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ECONOMIC FEASIBILITY OF HEATING SOURCE CONVERSION OF THE SWIMMING POOLS

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Conversion from conventional heating systems is developed to address the emission of CO₂ in the environment, global warming, rising costs, potential shortages of fossil fuels, for all energy source alternatives available. This study reviewed the economic feasibility associated with converting the current heat source to a renewable energy source of heating swimming pools located in Jordan. Many modern heating systems techniques are proposed in this study such as solar heat collectors, heat pump and photovoltaic assisted heat pump. Solar heat collectors are a device that collects and/or concentrate solar radiation from the sun and allow for heating the water. In addition, a growing interest in photovoltaic/heat pump systems is considered, which combines photovoltaic cells and heat pump systems. Hence converting solar energy into electricity and then heat through the heat pump. The Initial and operation cost for all proposed techniques is evaluated. As a result, it is found that the best economical alternative option that can be installed on the available area of the building is photovoltaic with a heat pump system during the heating season. The operation cost of the current source (diesel boiler) is about 179,974 US$ and the total cost of heat solar thermal collector is about 936,540 US$ but the total cost of the proposed photovoltaic/heat pump system is nearly 251,060 US$, which save about 45,134 US$ yearly of the total commercial building electricity bill that is selected with a payback period of fewer than two years. In addition, available space on the rooftop of the selected building is well fitted with photovoltaic panels which are around 2000 m². This result suggests that utilizing a PV/HP system for hotel pools is advantageous both financially and environmentally.

Key words: conventional heating source, economic feasibility, swimming pool, photovoltaic/heat pump

INTRODUCTION

Nowadays, environmental, global warming, rising costs, potential shortages of fossil fuels, and the need for more efficient biofuel conversion drive the development of equipment for more efficient energy consumption [1, 2]. Traditional heating options, such that diesel/gas boilers or electric heaters are commonly used to increase and maintain the temperature used for applications such as swimming pool heating which relatively has high initial and operating costs. As a result, it is important to create a renewable heating system with low operation costs for swimming pools. Therefore, due to rising fuel prices, environmental concerns, and potential fuel shortages in the future, alternative methods for heating swimming pools have been developed [3-5]. Many modern heating systems, such as heat pump, solar heat collectors, geothermal energy, biomass heaters, and waste heat recovery, have been developed to supply heat for many applications such that swimming pools. Solar energy is one of the most attractive energy sources for heating considering its abundance and widespread availability [6, 7]. Over the past decades, a major choice is connected to the usage of heat pump, which enables the use of renewable energy from the environment [8-10]. Therefore, a growing interest in photovoltaic/heat pump (PV/HP) systems are considered, which combines PV cells and heat pump systems as shown in figure 1. Hence converting solar energy into electricity and then heat through a heat pump [11-13]. With a combined solar PV system, the operation bills could be zero and can save money on pool heating.

Figure 1: The diagram of the PV-HP system applied in the swimming pool

Another technology, which focuses on harnessing solar energy is the solar heat collector. Solar collector systems are a long-standing technology that is receiving increase attention in term of research and development which is a device that collects and/or concentrates solar radiation from the sun and allow for heating the water as displayed in figure 2.
This paper aims to study the economic feasibility of using PV-HP system and solar water collector as a heating source of the swimming pools and comparing with the existing traditional heating source taking into consideration the operation cost and initial cost. The proposed system's performance is evaluated using the developed simulation platform (PVsyst), which would be a promising approach in this direction [14, 15].

**SYSTEM DESIGN METHODOLOGY**

**Commercial building**

The selected commercial building is an Ayla hotel building located in Aqaba-Jordan and covers huge areas, including 430 hectares of land which has three swimming pools. The building has about 2000 m² of available rooftop area. According to historical statistics, Aqaba has the greatest radiation on the horizontal plane of any Jordan governor [16], as shown in table 1. The highest irradiation on the horizontal plane at Aqaba comes during August throughout the whole year with average irradiation of 7420 Wh/m²/day approximately. While the lowest irradiation comes during December with average irradiation of 5330 Wh/m²/day approximately. The characteristics of the swimming pools facilities examined in this study as shown in table 2, namely the volume of each pool, the surface area, and the current heating source of each pool. Despite some similar features, there are clear differences in dimensions between the pools, the total volume about 465 m³ to 767 m³ and 570 m³ of the family pool, main pool, SPA pool respectively this difference is related to the difference in the surface area. Also, the water temperature is about 28 °C and 48 hours heating up time.

| Month     | Solar radiation in Wh/m²/day |
|-----------|------------------------------|
| January   | 5430                         |
| February  | 6230                         |
| March     | 7530                         |
| April     | 7190                         |
| May       | 7270                         |
| June      | 7400                         |
| July      | 7350                         |
| August    | 7420                         |
| September | 7270                         |
| October   | 7020                         |
| November  | 6050                         |
| December  | 5330                         |

Table 1: radiation distribution in Aqaba

| Pool name  | Volume (m³) | Surface area (m²) | Heating source       |
|------------|-------------|-------------------|----------------------|
| Family pool| 465         | 310               | Diesel boiler        |
| Main pool  | 767         | 515               | Diesel boiler        |
| SPA pool   | 570         | 380               | Steam (electrical heat) |

Table 2: Description of the three pools and the current source of its heating

While the Diesel boiler is used as a heat source for the family pool, the SPA pool is used as a steam heat exchanger (heat pump). The analysis is performed in two stages. Firstly, the data was collected from the past three years recorded bills of energy consumption as a monthly data record of consumption levels. Secondly, with the data collection, the three pools are characterized, and the operation and initial cost for the water heating system are calculated and analyzed. Finally, the heating load for the three swimming pools are evaluated and taking into consideration all heat gains in and out for the swimming pool according to live data from the previous three years and calculating the real heating loads and energy consumption is determined, therefore, the total heat transfer (Vaporization, Convection, Radiation) of the operation months at three pools (Family and main and SPA pools) is computed as shown in appendix A1, A2 and A3. Additionally, several saving measures are pointed out and examined. It should be noted that the calculation was done by using the PVsyst software based on the equations presented in detail elsewhere such as reference [5].

**Heating loss calculation**

The precise amount of heating energy and heat source consumption is computed to design the proposed
heating source and estimate the initial cost of alternative options as well as compare the operating costs. During the winter months, a significant amount of heat is required to keep both indoor and outdoor swimming pools warm. A swimming pool heat transfer model is the most basic prerequisite for studying the performance of swimming pool heating systems. As a result, the next sections discuss each of the heat gain and loss component calculations.

**Evaporation heat loss**

The calculation of the evaporative heat loss $Q_e$ of the ISPs or OSP are different as follow the first one is calculated according to the water evaporation rate.

$$Q_e = H_e A_p E_e$$  \hfill (1)

where $A_p$ describes the surface pool area, $H_e$ describes water evaporation latent heat and $E_e$ is a water evaporation ratio which is calculated elsewhere such as [17]. On the other hand, the heat loss from the OSP is calculated depending on the vapour pressure difference and evaporative heat transfer coefficient as elsewhere such as [18].

**Convection heat loss**

It is determined using the temperature difference between the water surface ($T_p$) and the surrounding air ($T_a$), which is stated as the following equation

$$Q_{cv} = h_{cv} A_p (T_p - T_a)$$  \hfill (2)

where $h_{cv}$ is the coefficient of the convection heat transfer and $A_p$ is the surface water area.

**Conduction heat loss**

It is computed by the result of the temperature difference between the pool water and pool walls which can be neglected because it is so small compared to other losses, However, the evaluations of conduction heat loss can be done by using the governing equation as follow

$$\rho_s c_s \frac{\partial T_s}{\partial t} = k_s \frac{\partial^2 T}{\partial x^2}$$  \hfill (3)

where $\rho_s, c_s, k_s$ and $T_s$ indicate the density, specific heat, thermal conductivity, and the temperature of the walls, respectively.

**Radiative heat loss**

it is calculated by deference between the pool water temperature and the temperature of the surrounded air as follow

$$Q_s = A_p \varepsilon_s \sigma_s (T^4_p - T^4_{\text{sur}})$$  \hfill (4)

where $\varepsilon_s$ represents the emissivity of the water and $\sigma_s$ is a Stefan-Boltzmann constant which is $(5.67 \times 10^{-11} \text{ kW/m}^2\text{K}^4)$.

**Refilling water heat loss**

The temperature differences between the pool water ($T_p$) and the refilling freshwater ($T_{rf}$) causes the refilling water heat loss ($Q_{rf}$). Because pool water evaporates and drains, new water is necessary to refill the pool. The refilling water heat loss expressed as [19],

$$Q_{rf} = c_w m_{rf} (T_p - T_{rf})$$  \hfill (5)

where $m_{rf}$ is the mass flow rate of the refilling freshwater and $c_w$ is the specific heat capacity of water $(4.18 \text{ kJ/kgK})$.

**Heat obtain from the sun**

The solar heat gain of pool water is computed using the equation prescribed by Lam and Chan [20], as follow.

$$Q_s = \alpha_s G_s A_p$$  \hfill (6)

where $\alpha_s$ is the absorption coefficient (0.85 is used) and $G_s$ global solar irradiation. Now, the summation of heat transfer (Vaporization, Convection, Radiation) of the operation months at three pools (Family and main and SPA pools) are computed as shown in the Appendix section.

**Heating load calculation results**

Figure 3 shows the monthly average of the heating load of the three pools during operation months, the swimming pool's operating months usually in winter are from October to March, and it takes a lot of heat to keep the water temperature at a comfortable level of 28 °C. The monthly average values of the radiation, vaporization and convection heat transfer by the pools are calculated as shown in the Appendix (Table A1, A2 and A3) and noted that the main pool is the highest heating load through the operation period from October to March about 221,166, 132, 155, 185 and 206 kW, respectively. Based on these results, we may conclude that higher consumption is related to larger facility sizes of about 767 m³, superior water utilization, and a greater number of visitors. The average energy loss by the 570 m³ SPA pool size is displayed as shown in figure 2, the higher and the lower consumption months are in October and December about 163 kW and 97 kW respectively. The required heating load for the family pool are calculated as presented in Figure 3, it can be observed the lowest heating load required for this pool, this is because the pool size is smallest about 465 m³ compared to other pools and a little number of visitors.
Traditional heating source

The current diesel boilers are the only equipment responsible for producing the thermal energy of three available pools. The boiler produces the hot-water supplying the energy to the swimming pool heat exchangers, the amount of the diesel oil consumption through the operation period is shown in tables 3, 4 and 5 for the family pool, main pool, and SPA pool respectively. In this study, about 255,202 litres of diesel oil are required annually for the heating of the pools, particularly, 65,655 litres, 109,068 litres and 80,479 litres for the family pool, main pool, and SPA pool respectively. The total costs can be estimated as follows; heating of the family pool 46,301 US$/year, main pool 76,917 US$/year and SPA pool 56,755 US$/year, for a total operation cost of 179,974 US$/year, main pool 76,917 US$/year and SPA pool respectively. The total costs can be estimated as follows; heating of the family pool 46,301 US$/year, main pool 76,917 US$/year and SPA pool 56,755 US$/year, for a total operation cost of 179,974 US$/year, main pool 76,917 US$/year and SPA pool respectively. It should be noted that the initial cost of a diesel boiler is neglected. As noted in tables 4, 5 and 6, the higher energy utilization is in October about 13,946 litres of diesel oil for the family pool and 23,767 litres for the main pool, also, 17,095 litres for the SPA pool which might be due to the daily operating hours of 24 h/day at the pools in the same month.

RESULTS AND DISCUSSIONS

A proposed heating technique including solar heat collectors, heat pump and photovoltaic-heat pump system is selected. A view of all the run times for our full range and the different heating source options, also, the approximate amount of operation cost on the operation time at the available three pools to make a concise and easy decision. Solar collectors have been widely used in swimming pools heating systems, due to their considerable energy-saving potential, different investigations of the use of solar collector technology are presented as [21-23]. The author found that the heating system with solar collectors was economically competitive when compared with a conventional heating system. The calculation of the collectors is performed from the beginning of October to the end of March as shown in tables 3, 4 and 5. Based on the collected data the average number of collectors needed for a family pool is about 291 solar collectors to meet the monthly heating requirement of the pool which are needed 500 m² as a space on the rooftop of the hotel buildings. 484 solar collectors are required for the main pool to offer a monthly heating consumption by installing them on the 1,300 m² roof space. For the third pool, 950 m² is wanted from the rooftop space to install 375 solar collectors as shown in table 5. The second alternative for the heating source is a heat pump which can always be chosen as an upgrade to have faster heat-up times or to match with solar generation. In some cases where power may be a problem where the heat pump will go and most often the pump controller is recommended for all-year-round swimming. In addition, an inverter heat pump has an extremely high-efficiency output with an average coefficient of performance of 10 [24]. The heat pump is known for its long lifetime, and this is shown by our extensive 25-year warranty on the heat exchanger, and extended warranty on all parts. Also, a heat pump requires very little maintenance throughout its lifetime. Once the unit is set up correctly, all that is required is ensuring the area around the unit is cleared from debris regularly with good airflow maintained. Tables 3, 4 and 5 show the calculated monthly energy loss and the initial cost for the proposed heat pump. The pools are considered to operate in the interval from October-March and the accumulated values for the whole operation period of the pools are also displayed. It can be noted that the initial cost of 8,466 US$, 14065 US$ and 10378 US$ for each pool family, main and SPA pools respectively. Table 3: Operation cost of diesel option as a heat source and initial cost of alternatives of the family pool through the operation period. Finally, it can be added third alternative heating source to enhance the energy-saving potential of heat pump, photovoltaic system assisted heat pump (PV/HP) have been proposed. It can create electricity and then heat the water by using heat pump technology [25]. This technology can provide us hot water with the temperature that can reach up to 80°C, this degree of heating can cover more than 90% of the heat process in the targeted facilities (swimming pools heating 40°C-45°C, domestic hot water 50°C-65°C and space heating 50°C-60°C). One of the most important factors a the heat pump is the COP (coefficient of performance) while the swimming pools have a high flow and low-temperature difference between the inlet and outlet it has the highest COP can reach up to 10 in some cases which are used in this study [24]. The simulation is performed in (PVsyst) to assess the overall system performance of different PV/HP system configurations. The PV/HP systems are designed based on the available area on the rooftop space at the hotel building. Thus, the PV installation area required to meet the 37 kWp output power capacity of the photovoltaic is about 230 m² for the family with a total
### Table 3: Operation cost of diesel option as a heat source and initial cost of alternatives of the family pool through the operation period

| Available options | Diesel Litter | Diesel US$ | Solar water heater (SWH) Req. area (SWH) m² | Solar water heater (SWH) Number of collectors | Heat pump kWh | Heat pump cost (US$) | Daily operation hours |
|-------------------|---------------|------------|---------------------------------------------|---------------------------------------------|--------------|---------------------|-----------------------|
| Month             |               |            |                                             |                                             |              |                     |                       |
| January           | 9,772         | 6,891      | 590                                         | 295                                         | 9,927        | 1,259               | 17                    |
| February          | 10,536        | 7,430      | 614                                         | 307                                         | 10,704       | 1,358               | 20                    |
| March             | 12,954        | 9,135      | 564                                         | 282                                         | 13,160       | 1,669               | 22                    |
| October           | 13,946        | 9,835      | 651                                         | 326                                         | 14,167       | 1,798               | 24                    |
| November          | 10,139        | 7,149      | 567                                         | 284                                         | 10,300       | 1,307               | 18                    |
| December          | 8,307         | 5,859      | 511                                         | 255                                         | 8,439        | 1,071               | 14                    |
|                   |               |            | Avg. collectors 291                         | Total 8,466                                 |

### Table 4: Operation cost of diesel option as a heat source and initial cost of alternatives of the family pool through the operation period

| Available options | Diesel Litter | Diesel US$ | Solar water heater (SWH) Req. area (SWH) m² | Solar water heater (SWH) Number of collectors | Heat pump kWh | Heat pump cost (US$) | Daily operation hours |
|-------------------|---------------|------------|---------------------------------------------|---------------------------------------------|--------------|---------------------|-----------------------|
| Month             |               |            |                                             |                                             |              |                     |                       |
| January           | 16,233        | 11,448     | 980                                         | 490                                         | 16,491       | 2,093               | 17                    |
| February          | 17,504        | 12,344     | 1,019                                       | 510                                         | 17,781       | 2,256               | 20                    |
| March             | 21,521        | 15,176     | 937                                         | 468                                         | 21,562       | 2,775               | 22                    |
| October           | 23,167        | 16,338     | 1,081                                       | 541                                         | 23,535       | 2,987               | 24                    |
| November          | 16,843        | 11877      | 943                                         | 471                                         | 17,110       | 2,172               | 18                    |
| December          | 13,800        | 13540      | 848                                         | 424                                         | 14,019       | 1,778               | 14                    |
|                   |               |            | Avg. collectors 484                         | Total 14,065                                 |

### Table 5: Operation cost of diesel option as a heat source and initial cost of alternatives of the family pool through the operation period

| Available options | Diesel Litter | Diesel US$ | Solar water heater (SWH) Req. area (SWH) m² | Solar water heater (SWH) Number of collectors | Heat pump kWh | Heat pump cost (US$) | Daily operation hours |
|-------------------|---------------|------------|---------------------------------------------|---------------------------------------------|--------------|---------------------|-----------------------|
| Month             |               |            |                                             |                                             |              |                     |                       |
| January           | 11,978        | 8,447      | 723                                         | 361                                         | 12,168       | 1,544               | 17                    |
| February          | 12,916        | 9,108      | 752                                         | 376                                         | 13,121       | 1,665               | 20                    |
| March             | 15,879        | 11,199     | 691                                         | 346                                         | 16,132       | 2,047               | 22                    |
| October           | 17,095        | 12,055     | 798                                         | 399                                         | 17,366       | 2,204               | 24                    |
| November          | 12,428        | 8,764      | 696                                         | 348                                         | 12,625       | 1,602               | 18                    |
| December          | 10,183        | 7,180      | 626                                         | 313                                         | 10,345       | 1,313               | 14                    |
|                   |               |            | Avg. collectors 357                         | Total 10,378                                 |
installed cost of the PV and HP system is approximately 59,239 US$ as displaced in table 6. Moreover, the PV installation area needed on the rooftop for the main pool and SPA pool is 400 m² and 260 m² respectively, with a total cost of 104,373 US$ and 87,448 US$ for the main pool and SPA pool. It should be noted the operation cost of the PV/HP system is neglected.

**System cost and economics**

The heating cost of the current boiler system can be comparable to the proposed heating source cost alternative systems namely, solar heating collector, heat pump and photovoltaic connected with heat pump. As shown in table 7 the yearly operation cost of the current pool heating system is displaced along the operation period, in addition, only the initial cost of the alternative system is also displaced. It should be noted the operation cost of the proposed heating source is negligible. A diesel boiler will heat the pools much quicker than other alternative options but normally costs more to do so, which is about 179,974 US$ yearly operation cost. It should be noted the installation cost of the boiler is ignored in the calculation. Normally, the heat pump is the least expensive option to heat the pools from an operational cost standpoint of 32,910 US$ in addition, about 125,530 US$ as fully installed cost, that means, the total cost will be 158,440 US$ as clearly seen in table 7. A heat pump also requires very little maintenance throughout its lifetime. Once the unit is set up correctly, all that is required is ensuring the area around the unit is cleared from debris regularly with good airflow maintained. The heat pump is known for its long lifetime, and this is shown by our extensive 25-year warranty on the heat exchanger, and extended warranty on all parts. Next, the availability of solar energy makes solar heating systems a good option for outdoor swimming pools which an economic analysis showed that solar pool heating systems are highly cost compared to conventional systems using conventional fuel, which is around 846,273 US$. However, according to an analysis of solar and conventional heated pools, this option is exempted due to the large rooftop area of 3,050 m² required. Even though the PV/HP systems have longer payback periods than available options [26]. It is worth pointing out the PV/HP systems take up significantly less roof space about 880 m² to maintain the

**Table 6: Sizing results for three pools cases**

| Item                             | Capacity | Unit                  | Price US$ | Total area required |
|----------------------------------|----------|-----------------------|-----------|---------------------|
| Solar water heater collectors    | 291      | collectors            | 225,672   | 800 m²              |
| Heat Pump (HP)                   | 150 kW   | -                     | 26,798    | -                   |
| P.V system                       | 37 kWp   | -                     | 32,440    | -                   |
| Main Pool                        |          |                       |           |                     |
| Solar water heater collectors    | 484      | collectors            | 409,031   | 1,300 m²            |
| Heat Pump (HP)                   | 2*115 kW | -                     | 49,365    | -                   |
| P.V system                       | 65 kWp   | -                     | 55,007    | 400                 |
| SPA Pool                         |          |                       |           |                     |
| Solar water heater collectors    | 357      | collectors            | 30,1837   | 950 m²              |
| Heat Pump (HP)                   | 2*115 kW | -                     | 49,365    | -                   |
| P.V system                       | 45 kWp   | -                     | 38,082    | 260                 |

**Table 7: Yearly heating cost for the current system and the initial cost of the alternative system**

|                | Diesel | Heat pump | Solar water heater | Heat pump with PV |
|----------------|--------|-----------|--------------------|--------------------|
|                | Initial cost | Operation cost | Initial cost Operation cost | Initial cost | Area (m²) | Initial cost | Area |
|                | (US$) | (US$)      | (US$)              | (US$)             |         | (US$)       |      |
| Family pool   | 0     | 46,301    | 27,798             | 8,467             | 225,670 | 800        | 59,240 | 230 |
| Main pool     | 0     | 76,917    | 49,365             | 14,065            | 409,030 | 1,300      | 104,370 | 400 |
| SPA pool      | 0     | 56,755    | 49,365             | 10,378            | 301,840 | 950        | 87,450 | 250 |
| Total         | 0     | 179,974   | 125,530            | 32,910            | 936,540 | 3,050      | 251,060 | 880 |
thermal source of the same pool as displayed in figure 2 presents the roof area occupied by the three pool heating systems. The total cost of this option is cost around 239,777 US$ when the operation costs could be zero. This option for heat pump with PV offers extra 1000 m² to be used for PV system with 186 kWp that can save about 45,134 US$ yearly. The big advantage of this system is the available roof space that would have had the photovoltaic system on it can now be generating electricity which can be used when the heat pump is not being used. Utilizing the space for the aesthetics of the site is needed, which is it possible to exploit areas within the site to install the largest possible number of photovoltaic panels. Therefore, the total area available is found to install the PV system about 2000 m² rooftops. Based on the shape and design of the building, this design was proposed for the installation of panels to exploit all the space and the direction of the panels is suitable for the angle of the sunlight to be efficient and the results are as high as possible. Overall, despite the higher upfront costs of PV/HP pool heating systems in comparison to the other available systems, PV/HP system presents a better cost alternative, particularly for the facilities with limited roof space or with inevitable shadings on the roof. Further, such systems can achieve good economic values with reasonable payback periods.

CONCLUSION

This work studies an alternative heating source option of the hotel pools. Through this work, we first studied data obtained from the real heating source system of a hotel’s pool. We trying to investigate the application of alternative options of the heating source systems which are solar collector pool heating system, heat pump and PV/HP system. The experiment is conducted in Jordan/Aqaba which has the greatest radiation on the horizontal plane of any Jordan governor. From the analysis, an initial design procedure was presented, and the energy source conversion was evaluated through the use of the PVsyst simulation tool. The results showed that the proposed systems can well satisfy the pools heating demands and it is found that the initial cost by applying a PV/HP is the cheapest and meet the available rooftop area of the hotel. The total cost of this system is 251,060 US$ and the payback period is less than two years when compared with diesel boiler system during the heating season, the result indicates that using PV/HP system for hotel’s pools are beneficial both financially and environmentally. The focus of future studies on this area should be on improving system exergy efficiency through system configuration optimization and parametric analyses. A life cycle study of the system should also be in place to analyze the consequences on the environment.

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APPENDIX

Table 1A: The monthly heating consumption of the family pool

| Month   | Vaporization | Convection | Rad | Feedwater | Solar | Total (GJ) | Operation hours | Average KW |
|---------|--------------|------------|-----|-----------|-------|------------|----------------|------------|
|         | Kg/h         | GJ         | GJ  | GJ        | GJ    |            |                |            |
| January | 110          | 199        | 20  | 39        | 5     | -12.45     | 250           | 514        | 93         |
| February| 155          | 254        | 9   | 17        | 7     | -17.81     | 270           | 554        | 111        |
| March   | 194          | 351        | 3   | 5         | 9     | -36.33     | 332           | 681        | 124        |
| October | 223          | 404        | -5  | -10       | 10    | -42.35     | 357           | 733        | 133        |
| November| 140          | 245        | 9   | 19        | 6     | -19.92     | 260           | 533        | 100        |
| December| 92           | 167        | 18  | 39        | 4     | -15.01     | 213           | 437        | 72         |

Table 2A: The monthly heating consumption of the main pool

| Month   | Vaporization | Convection | Rad | Feedwater | Solar | Total (GJ) | Operation hours | Average KW |
|---------|--------------|------------|-----|-----------|-------|------------|----------------|------------|
|         | Kg/h         | GJ         | GJ  | GJ        | GJ    |            |                |            |
| January | 183          | 331        | 33  | 64        | 9     | -20.69     | 416           | 516        | 155        |
| February| 258          | 422        | 15  | 29        | 11    | -29.59     | 448           | 556        | 185        |
| March   | 233          | 584        | 4   | 8         | 15    | -60.35     | 551           | 684        | 206        |
| October | 370          | 671        | -8  | -16       | 17    | -70.35     | 593           | 736        | 221        |
| November| 232          | 407        | 16  | 31        | 11    | -33.09     | 431           | 535        | 166        |
| December| 153          | 277        | 30  | 64        | 7     | -24.94     | 535           | 438        | 132        |
Table 3A: The monthly heating consumption of the SPA pool

| Month   | Vaporization | Convection | Rad | Feedwater | Solar | Total (GJ) | Operation hours | Average KW |
|---------|--------------|------------|-----|-----------|-------|------------|----------------|------------|
|         | Kg/h         | GJ         | GJ  | GJ        | GJ    |            |                |            |
| January | 135          | 244        | 24  | 47        | 6     | -15.24     | 307            | 514        | 114        |
| February| 191          | 312        | 11  | 21        | 8     | -21.83     | 331            | 554        | 137        |
| March   | 238          | 431        | 3   | 6         | 11    | -44.53     | 407            | 681        | 152        |
| October | 273          | 495        | -6  | -12       | 13    | -51.91     | 438            | 733        | 163        |
| November| 171          | 300        | 11  | 23        | 8     | -24.42     | 318            | 533        | 123        |
| December| 113          | 204        | 22  | 47        | 5     | -18.41     | 261            | 437        | 97         |

Table 4A: Energy unit prices of the present heating sources

| Energy source | Unit Price US$ | Unit   |
|---------------|----------------|--------|
| diesel        | 0.78           | Litter |
| LPG           | 942            | Ton    |
| Electricity   | 0.310          | kWh    |

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