Technological Institute possible. The deviation in performance by use of the different key numbers calls for more research with respect to determining a more representative one for FAEC in pool facilities. The only energy statistics available for Norway include the data from one year, for 27 swimming facilities [5], as mentioned above. This situation is not satisfactory, especially considering the large number, and the age of these facilities in Norway. The aim must be to establish a statistical database in order to evaluate the current status, and determine a possible direction of improvement of design and operation.

It is also interesting that there is not much data published concerning FAEC of swimming halls. In a book from Saunus [7] an FAEC of 7 240 600 kWh got reported for a spa in the north of Germany which equals 5984 kWh/m^2 ws. Finnish researchers [8] computed the annual energy use of one swimming facility with 636 kWh/m^2 ua which corresponds to 4475 kWh/m^2 ws and Trianti-Stourna et al. [9] describe the FAEC for swimming facilities located in Mediterranean climate with 4300 kWh/m^2 ws while it is about 5200 kWh/m^2 ws for facilities located in continental climate. Data from British swimming facilities is available as well and shows an FAEC of 1573 kWh/m^2 ua for “typical practice” and 725 kWh/m^2 ua for “good practice” [10].

More on factors influencing FAEC with respect to evaporation [11–13], heat pumps [14–16] and heat demand [17] are available.

2. Method

A total of more than 250 datasets (one dataset is defined as the FAEC from one swimming hall for one year) was collected with the help of a questionnaire. More than one third (37%) of the answers could not be used due to inaccuracy, missing data or the lack of

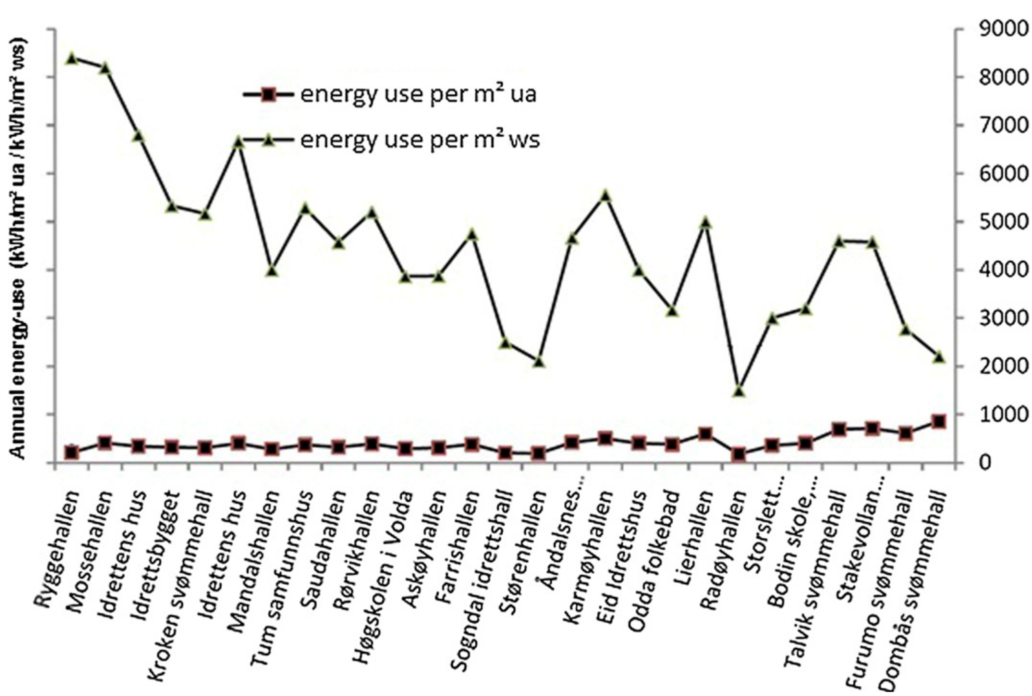

Fig. 2. FAEC in kWh/m^2 ua in comparison with kWh/m^2 ws [6].

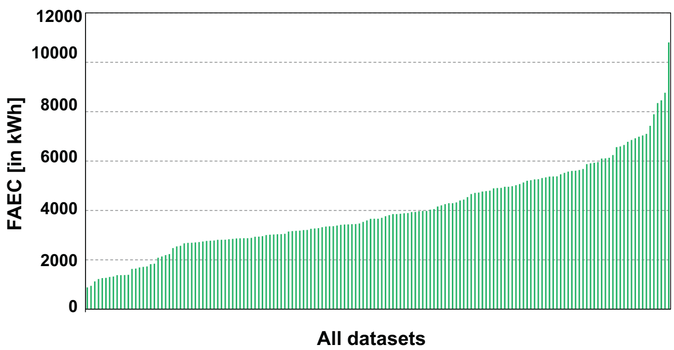

Fig. 3. FAEC in kWh/m² ws for all included datasets sorted from smallest to largest.

energy measuring devices at the facilities. The two main questions were about the FAEC in kWh and the ws, to be able to calculate the desired measurement unit (kWh/m² ws). The statistical analysis in this paper includes data from 41 different swimming pool facilities in Norway from the years 1998 to 2011. All data included are recalculated to match the Oslo climate in 2010 using the equation from Enova [18]:

$$\textit{Energy use}_{Oslo} = \textit{Energy use}_{actual\,facility} \left((1 - 0.4) + 0.4 \times \left(\frac{\textit{Degree days}_{Oslo}}{\textit{Degree days}_{actual\,facility}} \right) \right)$$

The Norwegian degree days originate from Enova's website [19], whilst the Danish data was retrieved from Denmark's meteorological institute [20].

The FAEC (in kWh) was divided by the area of water surface (m² ws) to achieve the desired measurement unit, accounting for one dataset. These datasets were divided into different categories which are supposed to influence the energy consumed (for example, different categories of ws and year built).

The data was not divided into groups with respect to different HVAC systems, operating hours, water temperature, etc., because of lack of available reliable data. None of the facilities are exactly the same and dividing them into detailed groups would make a statistic analysis impossible.

3. Results

Fig. 3 shows the FAEC in kWh/m² ws for all swimming facilities over all available years. It is evident that the energy consumed varies significantly between the different buildings. The lowest values are slightly below 1000 kWh/m² ws per year, while the highest value is almost 11 000 kWh/m² ws per year.

The average for all the datasets is 3991 kWh/m² ws per year, with a standard deviation of ±1757 kWh/m² ws). As not all swimming pools could provide an equal number of datasets, an average for every swimming facility was calculated to prevent a skewing of the data. The average FAEC for the years reported is 4004 kWh/m² ws with a standard deviation of 1821 kWh/m² ws. In order to analyze the data more accurately, and to take the different sizes of the facilities into account, the swimming pools were divided into three different categories:

(1) Facilities with up to 300 m² ws
(2) Facilities with 301–600 m² ws
(3) Facilities with more than 600 m² ws

As can be seen from Fig. 4, the smallest swimming halls (300 m² ws) use the most energy, while the category 301–600 m² ws shows a 804 kWh/m² ws lower average. The third category, consisting of the facilities with more than 600 m² ws, has a FAEC which is 116 kWh/m² ws lower than the one of category one.

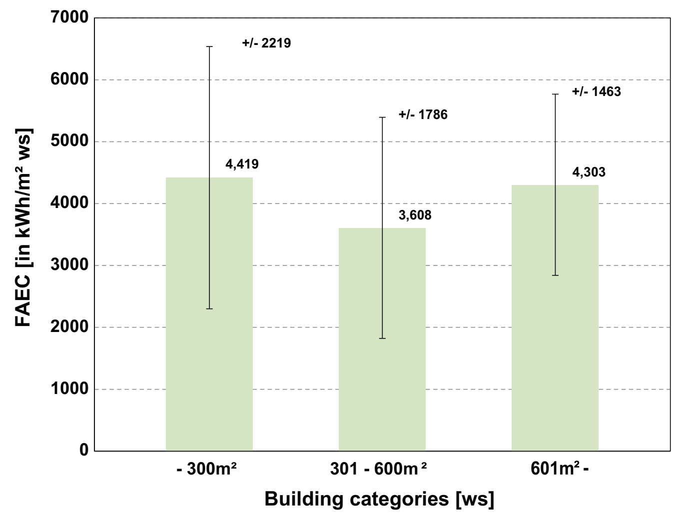

Fig. 4. FAEC in kWh/m² ws per category with standard deviation.

It is also interesting to look at the FAEC, sorted by the decades of the building year, as this can be used as a parameter for both the age and the technology used. The facilities were grouped in age by decades, and the average FAEC and the standard deviation was calculated. The period from 1950 until 1960 showed the highest value with the periods from 1960 until 2000 approximately 4000 kWh/m² ws below. The last decade shows a slightly higher FAEC.

4. Discussion

Fig. 3 shows a large variation in the FAEC within the different swimming facilities. It is a difficult task to collect accurate data on this area, especially data that can be trusted. A number of answers from the questionnaire could not be used, as the results were either inaccurate or too improbable. A major problem seems to be the use of energy measurement devices in the facilities. A lot of swimming halls are combined with sports halls, schools or culture halls, and do not have separate energy meters for each of them. The large variety in FAEC, as well as the large standard deviations, could be an indication of inaccurate measurements. This error source is hard to estimate, and should be taken into account. The findings call for the future regular collection of energy data, in order to train and educate the operators to install energy meters dedicated to the different sections of the buildings.

Another source of error could be dividing all swimming halls in only three groups by size. The facilities differ in opening hours, water temperature and consumption, HVAC systems, age and visitors.

Looking at the three categories concerning the ws, it was expected that the smallest buildings would have the lowest FAEC, but this category consumes the most of all three. An explanation can be found looking at the periods of construction within the categories. The first category (up to 300 m² ws) has an average age of 39 years, while the buildings in category 2 (301–600 m²) are 34 years, and the third category showed an average of 22 years. Old buildings imply old building codes and old technology, which reflects the high FAEC. The energy consumed for the second category in the middle shows a lower FAEC which can be explained by the age as well, but the largest category does not really fit into this paradigm. Following this line of argument, it should show the lowest FAEC as it

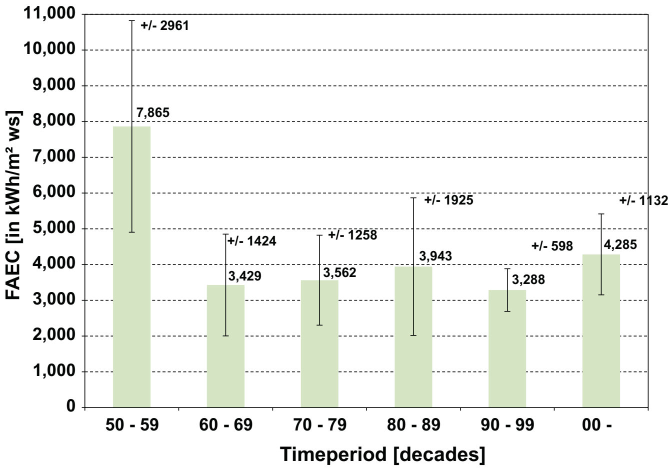

Fig. 5. FAEC in kWh/m^2 ws in relation to building year in decades.

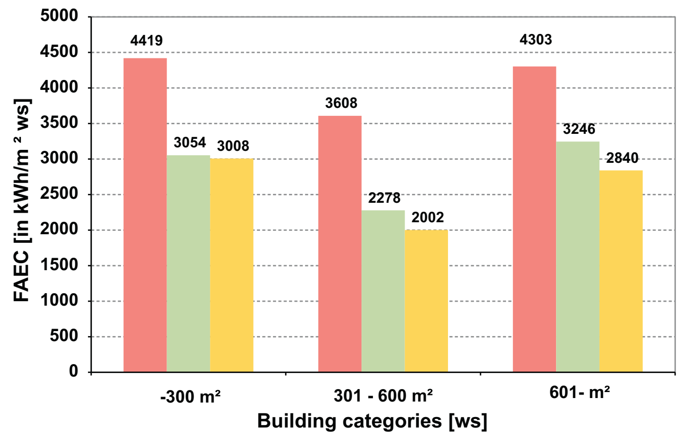

Fig. 6. Average of the total (red), the better half (green) and the best third (orange) of FAEC in kWh/m^2 ws in Norwegian swimming halls, per category. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

contains the newest buildings. But again, looking behind the results these large buildings are, in most cases, more complex pool facilities. They have pools with artificial waves, flow channels, saunas, steam baths and often very large glass facades that allow the visitors to enjoy the landscape outside. All these factors increase the FAEC.

Fig. 5 shows mostly predictable results. Very high values for the buildings built before 1960, which is due to old building techniques and technology standards. The results for buildings built in the 1960s show a large decrease which can be explained with more advanced technology, stricter building codes and more experience in the building sector.

The ups and downs from the 1960s until the 1990s are most likely random and evolve from different building sizes, different technology used and different practice.

The high FAEC for buildings built after 2000 was not initially expected, as they should have been built with more energy awareness, using the latest technology. But as stated before, these new buildings fall into the category of very large swimming facilities, and have a lot of additional services for their customers which consumes large amounts of energy.

The potential in terms of saving energy is hard to estimate, but a look at the standard deviations shows a large variation, and it should be possible to converge toward the “good” swimming facilities. The average for the best third and the better half of each category can be seen in Table 1, as well as the percent value if compared to the Norwegian average.

The difference between the Norwegian average FAEC and the average of the best third is very high. Easing the criteria to the better half of each category shows only slightly better results, which confirms the huge potential concerning energy saving.

Fig. 6 shows the results graphically, and it can be seen that there is only a minor difference between the average values of the better half compared to the average of the best third. This is an indicator for the large diversity in the use of energy in swimming halls, and confirms the substantial variations of FAEC from the collected data.

To make an even deeper analysis, the average of the annual energy consumed was divided into thirds for every category, as can be seen in Fig. 7. The average for the worst third is very high and definitely needs to be reduced. The difference between the averages of the middle and the best third is not that large; therefore, it seems reasonable to try to lower the FAEC of the worst third to the level of the middle third.

Another factor proving these findings is the comparison with the Danish statistics. They originate from the website of the Danish Technological Institute [4], where they are publicly accessible. The diagram in Fig. 8 shows the Norwegian and Danish values, compared for each of the three categories. As mentioned in the methods, all values are corrected to match the Oslo climate in 2010, making them comparable.

The Danish swimming facilities in category one use 808 kWh/m^2 ws less per year than the Norwegian ones. The difference is

Table 1
Potential for energy efficiency improvement in Norwegian swimming halls.

	300 m^2	301–600 m^2	601 m^2
Total average	4419	3608	4303
Average better half	3054	2278	3246
% Difference to total	31	37	25
Average best third	3008	2002	2840
% Difference to total	32	45	34
Danish average	3611	2847	2276
% Difference to total	18	21	47
% Difference to 1/3	−20	−42	20
% Difference to 1/2	−18	−25	30
Best third	3008	2002	2840
Middle third	3983	2278	4201
Worst third	6777	5390	5586

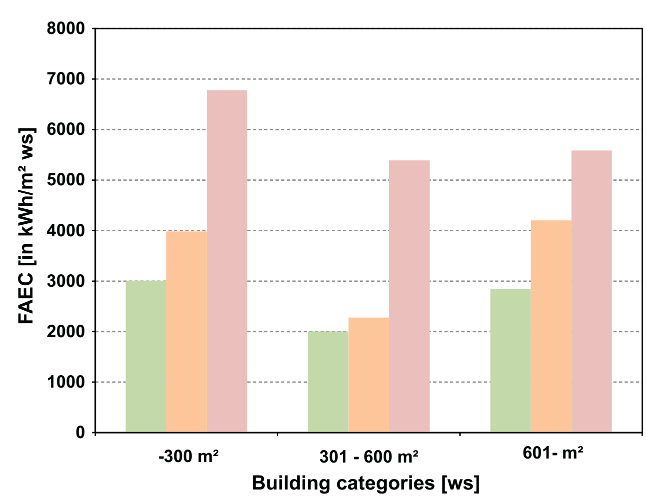

Fig. 7. Average of the FAEC in kWh/m^2 ws of the best (green), middle (orange) and worst third (red) of the different categories. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

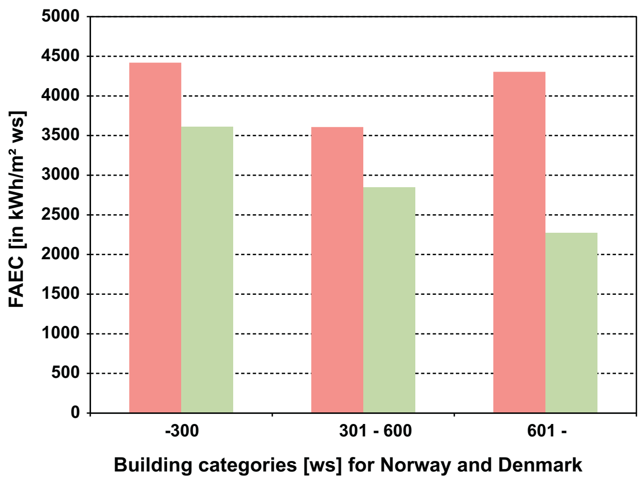

Fig. 8. Comparison between Norway (red) and Denmark (green) of FAEC in kWh/m^2 ws per category. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

about the same, with 761 kWh/m^2 ws per year if comparing to the buildings in category two which have a ws of 301–600 m^2. The largest potential, if compared to Danish facilities, can be found in the third category (swimming facilities with more than 600 m^2 ws). With 2027 kWh/m^2 ws per year, the Danish facilities use almost 50% less energy.

The Danish data sets are an important estimator of how realistic the analysis is, based on Norwegian data. The Danish facilities in category one use, on average, 18% less energy per year than the Norwegian. To expect an FAEC reduction of 31% (compared to the best half) or 32% (the best third) could mean aiming too high, but the potential improvement is still significant, with about 25% (mean of the average of the Norwegian better half and the Danish total average). The difference increases when analyzing the group for 301–600 m^2 ws. The FAEC of the Danish swimming facilities is 21% lower than that of the Norwegian ones. Here as well, the estimations of 37 and 42% (compared to the best half and the best third) improvement seem too high, but a possible improvement of 29% is very satisfying. The largest Danish facilities continue with the trend, using about half of the energy (−47%) of the Norwegian. In this case, the estimate of saving about 36% seems realistic. The average energy consumed by the best third of the Norwegian facilities still uses 564 kWh/m^2 ws more per year than the Danish ones. In general, it can be said that the swimming halls in category one have the largest potential, as they make up the largest share of all Norwegian halls (about 550 of 850), followed by the medium big halls

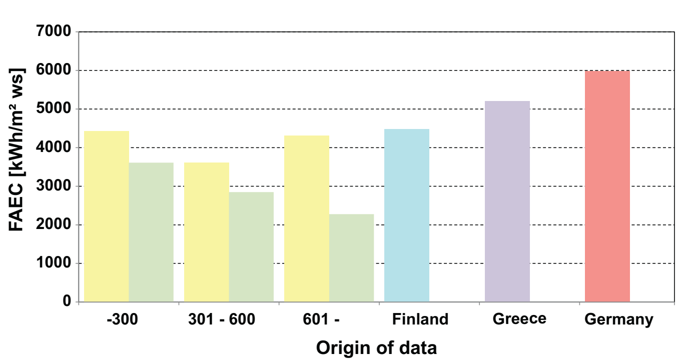

Fig. 9. Comparison between different countries of FAEC in kWh/m^2 ws [Norway (yellow), Denmark (green), Finland (blue), Greece (purple), Germany (red)]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(280 of 850). The largest category has the highest saving potential, with 36%, but as there are only about 20 such halls in Norway, the total amount of savings will not be very high.

Data from Finland [8] shows a slightly higher annual consumption of energy as in Norway most consuming categories. Denmark shows numbers well below. However, this comparison must be treated with care as the Finnish data was calculated, not measured. Additional it only includes one swimming hall. Trianti-Stourna et al. [9] report an FAEC of 5200 kWh/m^2 ws for swimming facilities with continental climate. The age of this publication could explain the significant higher values. An even higher consumption with almost 6000 kWh/m^2 ws is reported in the book from Saunus [7] but it contains only one swimming facility which is a spa (Fig. 9).

5. Conclusion

By estimates from the underlying statistics, the FAEC for all the 850 Norwegian swimming pools is roughly in the range of 883 GWh/year. Provided that the assumptions about saving potential are approximately correct, and using the average FAEC of the difference between Danish and Norwegian swimming halls, and the difference between Norwegian halls and the best 50%, this would mean the yearly FAEC in Norwegian swimming halls could be reduced by about 28%, or 246.5 GWh/year.

As expected, a large variation in the FAEC is identified in Norwegian swimming pools, which implies an equal potential for saving energy as well as money. The analysis of both the Norwegian and the Danish data sets seems to confirm this trend. A detailed analysis of the most efficient swimming pool facilities is required to better understand the variation of FAEC in the different functions within each facility. Furthermore, the objective must be to identify the most wasteful sources in the buildings with high FAEC, and apply new technologies in order to improve their energy efficiency.

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