Malaysian Journal of Industrial Technology (MJIT), Volume 8, No.1, 2024
eISSN: 2637-1081

MJIT 2024 Malaysian Journal of Industrial Technology

MINIMIZING THE SIZE OF LARGE-SCALE SOLAR CHIMNEY POWER PLANT

I. A. Abuashe
University of zawia , Azzawia, Libya.
*Ae.ibabdullah@zu.edu.ly

A. M. Mariamy
University of zawia , Azzawia, Libya.
Daknone@gmail.com

ARTICLE INFO

Handling Editor: Rahimah Mahat

Article History:
Received 25 December 2023
Received in revised form 6 January 2024
Accepted 15 February 2024
Available online 15 March 2024

Keywords:
Renewable energy; Solar energy; Solar chimney; Solar updraft tower, Large-scale solar power plant; Minimizing size.

ABSTRACT

This paper aims to minimize the size of large-scale Solar Chimney Power Plant (SCPP). A mathematical model was developed and experimentally validated in a previous research work. A subroutine of productivity improvements has been added to the model to minimize size. Four configurations of large-scale SCPP with nominal powers: 5MW, 30MW, 100MW and 200MW, were considered under conditions of the Ber Alganam area which is located south of the city of Az Zawia, Libya). The average monthly power curve through a year was presented and a good agreement was found between the nominal power and the pick summer for each configuration. Variable chimney diameter, a solar collector with helical paths, and virtual chimney height are the main modifications that that can be introduced to minimize plant size. The results show that chimney height and collector diameter can be minimized up to 83.58%, 25% respectively. This major reduction will make the construction of solar chimney power plant more feasible compared to the current conventional structural technologies.
.

1.0 Introduction

Solar chimneys are innovative solar system to produce electrical energy as a large-scale power plant. The performance of the solar chimney power plant depends mainly on the solar radiation available and its geometry; chimney height, collector diameter are main geometrical dimensions that effects on performance of SCPP. The challenge to construct large-scale solar chimney is the huge dimensions of plant. The solar air collector (the chimney) and wind turbine are main components of this technology. Firstly, the solar air collector collecting the solar radiation, then heated the air under the collector roof by the well-known phenomenon named a greenhouse effect, and then the slop of collector roof directs and accumulates the hot air at the collector center. Secondly, the chimney base located at collector center that used to convert part of heat energy of the collected air to kinetic energy by the well-known phenomenon named a buoyancy effect. Thirdly, the wind turbine that located at the entrance of the chimney, used to convert some of kinetic energy to the electrical energy. The main motive for conducting this study is the suitability of these plants to the Libyan conditions: high solar radiation level, large flat areas with low population density especially in south region, demand for electricity increases, and the water resources are limited. Unfortunately, the size of the system is very large, which makes the constructing the solar chimney plant depending upon the advanced technology to introduce some modifications to the system in order to minimizing its size. In the late 1970s, Prof. J. Schlaich originally proposed the first solar chimney power plant concept. Less than four years after he presented his ideas, the construction on a pilot plant with 50kW began in Manzanares, Spain [1]. The Manzanares solar chimney prototype proving that the solar chimney is a technology capable to generate electrical power from the sun. The data recorded from the Manzanares solar chimney prototype taken by researchers as a benchmark to examine the theoretical and experimental models of SCPP. After that, Schlaich [1-3] proposed some commercial large-scale solar chimney power plant, Haaf et al. [4], showed that an increase of the collector radius increased output power but reduced plant efficiency. On the other hand, efficiency increased with the tower height, and mass flow rate increased with the tower radius while the flow velocity remained constant. Pasumarthi and Sherif [5, 6], reported that, the increase of tower height resulted in higher velocity and mass flow rate, and when the insolation was fixed, an increase in the mass flow rate was accompanied by a lower air temperature at the collector outlet. Koonsrisuk and Chitsomboon [7], the influence of tower cross-sectional area changes on the potential of a solar tower power plant was investigated, the results show that, the divergent tower helps increase mass flow rate and kinetic energy over that of the constant area tower, the study gives that, the chimney area ratio f 16 can produce kinetic energy as much as 94 times that of the constant area tower. Das and Chandramohan [8], a 3D computational model was developed to investigate the influence of divergence angle of chimney on the flow and performance characteristics of solar updraft tower (SUT) plant. It was found that the velocity of air at the chimney base was enhanced by 59.4% compared to a cylindrical chimney-SUT plant. From the parametric study, it was observed that, divergence angle of chimney 2^o gives superior performance to the system than any other angle. Bouabidi et al. [9] investigated the effect of the chimney configuration on the solar chimney power plant performance. Results revealed that the chimney form affects the air velocity behavior and the maximum velocity emerges with divergent configuration. Tingzhen [10] proposed a new type of helical heat-collecting solar chimney power generating system to reduce the initial investment in the solar chimney power generating system. In his study, 8-helical-wall heat-collecting SC system was proposed, and the results showed that the collector radius was 25% shorter, and its area was 43.75% smaller than the traditional solar chimney system, which is obviously more economical and more commercially competitive. Ahmed et al. [11] presented a new design of a virtual height aided solar chimney. The solar chimney was attached with a passive cooling system at the top of it, and a passive solar heater at its base to virtually mimic larger heights of the chimney. The study have shown that the localized base heating and exit cooling have significantly enhanced the chimney performance for chimney heights up to 500m. The study also shows that, a chimney with height of 300m gains an increase in the air velocity more than 25% due to the heating and cooling actions. As a case, Ahmed et al. [11] revealed, the virtual height aided chimney with original height of 300m acts similarly to a conventional chimney with height of 500m if a vertical turbine is used. The present study extends the efforts [12-15] to evaluate the large-scale solar chimney power plant under the Libyan conditions. In order to minimize the system's size, this study was dedicated to implement productivity improvements technologies onto minimizing system rather than increase productivity. Two improvements have been studied; variable chimney diameter and solar collector with helical paths, the virtual height technology was not carried out because it is limited by chimney height up to 500m, which lies below the range of the proposed large-scale configurations presented in table (1).

2.0 Methodology

2.1 System configuration

All classifications of large-scale solar chimney power plants proposed by J. Schlaich [1-3] are presented in table (1).

Table (1) Specifications of four SCPP configurations [1], [2], [3].

Design specification	unit	prototype	proposed configurations for large scale			
			Model 1	Mode1 2	Model 3	Model 4
Chimney height	m	195	550	750	1000	1000
Chimney diameter	m	10	45	70	110	120
Collector diameter	m	240	1250	2900	4300	7000
Collector height (entrance)	m	2	2	4.5	6.5	3.5
Collector height (outlet)	m	6	10	15.5	20.5	25
Type of turbine		axial	Propeller			
Turbine shaft direction		vertical	Horizontal			
Turbine location at		chimney inlet	circumference of the chimney base			
Number of turbines		1	33	35	36	32
Power of single turbine	kW	50	152	857	2778	6250
Turbine pressure drop	%	97.0	82.0	82.0	82.0	67.0
Nominal load	MW	0.05	5	30	100	200
ΔT of air through collector	℃	20	25.6	31	35.7	46
Air speed through chimney	m/s	8	9.07	12.59	15.82	18

Some of the above values were estimated for the site under:

- Annual global horizontal solar radiation of 2301 kWh/(m^2 annual).
- Ambient temperature of 17℃.
- Average wind velocity 3.5 m/s.

2.2 Mathematical model

The comprehensive analyzed for the system was conducted by modelling and simulating the SCPP [13]. In this paper, the chimney was analysis and formulated to present the minimizing methods effect. The starting by integration of the static pressure gradient as follow:

2.2.1 Chimney analysis

The chimney converts the heat flow $\dot{Q}$ produced by the collector into kinetic energy and potential energy. Thus, the density difference of the air is caused by temperature rising in the collector works as driving force. A pressure difference Δp_{tot} produced between chimney base (collector outflow) and the ambient [16].

$$\Delta p_{tot} = \int_{0}^{H_{chim}} (\rho_a - \rho_{chim}) g \, \delta H \tag{1}$$

Where:

H_{chim}: Chimney height (m).

ρ_a: Air density at ambient temperature (kg/m^3).

ρ_{chim}: Air density through the chimney (kg/m^3).

Thus Δp_{tot} increases with chimney height. The total pressure difference causing the draught in the chimney increases with chimney height and the density difference. It can be divided into a static Δp_s, dynamic Δp_d and friction component $\Delta p_{friction}$ [17].

$$\Delta p_{tot} = \Delta p_s + \Delta p_d + \Delta p_{friction} \tag{2}$$

Using the standard definition for dynamic pressure:

$$\Delta p_d = \frac{1}{2}\rho_{chim} V^2{}_{chim} \tag{3}$$

Δp_s Is the static pressure difference drops at the turbine, when considering the system without the turbine, then:

$$\Delta p_s = 0 \tag{4}$$

Now introducing the pressure drop through the chimney due to friction loss ($\Delta p_{friction}$) that is direct proportion to the kinetic energy per unit volume and chimney height (H_{chim}) and inverse proportion to the hydraulic diameter of the chimney(D_{chim}). Then

$$\Delta p_{friction} \propto \frac{H_{chim}}{D_{chim}} \frac{1}{2} V^2{}_{chim}$$

The proportionality coefficient is the dimensionless "Darcy friction factor" or "flow coefficient" and denoted as (f), then:

$$\Delta p_{friction} = f \frac{H_{chim}}{D_{chim}} \frac{1}{2} \rho_{chim} V^2{}_{chim} \tag{5}$$

From equation (5), the pressure drop due to the friction losses was proportional to the kinetic energy per unit volume by the dimensionless term ($f \frac{H_{chim}}{D_{chim}}$), which can be denoted by (ξ).

$$\xi = f \frac{H_{chim}}{D_{chim}}$$

Then equation (5) can be rewritten as:

$$\Delta p_{friction} = \xi \, \frac{1}{2} \, \rho_{chim} \, V^2{}_{chim} \tag{6}$$

$$\Delta p_{tot} = \frac{1}{2} \rho_{chim} \, V^2{}_{chim} + \xi \, \frac{1}{2} \, \rho_{chim} \, V^2{}_{chim}$$

$$\Delta p_{tot} = \frac{1}{2} (1 + \xi) \, \rho_{chim} \, V^2{}_{chim} \tag{7}$$

With the total pressure difference and the volume flow of the air at $\Delta p_s = 0$, the power P_{tot} contained in the flow is now:

$$P_{tot} = \Delta p_{tot} * V_{chim} * A_{chim} \tag{8}$$

From which the efficiency of the chimney can be established [18]:

$$\eta_{chim} = \frac{P_{tot}}{\dot{Q}} \tag{9}$$

Actual subdivision of the pressure difference into a static and a dynamic component depends on the energy taken up by the turbine. Without turbine, a flow speed of V_{chim} is achieved, and the whole pressure difference is used to accelerate the air, and consequently is converted into kinetic energy [17]:

$$P_{tot} = \frac{1}{2} (1 + \xi) \dot{m} \, V_{chim}^2 \tag{10}$$

Using the Boussinesq approximation, the speed reached by free convection currents can be expressed as [17]:

$$V_{chim} = \sqrt{\frac{2 * g * H_{chim}}{(1 + \xi)} * \frac{\Delta T}{T_{amb}}} \tag{11}$$

Where:

ΔT: The difference between temperature of the air at chimney entrance and the ambient temperature

T_{amb}: Ambient temperature (K)

It should be noted that, equation (11) can also be derived directly by substituting equation (1) into equation (7), and integrate it for chimney height. The chimney efficiency can be written as:

$$\eta_{chim} = \frac{g * H_{chim}}{c_p * T_{amb}} \tag{12}$$

This simplified representation explains one of the basic characteristics of the solar chimney, which is states that the chimney efficiency is fundamentally dependent only on its height.

Then the total power resulting from the air flow:

$$P_{tot} = \eta_{chim} * Q_u = \frac{g * H_{chim}}{c_p * T_{amb}} * \rho_{chim} * c_p * V_{chim} * \Delta T * A_{chim}$$

$$P_{tot} = \frac{g * H_{chim}}{T_{amb}} * \rho_{chim} * V_{chim} * \Delta T * A_{chim} \quad (13)$$

Then from equation (8) the total pressure difference becomes [17]:

$$\Delta p_{tot} = \rho_{chim} * g * H_{chim} * \frac{\Delta T}{T_{amb}} \quad (14)$$

$$\boldsymbol{V_{chim}} = \sqrt{\frac{\boldsymbol{2 * \Delta p_{tot}}}{\boldsymbol{\rho_{chim}(1 + \xi)}}} \quad (15)$$

2.2.2 Turbine Analysis

The heat flow produced by the collector is converted into kinetic energy (convection current) and potential energy (pressure drop at the turbine) through the chimney. Thus, the density difference of the air caused by the temperature rise in the collector works as a driving force. The lighter column of air in the chimney is connected with the surrounding atmosphere at the base (inside the collector) and at the top of the chimney, and thus acquires lift. Between chimney base (collector outflow) and the surroundings. A pressure difference Δp_{tot} is produced. The turbine extracts a fraction (*xtm)* of the total driving potential Δp_{tot}, the rest is needed to accelerate the air flow and to make up for friction. We obtain [17].

$$\Delta p_{tot} = \Delta p_{tur} + \frac{1}{2}\rho_{chim} V^2{}_{chim} + \xi \frac{1}{2} \rho_{chim} V^2{}_{chim} \quad (16)$$

$$\Delta p_{tur} = xtm * \Delta p_{tot} \quad (17)$$

Now the equation (16) can be now written as:

$$\Delta p_{tot} = xtm * \Delta p_{tot} + \frac{1}{2}\rho_{chim} V^2{}_{chim} + \xi \frac{1}{2} \rho_{chim} V^2{}_{chim} \quad (18)$$

Follow the same derivation above, the air velocity through the chimney becomes:

$$V_{chim} = \sqrt{2 * g * H_{chim} \frac{\Delta T}{T_{amb}} * \frac{(1 - xtm)}{(1 + \xi)}}$$

$$V_{chim} = \sqrt{\frac{2 * \Delta p_{tot}(1 - xtm)}{\rho_{chim}(1 + \xi)}} \tag{19}$$

The theoretical useful power P_{tur} at the turbine becomes:

$$P_{tur} = V_{chim} * A_{chim} * \Delta p_{tur} \tag{20}$$

From equations (16) and (20), the power of wind turbine will be zero at $\Delta p_{tur} = 0$ and at $\Delta p_{tur} = \Delta p_{tot}$. It takes a maximum between these extremes as:

$$\frac{dP_{tur}}{dV} = 0$$

$$\frac{dP_{tur}}{dV} = 0 = \Delta p_{tot} - (1 + \xi)\,\frac{3}{2}\,\rho_{chim}\,V^2{}_{chim}$$

$$V_{chim} = \sqrt{\frac{2}{3} * \frac{\Delta p_{tot}}{\rho_{chim}(1 + \xi)}} \tag{21}$$

Comparing equation (21) with equation (19), the maximum power can be reached when:

$$xtm = \frac{2}{3}$$

The model was developed using Finite Different Method (FDM). This method needs to discretize the solar collector into finite number of annuli. Heat energy equations are applied for each annulus independently using guessed value of mass flow, until arrive the last annuli and satisfy the temperature at the chimney entrance, after that, apply the buoyancy force equation and estimate the mass flow through the chimney, the process is iteratively repeated until convergence occur (the mass flow estimated closed with guessed one), Figure (1) present the mathematical model flow diagram. It should be noted that, the maximum power theoretically is achieved when two thirds of the total pressure difference is utilized by the turbines. The thermo-physical properties of system components and meteorological conditions of Ber;Alganam (Azwaia-Libya) used in this study were mentioned in [14].

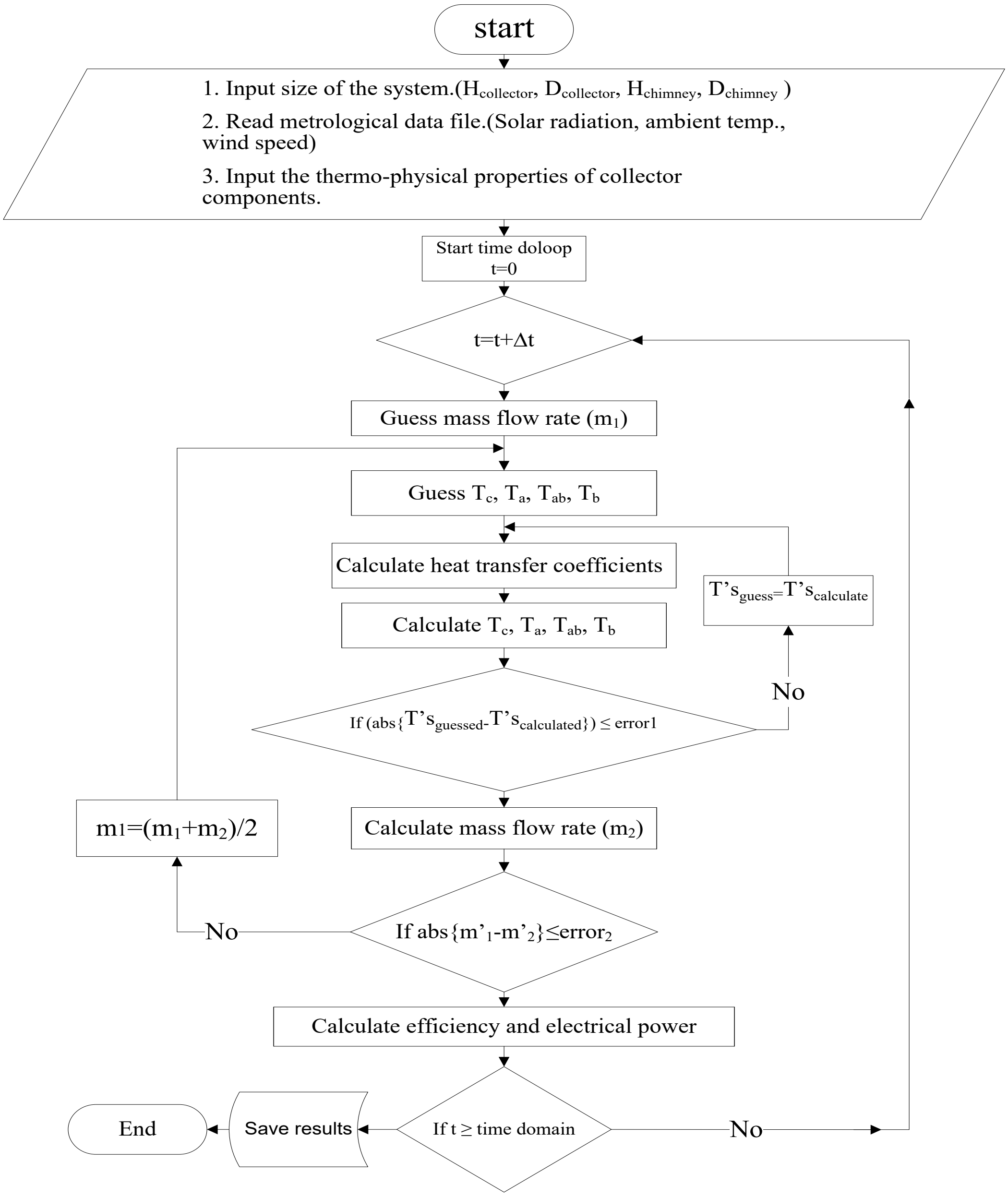


Figure 1. Mathematical model flow chart

3.0 Minimizing size

Considering each modification separately and then use the superposition theory to estimate the modified configurations of the proposed large-scale SCPP.

3.1 Minimizing chimney height

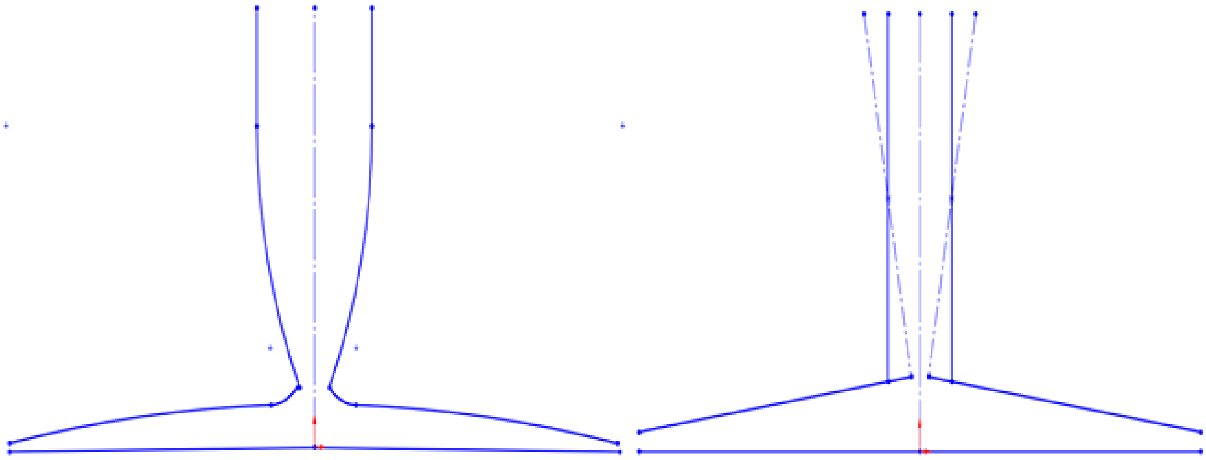
3.1.1 Variable chimney diameter

According to [7], the divergent tower increase mass flow rate and kinetic energy over that of the constant area tower, for a chimney area ratio of 16 can produce kinetic energy as much as 94 times that of the constant area tower. This benefit can be used to minimize the chimney height for same power output. Assuming the chimney diameter is a mean diameter of the divergent chimney and the temperature difference through the collector for modified systems remain as a standard configuration, then

$$\left(\frac{A_{outlet}}{A_{inlet}}\right) = 16 \quad \rightarrow \left(\frac{d^2{}_{outlet}}{d^2{}_{inlet}}\right) = 16 \quad \rightarrow \quad d_{outlet} = 4\, d_{inlet} \tag{22}$$

$$d_{Origin} = \frac{d_{outlet} + d_{inlet}}{2} \tag{23}$$

Where d_{Origin} is a standard chimney diameter reported in table (1), noteworthy, that is better to design the divergent chimney by a parabolic geometry figure (2,a) that more aerodynamically shape than a linear divergent. For simplicity, the linear divergent; figure (2,b) will be taken in calculation.



(a) (b)

Figure 2. Divergent chimney; (a) Parabolic divergent chimney, (b) Linear divergent chimney

Solve the above two equations for d_{outlet} and d_{inlet} for each large-scale configuration to calculate the modified dimensions of divergent chimney tabled in table (2).

Table 2. Divergent chimney diameters

Model	$d_{Original}$ (m)	d_{inlet} (m)	d_{outlet} (m)	$A_{original}/A_{inlet}$
Model 1	45	18	72	6.25
Model 2	70	28	112	6.25
Model 3	110	44	176	6.25
Model 4	120	48	192	6.25

The rate of thermal energy gained by solar collector of the SCPP

$$\dot{E}_{Thermal} = \lambda_{Collector} * I * A_{Collector} \tag{24}$$

The rate of thermal energy absorbed by air through the solar collector:

$$\dot{E}_{Thermal} = \dot{m}\, C_p \left(\mathrm{T}_{chimney} - T_{Ambaint}\right) \tag{25}$$

$$\dot{E}_{Thermal} = \rho_{chim}\, V_{chim}\, A_{chim}\, C_p \left(\mathrm{T}_{chimney} - T_{Ambaint}\right) \tag{26}$$

Substitute equation (11) into (26)

$$\dot{E}_{Thermal} = \rho_{chim} \sqrt{\frac{2 * g * H_{chim}}{(1+\xi)} * \frac{\left(\mathrm{T}_{chimney} - T_{Ambaint}\right)}{T_{amb}}}\, A_{chim}\, C_p \left(\mathrm{T}_{chimney} - T_{Ambaint}\right) \tag{27}$$

ξ: Roughness factor, assuming frictionless flow; $\xi = 0$, then

$$\dot{E}_{Thermal} = \rho_{chim} \sqrt{2 * g * H_{chim} * \frac{\left(\mathrm{T}_{chimney} - T_{Ambaint}\right)}{T_{amb}}}\, A_{chim}\, C_p \left(\mathrm{T}_{chimney} - T_{Ambaint}\right) \tag{28}$$

$$\dot{E}_{Kinatic} = \dot{E}_{Thermal} * \lambda_{Chimney} \tag{29}$$

Substitute equation (28) in equation (29), gets:

$$\dot{E}_{Kinatic} = \frac{\rho_{chim} A_{chim}}{2} \left(\sqrt{2\, g\, H_{chim} * \frac{\left(\mathrm{T}_{chimney} - T_{Ambaint}\right)}{T_{Ambaint}}} \right)^3 \tag{30}$$

Another manner

$$\dot{E}_{Kinatic} = \frac{\dot{m} {V_{chim}}^2}{2} \tag{31}$$

According to [7]

$$\left(\dot{E}_{Kinatic}\right)_{modified} = 94 \left(\dot{E}_{Kinatic}\right)_{Original} \tag{32}$$

Substitute equation (31) in equation (32)

$$\left(\dot{E}_{Kinetic}\right)_{modified} = 47\, \rho_{chim}\, A_{inlet} \left(\sqrt{2\, g\, H_{chim} * \frac{\left(\mathrm{T}_{chimney} - T_{Ambaint}\right)}{T_{amb}}} \right)^3 \tag{33}$$

Where:

$$A_{chim} = A_{inlet}$$

And

$$(\mathrm{T}_{chimney} - T_{Ambaint})_{modified} = (\mathrm{T}_{chimney} - T_{Ambaint})_{Original} \tag{34}$$

For minimization purpose, equalize the kinetic energy of both modified and original configuration and solve the above equation (for the chimney height).

Then,

$$(\dot{E}_{Kinetic})_{modified} = (\dot{E}_{Kinatic})_{Original}$$

$$H_{chim_{Modified}} = \left(\frac{(\dot{E}_{Kinetic})_{modified}}{47\ \rho_{chim}\ \ A_{inlet}}\right)^{\frac{2}{3}} \frac{2\ g\ (\mathrm{T}_{chimney} - T_{Ambaint})}{T_{Ambaint}} \tag{35}$$

According to [8], the velocity of air at the chimney base was enhanced by 59.4% compared to a Cylindrical Chimney. Then,

$$Enhanced\ persent\ \% = \frac{V_{chim_{Modified}} - V_{chim}}{V_{chim}} \tag{36}$$

Using any instance data

$$V_{chim_{Modified}} = V_{chim}\ \left(\frac{Enhanced\ persent\ \%}{100} + 1\right) \tag{37}$$

$$V_{chim_{Modified}} = V_{chim}\ \left(\frac{59.4}{100} + 1\right) \tag{38}$$

$$V_{chim_{Modified}} = \sqrt{2\ g\ H_{chim} * \frac{(\mathrm{T}_{chimney} - T_{Ambaint})}{T_{Ambaint}}}\ \left(\frac{59.4}{100} + 1\right) \tag{39}$$

For minimization purpose, equating the modified velocity for divergent chimney with that for a cylindrical chimney and solve the above equations for the chimney height.

$$V_{chim_{Modified}} = V_{chim}$$

$$H_{chim_{Modified}} = \left(\frac{V_{chim}}{\left(\frac{59.4}{100} + 1\right)}\right)^2 \frac{T_{amb}}{2\ g(T_{chim} - T_{amb})} \tag{40}$$

3.1.2 Virtual chimney height

According to [11], Virtual chimney height technology can be used to minimize chimney height for systems with chimney height below 500m. Figure (3) present the effect of passive cooling system at the top of the chimney and a passive solar heater at its base. Table (1) shows, the chimney height of four large scale models have chimney height above 500m, then, this technology not suitable to minimize chimney height even when using another modification because the horizontal turbines were choosing, and difference between Vx with modification and Vx without modification. found as small as the size minimizing can be neglected.

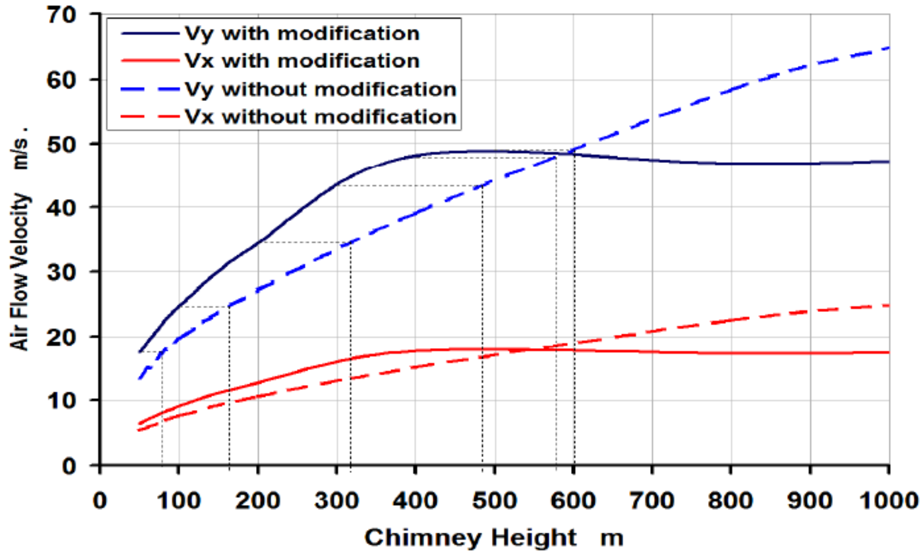


Figure 3. Airflow average velocities Vx entering horizontal turbines and Vy entering vertical turbine before and after applying heating chimney base and cooling chimney exit [11].

3.2 Minimizing collector diameter

According to [10], the collector radius can be minimized by 25% which means the area reduction is 43.75% than the traditional solar chimney system by introduce the helical paths in the solar collector as sketched in figure (4).

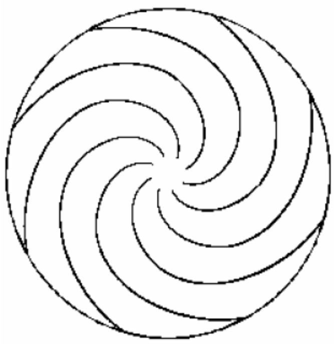


Figure 4. Helix Solar air collector [10]

Then, the collector diameter in table (1) can straightforward modified as:

$$d_{modified} = 0.25\ d_{origin} \tag{41}$$

4.0 Results and discussion

4.1 Electrical power variation throughout the daytime

Figure (5) show the potential power curve of four models of (SCPPs) listed in table (1) under conditions of Ber' Alganam (Az Zawia-Libya) [14], the results showed that, the maximum power gained in July and is reached the nominal power at a peak time, where the lowest levels of power output recorded in December, this means that the power output was mainly effected by solar radiation. In this paper the power curves remain the same for both original and modified configurations, and implement the production's improvements methods to minimizing system size

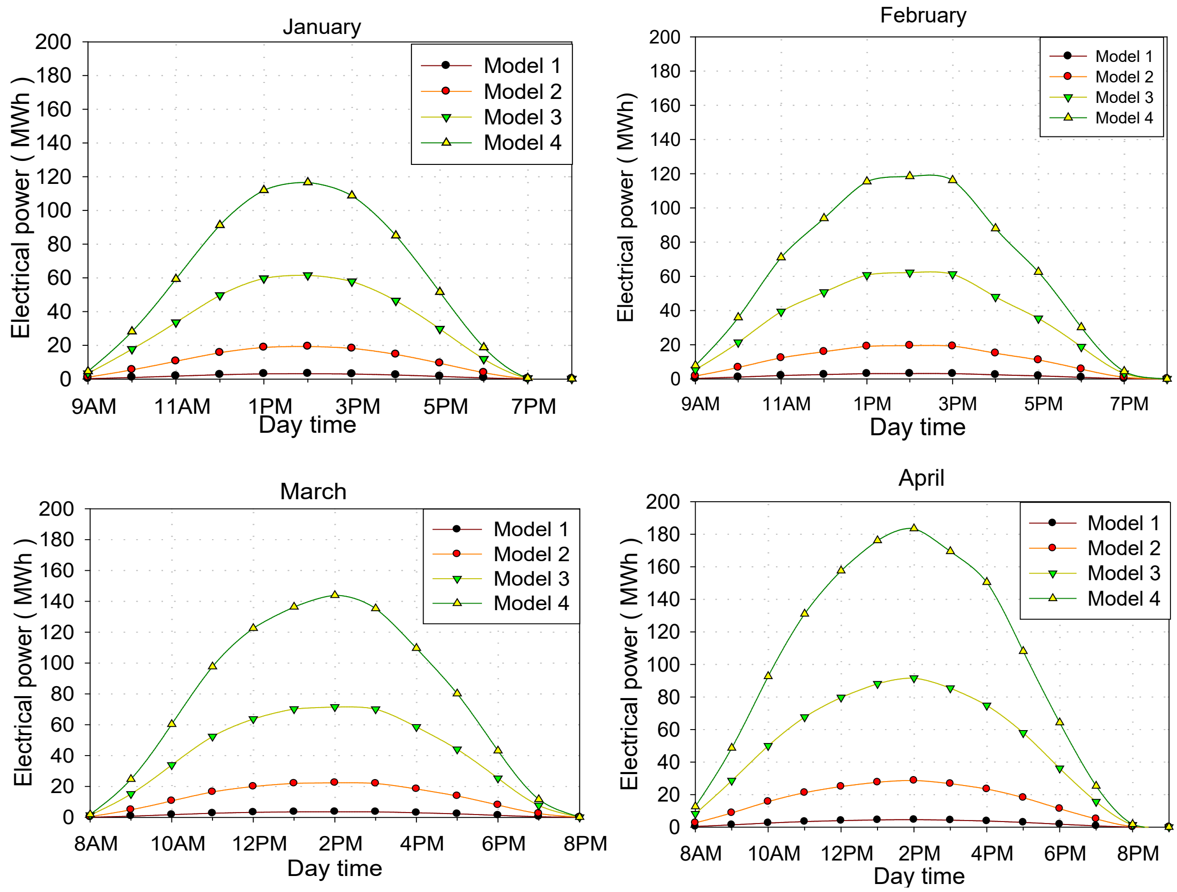


Figure 5. Average monthly power curve. (Continue)

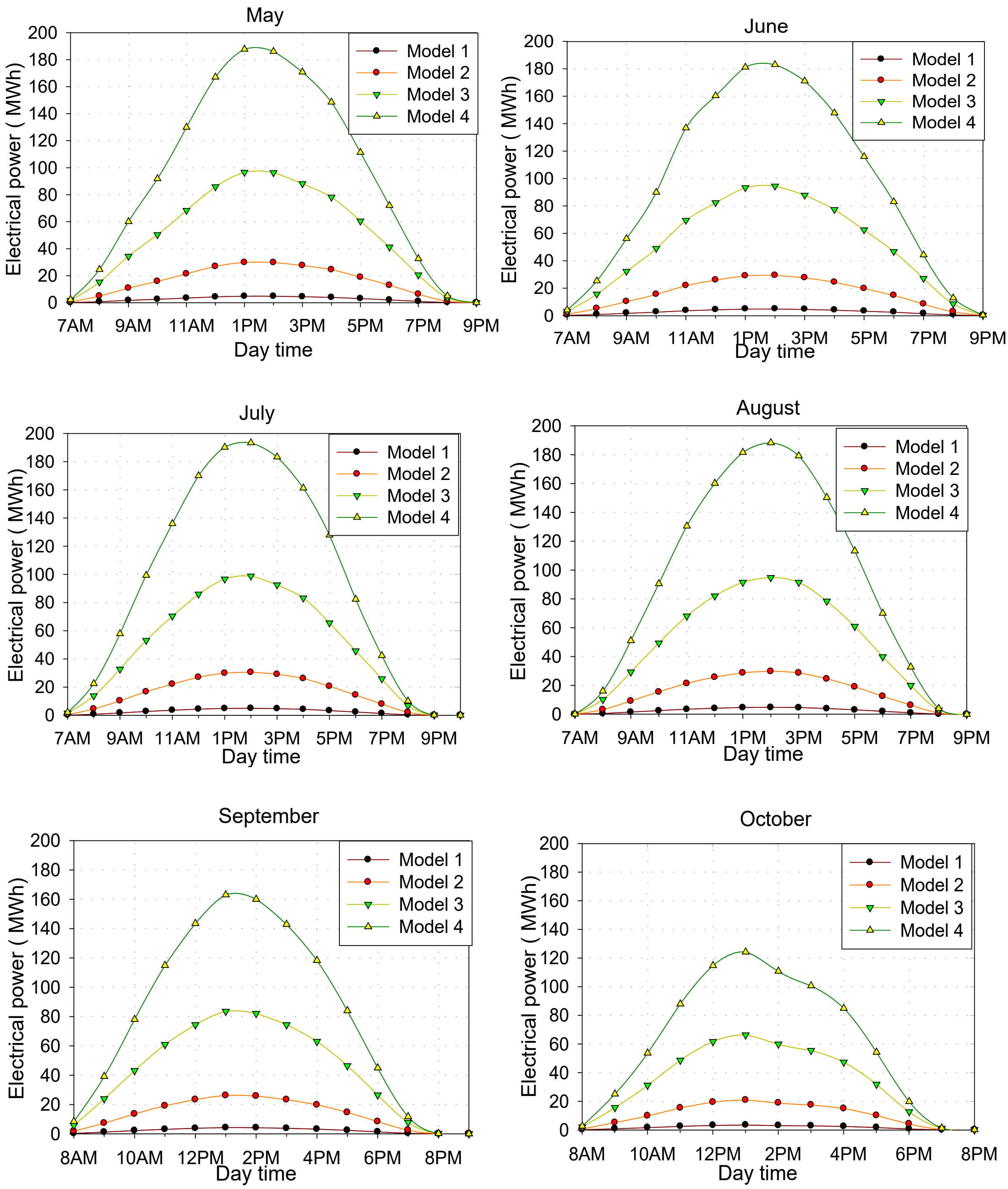


Figure 5. Average monthly power curve. (Continue)

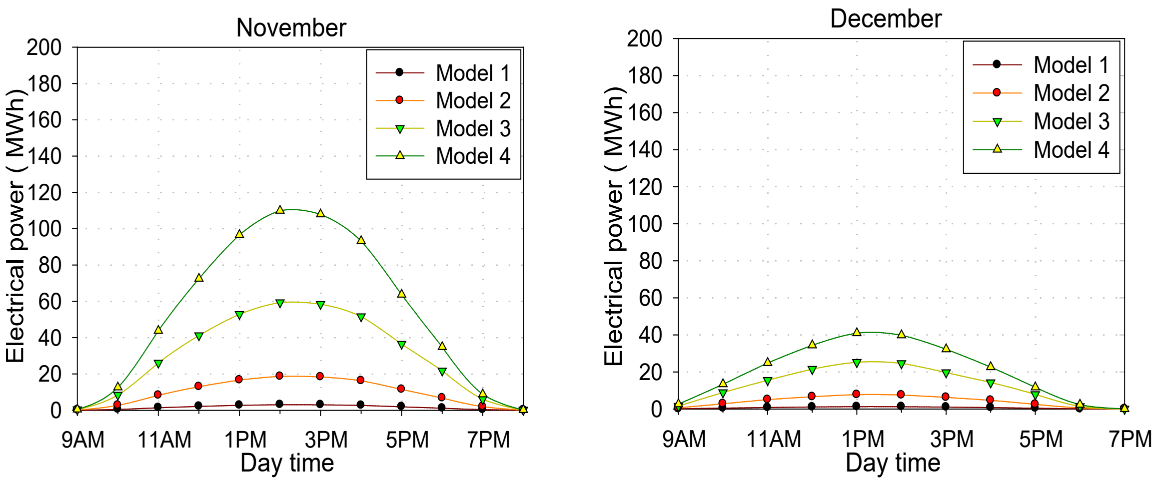


Figure 5. Average monthly power curve (MWh)

Figure (5) shows the power output at peak time in July, has a good agreement with the nominal power listed in table (1), the comparisons are tabulated in table (3).

Table 3. Comparison between nominal power and calculated Peak power in July

Power / Model	Model 1	Model 2	Model 3	Model 4
Nominal power (MWh)	5	30	100	200
Peak power in July (MWh)	4.9191	30.4879	98.7457	193.3707

From figure (5), the annual power output can be calculated and presented in figure (6).

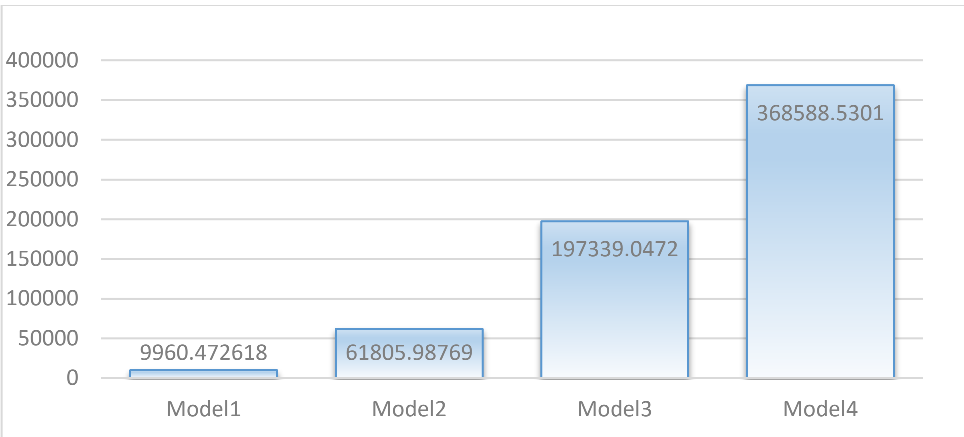


Figure 6. Annual power output (MWh/a)

4.2 Minimizing system configuration

The improvement technologies of solar chimney system were used to minimizing the size rather than increase productivity. Using the formulation in the section (2.2) the modified chimney heights and collector diameters of four large-scale models are tabulated in table (4).

Table 4. Minimizing size of SCPP large-scale plants

Model	Chimney height (m)					Collector diameter (m)		
	Original	Modified [7]	Modified [8]	Reduction %		Original	Modified [10]	Reduction %
Model 1	550	90.26	216.46	83.58	60.64	1250	937.5	25
Model 2	750	123.09	295.17	83.58	60.64	2900	2175	25
Model 3	1000	164.12	393.57	83.58	60.64	4300	3225	25
Model 4	1000	164.12	393.57	83.58	60.64	7000	5250	25

5.0 Conclusion

In the current work, the power curve of four large-scale models under conditions of Ber' Alganam area (Az Zawia-Libya), the annual productions were found 9.96, 61.8, 197.3 and 368.6 GWh/a for 5, 30, 100, and 200 MWh large-scale plants respectively. The improvement technologies were implemented to minimizing size to make the construction of large-scale SCPP feasible. The results showed that the SCPP has a good production level according to meteorological data and environmental condition relative to proposed site. The maximum power gain was in July, at a peak time of the day. However, the lowest levels of power was recorded in December. The results showed good agreements between the maximum annual power recorded with the nominal power for each configuration. The results also showed that, improvement technologies such variable chimney diameter (divergent chimney) and helix solar collector provides the major reduction of solar chimney power plant size for the same productivity, this major reduction makes the construction of solar chimney power plant is feasible by conventional present-day structural technologies.

6.0 References

[1] Schlaich, J., Bergermann, R., Schiel, W., Weinrebe, G., "Design of commercial solar updraft tower systems utilization of solar induced convective flows for power generation", Journal of Solar Energy Engineering 127, 117–124, 2005.

[2] Bernardes, M. A. d. S., "Solar Chimney Power Plants–Developments and Advancements", Solar Energy, Radu D Rugescu (Ed.), ISBN: 978-953-307-052-0, 2010.

[3] T. Z. Ming, Zheng Y., Liu C., Liu W., Pan Y., "Simple analysis on thermal performance of solar chimney power generation systems", Published by Maney on publishing © Energy Institute, DOI 10.1179/014426009X12519696923902, 2010

[4] Haaf, W., Friedrich, K., Mayr, G. and Schlaich, J., “Solar chimneys: part I: principle and construction of the pilot plant in Manzanares”, International Journal of Solar Energy, 2, (1), pp 3-20, 1983.

[5] Pasumarthi, N., Sherif, S.A., “Experimental and theoretical performance of a demonstration solar chimney model – part I: mathematical model development”, International Journal of Energy Research 22 (3), 277–288, 1998.

[6] Pasumarthi, N., Sherif, S.A., “Experimental and theoretical performance of a demonstration solar chimney model – part II: experimental and theoretical results and economic analysis. International Journal of Energy Research 22 (5), 443–461, 1998.

[7] Koonsrisuk A. and Chitsomboon T., “Effect of Tower Area Change on the Potential of Solar Tower”, The 2nd Joint International Conference on “Sustainable Energy and Environment, 21-23, 2006.

[8] Pritam Das, Chandramohan V.P., “Performance characteristics of divergent chimney solar updraft tower plant”, International Journal of Energy Research (IF 3.741), DOI: 10.1002/er.5304, 2020

[9] Bouabidi A., Ayadi A., Nasraoui H., Driss Z., Abid M. S., “ Study of solar chimney in Tunisia: Effect of the chimney configurations on the local flow characteristics”, Energy and Buildings Volume 169, Pages 27-38, 2018

[10] Tingzhen M.” Research on Thermo-kinetic Problems of the Solar Chimney Power Plant Systems”, PhD dissertation, Huazhong University of Science & Technology, Wuhan 430074, P.R. China, 2007.

[11] Ahmed K. I. E., Abdel-Rahman A. K., Ahmed M., Khairaldien W. M., “Virtual height aided solar chimney: a new design”, Proceedings of the ASME 2011 International Mechanical Engineering Congress & Exposition (IMECE2011-65819, 2011.

[12] Shuia E. M., Arebi B. H., Abuashe I. A., “Experimental and Theoretical Investigation of Performance of a Solar Chimney Model, Part I: Experimental Investigation”, Solar Energy and Sustainable Development, Volume (3) No (1) 2014.

[13] Abuashe I. A., Arebi B. H., Shuia E. M., “Experimental and Theoretical Investigation of Performance of a Solar Chimney Model, Part II: Model Development and Validation”, Solar Energy and Sustainable Development, Volume (5) No (2) 2016.

[14] Abuashe I. A., Shuia E. M., Mariamy, A. M., “Investigation of performance and production’s potential of large-scale solar chimney power plant in the area of Ber’Alganam (Az Zawia-Libya)”, 2nd Conference for Engineering Sciences and Technology -CEST2 29-31, 2019.

[15] Abuashe I. A., Shuia E. M., Mariamy, A. M.,” Parametric study of large-scale solar chimney power plant under conditions of Ber’Alganam area (Az Zawia-Libya), 2nd Conference Engineering Conference for the Engineering professions syndicate in Zawia, https://sec.leaboz.org.ly, 2019.

[16] Schlaich, J., Bergermann, R., Schiel, W., and Weinrebe, G., “Design of commercial solar tower systems - Utilization of solar induced convective flows for power generation”, paper presented at International Solar Energy Conference, Kohala Coast, HI, 2003.

[17] Weinrebe, G., Schiel, W., “Up-Draught Solar Tower and Down-Draught Energy Tower—A Comparison,” Proceedings of the ISES SolarWorld Congress 2001, 2001.

[18] KARA, Ö. "Upwind solar chimney application in izmir", MSC in mechanical engineering, Güneş Enerjisi Enstitüsü, Bornova İZMİR, 2002.