Foreword

In this edition the reviewers have selected twelve papers from different member states of ISESCO (6) and other countries (4) in a variety of scientific disciplines ranging from renewable energy to medical science, addressing fundamental theories, applications and simulations. What unites them is neither subject matter nor nationality of author but dedication to the advancement of scientific knowledge. This is very encouraging since it advances one of the major aims of this ISESCO Journal. Giving a voice to scientists benefits not only the authors and their institutions but contributes also to the promoting sustainable development and improving the quality of life in societies.

The opening paper deals with a complex fundamental heat transfer concept and makes a valuable contribution in this regard. A topic of great current interest worldwide, namely generation of energy from biomass agricultural waste is studied in paper two. Paper three constitutes an innovative study of solar collectors.

At a time of increasing concern about water supplies, paper four addresses the rationalized use of underground water in remote island communities in Malaysia. Paper five, authored by a researcher from Yemen, provides a new software to construct gene regulatory network from microarray data. The treatment of oxidative stress in the brain, liver and heart of chicks embryos is studied in paper six. From Jordan, we have paper seven, which deals with the solar tracking systems. The prediction of solar radiation potential in the islands of Indonesia is achieved through the use of ANN, as shown in paper eight.

Another topic which has triggered a heated debate is the planning of wind farms, is treated in paper nine in reference to the particular context of a province in Argentina. Paper ten explores the potential for hydrogen production in Pakistan, while Paper eleven outlines the great potential of generating electricity and producing water in the coastal regions in UK, using solar energy. Finally, paper twelve, which submitted by a researcher from Iran, discusses the effects of cultivation size on energy indices of irrigated wheat crop.

I am delighted that this issue promotes the scientific endeavors of such a diverse group of authors. I hope this will encourage more authors from ISESCO member states to share the fruits of their endeavors.

Dr. Hadi Azizzadeh
Editor-in-chief
1. Introduction

Many bodies of practical interest are bluff, and there are lots of studies which deal with various aspects of the complex flow around them. The efficiency of heat transfer and friction characteristics is governed by the shape of the obstruction.

A numerical investigation of low Reynolds number flows with thermal effect around airfoils using various turbulence models was investigated by Nadir Bekka et al. [1]. The study showed that the improvement of aerodynamic efficiency (increase lift and reduce drag) is achieved by the generation of a temperature difference between extrados and intrados of the airfoil (by cooling the upper surface and heating the lower surface). External heat transfer measurements on a highly loaded turbine vane with varying surface roughness were studied by M. Stripf et al. [2] covering the full range of roughness Reynolds numbers in the transitionally and fully rough regimes. The results showed a strong influence of roughness on the onset of transition even for the smallest roughness Reynolds numbers and the heat transfer coefficients in the turbulent boundary layer increased by up to 50% when compared to a smooth reference surface. Moreover, using numerical methods Raughunathan and Mitchell determined the effect of heat transfer in transonic flow about the NACA 0012 airfoil [3]. Kerho and Bragg [4] investigated the effect of surface roughness on the attack side of an airfoil on the formation of a boundary layer. Yilmaz [5,6] experimentally investigated the performance of NACA 0012 profile with three different aspect ratios at different subsonic flow speeds in the wind tunnel. Caroglia and Jones [7] investigated a methodology for the experimental extraction of indicial functions for streamlined and bluff deck sections. In addition the effect of aspect ratio on airfoil performance about axially symmetric wings as a function of the angle of attack was investigated by M. Kopac, et al [8] and it was concluded that the airfoil with the aspect ratio of 2.761 yielded the optimum performance out of the three different profiles tested.
In addition, Bunker [9] studied airfoil heat transfer distributions using a thin-walled stainless steel airfoil having imbedded thermocouples with varied conditions of air inlet free stream turbulence intensity and vane Reynolds number. Heat transfer and friction characteristics of turbulent flow in circular tubes with twist-tape inserts and axial interrupted rips were investigated by Zhang, and Han [10]. The results had shown that the heat transfer and pressure drop in the tube with twist-tape inserts increase by increasing the number of twist-tape turns.

Numerical prediction of fluid flow and heat transfer in a circular tube with longitudinal fins interrupted in the stream-wise direction has been studied by Kelkar et al. [11] and the results have indicated that in the periodic fully developed regime, for Prandtl number of 0.7, a tube with staggered arrangement of fins produces less heat transfer enhancement than a tube with continuous fins. Hsieh and Shou-Shing [12] have analyzed turbulent heat transfer and flow characteristics in a horizontal circular tube with strip-type inserts and found that Nusselt numbers were between four and two times of the bare tube values at low and high Reynolds numbers respectively. Moreover, a numerical study of flow field and heat transfer in a heated circular tube with an inner tube inserted has been investigated by Fu et al. [13]. The results had shown that, except at very low Peclet number, the heat transfer rate of the heated tube increases when an inner tube was inserted. Aoyama et al. [14] investigated turbulent heat transfer enhancement by a row of twisted plates at 90 degrees alternately in different directions and found that heat transfer coefficients increased. In addition, Mendes et al. [15] determined experimentally heat transfer coefficients and pressure drop data for turbulent flow through internally ribbed tubes and found that ribbed tubes have higher heat transfer performance for most of the cases investigated. A similar behavior for heat transfer augmentation was observed by Zhu et al. [16] using a flag type inserts in a circular tube. Moreover, a theoretical study by Wang et al. [17] to develop a novel heat transfer enhancement technique in a circular tube with micro-fiber fin found that the heat transfer improves with an increase in the length of the fin to diameter of tube ratio and the thermal conductivities ratio of the fin, and the fluid.

The work investigates the effect of an airfoil geometry and surface temperature on fluid flow characteristic, such as friction coefficient and heat transfer. The experimental investigations are supported by computational fluid dynamics (CFD) analysis and infra red imaging.

2. Experimental Setup and Technique

The experimental apparatus is shown in Figure 1. The impingement body is a thin streamlined airfoil made from aluminum alloy 6010-T4 of average roughness 0.4 µm with a chord length 195 mm, 63 mm wide. It is held in a horizontal square test pipe section of side 0.3m with a corresponding hydraulic diameter, \( D_h = 0.3m \), and a length of 720 mm. The test pipe section is designed and manufactured using plastic material. This section is positioned in the wind tunnel such that the airflow in this section is fully developed thus minimizing friction losses and ensuring full-developed boundary layer. The honeycomb at the inlet of the wind tunnel is designed to provide uniform fluid flow in the region immediately after the honeycomb and bell-mouth where the test section is positioned.

To study the flow characteristics on the airfoil, the airfoil is tilted at different angles of attack, namely: -20, 0, 10, 30 degrees. This is done by adjusting the wind tunnel tilt mechanism where the airfoil is attached. In this study, the flow characteristics are investigated experimentally for a range of Reynolds number from \( 0.5 \times 10^5 \) to \( 3 \times 10^6 \). The airflow is provided using a fan that has a rotational speed control unit. Measurement of the mean free-stream air velocity in the test section is performed using a Hot Wire Anemometer and a Dynamic Balance for dynamic drag force measurement. The foil is heated by passing an electric current through it and cooled by an air jet directed perpendicular and at different flow directions. The electric current is provided with a direct current power supply within 1% uncertainty. Surface temperature distributions at various locations on the foil in longitudinal and lateral directions are measured using fifteen thermocouples of type K. In addition, a computerized infrared thermal imager is employed to scan the foil surface temperature.
3. Simulation Technique

Next, the flow characteristics over the foil are simulated using Fluent code 6.3.26. First, the airfoil and pipe test section are drawn and meshed using Gambit code 2.2.30 as shown in Figure 2. Using the energy equation, the proper boundary conditions, and boundary types, the flow in the test section is simulated using the Fluent software.

4. Results

In this investigation, a cold and heated airfoil is used in order to test the effect of air flow characteristics on drag, friction, and heat transfer rate in the test section over the airfoil at different angles of attack and Reynolds numbers.

The cold drag coefficient values, i.e. without heating airfoil are calculated using the following relations:

\[
D_h = \frac{4ab}{2(a+b)}
\]  
(1)

The test section hydraulic diameter is calculated first;

The transverse average velocity per change of length from the test pipe section far wall is calculated for each investigation;

\[
S = \frac{(V_1 + 0)}{2} + \frac{(V_1 + V_2)}{2} + \frac{(V_1 + V_2)}{2} + \frac{(V_1 + V_4)}{2} + \frac{(V_1 + V_5)}{2} + \frac{(V_1 + V_6)}{2} + \frac{(V_1 + V_7)}{2} + \frac{(V_1 + V_8)}{2} + \frac{(V_1 + V_9)}{2} + \frac{(V_1 + V_{10})}{2}
\]
(2)

The air flow mean velocity and Reynolds number are determined afterwards from;

\[
V_m = \frac{S}{D_h}, \quad Re = \frac{\rho V_m D_h}{\mu}
\]
(3)

The recorded drag, D from each test is inserted in the following equation to calculate the drag coefficients, \(C_D\) for the air foil at different velocities, \(V_m\) and angles of attack, \(\alpha\):

\[
C_D = \frac{2D}{\rho A V_m^2}
\]
(4)

The drag force and drag coefficients at different air flow angles of attack with different Reynolds numbers are shown in Figure 3 and Figure 4.

Furthermore, Newton's cooling law is applied for convective heat transfer across the airfoil to determine the Nusselt number, Nu and the hot drag coefficients at different Reynolds numbers and air flow angles of attack by applying a constant heat source to the foil, using the following equations;

Mean temperature on the airfoil recorded by the 15 thermocouples;

\[
T_m = \frac{\sum_{i=1}^{15} T_i}{n}
\]
(5)

Heat loss due to radiation from airfoil;

\[
Q_{rad} = \varepsilon \sigma (T_m^4 - T_{sur})
\]
(6)
The convection heat transfer coefficient is calculated from:

\[ h = \frac{Q_s - Q_{rad}}{A \Delta T} \]  

(7)

Where \( Q_s \) is the supply power, and \( \Delta T \) is the temperature difference between the foil surface and surroundings. The Nusslet Number is afterwards calculated from:

\[ Nu = \frac{L_s h}{k} \]  

(8)

The results with the application of the heat source are exemplified by the different graphs shown in Figure 5 to Figure 7. The thermal imager frame showing the temperature distributions on the airfoil is shown in Figure 8.

The simulation results of velocity, pressure and Nusselt number for air inlet flow velocities of 21, 11.8 m/s and fluid flow angle of attacks of 0 and 30 degrees are delineated in Figure 9 to Figure 11.
5. Discussion of results

An experimental study is presented for the heat transfer rate and friction variations in a horizontal test pipe with the insertion of an airfoil. Fully developed laminar airflow is maintained in the test section, which is connected to a sub-sonic wind tunnel. The flow characteristics results are discussed as follows:

Figure 3 and Figure 4 show the drag force and drag coefficient variations on the unheated body with Reynolds number at different fluid flow angles of attack. The drag force and drag coefficient are large at larger angles of attack and the drag force tends to increase at higher Reynolds number, while the drag coefficient decreases. This behavior can be explained as follows, since boundary layer separation is not a factor at low Reynolds number, streamlining in the test body does not much change the pressure drag. But streamlining does increase considerably the viscous drag at the surface, simply because of the increased surface area over which the frictional stresses act. Thus, because streamlining increases the wetted area, the total drag is actually increased by streamlining at low Reynolds number. Changes in the angles of attack alter the pressure distribution, particularly on the upper surface. If the angle of attack exceeds a certain critical value, the boundary layer stalls on the upper surface and the main flow separates from the upper surface because the shape downstream of the foil shoulder is such as to produce a severe rate of pressure rise, and in turn leads to immediate boundary layer separation, to a low pressure in the wake, and consequently to a large pressure drag. The total drag then increases greatly, and more important, the lift suddenly decreases.

In the first part of the investigations, the relationship between the coefficient of friction and Reynolds number at different speeds are obtained without adding a heat source, while in the second part, a heat source is added to the experiment. Figure 5 shows the relation between the friction (drag) coefficient and Reynolds number while feeding the aerofoil with a fixed heat rate at different angles of attack. Comparing these results with the results obtained in part 1, the difference in the values of friction coefficient between these two conditions is noted. In the second condition (with heat source) the friction coefficient has lower values about half for angles of attack 0, 10, -20 degrees and a quarter for the 30 degrees angle than the one obtained in the first condition (without heat source). This is related to the thermal boundary layer thickness which increases by the increase in the supplied heat rate. A hot surface also reduces friction [18]. It is found that the lowest friction coefficient is obtained at zero angle of attack.

Figure 6 depicts the average Nusselt Number variation with the Reynolds Number. The heat transfer from the airfoil has the largest value (for the same speed pattern) when the angle of airfoil equals 30° and the lowest value is obtained when the angle equals 0°. This is due to differences in the projection area of the flow on the body. In front of the body and behind it, there is a recirculation flow domain, which is separate from the main flow stream. It can be seen that when the angle position increases, the recirculation flow domain increases, which in turn increases the heat transfer rate from the surface. It is also noted that the heat transfer rate increases with increasing air flow as expected. Figure 7 delineates the inverse relationship between Nusselt number and friction coefficient for the various angles of attack being highest at 30° and lowest at 0°.

Figure 8 shows the thermal image taken for the tested body at 30° position. The temperature distribution at the periphery of the foil is the lowest compared to the other parts. The maximum temperature is at the center of the test foil. This perhaps is attributed to the stagnation air velocity in the center. The air flow re-circulates after impact on the center of the foil causing the temperature away from the center to reduce due to convection heat transfer. However, the temperature on the foil periphery...
is lowest due to the larger air mass flow rate in that open region.

The simulation results using Fluent code 6.3.26 to validate the experimental work experiments are shown in Figure 9 to Figure 11.

Figure 9 and Figure 10 depict the velocity profiles and pressure distributions acting on the surface of the airfoil. On Bernoulli’s principle, the pressure distribution on the airfoil may be inferred from the velocity distribution. Far upstream and far downstream, where the speed is free-stream, the pressure is atmospheric. At the nose and just behind the tail, where the speed is zero, the pressure is a maximum when the foil is in the proper position (α = 0°). And, at the shoulder, where the speed is a maximum, the pressure is at its lowest position. Theoretically the pressure drag is minimal, and the friction in this position is mainly due to skin friction drag exemplified by the thin viscous boundary attached to the airfoil surface from nose to tail. However, when the foil is positioned at an unfavorable angle to the flow (α = 30°), the pressure distribution changes considerably, and the boundary layer stalls on the upper surface and the main flow separates from the upper surface as shown in Figure 9. The drag then increases greatly. This behavior complies with the experimental results shown in Figure 3 and Figure 4.

Figure 11 delineates Nusselt Number distribution on airfoil surface at α = 0° (a), and α = 30° (b). The frames show that heat transfer is highest when the foil is at 30 degrees position as indicated by the scale bar on the left of each picture. This agrees well with the experimental results shown in Figure 6.

Conclusions

The work in the test section has comprised different investigations of the flow characteristics over a symmetrical airfoil. The findings from the study are as follows:

Characteristics of friction coefficient
- The friction (drag) coefficient increases with each increase in the foil angle position.
- The friction coefficient has lower values when heat source is turned on.
- Increase in the flow speed results in a decrease in the friction coefficient.

Heat transfer characteristic
- The highest heat transfer enhancement (Nusselt Number) takes place at increasing foil tilt position and is highest when α = 30°. Nusselt Number increases as Reynolds number increases.
- Heat transfer enhancement increases as the friction coefficient is reduced.
- The thermal image at α = 30° indicates that the flow along the foil is not uniform due to changes in air flow. The lowest temperatures are at the periphery of the foil due to larger air mass flow rate.
- CFD results have shown that the temperature distribution and heat transfer rate along the airfoil is changing by the change of the fluid flow angle of attack.
References


Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
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<tbody>
<tr>
<td>A</td>
<td>Plan-form area of test foil, m²</td>
</tr>
<tr>
<td>Vₘ</td>
<td>Mean fluid velocity at inlet, m/s</td>
</tr>
<tr>
<td>Dₜ</td>
<td>Hydraulic diameter, m</td>
</tr>
<tr>
<td>h</td>
<td>Heat transfer Coefficient, W/m². K</td>
</tr>
<tr>
<td>k</td>
<td>Thermal conductivity of air, W/m.K</td>
</tr>
<tr>
<td>Q(conv)</td>
<td>Convection heat transfer rate, Watt</td>
</tr>
<tr>
<td>Q(rad)</td>
<td>Radiation heat transfer rate, Watt</td>
</tr>
<tr>
<td>Q’s</td>
<td>Supplied power to foil, Watt</td>
</tr>
<tr>
<td>Lc</td>
<td>Airfoil characteristic length, m</td>
</tr>
<tr>
<td>D</td>
<td>Drag force, N</td>
</tr>
<tr>
<td>S</td>
<td>Velocity parameter across test section, m²/s</td>
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<tr>
<td>a, b</td>
<td>Test section side length, m</td>
</tr>
<tr>
<td>V₁, V₂...V₇</td>
<td>Local air flow velocity across test section, m/s</td>
</tr>
<tr>
<td>Tᵣ</td>
<td>Thermocouple temperature, K</td>
</tr>
<tr>
<td>Tₛ</td>
<td>Mean airfoil surface temperature, K</td>
</tr>
<tr>
<td>Δx₁, Δx₂...Δx₇</td>
<td>Transverse incremental distance across test section, m</td>
</tr>
<tr>
<td>ɳ</td>
<td>Number of thermocouples</td>
</tr>
<tr>
<td>Re</td>
<td>Reynolds Number</td>
</tr>
<tr>
<td>Nu</td>
<td>Nusselt Number</td>
</tr>
<tr>
<td>Pr</td>
<td>Prandtl Number</td>
</tr>
<tr>
<td>Cₚ</td>
<td>Drag coefficient</td>
</tr>
<tr>
<td>∆T</td>
<td>Temperature difference between foil surface temperature and the surroundings, K</td>
</tr>
<tr>
<td>ρ</td>
<td>Air density, kg/m³</td>
</tr>
<tr>
<td>μ</td>
<td>Air viscosity, kg/m.s</td>
</tr>
<tr>
<td>α</td>
<td>Airfoil tilt angle, degrees</td>
</tr>
<tr>
<td>ε</td>
<td>Emissivity of airfoil surface = 0.045</td>
</tr>
<tr>
<td>σ</td>
<td>Stefan-Boltzman Constant 5.67E⁻⁸, W/m².K⁴</td>
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</table>

Greek Symbol

<table>
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1. Introduction

The development of alternative energies, in particular the energy of the biomass, aims at satisfying certain objectives whose principal ones consist in replacing the oil which is considered a fossil hydrocarbon clearly paid and occasionally available, and fighting against pollution and more global warming. Biomass is non-fossil, and includes solid waste, agricultural residues, in general, it is all non-fossil organic materials [1]. The oil crises of the too high production cost of the bio-fuels slowed down their development [2]. The usage of biomass as fuel has many environmental and economic advantages. Biomass is a cheap, clean and renewable source of energy. Combustion is the most direct technology for converting biomass into energy. Many countries consider the launching of national programmes in favor of the bio-fuels such as China, India, Malaysia and Thailand. These developing countries are quite naturally in favorable position for the production of raw materials useful for the bio-fuel’s manufacture in particular those whose sugar sector is traditionally significant, which is the case of Iran. This work consists in estimating the heating values of the bio fuels resulting form the agricultural products in Iran and to study the prospects of this new form of energy.

2. Methodology

The working method adopted by using Bomb Calorimeter which consists primarily of the sample, oxygen, the stainless steel bomb, and water.

The Dewar prevents heat flow from the calorimeter to the rest of the universe. Figure 1 shows the Bomb Calorimeter with stirring, a thermometer and combustor [3]. In the experiments of 10 biomass samples favored by their aptitude of adaptation to the Iran conditions. Table 1 shows different types of samples. Samples were ground and sieved into a powder with a particle size of 0.195-0.235 µm.

Abstract

This work consists in estimating the energy achieved from all land and water-based vegetations. This real potential is determined by identifying the vegetable resources as 10 biomass samples favored by their aptitude of adaptation to the Iran conditions. The net energy values of the 10 biomass samples change in the range of 13.65-18.00 MJ/kg using bomb calorimeters. The results of 10 different biomass materials have been used to develop a linear correlation.

Keywords: Estimation, Potential, Treated waste water, Biome biofuels.

Estimation of Energy from Forestry and Agricultural Residues

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Figure 1. Bomb calorimeter
3. Mathematical Method

The experimental results of 10 different biomass materials has been used to develop correlations for an estimation of the net heating value from the elemental composition and ash content of the dry biomass. One of the developed correlations are linear as follows.

\[ \text{NHV} = 18.2840\text{[O]} + 0.0831 \text{[C]} - 0.4890 \text{[H]} - 0.1920 \text{[ash]} \]

Where: [C] carbon content, [H] hydrogen content and [O] oxygen content all in weight percentage. This equation is as a function of carbon, hydrogen, oxygen and ash content of the dry biomass samples, contents of carbon, hydrogen, nitrogen and ash from the analyses results are given in Table 2.

| TABLE 1. The biomass samples and net heating values |
|---|---|---|
| Biomass Sample | Production in Region of Iran (in Tons) | NHV (MJ/kg) |
| Rice Husk | North (2800000) | 13.65 |
| Wheat Husk | Every where (1500000) | 15.7 |
| Sunflowerse Stalk | Center (13000) | 16.67 |
| Sourcheery Stalk | Centre & North east (222000) | 18.39 |
| Walnut Shell | West &South (170000) | 19.00 |
| Pistachios Shell | | |
| Watermelon & | West-South (230000) | 18.38 |
| Cantaloupe Peel | North, Centre & South (4500000) | 18.86 |
| Pine Cone | Every Where (3300000) | 18.75 |
| Olive Waste | North (125000) | 16.66 |
| Potato & Onion Peel | Centre:South & Northeast (6200000) | 17.69 |

Table 2. C, H, O and ash contents

<table>
<thead>
<tr>
<th>Biomass Sample</th>
<th>Ash</th>
<th>N</th>
<th>O</th>
<th>H</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Husk</td>
<td>23.20</td>
<td>0.58</td>
<td>40.04</td>
<td>4.79</td>
<td>31.39</td>
</tr>
<tr>
<td>Wheat Stalk</td>
<td>9.09</td>
<td>1.00</td>
<td>49.06</td>
<td>7.66</td>
<td>33.22</td>
</tr>
<tr>
<td>Sunflowerse Stalk</td>
<td>8.96</td>
<td>0.57</td>
<td>50.50</td>
<td>7.67</td>
<td>32.50</td>
</tr>
<tr>
<td>Sourcheery Stalk</td>
<td>5.10</td>
<td>0.69</td>
<td>54.31</td>
<td>4.79</td>
<td>35.19</td>
</tr>
<tr>
<td>Walnut Shell</td>
<td>3.80</td>
<td>0.09</td>
<td>55.00</td>
<td>4.75</td>
<td>36.40</td>
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<tr>
<td>Pistachios Shell</td>
<td>4.05</td>
<td>0.02</td>
<td>51.83</td>
<td>5.00</td>
<td>39.10</td>
</tr>
<tr>
<td>Watermelon &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cantaloupe Peel</td>
<td>5.70</td>
<td>0.01</td>
<td>59.38</td>
<td>4.09</td>
<td>30.80</td>
</tr>
<tr>
<td>Pine Cone</td>
<td>6.86</td>
<td>0.00</td>
<td>43.08</td>
<td>6.03</td>
<td>44.01</td>
</tr>
<tr>
<td>Olive Waste</td>
<td>21.06</td>
<td>1.01</td>
<td>35.00</td>
<td>4.01</td>
<td>38.01</td>
</tr>
<tr>
<td>Potato &amp; Onion Peel</td>
<td>7.00</td>
<td>1.70</td>
<td>39.60</td>
<td>6.96</td>
<td>45.30</td>
</tr>
</tbody>
</table>

Carbon, hydrogen and contents of the biomass samples were detected by an elementary analyzer. The oxygen content has been calculated by subtracting from 100 the sum of the other components of the ultimate analysis. The amount of ash of samples has been found according [5-6]. Figure 2 shows the experimental values of samples versus theoretical values from equation, to be in good accordance. Figure 3 shows the photographs of 10 biomass samples.

![Figure 2. The predicted NHV versus experimental NHV.](image)

![Figure 3.a. The bunch of rice.](image)

![Figure 3.b. The bunch of wheat.](image)
4. Results and Discussion

The introduction of the industrial crops (10 samples), the recourse to the technique of bomb-calorimeter, the use of the fallow, the re-use of treated worn water and the recovery of the national energy make it possible to cover only the 1.2% of it. The experimental results of 10 different biomass materials has been used to develop correlations for an estimation of the net heating value from the elemental composition and ash content of the dry biomass. Empirical equation has been used by means of least squares regression analysis, the regression coefficient and the standard deviation are 0.8322 and 0.6988, respectively, but empirical equations with the squared content of carbon haven’t been used due to lower prediction errors. The experimental values of samples versus theoretical values from equation, to be in good accordance. This result can be found with relatively uniform composition of the ash-free organic component of biomass.
Conclusions

The development of this alternative solution is based on the agricultural management and the other hand, the synergy between the applied agricultural and desired energetic policies, the coordination between the various services of the state are still essential. 10 biomass samples have been shown by the contents of carbon, hydrogen, oxygen and ash in the dry basis. Experimental analysis showed that the net heating values of biomass samples varied in the range of 13.65-19.00 MJ/kg. An equation has been developed to predict the net heating values of biomass samples from their analysis and ash content values; this indicates that there is a good estimation.

References

Abstract

The Cashew Nut Shell Liquid is extracted from the shells of the Cashew Nut. It is a black, acrid, powerful vesicant oil. It can be used as a preservative and water-proofing agent in insulating varnishes. It can also be used in the manufacturing of typewriter rolls, brake-linings, etc. It acts as an excellent lubricant in magneto armatures in airplanes, and for termite proofing in timbers. Apart from the above uses, the black fluid CNSL is tested for its absorption behavior of electromagnetic spectrum. Its capability of absorbing heat in the infra red region is analysed. The CNSL is coated on the Flat Plate Collector and its collector efficiency is calculated.

Keywords: Cashew Nut Shell Liquid (CNSL); Infra Red; Absorption; Solar Collector; Efficiency.

1. Introduction

The cashew (Anacardium occidentale) is a tree in the flowering plant family Anacardiaceae. It is widely grown in tropical climates for its cashew "nuts" and cashew apples. It is a small evergreen tree growing to 10-12m (~32 ft) tall, with a short, often irregularly-shaped trunk. The leaves are spirally arranged, leathery textured, elliptic shaped, 4 to 22 cm long and 2 to 15 cm broad, with a smooth margin. The flowers are produced in a panicle up to 26 cm long, each flower small, pale green at first then turning reddish, with five slender, acute petals 7 to 15 mm long.

The true fruit of the cashew tree is a kidney or boxing-glove shaped drupe that grows at the end of the pseudo fruit. Actually, the drupe develops first on the tree, and then the peduncle expands into the pseudo fruit. Within the true fruit is a single seed, the cashew nut. Although a nut in the culinary sense, in the botanical sense the fruit of the cashew is a seed. The seed is surrounded by a double shell.

Solar Flat Collector: Solar flat collector employs a black coated collector plate to absorb sun radiations. The CNSL is painted or brushed over the collector plate for greater absorbance. The absorbance increases the efficiency of the collector than the conventional coating of a flat plate collector.

Infrared (IR) radiation: It is an electromagnetic radiation whose wavelength is longer than that of visible light, but shorter than that of terahertz radiation and microwaves. The name means "below red" (from the Latin infra, "below"), red being the color of visible light with the longest wavelength. Infrared radiation has wavelengths between about 750 nm and 1 mm, spanning three orders of magnitude. Humans at normal body temperature can radiate at a wavelength of 10 micrometres (μm).

The commonly used division scheme of infrared are as follows:

Mid-wavelength infrared (MWIR, IR-C DIN) also called intermediate infrared (IIR): 3-8 μm. In guided
missile technology, the 3-5 μm portion of this band is
the atmospheric window in which the homing heads of
passive IR 'heat seeking' missiles are designed to work,
homing on to the IR signature of the target aircraft,
typically the jet engine exhaust plume.

**Long-wavelength infrared (LWIR, IR-C DIN):** 8-
15 μm. This is the "thermal imaging" region, in which
sensors can obtain a completely passive picture of the
outside world based on thermal emissions only and
requiring no external light or thermal source such as the
sun, moon or infrared illuminator. Forward-looking
infrared (FLIR) systems use this area of the spectrum.
Sometimes is also called the "far infrared."

**Far infrared (FIR):** 15-1,000 μm. NIR and SWIR is
sometimes called reflected infrared while MWIR and
LWIR is sometimes referred to as thermal infrared. Due
to the nature of the blackbody radiation curves, typical
'hot' objects, such as exhaust pipes, often appear
brighter in the MW compared to the same object viewed
in the LW.

Astronomers typically divide the infrared spectrum
as follows:
- **near:** (0.7-1) to 5 μm
- **mid:** 5 to (25-40) μm
- **long:** (25-40) to (200-350) μm

These divisions are not precise and can vary
depending on the publication. The three regions are
used for observation of different temperature ranges,
and hence different environments in space.

**Heat:** Infrared radiation is popularly known as
"heat" or sometimes "heat radiation". Light and electro-
magnetic waves of any frequency will heat surfaces that
absorb them. Infrared light from the Sun only accounts
for 49% of the heating of the Earth, with the rest being
caued by visible light that is absorbed then re-radiated
at longer wavelengths.

Heat is energy in a transient form that flows due to
temperature difference. Unlike heat transmitted by
thermal conduction or thermal convection, radiation can
propagate through a vacuum.

The concept of emissivity is important in under-
standing the infrared emissions of objects. This is a
property of a surface which describes how its thermal
emissions deviate from the ideal of a black body.

2. **Infrared trapping**

The Solar energy converters, especially the solar flat
plate collectors are pasted or painted with black
materials to absorb the radiations of heat from the
spectrum of light.

Most of all black energy absorbing materials are
efficient in the visible spectrum of light. If the materials
can absorb the Infra Red radiations along with the
visible radiations, the efficiency of the materials will
certainly increase. Such behavior of IR trapping may
need less visible source of light and it will be very
efficient in less light/less sunny areas of high ranges and
rain shadow regions.

3. **Sample preparation**

The Cashew Nut Shell Liquid was collected from the
Cashew Nut factory. It was kept for 5 to 6 six months,
so that water particles, small and micro particles would
settle at the bottom of the container and low density
materials and less weight materials might stay at the
surface of the liquid. The unwanted such materials were
carefully separated and the clear Cashew Nut Shell
Liquid was collected. The liquid was black and thick.

4. **Ftir analysis**

![Figure 1](image)

5. **Observations**

Cashew Nut Shell Liquid was subjected to FTIR
spectrometer and the above graph of **Figure 1** was
obtained. The spectrum was analyzed and the results are
tabulated as follows:
The Flat plate of the Solar Collector was pasted with the given cashew nut shell liquid and the collector was exposed to the direct light of the Sun as follows: water was circulated from a tank. Water was then heated and its temperature was noted in correspondence to the atmospheric temperature. The procedure was continued until the sun set. The values were tabulated.

<table>
<thead>
<tr>
<th>Time</th>
<th>Atmospheric temperature</th>
<th>Output temperature</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 AM</td>
<td>14.5</td>
<td>24</td>
<td>920</td>
</tr>
<tr>
<td>7:30</td>
<td>15.5</td>
<td>26.5</td>
<td>927</td>
</tr>
<tr>
<td>8:00</td>
<td>16</td>
<td>30</td>
<td>931</td>
</tr>
<tr>
<td>8:30</td>
<td>17</td>
<td>34.5</td>
<td>935</td>
</tr>
<tr>
<td>9:00</td>
<td>18.5</td>
<td>36</td>
<td>939</td>
</tr>
<tr>
<td>9:30</td>
<td>19</td>
<td>40</td>
<td>943</td>
</tr>
<tr>
<td>10:00</td>
<td>19.5</td>
<td>44.5</td>
<td>945</td>
</tr>
<tr>
<td>10:30</td>
<td>21</td>
<td>49</td>
<td>947</td>
</tr>
<tr>
<td>11:00</td>
<td>22</td>
<td>52</td>
<td>950</td>
</tr>
<tr>
<td>11:30</td>
<td>22.5</td>
<td>56</td>
<td>955</td>
</tr>
<tr>
<td>12:00PM</td>
<td>23.5</td>
<td>61</td>
<td>961</td>
</tr>
<tr>
<td>12:30</td>
<td>24.5</td>
<td>65</td>
<td>948</td>
</tr>
<tr>
<td>1:00</td>
<td>25</td>
<td>71</td>
<td>935</td>
</tr>
<tr>
<td>1:30</td>
<td>26.5</td>
<td>76</td>
<td>932</td>
</tr>
<tr>
<td>2:00</td>
<td>27.5</td>
<td>79.5</td>
<td>929</td>
</tr>
<tr>
<td>2:30</td>
<td>27</td>
<td>78</td>
<td>927</td>
</tr>
<tr>
<td>3:00</td>
<td>26.5</td>
<td>76</td>
<td>925</td>
</tr>
<tr>
<td>3:30</td>
<td>25</td>
<td>73</td>
<td>923</td>
</tr>
<tr>
<td>4:00</td>
<td>25</td>
<td>71</td>
<td>919</td>
</tr>
<tr>
<td>4:30</td>
<td>24</td>
<td>68</td>
<td>917</td>
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<td>5:00</td>
<td>23.5</td>
<td>67</td>
<td>915</td>
</tr>
<tr>
<td>5:30</td>
<td>23</td>
<td>64</td>
<td>913</td>
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<tr>
<td>6:00</td>
<td>22.5</td>
<td>62</td>
<td>912</td>
</tr>
<tr>
<td>6:30</td>
<td>21</td>
<td>60</td>
<td>910</td>
</tr>
</tbody>
</table>

**Table 1**

<table>
<thead>
<tr>
<th>Absorption Frequencies (cm⁻¹)</th>
<th>Visual Intensity</th>
<th>Tentative Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>3410.52</td>
<td>Very strong</td>
<td>Bonded OH stretching</td>
</tr>
<tr>
<td>2924.99</td>
<td>Medium</td>
<td>CH-aliphatic</td>
</tr>
<tr>
<td>1922.22</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>1600.75</td>
<td>Strong</td>
<td>Amino acid-I</td>
</tr>
<tr>
<td>1457.92</td>
<td>Strong</td>
<td>Aromatic ring</td>
</tr>
<tr>
<td>1380.83</td>
<td>medium</td>
<td>Phenyl ring</td>
</tr>
<tr>
<td>1267.55</td>
<td>Strong</td>
<td>C-O-esters</td>
</tr>
<tr>
<td>1154.01</td>
<td>Strong</td>
<td>C-N-Amines</td>
</tr>
<tr>
<td>995.95</td>
<td>Strong</td>
<td>CO-stretching-Ester</td>
</tr>
<tr>
<td>838.43</td>
<td>Strong</td>
<td>CH-out of plane</td>
</tr>
<tr>
<td>778.09</td>
<td>Medium</td>
<td>CH-out of plane</td>
</tr>
<tr>
<td>698.05</td>
<td>Medium</td>
<td>OH-phenol</td>
</tr>
</tbody>
</table>

**Table 2**

**Figure 2**

**Figure 3**
Conclusions

From the Table 1, the wavelengths of 838.43 cm⁻¹, 995.95 cm⁻¹ and 1154.01 cm⁻¹ correspond to strong absorption and in the wavelengths 698.05 cm⁻¹ and 778.09 cm⁻¹ correspond to medium absorption.

This innovative collector maintains an average maximum temperature of 70 to 80°C and an average efficiency of 48% (Figure 3). As the temperature persists for quite long time, even after the sun set (after 6 O’Clock) the hot water temperature is maintained around 50°C. (Table-2).

The construction cost and the erection cost are comparatively low and any average-income family can afford to construct such a collector. The Cashew Nut Shell Liquid coating avoids corrosion. The Collector needs very less maintenance after commissioning.

The Cashew Nut Shell Liquid is a good absorbent or trapper of IR radiations. By using it as a coating, the efficiency of the Solar Flat collectors can be increased.

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References

1. Introduction

Islands can be divided as large, small or very small island. Large islands are any islands larger than 2000 km$^2$ whereas small islands are defined as islands with an area not greater than 200 km$^2$ or the width is not greater than 10 km. A very small island has an area of not greater than 100 km$^2$ or a width that is not greater than 3 km [1]. Moreover, Falkland developed a detailed classification of small islands based on key aspects of geology, freshwater lens, water balance and climate [1]. In small islands classifications, small islands can be divided into high and low islands. High islands are comprised of volcanic and much older as well as larger than low islands. It usually has good groundwater quality and receives sufficient groundwater recharge. Small island resources such as freshwater are very limited and vulnerable to many challenges especially to its groundwater. In small and very small islands, surface water does not exist in an exploitable form and fresh groundwater resources are limited [2]. According to White et al. [3], groundwater of small islands is the only source of water supply for the small islands community and tourism which balanced between rainfall recharge and continuous depletion by extractions, evapotranspiration and outflow as well as mixing with seawater (Figure 1).

Groundwater explorations, development and management of small islands in Malaysia are mainly conducted by Department of Environment along with Department of Mineral and Geoscience as well as National Hydraulic Research Institute of Malaysia for research and development. Existing laws for groundwater management in small islands are Geological Survey Act (1974), State Water Supply Enactments, and Environmental Quality...
Act (1974) to ensure the quantity, quality and the extent of contaminated groundwater [4].

The attractive small islands promote Malaysia as an outstanding tourist destination. The tourism industry has experienced a rapid growth and gained an important sector in the Malaysian economy. It is the second largest foreign exchange earner, after manufacturing. In 2005, tourism accounted for 7% of Malaysia's economy. For an example, tourism revenue increased from RM17.40 billion (USD 4.833 billion) in 2000 to RM32.00 billion (USD 8.89 billion) in 2005 [5, 6]. Although tourism is an important economic vehicle however uncontrolled tourism development will degrade the coastal development, threaten the integrity of the near shore landscapes and corals and depletion of its groundwater. Great care needs to be taken to avoid depleting the freshwater resources and to define the limits of acceptable change in terms of interrelated carrying capacities [5].

Much of the limited small literatures in Malaysia consist of impact studies on a single island. The impact studies on a single island deal with environment done by Teh & Cabanban [7] in Banggi Island, Fisher et al. [8] in Redang Island as well as Yap & Kahoru [9] in Perhentian Island. Meanwhile, reviews of small islands in Malaysia focusing groundwater are less common. Thus, this paper presents a perspective of groundwater challenges in Malaysian small islands. The groundwater in Malaysian small islands was analyzed and reviewed to address the challenges in order to conserve and protect its quality. A review of groundwater in Malaysian small islands as an overall can provide a contextual understanding of challenges which shape the prospects for sustainable tourism development in Malaysia. The update of current groundwater condition in small islands is important as it influences the future sustainable ecotourism development and provides basis for management of groundwater resources and ecosystem in the assessment of sustainable ecotourism development.

2. Studies of groundwater challenges in Malaysia

Small islands in Malaysia were selected for an evaluation of groundwater challenges (Figure 2). As there have been limited studies on Malaysian small islands, the review was based on existing literatures and studies conducted (Table 1). The evaluation assesses the existing condition of groundwater challenges in Malaysian small islands.

3. Challenges of groundwater in small islands

Challenges of groundwater in Malaysian small islands are divided into two categories: natural challenges and challenges associated with human settlement. Natural
challenges are such as climate change, sea level rise whereas challenges associated with human settlement are such as pumping rates and over-pumping. Table 2 summarizes the natural challenges and challenges associated with human settlement of groundwater in Malaysian small islands.

4. Natural challenges in groundwater

Fresh groundwater in Malaysian small islands faces challenges from natural challenges such as climate change, sea level rise and variations in tropical and extra-tropical cyclones, hurricanes as well as typhoons. Such natural challenges can affect both quantity and quality of groundwater in small islands. Climate variability causes changes in rainfall patterns, groundwater recharge and discharge as well as evapotranspiration in small islands [39]. Effects of climate change will alter the global hydrological cycle in terms of distribution and availability of regional groundwater resources [10].
A raised sea level is a phenomenon of global warming, which will also raises sea and air temperature. Current predictions showed that a rise in sea level rise is approximately 20 cm by the year 2030. This will threaten low lying coastal areas especially to small islands. The increase of flooding and storm surges as well as groundwater salinity threatening freshwater quality [11]. Sea-level rise will cause saline intrusion into coastal aquifers, with the amount of intrusion depending on local groundwater gradients where shallow coastal aquifers are at greatest risk. Moreover, reduction in precipitation coupled with sea-level would reduce the size of freshwater lens [10]. Droughts decrease the thickness of freshwater lenses and increase the salinity of fresh groundwater as evidenced in Sipadan and Mabul islands.

According to Intergovernmental Panel on Climate Change [10] and Anderson [11], Asia Pacific region specially developing countries including Malaysia is also already vulnerable to sea level rise, variations in tropical and extra-tropical cyclones, hurricanes and typhoons, the 2004 Indian Tsunami has affected the northwestern states of Peninsular Malaysia. Most of the areas were Langkawi (Kedah), Kota Kuala Muda (Kedah) and Penang. Impacts of tsunami effect salinisation in groundwater aquifers by seawater intrusion attributable to the quick and effective washout or leaching of salt by the high precipitation in Malaysia [13]. Inundation of low atolls by waves during tides can salinise the shallow groundwater of small islands. Variations in tides have been seen the greatest challenges facing groundwater of small islands in Malaysia. Study done by Abdullah et al. [14] showed that tides do affect the water quality in Sipadan Island. It was found that the percentages of salinity changes during the high and low tides were 58% and 42% respectively at each station.

### 5. Challenges associated with human settlement in groundwater

Challenges associated with human settlement in groundwater of Malaysian small islands are such as human pressures (over-pumping) and seawater intrusion problem, tourism competition pressures with other islands and others. Human pressures are by over-pumping are

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td>Climate change&lt;sup&gt;1, 2, 4&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Sea level rise&lt;sup&gt;1, 4&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Variations in tides, tropical and extra-tropical cyclones, hurricanes and typhoons in many small-island regions&lt;sup&gt;1, 2, 5, 8, 12, 16&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Impacts of natural hazards such as drought&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Seawater intrusion due to natural pressures&lt;sup&gt;1, 4, 16&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Human pressures (overpumping)&lt;sup&gt;1, 2, 5, 8, 12&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Seawater intrusion due to human pressures&lt;sup&gt;2, 2, 3, 4, 5, 6, 8, 9, 11, 12&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Tourism competition pressures with other islands&lt;sup&gt;1, 2, 3, 4, 7, 8, 9, 10, 12, 13, 16&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Scarcity of resources on island (water, electricity &amp; food)&lt;sup&gt;1, 2, 12&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Conflicts between tourist development and conservation&lt;sup&gt;8, 10, 11, 14&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Small island ecological balance due to over extraction of its groundwater&lt;sup&gt;1, 2, 4, 6, 12, 13&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Environmental degradation&lt;sup&gt;1, 2, 4, 5, 7, 8, 9, 10&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Waste management&lt;sup&gt;8, 10, 11, 15, 16&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Groundwater contamination due to spillage&lt;sup&gt;5, 3, 12, 13, 16&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

The numbers 1 to 6 indicate the name of islands as in Table 1.
the main critical factor in Malaysian small islands. The groundwater of small islands is the only source of water supply for the small islands community and tourism. In order to meet the water demand, over-pumping resulted in seawater intrusion in groundwater of Malaysian small islands. One of the examples is in Manukan Island, Sabah. Aris et al. [15] showed that Manukan Island revealed that the mixing rates of seawater intrusion in low lying area of Manukan Island were about 13%. Over-pumping of groundwater and wells shutdown in Manukan Island's aquifer are indicators to specify that the natural equilibrium between fresh and seawater has been disturbed. Moreover, in Mabul, Sipadan and Turtle islands, seawater intrusion in its groundwater is also caused by over-pumping [16, 17, 18]. Studies done by Abdullah et al. [14, 19, 20] and Lestari UKM [21] in Sipadan Island showed that the island is fast depleting in its source of groundwater. The numerical model (SEAWAT-2000) suggested that the seawater intrusion in the interior part of the Sipadan Island is about 14. % which took place at the bottom of the wells due to the activities of over-extraction of the freshwater resource. Similar condition was found in Rawa with high chloride concentration in its groundwater [20]. Existing wells in Banggi Island showed seawater intrusion has occurred in well water representing the poor groundwater quality [7]. Saltwater intrusion into a freshwater aquifer occurs when pumping of wells lower the groundwater levels enough to cause salt water to move towards the well by reversal of hydraulic gradients or decrease in fresh water heads. Close association of freshwater with saline water in coastal regions, groundwater is exploited in such a way that upcoming of saline water and seawater intrusion [23].

Blessed with pristine white sandy beaches that promise a comeback for most tourists compete with other small islands to attract tourists. The tourism competition pressures pose challenges to the continuation of ecosystem, biodiversity conservation as well as groundwater resources [24]. Coastal and environmental attractions as well as safe groundwater quality are the major tourists attractions to small islands [25, 26]. For examples, small islands such as Perhentian Island, Tenggol Island and Redang Island in Terengganu compete each other to attract more tourists to the island. Another example is in Sabah which has about hundreds of small islands. Competition between Sipadan, Mabul, Manukan, Tiga and Turtle islands is to attract tourists to the islands. Added to this is the growing competition of limited water resources for tourism, which is extremely water-intensive. Conflict arises between tourist development and water conservation with respect to small islands water resource management and planning. Due to its limited water resources, at least one resort on Pulau Babi Besar caters only to 50 tourists although the resort built for 200 people [22]. Without thrifty evaluations, planning and management can be a possible sustainable impetus to small islands ecosystems [27, 28, 29, 30]. Thus, there is an increasing pressure on small islands to overcome the problems for conservation and protection of groundwater [31].

Environmental degradation in the context of improper disposal of liquid and solid waste generated by the tourism industry has contributed to groundwater quality degradation in few small islands in Malaysia. Tourist activities can also lead to land contamination from solid waste and the contamination of marine waters and coastal areas from pollution generated by hotels and marinas, as well as cruise ships. The presences of garbage and human waste are the major deterrents in groundwater of Malaysian small islands. Few of them are Sipadan, Perhentian, Tenggol and Banggi islands. A good example on environmental degradation towards groundwater quality degradation is in Sipadan Island. Uncontrolled mass tourism is on Sipadan Island gradually destroys the groundwater resources on which it very much depends. This resulted in water shortages and degradation of water supplies, as well as generating a greater volume of wastewater [20, 32]. This has been a contributing factor to the degradation of the corals in Sipadan Island. Environmental degradation is caused mainly because of the low awareness of environmental issues among stakeholders (hotel/resort operators, dive operators, tour guides and boat operators), coastal communities and tourists which has resulted in environmental degradation in Sipadan Island. However the removal of all resorts from the island was a very positive move to allow the island to recover from the exhausting role of playing host to hundreds of visitors over the last 15 years [32].

While in Langkawi, Perhentian Kecil and Crab islands, ineffective solid waste disposal is the problem that needed a special attention [33, 34]. Similarly in Tioman Island, it is a challenging part to plan for efficient wastewater treatment and management [35]. In opposition, Rawa Island practices excellent waste
management which can be applied in any small islands. All the wastes are recycled including organic waste in Rawa Island. Rawa Island could be a leading example to other small islands and tourist destinations in Malaysia to adopt such waste management (www.wildasia.net). Moreover, government awareness projects, campaigns and environmental education played an important role educating the public as well as tourists in waste management. In Langkawi case, The Langkawi Local Authority has expressed the need to pay high attentions in impacts of tourism development and environmental management.

Sewage problem is another common problem on many small islands. Groundwater contamination due to spillage of septic tanks can contaminate the groundwater and resulted in human health. Traditionally, septic tanks were built and discharge untreated sewage directly into the sea. Study done by Teh & Cabanan [7], Ling et al. [16], Annamala [36] and Yap & Kahuro [9] in Banggi, Mabul, Sipadan & Perhentian islands respectively showed that Escherichia coli (E.coli) contamination is detected in most of sampling wells. This pointed out that the sewage treatment and disposal and septic tanks potentially were the causes of groundwater contamination due to spillage. Health risk from water borne disease may occur from sewage polluted groundwater [16]. Conversely, the E. coli quantity in Manukan, Tiga and Rawa islands are still in excellent quality. For instance in Banggi Island, there are no modern toilets facilities and untreated sewage enters directly into waters. This will give invertebrate water borne disease problems when the water levels rise and the groundwater is used for daily purposes [7].

Conclusions

This review demonstrates the challenges received by groundwater of small islands in Malaysia. Challenges of groundwater in Malaysian small islands are divided into two categories which are natural challenges and challenges associated with human settlement. Main natural challenges in groundwater of small islands in Malaysia are climate change and sea level rise. Main challenges associated with human settlement in groundwater of small islands in Malaysia are over-pumping and seawater intrusion problem. This review has provided a contextual understanding of challenges which shape the prospects for sustainable tourism development in Malaysia with a good relationship between small islands, environment and tourism. Appropriate approaches sustainable ecotourism development is fundamental to facilitate the sustainable groundwater management in order to conserve and protect its quality. Sustainable ecotourism puts effective planning, management and control in a good relationship between small islands, environment and tourism.

Acknowledgements

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References


Abstract

As basic building blocks of life, genes, as well as their products (proteins), do not work independently. Instead, in order for cells to function properly, they interact with each other and form a complicated network. Recently, many researchers agree that most of biological ambiguous questions might be easily being answered if a sophisticated modeling of the gene regulatory network (GRN) was constructed. Also, GRN was used to help understanding disease ontology and reducing the cost of drug development. During the last decade, many GRN inference algorithms that are based on microarrays data have been developed to unravel the complexity of gene regulation. One of the major problems with microarrays is that a dataset consists of relatively few time points with respect to a large number of genes. The dimensionality and high degree of noise are interesting problems in GRN modeling. In this paper we proposed a new integrated algorithm to overcome these problems. Our software shows good performance comparable to previous methods and many of produced edges have evidence in the literature data. The proposed method was applied to time series gene expression data of Saccharomyces Cerevisiae and could potentially be applied to other networks in yeast as well as higher organisms.

Keywords: Gene Regulatory Network, Gene Ontology, Bioinformatics, System Biology, Biclustering, Microarrays, Reverse Engineering.

1. Introduction

One of the main research areas of bioinformatics is functional genomics; which focuses on the interactions and functions of each gene and its products (mRNA, protein) through the whole genome (the entire genetics sequences encoded in the DNA and responsible for the hereditary information). In order to identify the functions of certain genes, we should be able to capture the gene expressions which describe how the genetic information converted to a functional gene product through the transcription and translation processes. Functional genomics uses microarrays technology to measure the genes expressions levels under certain conditions and environmental limitations. In the last few years, Microarray has become a central tool in system biology. Consequently, the corresponding data analysis becomes one of the important work disciplines in bioinformatics.

The major goal of system biology is to understand how genes and their products interact to regulate cell cellular process. To achieve this goal, it is necessary to reconstruct the gene regulatory networks (GRN) which help us to understand the working mechanisms of the cell in patho-physiological conditions. The structure of the GRN can be described as a wiring diagram that shows the direct and indirect influences on the expression of a gene and that describes which genes, in turn, can be regulated by such a gene through its translated protein or transcribed RNA product [1].

Over the last few years, a number of sophisticated approaches for the reverse engineering of cellular networks from gene expression data have emerged. This may include Boolean networks [2], Bayesian networks [3], association networks [4], linear models [5], and differential equations [6].
A broad overview of the steps involved in the modeling of GRN is shown in Figure 1. The first step starts with the question biologist required to be answered. For example, which genes are involved in controlling the cell cycle [7] and which genes showed a similar drastic response to the environmental changes [8]. The next step is to prepare appropriate experiments relative to biological question. Next is the extraction of the gene expression matrix (rows are genes and columns are the different experiments or cells) from the microarray experiments using image processing techniques. Removing of non-informative genes and conditions, normalization and data denoising are described in the preprocessing step. The next step is the partitioning of the data set into small overlapped biclusters. In learning step the produced biclusters were learned using the reverse engineering approaches to produce the corresponding subnetworks i.e each bicluster produces one subnetwork. Learning step will be followed by integration of the generated subnetworks to produce the whole network. Assessment of the performance of the resultant network using existing interactome databases and literature databases is performed in the validation step. The last step is that the generated validated network will open new hypotheses which need to be verified. For more details about these steps, the reader could refer to [9].

In this study we propose a new algorithm to reduce data noise using spectral subtraction and data dimension using biclustering algorithms.

2. Methodology

2.1. Data Acquisition

The microarray data used in this work is a well-known dataset of yeast microarray gene expression provided by Spellman et al. [7], which can be downloaded from Stanford Microarray Database http://smd.stanford.edu. The Spellman dataset consists of four synchronization experiments (alpha factor arrest, elutriation and arrest of CDC15 and CDC28 temperature-sensitive mutants) which were performed for a total of 73 microarrays during cell-cycle.

2.2. Data Prepossession

Measurements of microarrays may be biased by diverse effects such as efficiency of RNA extraction, reverse transcription, label incorporation, exposure, scanning, spot detection, etc. This necessitates the preprocessing of microarrays prior to data analysis. The datasets used in this work have been already preprocessed for background correction and normalization. In addition, further preprocessing steps should be applied for data refinement. In this paper, we applied the commonly used preprocessing such as gene filtration and missing value imputation[9, 10].

2.3. Data Denoising

For data cleaning, we developed a new denoising algorithm for further preprocessing and refinement. The proposed algorithm is an adaptive signal-preserving technique for gene expression data based on spectral subtraction. The new technique uses the uncorrelatedness of the random noise and the deterministic components of the signal to separate the two in the original power spectrum.

Figure 2 is a block diagram for the proposed denoising method. We will consider a model that is composed of the sum of one deterministic component $d(t)$ incorporating both the true gene expression signal and the experimental noise and an uncorrelated stochastic component $n(t)$. That is:

$$s(t) = d(t) + n(t)$$
Since these two components are assumed to be independent, the corresponding power spectra are related by

\[ P_{ss}(w) = P_{dd}(w) + P_{nn}(w) \]

where cross terms vanish because the two components are assumed uncorrelated. Hence, an estimate of the power spectrum of the deterministic component takes the form below \[11\]

\[ P_{dd}(w) = P_{ss}(w) - P_{nn}(w) \]

That is, the signal power spectrum is obtained by spectral subtraction of the noisy signal and noise power spectra. In order to compute the deterministic signal component from its power spectrum, the magnitude of the Fourier transform can be obtained as the square root of the power spectrum. The problem now is that of reconstructing the signal using magnitude only information about its Fourier transform. Several techniques can be used to do that. The one used for this paper relies on an estimate obtained from the phase of the Fourier transform of the original signal \( S(w) \). Hence, the Fourier transform of the processed signal \( S_d(w) \) can be expressed as

\[ S_d(w) = \sqrt{P_{dd}(w)} e^{j \text{phase}(S(w))} \]

The enhanced deterministic signal \( s_d(t) \) is then computed as the real part of the inverse Fourier transformation of this expression.

The following are the steps needed to implement the spectral subtraction denoising procedure in practice.

Step 1) Compute the variance of the gene expression values of each gene. Averaging the estimate from all time points to obtain the noise power spectrum level.

Step 2) Compute the Fourier transform of the gene time course and save the phase and magnitude parts of the result separately.

Step 3) Compute the original power spectrum of this time course using the periodogram method as the square of the magnitude of the Fourier transform in Step 2.

Step 4) Compute the denoised power spectrum by subtracting the noise power spectrum from Step 1. Observe any scaling factors that are introduced by the Fourier transform definition before performing the subtraction in addition to the factor \( \alpha \) in (5) (use a default value of \( \alpha = 1 \)).

Step 5) Compute the denoised signal Fourier transform as the square root of the denoised power spectrum from Step 4 multiplied by the phase retained in Step 2.

Step 6) Compute the denoised time course as the real part of the result of Step 5.

2.4. Data Partitioning

Clustering algorithms [12-14] were used to reduce data dimension. This is based on the assumption that genes which show similar expression patterns are co-regulated or part of the same regulatory pathway. But unfortunately, this is not always true. There are two limitations to using clustering algorithms with microarrays data. First, all conditions are given equal weights in the computation of genes similarity; whereas, most conditions do not contribute information but instead increase the amount of background noise. Second, each gene is assigned to a single cluster, whereas in fact genes may participate in several functions and should thus be included in several clusters [15].

A new modified clustering concept to uncover processes that are active only over some but not all samples emerged which is called biclustering. A bicluster is defined as a subset of genes that exhibit compatible expression patterns over a subset of conditions \[16\].

Over last decade, many biclustering algorithms have been proposed (see \[17\] for a survey), but the important questions are: which algorithm is better? And do some algorithms have advantages over others?

Generally, comparing different biclustering algorithms is not straightforward as they differ in strategies, approaches,
time complexity, number of parameters and prediction ability. They are strongly influenced by user-selected parameter values. For these reasons, the quality of biclustering results is also often considered more important than the required computation time. Although there are some analytical comparative studies to evaluate the traditional clustering algorithms [18-20], for biclustering, no such extensive comparison exists even after initial trials have been taken. At the end, biological merit is the main criterion for evaluation and comparison of the various biclustering methods.

We have developed a comparative tool BicAT-Plus [21] that includes the biological comparative methodology to be used as an extension to the BicAT program [22]. BicAT-Plus and its manual can be downloaded from the following two links:

http://home.k-space.org/BicAT-plus.zip
and

BicAT is a java biclustering toolbox which contains five biclustering (XMOTIF, ISA, OPSM, BIMAX, CC) and two traditional clustering algorithms (K-means and HCL).

For more details about BicAT-Plus the reader could refer to our previous paper [21].

2.5. Network Generation

Many reverse engineering approaches to learn cellular networks from gene expression data have emerged.

Bayesian networks (BN) which were first used by Friedman et al [3] have been widely used because of solid basics in statistics. Also BN are able to handle missing data and permit the incomplete knowledge about the biological system. There are two important components to represent BN, the qualitative part which is called the directed acyclic graph (DAG) and the quantitative part which is the conditional probability of children given its parents. The popular approach to find the best DAG is to search the DAG space and find the DAG which has the best score. Due to huge DAG space we have to use the heuristic searches. k2 algorithm, Greedy Search, Genetic Algorithm and Greedy Hill Climbing are the popular search algorithms. The common objective of these algorithms is how to reduce the search space.

In this step, we first learn the biclusters produced from the previous step using Greedy Hill Climbing search algorithm and BDe Scoring Function implemented in Biolearn [23] at Department of Biological Sciences, Columbia University. For examples, for the 219 biclusters generated by ISA algorithm (See Table 1), learning these biclusters will produce 219 subnetworks. Integrating or merging these subnetworks produces the whole network from ISA algorithm.

<table>
<thead>
<tr>
<th>Biclustering Algorithm</th>
<th>Number of produced Biclusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA</td>
<td>219</td>
</tr>
<tr>
<td>OPSM</td>
<td>12</td>
</tr>
<tr>
<td>CC</td>
<td>100</td>
</tr>
<tr>
<td>Bivisu</td>
<td>100</td>
</tr>
<tr>
<td>SAMBA</td>
<td>52</td>
</tr>
<tr>
<td>K-means</td>
<td>100</td>
</tr>
</tbody>
</table>

2.6. Network Analysis and Validation

Now after inferring the interactions between genes, how can one assess if these relationships are biologically exists. It is consuming time and money to experimentally validate the full set of predictions. Over the last decade, the interaction databases have grown exponentially. More than 230 web-accessible biological pathway and network databases were reported (www.pathguide.org). These large databases are very promising to assist the GRN inference and to validate the inferred networks.

These interaction databases use different identifiers to identify the same gene (GI, SwissProt, internal identifiers, etc.) which is requiring the resolution of synonymous names/IDs across databases. So, we want to integrate molecular interactions and other types of high-throughput data from different public databases to build biological networks automatically. For this purpose we used BioNetBuilder [24] which is an open-source client-server Cytoscape plug-in that offers a user-friendly interface to create biological networks integrated from several databases. For example, BioNetBuilder client-server [24] retrieved for S. Cerevisiae more than 100,000 interactions from different databases as follows:

(BIND,16244);(BioGrid,99485);(DIP,17465);(IntAct,14331); (Interologger,5395); KEGG,5478); (MINT,11907); numbers here represent the number of interactions per each corresponding database.
Although the network retrieved by BioNetBuilder is still incomplete we consider it as gold standard network which we will compare with.

In addition, we have to compare our algorithm's performance via previous methods. In this paper we compare our algorithm with Friedman algorithm. Friedman [3] developed a new framework for discovering interactions between genes based on multiple expression measurements which are capable of discovering causal relationships, interactions between genes other than positive correlation, and finer intra-cluster structure. He applied his approach to the dataset of Spellman et al. [7], containing 76 gene expression measurements of the mRNA levels of 6177 S. cerevisiae ORFs. Friedman network is available from http://www.cs.huji.ac.il/nirf/GeneExpression/top800/.

As usual, receiver operator characteristic (ROC) curve and precision recall (PR) curves are commonly used for binary decision problems. We used the DREAM2 [25] evaluation script to compute area and ROC and PR curves. We have to define some important terms as follows:

- **TP**: Number of edges present in the gold network and in the predicted network.
- **FP**: Number of edges not present in the gold network but included in the predicted network.
- **FN**: Number of edges present in the gold network but not in the predicted network.
- **TN**: Number of edges not present in the gold network and also not included in the predicted network.

Definition of TPR, FPR, Recall and Precision could be found in [26].

### 3. Results and Discussion

By applying our software to the Spellman dataset we could summarize the produced results in the following steps:

1- We applied KNN imputation algorithm [10] to Spellman dataset in order to substitute the missing data point with the nearest values.

2- All dataset's genes that do not show significant changes were removed.

3- We applied spectral subtraction denoising algorithm to the dataset.

4- Using BicAT-plus toolbox [21] we applied the six biclustering algorithms (ISA [27], CC [28], MSBE [29], Bivisu [30], OPSM [31], SAMBA [32]) and one traditional clustering algorithms (k-means [33]) to the Spellman dataset. The total number of produced biclusters/clusters is 683 and its statistics is shown in Table 1.

5- We run Greedy Hill Climbing search algorithm implemented in Biolearn program [23] to these biclusters and produced 683 subnetworks.

6- These subnetworks were integrated to generate the whole gene network per each biclustering algorithm. Edges count of these networks is shown in Table 2. If we merged the edges from all the biclustering/clustering algorithms, we produced a big network contains 5440 unique edges. We refer to this network as ALL network. Also, in the bottom of this table is the number of edges of Friedman network.

![Figure 3](image_url)

Figure 3 shows the performance of the biclustering networks via the gold network retrieved by BioNetBuilder [24] and Friedman network [3].

Inspecting Figure 3, we reveal that neither the generated networks from different biclustering algorithms nor the ALL network perform well.

There is an important note to be considered when interpreting the results of this comparison. First, the interactions documented are either physical or genetic. This implies that they may not be direct interactions. The precision may be lower than the actual precision since links may be missing in the interactome databases; and the recall may be lower than the actual recall in part because some of the links reported in the interactome

<table>
<thead>
<tr>
<th>Biclustering Network</th>
<th>Number Edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA</td>
<td>2258</td>
</tr>
<tr>
<td>OPSM</td>
<td>220</td>
</tr>
<tr>
<td>CC</td>
<td>590</td>
</tr>
<tr>
<td>Bivisu</td>
<td>1515</td>
</tr>
<tr>
<td>SAMBA</td>
<td>1611</td>
</tr>
<tr>
<td>K-means</td>
<td>380</td>
</tr>
<tr>
<td>ALL Total Number of unrepeated Edges</td>
<td>5440</td>
</tr>
<tr>
<td>Friedman</td>
<td>947</td>
</tr>
</tbody>
</table>

Table 2: Number of Network Edges Generated by learning biclusters shown in Table 1 using Biolearn program [23].
databases may be indirect rather than the direct [34]. Second, some presently unsupported edges in the constructed network may find experimental evidence in the future. Therefore, these unsupported edges are not necessarily false ones [35].

For the above reasons, the False Positive (FP) edges could be considered as True Positive (TP) if it has evidence in the interaction databases (gold network). For example if the inference network include edge between gene1 and gene3 which does not exists in gold network and if these two genes are connected indirectly via another intermediate gene like gene2 we can now consider the edge between gene1 and gene3 as true positive edge.

Figure 4 shows the networks performance improvement after taking into consideration the above evaluation modification. Furthermore they show how almost the false positive edges in these networks have evidence in the gold network.

Also it should be mentioned that as we expected the sparseness nature of gene regulatory network, using biclustering techniques (ISA, SAMBA, Bivisu) outperforms the Friedman network. This will open the usage of biclustering algorithms to overcome the problem of dimensionality in the GRN inference problem.

**Conclusions**

The increasing development of high throughput technology like microarray, promotes researchers to study the complexity of gene regulatory network (GRN) in biological cells. GRN inference algorithms have much impact in drug development and in understanding disease ontology. Many GRN inference algorithms that are base on genome-wide data have been developed to unravel the complexity of gene regulation. Transcriptomic data measured by genome-wide DNA microarrays are traditionally used for GRN modelling. This is because RNA molecules are easily accessible in comparison to proteins and metabolites. One of the major problems with microarrays is that a dataset consists of relatively few time points with respect to a large number of genes. The dimensionality and high degree of noise are interesting problems in GRN modelling. The most common and important design rule for modelling
gene networks is that their topology should be sparse. This means that each gene is regulated by only a small number of other genes. In this work a new gene regulatory network (GRN) construction system from microarray large dataset and prior biological information was proposed. As we expected the sparseness nature of GRN make biclustering techniques to show significance results compared to Friedman network [3]. In this paper we show the impact of using biclustering algorithms in GRN construction. A sophisticated filtration procedure (data filtration, missing values imputation, normalization, discretization) were used to reduce the number of expression profiles to some subset that contains the most significant genes. Also, we used our novel denoising method (Spectral Subtraction) which accurately may account for the low SNR and able to suppresses random noise or removes some of its components. It is clear from comparison SS with previous denoising methods like Multi-Wavelet that the spectral subtraction denosing method outperforms the Multi-Wavelet method and offering a substantial improvement of the SNR. Also, the Biclustering comparison toolbox (BicAT-Plus) implemented in this paper confirms that the bicluster and cluster algorithms can be considered as integrated modules; there is no certain algorithm that can recover all the interesting patterns. Where algorithm A succeed to recover in certain data sets, Algorithm B might fail, and vice verse. We can identify the highly enriched bi/clusters of the whole compared algorithms, integrating them to solve the dimensionality reduction problem of the gene regulatory network construction.

Surprisingly, the generated networks from this study shows sufficient accuracy when comparing it via previous works and existing biological databases like BIOGRIDE.

Acknowledgements

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References


1. Introduction

Organophosphorus insecticides (OPI) may induce oxidative stress leading to generation of free radicals and alteration in antioxidant system. The organisms possess antioxidant defense systems, including antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT), to deal with the reactive oxygen species generated in response to both external and internal stimuli (Mates et al, 1999). There is a balance between the activities of these antioxidants and the levels of reactive oxygen species that is essential for the survival of organisms and their health. An unbalanced production of reactive oxygen species also plays an important role in the pathogenesis of number of diseases such as ischemia/reperfusion injury, atherosclerosis, neurodegenerative disease, cancer and sepsis (Mates et al, 1999 and McCord, 1993). In contrast, high doses and/or inadequate removal of reactive oxygen species result in oxidative stress, which may cause severe metabolic malfunctions and damage in biological macromolecules (Yerer & Aydogan, 2000 and Konukoglu et al, 1998). Exposure to low-level of pesticides is known to produce a variety of biochemical changes, some of which may be responsible for the adverse biological effects reported in human and experimental studies (Gupta et al., 1998 & Banerjee et al., 1999). The biochemical changes induced after exposure to pesticides or their active metabolites include target cell/receptor binding, protein and DNA...
adduct formation, and induction or inhibition of enzymes (Heinzow and McLean, 1994). Oxidative stress can also be induced by pesticides, either by overproduction of free radicals or by alteration in antioxidant defense mechanisms, including detoxification and scavenging enzymes (Abdollahi et al., 2004). The oxidative stress has been reported to play an important role in the toxicity of various pesticides, including organochlorines, organophosphates (Stevenson et al. 1995; Ranjbar et al. 2002 & Lee et al., 2006), carbamates and pyrethroids (Kale et al., 1999). The higher oxidative stress in pesticide sprayers is evidenced by changes in antioxidant status, and altered activities of cellular enzymes (Prakasam et al., 2001). In blood, normal erythrocyte function depends on the intactness of cell membrane which is the target for many toxic factors including pesticides. Erythrocyte superoxide dismutase (SOD) and catalase (CAT), efficiently scavenge toxic free radicals and are partly responsible for protection against lipid peroxidation due to acute/chronic pesticide exposure (Agrawal et al., 1991). The available data on experimental animals (Altuntas et al., 2002; Łukaszewicz-Hussain and Moniuszko-Jakoniuk, 2002) and human (Wagida 1997; Olga et al., 2007) indicate that the enzymes associated with antioxidant defense mechanisms are altered under the influence of pesticides. However, the studies have led to controversial results since either increased or decreased activities of antioxidant enzymes were reported. When increased activities are found they might result from an activation of the compensatory mechanism leading to the induction of free radical scavenging enzymes to counteract the oxidative stress generated by pesticides. In contrast the decrease in antioxidant enzymes has been interpreted as an indirect inhibition of the enzymes resulting from the binding of oxidative molecules produced during pesticide metabolism.

The use of mixtures of organophosphate insecticides prepared according to the experience of the Qat farmers has become very common in Yemen and has resulted in an increase in the prevalence of toxicity, especially in case of pregnant women who used to chew Qat. The present study aimed to evaluate the early biochemical signs of cytotoxicity, such as changes in antioxidant enzymes of a mixture preparation of the pesticides (PM) which include dimethoate 30% and methidathion 40% prepared by the farmers and engaged in intensive agriculture. Chick embryo model is becoming favorable for studying the antioxidant enzymes. Sung-Hyen Lee et al., 2007 used chick embryo for the study of free radical scavenging activity.

2. Materials and methods

The chemicals were obtained from Alsayah Market, Sana'a city, Yemen. The PM was prepared according to the manner followed by the farmers; by mixing Dimethoate 30% with Methidathion 40% in a ratio of 1:1. A group of 16 fresh fertilized eggs (Gallus domesticus) weighing 54 ± 1 gm (8 control + 8 experimental) were incubated at 38 ± 0.5˚C and 60% humidity. The exposure to pesticide mixture is performed by injection of 0.100 ml of 5 ppm into the air sac by making a tiny hole. The embryos were exposed to PM starting from day seven till the day 21 each alternative day. The control embryos received the same volume of normal saline. After each injection the hole is sealed with cello tape and the embryos were re-incubated until day 21. On day 21 after administration of the last dose of PM by 2 hours, the embryos were removed from their shells and dissected for isolation of the brain, liver and heart for enzyme assay. The brain, liver and heart were taken out, washed with normal saline, weighed and homogenized in phosphate buffer, pH 7, in a ratio of 1:5 w/v. The homogenization was performed with the use of the Teflon Homogenizer of the Potter-Elvehjem type in ice-cold water bath. The homogenates were centrifuged at 10,000 rpm for 15 minutes at 0-4°C and the supernatants were used for the enzyme assay.

Superoxide dismutase activity:

The activity of superoxide dismutase (SOD) was measured according to Misra and Fridovich (1972). The oxidation of epinephrine was followed in terms of the production of adrenochrome, which exhibits an absorption maximum at 480 nm. Adrenochrome is unstable at pH 10.2 in air. Epinephrine is quite stable in acid solutions but get auto-oxidized with rapidly increase in the pH. At pH 10.2 the linear rate of accumulation of adrenochrome in solutions of epinephrine is a complex function of the concentration of epinephrine. The autoxidation of epinephrine at pH 10.2 is strongly inhibited by superoxide dismutase. EDTA increases the sensitivity of epinephrine to superoxide dismutase, at the same time has no effect on the maximum degree of inhibition which could be achieved. It also chelate with heavy metals that might
affect the enzyme activity in the reaction mixture. The sensitivity of the oxidation of epinephrine towards the inhibition by superoxide dismutase, decreases with pH and become zero at pH 8.5 and below. The reaction mixture contains 0.1M epinephrine, 0.1mM EDTA and carbonate buffer (pH 10.2). The temperature was maintained at 30°C and the absorbance measured at 480 nm using spectrophotometer (Hitachi, U-2000). One unit of SOD activity was defined as the enzyme amount that inhibits the rate of epinephrine oxidation by 50%.

Catalase activity:

The activity of catalase (CAT) has been done according to S. Sadashivam and A. Manickam (1997). Decomposition of hydrogen peroxide by catalase was measured in terms of decreasing the absorption with time. The enzyme activity could be arrived at from this decrease. The control cuvette contains enzyme solution as in the experimental cuvette, but containing H2O2-free Phosphate buffer (0.067M). The experimental cuvette contains 3mL H2O2-Po4 buffer and 0.020 ml sample and the absorbance was measured at 240 nm. The time required for the decreasing of the absorbance is used for calculation of the enzyme activity.

3. Results

<table>
<thead>
<tr>
<th>Organ</th>
<th>Control (gm)</th>
<th>Test (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>0.640 ± 0.02</td>
<td>0.503 ± 0.02*</td>
</tr>
<tr>
<td>Liver</td>
<td>0.541 ± 0.01</td>
<td>0.508 ± 0.05</td>
</tr>
<tr>
<td>Heart</td>
<td>0.184 ± 0.01</td>
<td>0.180 ± 0.02</td>
</tr>
</tbody>
</table>

Results are expressed as means ± SEM (n = 8), student ‘t’ test. *P < 0.05 is considered as significant.

4. Discussion

OPIs can induce oxidative stress by generating free radicals and altering antioxidant levels of the free radical scavenging enzyme activity (Sharma et al., 2005 & Rajeswary et al., 2007). In the present study the brain weight showed significant decrease in the PM treated group (Table 1). SOD and CAT showed significantly increased levels in the PM treated group with respect to controls (Table 2,3). The most outstanding results of this study were found for SOD activity. Exposed embryos presented significant increase levels of SOD with respect to control in the brain and the heart tissues, (P<0.05, Table-2). This observation is in accordance with other studies reported that pyrethroid insecticide and cypermethrin, significantly induced free radical production in plasma, liver, brain and testes in male rabbits, (Al-Demerdash et al., 2003). Lin et al., 2003 reported that profenofos increased the antioxidase activities SOD and CAT in rabbits. Also, A. Lukaszewicz-Hussain 2001 observed an increase in the activity of SOD and CAT of rat liver treated with Chlorfenvinphos. The increased level of the antioxidant enzymes may result from the oxidative stress induced by pesticide exposure (Gultekin et al., 2001). This observed increase in antioxidant enzymes might provide protection against PM-induced free radical stress because it is known that peroxidation is reduced by the antioxidant enzymes (Machlin & Bendich, 1987). In contrast to the results obtained in this study, Zama et al. 2007 found that chlorpyrifos caused significant decrease in SOD activity of erythrocytes of pregnant rats. Altuntas et al., 2003 also reported that Phosalone caused decrease in the activities of SOD and CAT, and these effects were seen only at extremely high concentrations of phosalone. The antioxidant enzyme levels decrease as a result of the consumption of enzymes to neutralize free radicals generated by pesticides, (Amer...
et al., 2002). In this study initially, SOD activity increased, but owing to prolonged exposure to pesticides, the decrease in the SOD activity may occur. That is the efforts of the endogenous antioxidant enzymes to remove the continuously generated free radicals initially increase due to an induction but later enzyme depletion results, resulting in oxidative cell damage (Kalra et al., 1994). Increased catalase activity may be explained by their influence on hydrogen peroxide as substrate, which is formed in the process of dismutation of superoxide anion radicals (Shaikh et al., 1999). As catalase is a heme containing enzyme and the fact that OPIs inhibit ALAD activities (Panemangalore and Byers, 1995), which is involved in heme synthesis, it is might be that later decrease in catalase activity may occur due to more generation of H2O2 or decreased heme synthesis by the PM. In case of human studies, Panemangalore et al., 1999 & Vidyasagar et al. 2004 reported the increased SOD levels followed organophosphorous insecticides poisoning which indicate an elevated antioxidant status. And a parallel increase in SOD levels with an increase in the severity of poisoning shows that, more the stress, more the free radicals are generated. On the other hand the liver is a highly metabolically active organ, with a high activity of antioxidant enzymes, so that the SOD level did not change at all in the liver as compared to the control embryos, (Table 2), with only diminished elevation in the CAT activity level (Table 3). From these results it seems that the liver, as high metabolically active organ, was able to counter much of the oxidative stress induced by PM because of the higher level of SOD. This finding agree with the results reported by Elzbieta et al. 2003, that SOD activity in the liver of Rana esculenta L. after the paraquat or metoxychlor treatment, both for 6 and 12 days, seems to be sufficient to protect the liver against the superoxide anion, which can be produced during the microsomal biotransformation of pesticides. An increase in the liver catalase activity was observed in rats treated with profenofos, (Mogda et al. 2009). However, some studies have indicated that superoxide radicals can inhibit CAT activity and the increased H2O2 levels resulting from CAT inhibition could finally inhibit SOD activity (Gultekin et al., 2001). Thus, increased level of SOD and CAT found in this study indicated the capability of SOD and CAT to scavenger the ROS induced by PM at the concentration of the tested dose. Since SOD is a Zn-Cu containing enzyme, it is might be that SOD activity increase with the increase of ROS generation but the decrease of SOD activity may be occur by the decreased serum zinc and copper levels, (Jyotsna et al., 2009). It is well reported that OPIs induce production of reactive oxygen species and oxidative tissue damage. Generation of oxidative stress and consequent lipid peroxidation by pesticides is also reported in rat and human brain (Ranbar et al., 2002). Moreover, (Barlow et al., 2005) indicated that many widely used agricultural chemicals induce oxidative damage in various systems of the body such as in dopaminergic cells of the brain by modulating the antioxidant defence system. So, the low SOD activity in the brain and heart tissues as compare to its activity in the liver tissue, favours the accumulation of oxygen free radicals which may lead to tissue damage as a result of oxidative binding of key intracellular molecules containing thiol groups and lipid peroxidation of biological membranes, which might be of greatest importance in the cytotoxicity of pesticides. This also can be eventually responsible for cellular death and developmental defects in these organs reported by organophosphorous insecticides (Alhifi et al., 2004). Bagchi et al., 1995 reported that endosulfan (13 mg/kg/day), an organochlorine insecticide, caused kidney degeneration in mouse kidney due to oxidative stress (Caglar et al., 2003). Osman 2003, reported some histopathological changes like infiltration with mono-nuclear cells at parenchymal tissue, sinusoidal dilatation, focal necrotic areas, granular degeneration and picnotic nuclei in the hepatocytes in rat liver treated with methidathion. Yavuz et al., 2005 also reported that sub-chronic methidathion administration to rats caused vascular wall damage, and he related that to the lipid peroxidation involved in methidathion induced vascular toxicity. All the major biomolecules like lipids, proteins, and nucleic acids may be attacked by free radicals, but lipids are probably the most susceptible (Cheeseman and Slater 1992). As a matter of fact, free radicals can damage DNA and proteins, either through oxidation of DNA bases (primarily guanine via lipid peroxyl or alkoxyl radicals) or through covalent binding to DNA resulting in strand breaks and cross-linking. Reactive oxygen species can also induce oxidation of critical Sulphhydryl (SH) groups in proteins and DNA, which will alter cellular integrity and function (Fatemeh-Teimouri, 2006).

It seems that toxicity of OPIs is much complicated as it inhibit AChE and this has related effect on the SOD level as the decrease in AChE above a 15% is a deter-
minant of lower SOD activity at high exposure of human to pesticides (Olga Lopez et al., 2007). The relationship between AChE, RBC-Zn and SOD suggests a compromise of the antioxidant enzyme status, Panemangalore & Byers 1995 reported that plasma cholinesterase, erythrocyte SOD activities of farm workers inhibited by 32 and 56%, respectively, and the RBC-Zn decreased by 35% after 30 days of working on sprayed fields with maleic hydrazide and acephate. Sharma et al. 2005, concluded that the oxidative stress due to dimethoate ascribed to the induction of Cytochrom P450, inhibition of AChE and disturbance in the activity of antioxidant enzymes causing lipid peroxidation and histological changes in the liver and the brain.

Previous studies have demonstrated the oxidative stress by dimethoate and methidathion separately, Fatma et al., 2010 reported dimethoate to cause significant increase in SOD, and CAT level in human erythrocytes. Methidathion reported to reduce the activity of SOD and CAT in rat erythrocytes (Altuntas et al.,2002). Dimethoate also reported to reduce the level of other antioxidants such as glutathione in subchronic exposure in both liver and brain tissues of male Wistar rats, (Sharma et al., 2005). Few studies have been reported the effect of dimethoate or methidathion mixture with other insecticides. Troy D. Anderson and Kun Yan Zhu 2004, reported that the toxicity of dimethoate increased by 15% when in combination with atrazines compared to dimethoate only treatments. Atrazine also reported to induce cytochrome P450 monooxygenases in order to confer the synergistic effects on the toxicity of dimethoate (Y. Jin-Clark et al., 2002 & T.D. Anderson and M.J. Lydy, 2002). Biochemical analysis showed that diazinon or deltamethrin individually cause alteration in SOD, while mixture treatment induced antagonistic effects toward SOD (Manal & Nashwah, 2009). It is also reported that the effect of the lindane and permethrin mixture on the level of antioxidant enzymes is not significantly different than individual components of the mixture (Olgun and Misra, 2006).

Conclusions

The results of this study indicated that dimethoate and methidathion mixture in a manner made by the Qat farmers in Yemen induces oxidative stress at 5ppm and the brain was the most susceptible organ towards the oxidative stress induced by PM. The liver as high metabolically active organ is capable of removing the OFR at the tested dose. From previous studies and from results of this study the effect of dimethoate and methidathion mixture on SOD and CAT level is not different than the effect of individual insecticides. More studies are recommended at higher doses and for longer intoxication.

References


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Abstract

It is important to state that Jordan, with global radiation of 2080 kWh/m² and more than 300 sunny days a year, has excellent potential for solar energy generation. The generated solar energy is given, in general, as a global radiation on a horizontal solar collector. However, fixed panels receive solar radiation at an angle that reduces the amount of energy considerably. Therefore, it is important to determine the optimal angle that generates maximum energy if tracking is not available.

The experimental optimum slopes were achieved by testing 6 collectors that were placed at tilt angles 15, 25, 35, 45, 55, and 65 to the horizontal surface south (γ=0).

The total sun insolation and the various temperatures at inlet, outlet, ambient, and tank were recorded instantaneously every hour over the day for several months in 2007.

A computer programme is constructed on mathematical formulation to find the hourly, daily and monthly average values of optimum tilt angle, optimum orientation and maximum total radiation on the tilted surface of the collector. The daily and monthly average values of optimum tilt angle are calculated, so that the average values of the maximum total radiation will be near to its hourly values.

In general good agreement was found to exist between calculated and measured data.

Keywords: Optimum Tilt Angle, Optimum Surface Azimuth Angle, Flat Plate Collector, Mathematical Modeling, Solar Radiation, Isotropic and Anistropic sky model.

1. Introduction

Jordan lies between Latitude 28°4’-33°30’ N and between Longitude 35° -39° E. The total area of Jordan is about 89,206 Square Kms, around 90% of which is desert and rural areas. The population of Jordan was about 5.723 million in 2007 with growth rate of about 3.4%. Almost 90 per cent of the population lives in the north-west of Jordan, situated in areas which together constitute about 10% of the country's total land area. Jordan like other developing countries in general has to meet the energy challenges for achieving the requirements of the government strategy for a comprehensive and sustainable social and economic development. The lack of commercial energy resources in Jordan and dependence on crude oil and oil products imports, high population growth rate, an expected continuous high energy consumption growth rate of about (3%/year) and (6%) for the electricity consumption, all these yearly costs make the energy bill a big burden on the national economy. Part of the solution to this problem is to utilize Jordan's renewable energy resources like solar energy. According to the energy sector's strategy of Jordan, it is planned that the renewable energy contribution will reach 3% of the overall energy mixture until the year 2015.

Several studies have shown that solar energy is promising in Jordan. Jordan is one of the sun belt countries according to the international classification since the average annual solar radiation per day is (3.8) Kwh/square meter in winter to more than (8) Kwh/square meter in summer. The yearly global solar radiation in Jordan ranges from (1700) kWh/m² in Jordan Valley to more than (2250) kWh/m² for Hill area which facilitates building investment projects utilizing solar energy for the generation of electricity [5,6].
The sun is the largest regenerative source of energy in our world. It is estimated that the annual sunexposure amounts to $3.9 \times 10^{24} \text{J} = 1.08 \times 10^{18} \text{kWh}^2$. This corresponds to more than 10000 times of the present world energy needs [1]. Furthermore, the constant fluctuation in oil prices, as shown in Figure 1, has pushed people and institutions to think more seriously of renewable energy resources and somehow reduce their dependence on oil.

![Figure 1. Yearly oil prices](image1)

Another urgent reason to seriously consider renewable energy resources is that studies show that the oil depletion point has been reached in 2006. This is a direct result of consuming oil much faster than it is naturally produced.

Since formation of new petroleum is a complicated geological process takes millions of years. In addition, energy demands are increasing at alarming rate as shown for example for the electrical energy in Jordan in Figure 2.

![Figure 2. Electricity production in Jordan](image2)

We think that the time is coming soon where world governments will be required to offer alternative energy sources to keep their economies running or practice programmed blackouts.

### Solar Tracking

The generated solar energy is given, in general, as a global radiation on a horizontal solar collector. However, fixed panels receive solar radiation at an angle that reduces the amount of energy considerably. Therefore, it is important to determine the optimal angle that generates maximum energy if tracking is not available.

In general, relative sun position with respect to the earth depends on rotation of the earth around the sun and rotation of the earth around itself. The first rotation generates the inclination angle and the second rotation generates the azimuth angle. Moreover, the tracking with respect to inclination angle is called one-axis tracking and the tracking with both inclination and azimuth angles is called two-axis tracking.

### Literature Review

The energy absorbed by a solar collector depends upon its angle of tilt. The best way to collect maximum daily energy is to use tracking systems, but they are expensive, need energy for their operation, and are not always applicable. Therefore it is often more feasible to orient the absorber plate at an optimum tilt angle, and to correct the tilt from time to time. For this purpose, one should be able to determine the optimum slope of the absorber plate at any latitude, for any surface azimuth angle, and on any day of the year.

A flat plate collector is the simplest means available for solar energy collection. It is widely employed for applications such as water heating, the performance of a flat plate collector is highly influenced by its orientation and its angle of tilt with the horizontal. This is due to the fact that both the orientation and tilt angle change the solar radiation reaching the surface of the absorber and the overall heat losses.

Several interesting articles have been devoted to this problem. Most of these articles treat the problem qualitatively and quantitatively. Practice for a long time has shown that in the northern hemisphere the optimum orientation is south facing and the optimum tilt depends on the latitude. Various papers have also pointed out this fact, and have made different recommendation for different locations.

Kern and Hrris have optimized the slope based on only beam radiation and for equator-facing collectors, and obtained the following formula.
Koronakis has carried out a computer simulation to determine the total solar insolation on a south facing inclined surface and has used it to calculate optimum absorber tilt in Athens basin area.

Badescu who performed calculations by using actinometric and thermal data measured in Bucharest, Romania, showed that solar air heater performances were strongly dependent on tilt, and orientation. Better performances of solar air heaters were obtained in the case of S, SE and SW orientations. Also, he concluded that optimum tilt angle was a function of orientation and there were no significant difference between the tilt angles, which optimize the incident solar radiation and the energy supplied by the collector. The studies on the determination of the optimum slope of solar radiation receiving surfaces were of broader interest.

Further review of literature shows:
1. There is a wide range of $\beta_{opt}$ as recommended by different authors, and they are mostly for specific locations
2. None of analytical methods use $\gamma \neq 0$.

Therefore, in the present work, the main focus is to find the optimum tilt angle for a flat plate collector facing south and the optimum orientation and tilt angle for concentrating or flat plate solar collectors tracking the sun on the basis of maximizing the total solar radiation reaching the collector surface over a specified period (a day, a month, a season, a year, etc.). The collectors are located in Mutah (latitude of 32 N, Jordan).

**Experimental Measurement of optimum slope**

This study analyzes the most optimum parameter that increases the energy usable from the flat plate collector as shown in *Figures (3-5).*

The two basic methods for determining fundamental collector characteristics are the instantaneous and the calorimetric procedures. In the former procedure it is only required to measure simultaneously the mass flow rate of water circulating through the collector, temperature difference, the collector inlet and outlet temperatures, and insulation incident on the plane of the collector. The instantaneous efficiency will be computed.
To achieve this goal testing 6 collectors were placed at tilt angles 15, 25, 35, 45, 55, and 65 to the horizontal surface south (\(\gamma = 0\)) as shown in Figure 6.

![Figure 6. Flat plat orientation](image)

The flat-plate collector comprised a glass cover of 4 mm thickness, 12 half inch diameter longitudinal pipes 0.9 m long each welded from both ends to two horizontal header pipes, 1.25 inch diameter each. The distance between the centerlines of each two successive pipes is 100 mm. The pipes are welded on top of an absorber steel plate with an area of 1.2 m x 1.0 m and a thickness of 1.2 mm, and the whole of the inside was painted matt black. Rockwool insulation of 50 mm in thickness was used at the bottom and all sides. The tank is made out of galvanized steel and has a length of 0.5 m and a diameter of 0.3 m.

In each collector,
1. The water temperature at inlet and outlet are measured using calibrated thermocouples type K (Nickel-Chromium/Nickel-Aluminium).
2. The water temperature inside the storage tanks was measured using thermocouples positioned at the tank center.
3. A pyranometer was attached to the side of the conventional type collector in order to record the total incident insolation.

The total sun insolation and the temperatures at inlet, outlet, ambient, and tank were recorded instantaneously every hour over the day for several months.

The comparison between the experimental results and the optimum simulation tilt angle and maximum radiation of the thermal performance tests of the solar energy collector systems are made on basis of the system inlet and outlet temperatures, storage cylinder temperature, delivered energy and collection efficiency.

The results are based on the data collected for the collector taken at the same time March, April, May, June, and in July in 2006-2007.

Figures 7 and 8 show the global radiation and ambient temperature in represented day of May during the solar energy collection period, extending from 8:00 a.m until 5:00 p.m.

![Figure 7. Ambient temperature in May 2007 (C)](image)

![Figure 8. Global radiation variation in May 2007](image)

Figure 9 presents the inlet temperature, outlet temperature, and storage temperature for a represented day of May.

![Figure 9. Variation of inlet, outlet and storage temperature in May 2007](image)
Figure 10 shows the measured mass flow rate of water in the represented day of May are plotted against the hour.

The instantaneous efficiency curves weekly averaged are plotted for the systems vs. time in Figure 11. The trends embark to behave similarly with efficiency differences of 1-2 per cent which is well within the measurements accuracy, but large differences started to be apparent in the afternoon periods where the difference reached as much as 12 and 16 per cent at 4 and 5 pm, respectively, in favor of the arc system.

Figure 12 shows the measured global radiation versus slope of inclined collector in May 2007.

In general good agreement was found to exit between calculated and measured data.

2. Mathematical formulation

Global radiation received on an inclined surface is composed of beam and diffuse radiation as well as reflected radiation from the surroundings. The beam component depends on geometrical considerations whereas the diffuse radiation depends on the distribution of diffuse radiation in the surrounding atmosphere as well as on the shape factor of the inclined surface. Reflected radiation, on the other hand is a function of the characteristics of the surrounding surfaces are diffuse reflectors.

Models available in literature to calculate the global radiation on an inclined surface are similar except for the diffuse radiation component.
The main subjects of the analysis are as follows:

Optimum Tilt Angle For The Collection of Beam Radiation

1. Daily Optimum Tilt Angle
2. Monthly Optimum Tilt Angle
3. Yearly Optimum Tilt Angle

Atmospheric transmittance models and diurnal profile of solar radiation

According to Desnica $\tau(\omega)$ can be approximated by a simple hour angle dependent function $f(\omega)$, so that one can express $I_{bn}$ as:

$$I_{bn} = I_{bn,n} f(\omega)$$

Where $I_{bn,n}$ is a constant various forms of the function $f(\omega)$, known as atmospheric transmittance function have been proposed by different authors.

The following are the most commonly used models from the literature:

1) Klein model: $f(\omega) = 1$

2) Desnica model: $f(\omega) = \cos\left(\frac{k \omega}{W_S}\right)$

3) Revfein model: $f(\omega) = \cos\left(\frac{\pi \omega}{2W_S}\right)$

4) Zelenka asymmetrical model: $f(\omega) = \cos\left(\frac{k(\omega - W_P)}{W_S}\right)$

5) Gordon and Zarmi model:

$$f(\omega) = 1 - \left(\frac{\omega}{W_S}\right)^4$$

6) Modified Gordon and Zarmi Model: $f(\omega) = 1 - \left(\frac{\omega}{\pm W_S}\right)^3$

7) Nijegorodove model: $f(\omega) = 1 - \left(\frac{\omega}{\pm W_S}\right)^3 + \frac{\omega}{a(\pm W_S)}$

8) Modified Nijegorodove model: $f(\omega) = 1 - \left(\frac{\omega - W_P}{\pm W_S}\right)^3 + \frac{(\omega - W_P)}{a(\pm W_S)}$ where $a$ is an empirical constant.

Analytical method to determine the optimum slope:

The instantaneous global radiation intensity on tilted surface, $I_T$ is

$$I_T = I_{bT} + I_{dT} + I_{rT}$$  \hspace{1cm} (1)

The daily total insulation is obtained by end integrating eq.(1) From the hour sunrise to sunset ,i.e.:

$$H_T = \int_{h_p}^{h_s} I_{bT} \, dt + \int_{h_p}^{h_s} (I_{dT} + I_{rT}) \, dt$$  \hspace{1cm} (2)

Where $t$ is in hours and its equal $t = \frac{180\omega}{15\pi}$ consequently
At the optimum tilt of the absorber plate $H_t$ must be a maximum so that:

$$\frac{d}{d\beta}(H_t)_{\beta_{opt}} = 0$$

Solving eq.5 for $\beta$ gives an analytical expression for $\beta_{opt}$.

Isotropic sky model

If an isotropic sky model is used, then:

$$\cos \theta = \begin{pmatrix} \sin \delta \sin \phi \cos \beta - \sin \delta \cos \phi \cos \gamma \sin \beta + \cos \delta \cos \phi \cos \cos \omega + \\
\cos \delta \sin \phi \cos \gamma \sin \beta \cos \omega + \cos \delta \sin \gamma \sin \beta \sin \omega \end{pmatrix}$$

$$\cos \theta_z = \cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta$$

$$I_T = I_{br,n} f(\omega) \cos \theta + C f(\omega) \left(\frac{1+\cos \beta}{2}\right) + f(\omega)(\cos \theta_z + C) \rho \left(\frac{1-\cos \beta}{2}\right)$$

Now one can use any suitable function $f(\omega)$ for the atmospheric transmittance such that eq. (6) is analytically inferable, and follow the procedure of maximizing $HT$ with respect to $\beta$ to obtain $\beta_{opt}$.

We can find $\beta_{opt}$ for Desnica model as follow:

$$f(\omega) = \cos \left(\frac{k \omega}{W_S}\right)$$

$$I_T = I_{br,n} \left[ f(\omega) \cos \theta + C f(\omega) \left(\frac{1+\cos \beta}{2}\right) + f(\omega)(\cos \theta_z + C) \rho \left(\frac{1-\cos \beta}{2}\right) \right]$$

$$I_T = I_{br,n} \left[ C f(\omega) \left(\frac{1+\cos \beta}{2}\right) + f(\omega) (\cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta + c) \rho \left(\frac{1-\cos \beta}{2}\right) \right]$$

$$I_T = I_{br,n} \left[ \cos \left(\frac{k \omega}{W_S}\right) \sin \delta \sin \phi \cos \beta - \sin \delta \cos \phi \cos \gamma \sin \beta + \cos \delta \cos \phi \cos \cos \omega + \right. \left. \cos \delta \sin \phi \cos \gamma \sin \beta \cos \omega + \cos \delta \sin \gamma \sin \beta \sin \omega \right]$$

$$I_T = I_{br,n} \left[ C \cos \left(\frac{k \omega}{W_S}\right) \sin \beta + \cos \left(\frac{k \omega}{W_S}\right) (\cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta + c) \rho \left(\frac{1-\cos \beta}{2}\right) \right]$$

$$H_T = \frac{12 \times 3600}{\pi} \int_{-W_S}^{W_S} I_T d\omega$$
But
\[ \int_{-\pi}^{\pi} I_{r} d\omega = \int_{-\pi}^{\pi} \sin \delta \sin \phi \cos \cos (k \omega/W) d\omega - \int_{-\pi}^{\pi} \sin \delta \cos \phi \cos \gamma \sin \beta \cos (k \omega/W) d\omega + \]
\[ \int_{-\pi}^{\pi} \cos \delta \cos \phi \cos \beta \cos \omega \cos (k \omega/W) d\omega + \int_{-\pi}^{\pi} \cos \delta \sin \phi \cos \gamma \sin \beta \cos \omega \cos (k \omega/W) d\omega + \]
\[ \int_{-\pi}^{\pi} \cos \delta \sin \gamma \sin \beta \sin \omega \cos (k \omega/W) d\omega + \int_{-\pi}^{\pi} \rho \left(\frac{1-\cos \beta}{2}\right) \cos \phi \cos \delta \cos \omega \cos (k \omega/W) d\omega + \int_{-\pi}^{\pi} \rho \left(\frac{1-\cos \beta}{2}\right) (\sin \phi \sin \delta + c) \cos \beta \cos (k \omega/W) d\omega \]
\[ = \left[ \sin \delta \sin \phi \cos \beta \ast \frac{2W_s}{k} \sin k - \sin \delta \cos \phi \cos \gamma \sin \beta \ast \frac{2W_s}{k} \sin k + \right. \]
\[ \cos \delta \cos \phi \cos \beta \ast 2sB + \cos \delta \sin \phi \cos \gamma \sin \beta \ast 2B + 0 + \]
\[ \left. \rho \left(\frac{1-\cos \beta}{2}\right) \sin \phi \sin \delta + \rho \left(\frac{1-\cos \beta}{2}\right) \cos \phi \cos \delta \ast 2B + \right. \]
\[ \left. \rho \left(\frac{1-\cos \beta}{2}\right) (\sin \phi \sin \delta + c) \ast \frac{2W_s}{k} \sin k \right] \]

Where:
\[ B = \frac{W_s}{2} \left( \frac{\sin (k - W_s)}{k} + \sin \left(\frac{k + W_s}{k}\right) \right) \]

Let:
\[ F = \cos \delta \sin \phi \cos \gamma, M = \sin \delta \cos \phi \cos \gamma \]
\[ N = \sin \phi \sin \delta, P = \cos \delta \cos \phi \]

\[ H_r = \left(\frac{12*3600}{\pi}\right) I_{\text{b,n}} \left[ 2N \cos \beta \frac{W_s}{k} \sin k - 2M \sin \beta \frac{W_s}{k} \sin k + 2P \cos \beta B + 2F \sin \beta B + \right. \]
\[ \left. 2N \frac{W_s}{k} \sin k + \left(1 + \cos \beta \right) + 2P \left(\frac{1-\cos \beta}{2}\right) \rho B + \right. \]
\[ \left. 2P \left(\frac{1-\cos \beta}{2}\right) (N + c) \frac{W_s}{k} \sin k \right] \]

\[ H_r = \frac{24*3600}{\pi} I_{\text{b,n}} \left[ \left(1 + \frac{W_s}{k} \sin k + PB \right) \times \left(1 + \rho \frac{1-\cos \beta}{2}\right) + C \frac{W_s}{k} \sin k \left(1 - \rho \right) \cos \beta \right] + \]
\[ \frac{24*3600}{\pi} \left[ F \times B - M \frac{W_s}{k} \sin k \right] + \sin \beta \right] + \]
\[ \frac{24*3600}{\pi} \left[ C \times B \times \rho + N \rho \frac{W_s}{k} \sin k \right] \]

Now by maximizing HT:
\[ \left[ \frac{d}{d\beta} \left( H_r \right) \right]_{\text{opt}} = 0 \]
\[ 0 = \left(1 + \frac{W_s}{k} \sin k + PB \right) \times \left(1 + \rho \frac{1-\cos \beta}{2}\right) + C \frac{W_s}{k} \sin k \left(1 - \rho \right) \sin \beta + \left[ F \times B - M \frac{W_s}{k} \sin k \right] \cos \beta \]
Dividing by \( \cos \beta \):

\[
0 = -\left( N \frac{W_s}{k_2} \sin k + PB \right) \times \left( 1 - \frac{\rho}{2} \right) + C \frac{W_s}{k_2} \sin k (1 - \rho) \tan \beta + \left[ F \times B - M \frac{W_s}{k_2} \sin k \right]
\]

Then:

\[
\beta = \tan^{-1} \left( \frac{F \times B - M \frac{W_s}{k_2} \sin k}{\left( N \frac{W_s}{k_2} \sin k + PB \right) \times \left( 1 - \frac{\rho}{2} \right) + C \frac{W_s}{k_2} \sin k (1 - \rho)} \right)
\]

Anisotropic sky model

Since it is shown that all anisotropic models have comparable performance, we use the simplest one, i.e. the high and Device model (12). According to this model the total radiation on a tilt surface can be expressed as follows:

\[
I_T = (1 + I_d A_i) R_h + I_d (1 - A_i) \times \left( \frac{1 + \cos \beta}{2} \right) + I \rho \left( \frac{1 - \cos \beta}{2} \right)
\]  

(1)

Even with simplest anisotropic sky model this case becomes very complicated because, in order to calculate HT, one deals with a very difficult integral:

\[
\int_{-\omega}^{\omega} f(\omega) R_s d\omega
\]

In order to simplify a problem eq.(1) can be rewritten in the following form:

\[
I_T = I_{bn} \cos \theta + ZA_i \frac{I_{bn} \cos \theta + (1 - A_i)}{2 \times \left( \frac{1 + \cos \beta}{2} \right) + I \rho \left( \frac{1 - \cos \beta}{2} \right)}
\]  

(2)

Where \( I_d A_i R_h = ZI_{bn} A_i R_h = ZA_i I_{bn} \cos \theta \). Now eq. (2) can be easily integrated, and the anisotropic sky model case becomes almost the same as the anisotropic sky model case, only mathematically more unwieldy.

Repeating the same procedure we use in isotropic model in Desnica model we can determine the optimum slope:

\[
I_Y = I_{bn,m} \left[ f(\omega)(1 + Z_{di}) \cos \theta + C f(\omega)(1 - A_i) \right] \left( \frac{1 + \cos \beta}{2} \right) + f(\omega)(\cos \theta_i + C) \rho \left( \frac{1 - \cos \beta}{2} \right)
\]

\[
I_Y = I_{bn,m} \left[ f(\omega)(1 + Z_{di}) \sin \delta \sin \phi \cos \beta - \sin \delta \cos \phi \cos \gamma \sin \beta + \cos \delta \cos \phi \cos \beta \cos \phi \gamma \sin \beta \sin \omega + \cos \delta \sin \phi \cos \gamma \sin \beta \cos \omega + \cos \delta \sin \phi \cos \beta \sin \omega \right] + f(\omega)(1 - A_i) \left( \frac{1 + \cos \beta}{2} \right) + f(\omega)(\cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta + c) \rho \left( \frac{1 - \cos \beta}{2} \right)
\]
\[ f(\omega) = \cos\left(\frac{k \omega}{W_S}\right) \]

\[ I_2 = I_{\text{in,2}} \cos\left(\frac{k \omega}{W_S}\right) \left[ (1 + Z_{ai}) \cos\left(\frac{k \omega}{W_S}\right) \left( \sin \delta \sin \phi \cos \beta - \sin \delta \cos \phi \cos \gamma \sin \beta + \cos \delta \cos \phi \cos \beta \cos \omega + \cos \delta \sin \gamma \sin \beta \sin \omega \right) \right] + \]

\[ C (1 - A_i) \cos\left(\frac{k \omega}{W_S}\right) \left( \frac{1 + \cos \beta}{2} \right) + \cos\left(\frac{k \omega}{W_S}\right) \left( \cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta + c \right) \rho \left( \frac{1 - \cos \beta}{2} \right) \]

\[ H_T = \frac{12 \times 3600}{\pi} \int_{-W_S}^{W_S} I_2 \, d\omega \]

But

\[ \int_{-W_S}^{W_S} I_2 \, d\omega = \]

\[ \int_{-W_S}^{W_S} (1 + Z_{ai}) \sin \delta \sin \phi \cos \beta \cos\left(\frac{k \omega}{W_S}\right) \, d\omega - \int_{-W_S}^{W_S} (1 + Z_{ai}) \sin \delta \cos \phi \cos \gamma \sin \beta \cos\left(\frac{k \omega}{W_S}\right) \, d\omega + \]

\[ \int_{-W_S}^{W_S} (1 + Z_{ai}) \cos \delta \cos \phi \cos \beta \cos \omega \cos\left(\frac{k \omega}{W_S}\right) \, d\omega - \int_{-W_S}^{W_S} (1 + Z_{ai}) \cos \delta \sin \phi \cos \gamma \sin \beta \cos \omega \cos\left(\frac{k \omega}{W_S}\right) \, d\omega + \]

\[ \int_{-W_S}^{W_S} (1 + Z_{ai}) \cos \delta \sin \gamma \sin \beta \sin \omega \cos\left(\frac{k \omega}{W_S}\right) \, d\omega + \int_{-W_S}^{W_S} (1 + Z_{ai}) \left( \frac{1 + \cos \beta}{2} \right) \cos\left(\frac{k \omega}{W_S}\right) \, d\omega + \]

\[ \int_{-W_S}^{W_S} (1 + Z_{ai}) \rho \left( \frac{1 - \cos \beta}{2} \right) \cos \phi \cos \delta \cos \omega \cos\left(\frac{k \omega}{W_S}\right) \, d\omega + \int_{-W_S}^{W_S} (1 + Z_{ai}) \rho \left( \frac{1 - \cos \beta}{2} \right) \sin \phi \sin \delta + c \cos\left(\frac{k \omega}{W_S}\right) \, d\omega \]

\[ = \left[ (1 + Z_{ai}) \left( \sin \delta \sin \phi \cos \beta \ast \frac{2W_S}{k} \sin k - \sin \delta \cos \phi \cos \gamma \sin \beta \ast \frac{2W_S}{k} \sin k + \right) + 0 + \cos \delta \cos \phi \cos \beta \ast 2B + \cos \delta \sin \phi \cos \gamma \sin \beta \ast 2B \right] \]

\[ c (1 - A_i) \left( \frac{1 + \cos \beta}{2} \right) \ast \frac{2W_S}{k} \sin k + \rho \left( \frac{1 - \cos \beta}{2} \right) \cos \phi \cos \delta \ast 2B + \]

\[ \rho \left( \frac{1 - \cos \beta}{2} \right) \left( \sin \phi \sin \delta + c \right) \ast \frac{2W_S}{k} \sin k \]

Where:

\[ B = \frac{W_S}{2} \left( \sin \left( k - W_S \right) \right) + \sin \left( k + W_S \right) \]

Let:

\[ F = \cos \delta \sin \phi \cos \gamma, M = \sin \delta \cos \phi \cos \gamma \]

\[ N = \sin \phi \sin \delta, P = \cos \delta \cos \phi \]

\[ H_T = \left( \frac{12 \times 3600}{\pi} \right) I_{\text{in,2}} \left[ (1 + Z_{ai}) \left( 2N \cos \beta \frac{W_S}{k} \sin k - 2M \sin \beta \frac{W_S}{k} \sin k + 2P \cos \beta \cos \gamma \sin \beta \ast \frac{2W_S}{k} \sin k \right) + \right] \]

\[ 2c (1 - A_i) \frac{W_S}{k} \sin k \left( \frac{1 + \cos \beta}{2} \right) + 2\rho \left( \frac{1 - \cos \beta}{2} \right) \frac{PB}{2} + \]

\[ 2\rho \left( \frac{1 - \cos \beta}{2} \right) \left( N + c \right) \frac{W_S}{k} \sin k \]
Now, by maximizing HT:

\[
\left[ \frac{d}{d \beta} (H_T) \right]_{\beta_{\text{opt}}} = 0
\]

\[
0 = -\left( N \frac{W_S}{k} \sin k + PB \right) \times \left( 1 - \frac{\rho}{2} + Z_{A_i} \right) + C \frac{W_S}{k} \sin k \left( 1 - \rho - A_i \right) \sin \beta + \left( F \times B - M \frac{W_S}{k} \sin k \right) \left( 1 + Z_{A_i} \right) \cos \beta
\]

Dividing by \( \cos \beta \):

\[
0 = -\left( N \frac{W_S}{k} \sin k + PB \right) \times \left( 1 - \frac{\rho}{2} + Z_{A_i} \right) + C \frac{W_S}{k} \sin k \left( 1 - \rho - A_i \right) \tan \beta + \left( 1 + Z_{A_i} \right) F \times B - M \frac{W_S}{k} \sin k
\]

\[
\beta_{\text{opt}} = \tan^{-1} \left( 1 + Z_{A_i} \right) \left[ F \times B - M \frac{W_S}{k} \sin k \right]
\]

Then:

\[
\beta_{\text{opt}} = \tan^{-1} \left( \cos \delta \sin \phi \cos \gamma B - \sin \delta \cos \phi \cos \gamma \frac{W_S}{k} \sin k \right)
\]

\[
\left( \sin \phi \sin \delta \frac{W_S}{k} \sin k + \cos \delta \cos \phi B \right) \times \left( 1 - \frac{\rho}{2} + Z_{A_i} \right) + C \frac{W_S}{k} \sin k \left( 1 - \rho - A_i \right)
\]

Where:

\[
B = \frac{W_S}{2} \left( \sin \left( k - W_S \right) \left( k - W_S \right) + \sin \left( k + W_S \right) \left( k + W_S \right) \right)
\]

Repeating the same procedure that we did as above, we will reach the following derive equation.

1-Klein model:

\[
\beta_{\text{opt}} = \left[ (1 + Z_{A_i}) \left( \cos \delta \sin \phi \cos \gamma \sin w \right) - \sin \delta \cos \phi \cos \gamma \frac{W_S}{k} \sin k \right]
\]

\[
\left( 1 - \frac{\rho}{2} \right) \sin \phi \sin \delta \sin w \left( 1 - \rho - A_i \right) + C \frac{W_S}{2} \left( 1 - \rho - A_i \right)
\]
2-Desnica model:
\[
\beta_{\text{opt}} = \frac{(1 + Z A_i)(\cos \delta \sin \phi \cos \gamma B - \sin \delta \cos \phi \cos \gamma w_s (\sin k) / k)}{(1 - \rho / 2)(\sin \delta \sin \phi w_s (\sin k) / k + \cos \delta \cos \phi B) + \frac{\cos \phi B}{k}(\sin k) / k (1 - \rho - A_i)}
\]

3-Rev fleim model:
\[
\beta_{\text{opt}} = \frac{(1 + Z A_i)(\cos \delta \sin \phi \cos \gamma B (k = \pi / 2) - \sin \delta \cos \phi \cos \gamma w_s (2/\pi))}{(1 - \rho / 2)(\sin \delta \sin \phi w_s (2/\pi) + \cos \delta \cos \phi B (k = \pi / 2)) + \frac{\cos \phi B}{\pi}(2/\pi) / k (1 - \rho - A_i)}
\]

4- Zelenka model:
\[
\beta_{\text{opt}} = \frac{(1 + Z A_i)(\cos \delta \sin \phi \cos \gamma B - \sin \delta \cos \phi \cos \gamma w_s (4/5))}{(1 - \rho / 2)(\sin \delta \sin \phi w_s (4/5) + \cos \delta \cos \phi \sin w_s - A_i) + \frac{\cos \phi B}{5}(4/5)(1 - \rho - A_i)}
\]

5-Gordon and Zarmi:
\[
\beta_{\text{opt}} = \frac{(1 + Z A_i)(\cos \delta \sin \phi \cos \gamma \sin (w_s - D) - \sin \delta \cos \phi \cos \gamma w_s (3 / 4))}{(1 - \rho / 2)(\sin \delta \sin \phi w_s (3 / 4) + \cos \delta \cos \phi \sin (w_s - D) + \frac{\cos \phi B}{4}(3 / 4)(1 - \rho - A_i)}
\]

6-Modified Gordon and Zarmi:
\[
\beta_{\text{opt}} = \frac{(1 + Z A_i)(\cos \delta \sin \phi \cos \gamma \sin (w_s - A) - \sin \delta \cos \phi \cos \gamma w_s (4 / 5))}{(1 - \rho / 2)(\sin \delta \sin \phi w_s (4 / 5) + \cos \delta \cos \phi \sin (w_s - A) + \frac{\cos \phi B}{5}(4 / 5)(1 - \rho - A_i)}
\]

**Analytical method to determine optimum surface azimuth angle \( \gamma_{\text{opt}} \):**

When a phase shift is observed the optimum azimuth angle \( \gamma \) of an absorber plate is not equal to zero. To obtain a formula for \( \gamma_{\text{opt}} \) is similar to the procedure we have used to obtain the formulae for \( \beta_{\text{opt}} \): maximize \( H_T \) with respect to \( \gamma \) and solve for \( \gamma_{\text{opt}} \):

\[
\left( \frac{d}{d \gamma} H_T \right)_{\gamma_{\text{opt}}} = 0
\]

1-Klein model:
\[
\gamma_{\text{opt}} = \tan^{-1}\left[ \frac{\sin \omega}{(\sin \phi \cos \omega) \sin \phi - \tan \delta \cos \phi} \right]
\]

2-Zelenka model:
\[
\gamma_{\text{opt}} = \tan^{-1}\left[ \frac{\tan \left( \frac{k w_p}{w_s} \right)}{W_s \left( \frac{\sin (k - W_s)}{2(k - W_s)} + \frac{\sin (k + W_s)}{2(k + W_s)} \right) \sin \phi - \frac{w_s}{k} \tan \delta \cos \phi \sin k} \right]
\]
A computer programme is constructed on the basis of the aforementioned mathematical formulation to find the hourly, daily and monthly average values of optimum tilt angle, optimum orientation and maximum total radiation on the tilted surface of the collector. The daily and monthly average values of optimum tilt angle are calculated, so that the average values of the maximum total radiation will be near to its hourly values.

3. Results and discussions

Figure 14 shows the hourly variation of the maximum total solar radiation on a flat plate solar collector tilted with the optimum tilt angle and facing south in Mutah for the average day of the selective months. It is clear from the figure that minimum and maximum radiations occur in December and June.

Figure 15 shows the hourly variation of the optimum tilt angle for the average day for each month in the year for a flat plate solar collector facing south in Mutah. The average day of the month is that day which has the extra-terrestrial radiation closest to the average for the month. The figure shows that optimum tilt angle increases in day time, reaching a maximum value at solar noon and then decreases during the months of April-September. Meanwhile, the optimum tilt angle decreases in day time, reaching a minimum value at solar noon and then increases during the months of October-February. During March the optimum tilt angle is constant in day time. The minimum and maximum variations of the optimum tilt angle during the year occurs in June and December, respectively.

Figure 16 shows the variations of the daily average optimum tilt angle and maximum total radiation throughout the year for a flat plate collector tilted with the daily average optimum tilt angle and facing a flat plate collector with a fixed tilt angle 27. It is observed...
that the daily optimum tilt angle varies from about 0 to
59, being a minimum in June and a maximum in
December.

The yearly average of the daily optimum tilt angles
was found to be 32.63, which is near to the local
latitude angle of Mutah (32.), as commonly proposed
by many researchers.

The daily total radiation for a flat plate collector with
a fixed tilt angle equal to 27 and facing south is also
shown in Figure 3. It is obvious that the yearly
maximum total radiation calculated at the daily optimum
tilt angle is greater than the yearly total radiation calcu-
lated at fixed tilt angle.

The fixed tilt angle for each month was determined
as the average of daily optimum tilt angles for that month.

Figure 18 shows the hourly variation of optimum
surface azimuth angle for the average day for each
month of the year. This variation is determined for a
concentrating or a flat plate solar collector tracking the
sun in Mutah. It should be pointed out that a variety of
orienting systems have been designed based on manual
or mechanized operation. Manual systems are used in
areas of low labour cost.

Figure 5 shows that the optimum surface azimuth
angle reaches maximum in June (-110.8 < γ_{opt} < 110.8),
then decreases gradually to a minimum value in
December (-69.3 < γ_{opt} < 69.3) and increases gradually
to reach its maximum value again in June. Surface
azimuth angle equals zero for collectors facing south,
east negative and west positive.

Figure 19 shows the hourly variation of optimum
tilt angle for the average day for each month of the year
of the optimum orientation. This optimum tilt is calcu-
lated for the corresponding optimum surface azimuth
angle at the same time. The figure shows that optimum
tilt angle decreases with the day time, reaching a
minimum value at solar noon and then increases during
all months of the year. The minimum and maximum
variations of the optimum tilt angle during the year
occur in December and June, respectively.
**Figure 21** shows the variations of daily average optimum tilt angle and maximum total radiation throughout the year for a collector tracking the sun and tilted with the daily average optimum tilt angle.

**Figure 22.** The monthly variation of daily optimum tilt angle for a solar collector with optimum orientation.

**Figure 22** shows the monthly variation of daily optimum tilt angle. It shows that the variation of tilt angles during the periods May-July and November-January is insignificant, and therefore, a fixed tilt angle during these periods can be used without much error.

### Conclusions

Global and diffused radiation and meteorological data were investigated to explore the potential of solar energy generation in the area of Mutah University in Jordan. A comparison was drawn between measured radiation and simulated data. This comparison revealed close match between both sets of data.

The optimum values of tilt angles and orientation for solar collectors in Mutah were determined by developing a mathematical model and using a computer program.

The mathematical model and computer program developed can be used to calculate the optimum tilt, surface azimuth angles and maximum total radiation on the solar collector at any time, altitude, climate and latitude.

The following conclusions have been drawn:

1. The optimum slope is found to depend on several parameters, namely $\beta_{opt} = f(\varphi, n, \gamma, \rho, C, Z, A_i, W_p)$ the first three of these parameters are the most important; the effect of the remaining parameters is not so strong. Since diffuse radiation decreases $\beta_{opt}$ and reflected radiation increases $\beta_{opt}$ combined they tend to neutralize each other’s effect, resulting in surprisingly good estimates for $\beta_{opt}$.

2. The daily optimum tilt angle, for a flat plate collector facing south, changes throughout the year with its minimum value in June and maximum value in December.

3. The daily optimum tilt angle, for a concentrating or a flat plate solar collector with optimum orientation, changes throughout the year with its minimum value in June and maximum value in December. Its value at any day of the year can be determined.

4. The yearly average of the daily optimum tilt angles is found to be 32.63° and 54.19° for a flat plate collector facing south and a collector with the optimum orientation, respectively.
References


Nomenclature

\( a_0, a_1 = \) constants for the standard clear atmosphere with 23 km visibility
\( a_0^*, a_1^* = \) constants for the standard clear atmosphere for altitudes less than 2.5 km
\( A = \) altitude of the observer (km)
\( C = \) Diffuse Sky Factor
\( D = \) Daily Radiation Received on a surface
\( H_r = \) daily total radiation on a tilted surface (MJ m\(^{-2}\))
\( H_t = \) monthly average daily total radiation on a tilted surface (MJ m\(^{-2}\))
\( I = \) the direct solar radiation at normal incidence
\( I_b = \) hourly beam radiation on a horizontal surface (MJ/m\(^2\))
\( I_{db} = \) hourly clear sky beam radiation on a horizontal surface (MJ/m\(^2\))
\( I_{sd} = \) hourly clear sky diffuse radiation (MJ/m\(^2\))
\( \eta = \) the angle between the direction of the sun and the normal of the tilted plane
\( \psi = \) solar azimuth angle
\( \gamma = \) solar elevation angle
\( \alpha = \) azimuth angle of the normal of the plane
\( \delta = \) declination angle (degrees)
\( \theta = \) incidence angle (degrees)
\( \theta_o = \) zenith angle (degrees)
\( \rho = \) diffuse ground reflectance
\( \tau_b = \) atmospheric transmittance for beam radiation
\( \tau_d = \) atmospheric transmittance for diffuse radiation
\( I_d = \) hourly diffuse radiation on a horizontal surface (MJ/m\(^2\))
\( I_o = \) hourly extra-terrestrial radiation on a horizontal surface (MJ/m\(^2\))
\( I_{os} = \) hourly extra-terrestrial radiation, measured on the plane normal to the radiation (MJ/m\(^2\))
\( I_r = \) hourly total radiation on a tilted surface (MJ/m\(^2\))
\( D(\beta, \alpha) = \) the diffuse solar radiation
\( R(\beta, \alpha) = \) the reflected global radiation
\( I(\beta, \alpha) = \) the direct solar radiation on the tilted plane
\( k = \) constant for the standard clear atmosphere with 23 km visibility
\( K^* = \) constant for the standard clear atmosphere for altitudes less than 2.5 km
\( n = \) day of the year
\( r, r_b, r_o = \) correction factors for climate types
\( R_b = \) geometric factor
\( I_{ST} / I_s = \) the ratio of beam radiation or the tilted surface to that on a horizontal surface

Greek Symbol

\( \beta = \) collector tilt angle (slope), that is, the angle between the collector and the horizontal (degrees)
\( \beta_{o}^* = \) optimum tilt angle (degrees)
\( \gamma = \) surface azimuth angle (degrees)
\( \gamma_{o} = \) optimum surface azimuth angle
\( \Phi = \) latitude angle (degrees)
\( \omega = \) hour angle (degrees)
\( W = \) is the sunset hour

1. Introduction

Indonesia consists of many small islands surrounding mainland which is facing electricity power shortage problem. Renewable energy such as solar energy system can be an alternative energy supply to the islands where are not connected to the grid. PV system can be used for electrification and it most suitable for remote and island area such as Indonesia in the term of resource availability and economic feasibility [1]. At the present, island communities rely on fossil fuel to supply energy needs. Consequently, energy supply to such communalities is of considerable concern. These islands have adequate amount of locally available resources of renewable energy potential, such as solar energy.

Global solar irradiation data provide information on how much of the sun’s energy strikes a surface at a location on earth during particular time period. The amount of solar irradiation potential in the particular location is important for solar energy system design, such as stand alone PV and hybrid system. Solar irradiation potential is also required for crop models (in agriculture engineering field) as well as building thermal performance (in agriculture field).

Due to the geographical condition, the measurement of solar irradiation for all location of interest in island community of Indonesia that spread out widely in many location become difficult and expensive. Prediction of solar radiation data using appropriate model can be an
alternative solution to develop for developing country, such as Indonesia. This paper study about the development and usage of the ANN models in such location.

The purposes of this study are defined as follow:
- To explore the ability of the ANN method to predict monthly average global solar irradiation value in the island area of Indonesia
- To select the best ANN model for predicting monthly average global solar radiation in the horizontal surface by meteorological data in Indonesia.

This paper is organized as follows: literature review about ANN theory and previous works on predicting solar irradiance is described in section 2. The database used in this study and the method of ANN application for predicting solar irradiations are presented in section 3. The result of simulation ANN model and evaluations are shown in section 4. Conclusion is given in section 5.

2. Literature Review and Previous Work

This section describes about literature review and previous works on predicting solar radiation by using ANN method.

Artificial Neural Networks are computational systems that their model and functionality is inherited from the recently acquired knowledge of the biological computational units, namely, the brain’s neurons. An ANN consists of many interconnected identical neurons. A typical neural network usually has 3 layers of neurons, each of which is connected to the neurons in the next layer. These connections are weights which are applied to values passed from one neuron to the next. Input values in the first layer are weighted and passed to the second (hidden layer). Neuron in the hidden layer produce outputs that are based upon the sum of weighted values passed to them. The hidden layer passes values to the output layer in the same fashion and the output layer produces the desired result. The network learns by adjusting the interconnection weights. The answers the network is producing are repeatedly compared with the correct answers, and each time the connection weights are adjusted in the direction of the correct answers [2].

There are many ANN types, one of the typical one is Back Propagation (BP). The Back Propagation (BP) algorithm is a supervised iterative training method for multilayer feed forward nets with a differential nonlinear function. The BP algorithm minimizes the mean square difference between the network output and the desired output.

Basically there are many parameters in the ANN, which the designer of the ANN should assign, such as learning rate, momentum rate, weight and so forth. Here, we only explain about three important parameters in MLP type of ANN model. Learning rate term, L, indicates how much the weight change to effect on each pass. This is typically a number between 0 and 1. Momentum term, M, indicates how much a previous weight change should influence the current weight change. As neuron pass values from one layer of the network to the next layer, the values are modified by a weight value in the link that represents connection strengths between the neuron. The weights of connection between neurons are adjusted during the training process to achieve the desired input and output relation of the network. ANNs perform in many different forms, some require model with total interconnection among neurons and others require arrangement in layers [3].

The advantage of neural networks is their learning ability to perform specific tasks. Learning is accomplished by adjusting the weights of the connections between neurons. Weights are adjusted so that the network can be producing the outputs as close as possible to the known correct answers of training data. During the training stage, the network is learning the rule for associating the inputs with the target outputs. Due to the generalization capabilities of the neural networks, it performs similarly on data for testing that have not used for training [4].

There are several studies to predict monthly average global solar irradiation potential based on ANN method. Since ANN are highly nonlinear and require no prior assumption concerning the data relationship, they have become useful tool for predicting solar irradiation. Particularly, in the meteorological and solar energy resources fields, ANN based models have been successfully developed to model different solar radiation variable in many location. Jiang [5] developed estimation of monthly mean daily global solar irradiation using ANN method in China. The data period used are from 1995 to 2004 and the inputs for the networks are latitude, altitude and mean sunshine duration. The result indicated that MAPE of 3.75%, 5.43%, 0.16%, 4.96% and 0.16% for Kashi, Geermu, Shenyang, Chengdu and Zhengshou respectively.
Mubiru and Banda [6] explored the possibility of developing a prediction model using ANN to estimate monthly average daily global solar irradiation for locations in Uganda based on weather station data: sunshine duration, maximum temperature, cloud cover and location parameters: latitude, longitude, altitude. A correlation coefficient of 0.974 was obtained with mean bias error of 0.59 MJ/m² and RMSE of 0.385 MJ/m².

Mohandez et al (1998) used neural network technique for modeling monthly mean daily values of global solar radiation for locations in Saudi Arabia based on data: latitude, longitude, altitude and the sunshine duration as inputs. The result obtained MAPE for 10 locations used for testing, such as 10.7% for Tabuk station, 6.5% for Al-Ula station, 14.6% for Unayzah station, 10.5% for Shaqra station, 13.4% for Dawdami station, 10.1% for Yabrin station, 16.4% for Turabah station, 11.3% for Heifa station, 19.1% for Kwash station, 13.5% for Najran station [4].

Alawi and Hinai (1998) have developed ANN to predict solar radiation in Seeb location, a city in Oman. The input data to the network included: location parameters, month, averages of pressure, temperature, vapor pressure, relative humidity, wind speed and sunshine duration. The ANN model proposed performed an accuracy of 7.3% as the mean absolute percentage error [7].

From the above reviewed, ANN models have been successfully demonstrated to have potential in estimating monthly average global solar irradiation by many researchers in many countries. However, these ANN models are location dependent and specific to each location. So far, there is no report about prediction of solar radiation potential for Indonesia by using ANN method. We aim to develop neural network based models for predicting monthly average global solar irradiation potential in Manado, a city in Indonesia based on meteorological data available.

3. Data and Developed model of ANN

This section is described about database used in this study and the method of ANN application for predicting global solar irradiation in island area of Indonesia.

As case study in Manado, a city situated in the Sulawesi island (Figure 1) was chosen to represent meteorological data measurement for training in the ANN based. The data is taken from meteorological station in Manado, which is situated at altitude 1.3 N, longitude 124.9 E and altitude 85 m. Manado lies in equator where has solar radiation through all the year with average solar radiation 5.73 kWh/m² and average sunshine duration 5.8 hours a day [8].

The database consists of 5 years data meteorological data, which is collected from 2005 until 2009 by meteorological station in Manado city. The data were split into two, as 48 months (January 2005 to December 2008) were used for training a neural network and the rest data for testing. The model was tested to predict solar irradiation values for Manado location over a 12 month period. In this study, the training of the models uses a feed-forward neural network with Back Propagation training algorithm. The inputs were monthly average sunshine duration (hours), monthly average maximum wind speed (m/s), monthly average relative humidity, monthly average rainfall (mm), monthly average temperature (˚C). The output was monthly average global solar irradiation potential. Training the model was done using a neural net simulator known as “NeuroShell.”

Wind speed is taken by anemometer, sunshine duration was measured with a Campbel-Stokes heliograph, temperature is measured by thermometer, rainfall is taken by rain gauge measurement and solar radiation was recorded manned by Gun Bellani pyranometer. No information is available regarding instrument calibration and other possible error during measurement. However, based on previous work that has been studied by Rumbayan (the author) [8] to verify data, found the measured data in meteorological station appears to be satisfactory as the values compare well with those at nearby location, such
as Kuching at the latitude 1.5 N and longitude 110.3 E and Senai, Malaysia at latitude 1.6 N and longitude 103.7 E.

Since there is no method to predetermine the best combination of neuron/layers, as this depend on the specific model, the physical process and the training data that the network will simulate. From references, there are some empirical relationships to solve this problem but the best method is up to the researcher to build several models and choose the best suited for the particular application [9].

Based on this, the training in this study starts with defining the parameters with minimum error by trial and error using fixed and change parameter one by one, then use the selected parameter in neural network for several case of the number of neurons in the hidden layer. Then the model of ANN was used for training and testing. By several attempts from 3 to 5 neurons in the hidden layer, the least error was found. This configuration is used to present the network model to be reported in this study.

In this study, the process of neural networks for predicting the monthly global solar irradiation potential is divided into two sections, i.e training and testing.

**a. Training section**

The process of the research is done by two thresholds in the training section. First, varying the parameter (by trial and error attempt) in order to determine the appropriate parameters with the optimum value. Second, varying the number of neurons in hidden layer in order to get minimum error value. The number of hidden layer is set to vary from 2 to 4 in single hidden layer. To train the network, 48 monthly data from historical meteorological data is used by defining input and output.

**b. Testing section**

In the testing section, data of monthly average for one year were used as an evaluation. By using ANN model, the result of monthly solar irradiation has been identified, then it has been compared with the actual measured of meteorological data. Predicted values of global solar irradiation were compared with measured values taken from meteorological data through analysis of error, in terms of Mean Absolute Percentage Error (MAPE), Mean Absolute Bias Error (MABE) and Root Means Square Error (RMSE).

Models are evaluated in terms of errors that are given by equation 1, 2 and 3 where Hmi is measured values and Hpi is predicted values for monthly average global solar irradiation, n is the number of testing examples.

The mean absolute percentage error (MAPE) is defined by equation 1.

\[
MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{H_{mi} - H_{pi}}{H_{mi}} \right|
\]  

(1)

In MAPE, sign of errors are neglected and percentage errors are added up to obtain the average. MAPE is commonly used in quantitative forecasting methods because it produces a measure of relative overall fit. It usually expresses accuracy as a percentage. The mean absolute bias error (MABE) is defined by equation 2.

\[
MABE = \frac{1}{n} \sum_{i=1}^{n} \left| H_{mi} - H_{pi} \right|
\]  

(2)

The MABE represents the absolute value of the bias error and is a measure of the goodness of correlation.

The mean absolute bias error (MABE) is defined by equation 3.

\[
RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( H_{pi} - H_{mi} \right)^2}
\]  

(3)

The RMSE gives information on short-term performance by allowing a term by term comparison of actual deviations between estimated and measured values. The RMSE is the fundamental measure of accuracy, as the lower the RMSE, the more accurate the estimate.

4. Simulation Result and Evaluation

This section presents the results of ANN model simulation and evaluation by comparing between measured and predicted neural network values based on statistical error. The neural networks with multilayer perception (MLP) type were trained to predict global solar irradiation potential for 12 monthly data as testing.

There was no significant difference in the use of one, two and three hidden layers architectures. One hidden layer was used in order to minimize the complexity of the proposed ANN model. One hidden layer is chosen to simplify the network architecture proposed. Tymvios [10] found that increasing the number of hidden layers from one to two do not necessary lead to improve the performance of neural network. Also increasing the number of hidden layer to three could lead to performance deterioration.
The parameters of learning rate, momentum, initial weight were selected from trial and error attempts, by setting 2 parameters fixed and vary 1 parameter in software simulation. The parameter selection of learning rate, momentum, initial weight of 0.3, 0.5, 0.7 respectively were used as optimum parameter for ANN model for reporting the result of prediction. The above parameter has been used for training the ANN model with varying neurons in single hidden layer by MLP type.

The amounts of the neurons within hidden layers are optimized during learning step of the ANN, with criteria of statistical error. This study explores three models of MLP structures i.e two, three and four neurons at hidden layer. The MLP structure of 5-2-1 indicated the number of neurons in input layer is 5, the number of neuron in hidden layer is 2 and the number of neuron in output layer is 1. The MLP structure of 5-3-1 indicated the number of neurons in input layer is 5, the number of neuron in hidden layer is 3 and the number of neuron in output layer is 1. The MLP structure of 5-4-1 indicated the number of neurons in input layer is 5, the number of neuron in hidden layer is 4 and the number of neuron in output layer is 1.

Statistically error for 3 models of ANN was evaluated based on MAPE, MABE and RMSE criteria from test data. Data testing were not included as part of ANN training data. Hence, these results demonstrate the generalization capability of this method over unseen data.

The evaluations of predicted and measured values for 3 models were presented in the Table 1.

<table>
<thead>
<tr>
<th>MLP structure</th>
<th>MAPE (%)</th>
<th>MABE (MJ/m²)</th>
<th>RMSE (MJ/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-2-1</td>
<td>4.8</td>
<td>0.59</td>
<td>0.22</td>
</tr>
<tr>
<td>5-3-1</td>
<td>6.1</td>
<td>0.76</td>
<td>0.26</td>
</tr>
<tr>
<td>5-4-1</td>
<td>6.5</td>
<td>0.81</td>
<td>0.29</td>
</tr>
</tbody>
</table>

After several trials in varying the number of hidden neuron, it was found two amounts of neuron to be least error for the testing process in the neural network. Performance of predicted values of ANN model 1, 2, and 3 as compared to measured values of monthly average daily values of global solar irradiation on horizontal surface for 3 configuration models were presented in Figure 2a, 2b and 2c.
The best estimator with the minimum error with two neurons at hidden layer was chosen to be presented in this paper (Figure 3). The result of measured and predicted values of monthly global solar irradiation for testing stage in ANN model with 5-2-1 configuration were shown in Table 2.

The best predicted versus measured irradiation values for ANN model was presented in Figure 2a and the values were presented in Table 2. The maximum difference occurred for January, followed by June and March. Other 9 months (for February, April, May, July, August, September, October and December) were shown good agreement between measured and predicted values with acceptable difference value between 0.09 to 0.85 MJ/m².

It was found that the prediction of global solar irradiation obtained for the 12 months testing data well compared with the actual measured value, giving a correlation coefficient of 0.86 and MABE is 0.59 MJ/m². It can be seen that in general, there it was good agreement between measurements and predictions value of monthly global solar irradiation potential in Manado, Indonesia. This shows the potential of ANN method to predict monthly global solar irradiation in island area of Indonesia in reasonable accuracy.

Comparison between the MAPE of the proposed ANN model in this study and the MAPE of other selected references has been showed in Table 3.

TABLE 2. The result for testing stage in ANN model with configuration 5-2-1

<table>
<thead>
<tr>
<th>Month</th>
<th>Predicted (MJ/m²)</th>
<th>Measured (MJ/m²)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>10.48</td>
<td>12.31</td>
<td>-1.83</td>
</tr>
<tr>
<td>February</td>
<td>11.33</td>
<td>11.9</td>
<td>-0.57</td>
</tr>
<tr>
<td>March</td>
<td>13.08</td>
<td>12.04</td>
<td>1.04</td>
</tr>
<tr>
<td>April</td>
<td>12.82</td>
<td>13.15</td>
<td>-0.33</td>
</tr>
<tr>
<td>May</td>
<td>13.65</td>
<td>13.95</td>
<td>-0.3</td>
</tr>
<tr>
<td>June</td>
<td>12.92</td>
<td>14.15</td>
<td>-1.23</td>
</tr>
<tr>
<td>July</td>
<td>13.51</td>
<td>13.69</td>
<td>-0.18</td>
</tr>
<tr>
<td>August</td>
<td>14.82</td>
<td>15.06</td>
<td>-0.24</td>
</tr>
<tr>
<td>September</td>
<td>15.99</td>
<td>15.61</td>
<td>0.38</td>
</tr>
<tr>
<td>October</td>
<td>13.17</td>
<td>14.02</td>
<td>-0.85</td>
</tr>
<tr>
<td>November</td>
<td>13.69</td>
<td>13.78</td>
<td>-0.09</td>
</tr>
<tr>
<td>December</td>
<td>11.96</td>
<td>12.05</td>
<td>-0.09</td>
</tr>
</tbody>
</table>

Similar studies have been reached by many studies in the other area dealing with meteorological data with reasonable accuracy. The proposed ANN model for this study performs a smaller MAPE.
Conclusions

This study has been proposed the model of ANN to predict monthly average daily global solar irradiation in horizontal surface in Manado, Indonesia as area of study. This study proves that ANN can be used predicting of global solar irradiation potential in Manado, Indonesia by using meteorological data.

In this research, an accuracy of 95% and a mean absolute percentage error of 4.8% can be achieved by the best estimator with MLP structure that consists of 5, 2, 1 neurons in input layer, hidden layer and output layer respectively. Result has shown good agreement between the estimated and measured values of monthly average global solar irradiation. A correlation coefficient of 0.86 was obtained with mean absolute bias error of 0.59 MJ/m² and RMSE of 0.2 MJ/m². The feed-forward back propagation algorithm with single hidden layer was used in this analysis.

For further study, it is considered to develop prediction model for many location of Indonesia, where spread out from eastern to western part of Indonesia in order to represent the whole solar irradiation potential for this country. This study plan can be introduced neural network technique for modeling the spatial variation of global solar irradiation in Indonesia.

References

1. Introduction

As it is known, the Patagonia Argentina (Figure 1) presents wind conditions that would make possible capacity factors which they could duplicate the world-wide averages even so, the portion of the supplied national electrical consumption with wind energy is insignificant.

Considering the registered factors of capacity in the country, the theoretical potential of eolic generation in Argentina could arrive at but from 2,000 GW, a value equivalent to twice the capacity of at the moment existing total generation in the United States [1].

Recently in Argentina, they have been adjudged to 754 MW for Eolic generation with licitation GENREN (Program: Licitation of Electrical Generation from Renewable Sources), of which approximately 50 MW will be installed in sites of the Neuquén Province [2].

In the leading countries in the development of renewable power plants, the probability of a good project of wind energy depends on an amount of aspects, between which the main ones stand out:

- Wind potential
- Environmental conditions
- Restrictions several
- Characteristics of the sites

A suitable planning and integration of all these criteria determine the location and the identification of the best possible sites with capacity of admittance for the installation of Wind Farms.

This paper analyzes the initial criteria for the planning of Wind Farms in the Province of Neuquén, analyzing the technical, institutional and economic aspects of the future possible sites for the development of these locations.
1.1. Neuquén Province

The Province of Neuquén is located in the extreme northwest of the Region Patagónica (Figure 2) between 36° 39’ and 41° 01’ of South latitude and 68° and 71° 58’ de west longitude, Argentine Republic.

The total surface of the Province is of 94,078 km², its population is of approximately 565,000 inhabitants and the density of population is of 6 hab/km².

The main productive activity of the Province is the hydrocarbon operation. The neuquina basin form leaves from an immense geographic zone of 124,000 km² that shares with Río Negro, La Pampa and Mendoza Province. The neuquina basin is one of the oil and gas-bearing zones more important of Argentina and occupies a surface of 26,000 km². The prospection tasks - 35,000 hydrocarbon location km² includes.

Considering which most of the inhabitants they live in the main cities and that the climate of the province is semidesert, it is possible to affirm that the possibilities of use of the land for the development of wind projects are significant. As the density of the population is so low and the wind resources are not an impediment, there is no necessity to construct to turbines next to the houses and near populations Added to this, more of 50% of lands of the Province of Neuquén they are fiscal land, this facilitates a Provincial Decree along with, that do not exist conflicts of land owners and with the obtaining of permissions.

For the planning and evaluation of the suitable places but for the installation of wind farms in the province of Neuquén, technical, economic and institutional aspects would have to be evaluated altogether to determine the feasibility of the proposed projects, also considering the environmental impacts that could take place.

This paper analyzes and it proposes the initial considerations and the previous planning that would have to
be made to develop and to evaluate the feasibility of wind projects in the Province of Neuquén, Argentina.

2. Methodology

A territorial planning like methodology for an suitable planning of the installation of Wind farms in underdeveloped countries, would have to begin with a process of investigation and evaluation of the economic, social and environmental development of the considered areas.

The main considerations and more excellent parameters for the development of the proposed projects would have to be taken ahead by means of an equipment to multidisciplinary in which they participate professional and expert in the thematic one, local inhabitants in audience publish processes, local government and developer of projects [3].

The items to analyze would have to include:

1) Identification of the areas and sites with good wind conditions and how they could be used; Identification of parameters such as orography of the sites, altitude, slope of the land, influences of the wind.

2) Evaluation of the distance to the network and possibilities of interconnection:
Factors of location such as network structure, distances to the network, possibilities of interconnection, accessibility (routes and roads).

3) The sensitive Areas must be excluded:
For the evaluation of the sensitive areas parameters of restrictions like exclusion of protected areas will have to be analyzed, archaeological and paleontological protection to the nature, birds, resources, conflicts with land owners, obtaining of permissions, use of the ground and access to the land.

4) Consequences in other areas:
Environmental impact assessment, identifying the populated Areas nearer and considering a distance with 500 meters of damping [4].

2.1. Projects in study. Wind Conditions

Nowdays in the Province of Neuquén, this being made a feasibility study, that involves the installation of 28 wind turbines in the north zone of Auquinco and anticipates to generate 50 MW that will be interconnected to the system through the 132 line of kv that exists in Puesto Hernandez and arrives at Chos Malal (to see Figure 4). The election of the place in which the located Wind Farms between Chos Malal and Buta Ranquil will be located arises from studies made by the EPEN (Provincial Being of Energy of Neuquén), that I elaborate altogether with CREE (Regional Center of Wind Energy) the provincial wind map.

Also wind measurements are being made for the installation of Wind Farm in four zones near Zapala and Picun Leufu. Once verified the wind aptitudes of the regions and being fiscal land, the interested investors will be able to make their investments with a single tax of servitude and being paid a rate that granted the Nuquen Government to him.

In the Province of Neuquén has estimated that approximately 29,000 km$^2$ of land exist with potential a wind resource of good to excellent (classes from 4 to 7) as it is possible to be seen in the following table:

<table>
<thead>
<tr>
<th>Classes</th>
<th>Wind Speed (m/s) a 90 m height</th>
<th>Power (W/m$^2$)</th>
<th>Surface (km$^2$)</th>
<th>Percentage of total area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-5,6</td>
<td>0-200</td>
<td>15602</td>
<td>16,3</td>
</tr>
<tr>
<td>2</td>
<td>5,6-6,4</td>
<td>200-300</td>
<td>28078</td>
<td>29,3</td>
</tr>
<tr>
<td>3</td>
<td>6,4-7</td>
<td>300-400</td>
<td>22961</td>
<td>24,0</td>
</tr>
<tr>
<td>4</td>
<td>7,0-7,5</td>
<td>400-500</td>
<td>12498</td>
<td>13,0</td>
</tr>
<tr>
<td>5</td>
<td>7,5-8</td>
<td>500-600</td>
<td>5451</td>
<td>5,7</td>
</tr>
<tr>
<td>6</td>
<td>8,0-8,8</td>
<td>600-800</td>
<td>4866</td>
<td>5,1</td>
</tr>
<tr>
<td>7</td>
<td>8,8-11,9</td>
<td>800-2000</td>
<td>5634</td>
<td>5,9</td>
</tr>
<tr>
<td>&gt;2000</td>
<td></td>
<td></td>
<td>777</td>
<td>0,8</td>
</tr>
</tbody>
</table>
This surface represents 30% of the provincial total surface. The winds that surpass class 7 and that are in 0.8% of the provincial surface correspond to high summits.

The obtained results confirm that the Province of the Neuquén has very significant a wind resource. The average wind speed predicted by the model in the most favorable zones surpasses the 7.5 m/seg to 90 m a.g.i, that would be sufficient to maintain to economic projects of Wind energy [5].

2.2. Possibilities of Connection to the grid

The SADI (Argentinean Electrical System of Interconnection) this constituted by lines of transport and stations of transformation that integrate the primary system of interchange of electrical energy of all the national territory [1].

As a result of the geographic characteristics and of the socioeconomic development of the country, the structured SADI this like a system of transport of radial type that covers great distances connecting the centers with generation with the main center of demand (Buenos Aires).

However, to connect the eolic generation with the demand it will be required to reinforce and to extend the runners 500 kv of Patagónico, Comahue-GBA, Comahue-Region Cuyo which as it is possible to be seen in the Figure 6, this in construction process. These lines constitutes assets for the development of the wind energy, since it will do possible to transmit great amounts of energy produced with wind resources.

The extension of 132 lines of kv is significant. Its development in zones of wind interest like the Patagonia is particularly remarkable. These transmissions net would support, without greater investments and at least initially, the installation of several distributed wind farms of small and medium size.

In the province of Neuquén, the existing line of 132 kv linking Puesto Hernandez-Chos Malal would allow the connection of the wind turbines of the Wind Farm proposed “Auquinco”, where as the line of 132 kv Zapala - Cutral Co would support without problems the connection of the Wind turbines that would settle in the zone near of the Zapala City.

2.3. Road accesses

The identified areas in this paper for the installation of wind farms have roads and accesses in conditions that allow to the transport of the great cranes and the heaviest components like the towers, blades and rotors, both in greater degree for the use of turbines of greater power. Also the sites must have access for the cranes, the izaje in the phase of construction and for the maintenance of the turbines.

In the zones analyzed exist national routes that count on the characteristics and the maintenance for the transport of the components.

2.4. Legal Framework. Identification of Legal Requirements

Starting off of which national law 26,190 establishes a goal of participation of renewable sources of energy in
the consumption of national electrical energy of 8%, that will have to be fulfilled not beyond year 2016, in the Province of Neuquén were adjudged recently 50 MW of the 754 MW adjudged for wind generation with licitation GENREN (Program of Electrical Generation from Renewable Energies).

With the aim to promoting solar and wind energy, the Argentinian Government implemented the national Law 25.019/1999 Nº “Regimen Nacional de Energia Eolica y Solar” (National Regime of Solar and Wind Energy).

The main aspects of the legislation consist of subventions and tax relief on capital investment for the wind turbines or solar panels.

In Argentina, the Wholesaler Electrical Market (MEM) pays a certain price the generating ones. This price usually varies according to the hour of the day, and if it is power firm or no. In the middle of the 2008, it varies between 0,07 and 0,09 $/kWh.

The restrictions to the dominion that produces a Wind Farm installation are minimum and, in no case they alter the use that is occurring at the moment to the land, is this one farmer or cattle farmer.

2.5. Conflicts with land owners

Land: In the province of Neuquén exists the law Nº 2183 of Environmental Damage and administrative servitudes, nevertheless more of 50% of the provincial territory is fiscal and it counts on land owners that are not proprietors single are holding with improvements that with time are transformed into proprietors once they fulfill the requirements of the Land Provincial Law.

Also exists the provincial Decree 1837/09 that declares of public utility the generation of Wind energy in fiscal land.

2.6. Environment and land use

Local acceptance: In the Province of Neuquén, the Environmental Impact Assessment (EIA) are required by the Provincial Law Nº 1875 and its regulation of which the obligation emerges to carry out them based on the activities that will be undertaken. The procedure for the approval must contemplate a regime of public hearings and environmental licenses.

The stage of public hearing will have to include surveys with the settlers near the proposed locations with the purpose of informing, knowing and to have the local acceptance.

For this stage the opinion of the settlers of the nearest cities like Chos Malal and Buta Ranquil would have to be considered.

Opposite interests and Sensitive Areas:

Neuquén counts on eleven natural protected areas of provincial jurisdiction, that approximately represent 3.28% of the territory, since in his totality they add 308,927 hectares. One of the areas of main interest to consider is the Natural Protected Area “The Tromen” (To see Figure 7), nevertheless the proposed location Wind Farm “Auquinco” is within a denominated zone of damping, which is excluded and outside you limit them of the Natural Protected Area “the Tromen”.

The nearest populations as Chos Malal and Buta Ranquil are located to a considerable distance greater to 20 km of the propose installation. This way, the location proposed would not produce a visual impact, nor would affect to the populations and the native fauna of the zone with the noise emitted by the Wind turbines. In Argentina, the levels of noises are controlled by a national law that recommends limits of noise emission.

The archaeological sites, zones of protection are excluded from the analyzed sites. In the province, exists the Law Nº 2184 “Cultural Heritage, archaeological and paleontological Patrimony” which is contemplated in the Environmental Impact Assessment.

Figure 7. Natural Area “The Tromen”, Neuquén, Province, Argentina.
3. Results

After the identification of the areas with good wind conditions, and the evaluation of the distance to the network and its possibilities of interconnection excluding the sensitive areas, are due to consider the bordering possibilities of accesses, routes, airports and proximities to the cities.

The evaluated zones conform an area of approximately 6000 hectares.

The accesses and routes to the sites identified in this paper, are prepared for the transport and the logistics of the components of the wind turbines, as well as to transport the used cranes and heavy machineries for the installation of the towers. These equipment is available of the oil industry of the Province.

Conclusions

The province of Neuquén counts on great possibilities for the energy conversion taking advantage of the Wind potential.

The location of the sites with good wind resource, free of conflicts and with sites that, according to the analyzed thing allows a fast procedure but for the obtaining of permissions, among other factors; they give like result a high probability of accomplishment avoiding that they take place lost of time, costs and campaigns of wind measurement in inadequate locations.

Nowadays the Argentinean Republic can to enter with 2,100 MW to wind energy, 200 of them in immediate form, the System Interconnected National without affecting its correct operation [6]. The Province of Neuquén has 132 kv lines with capacity to inject the energy produced by the Wind Farm proposed “Auquinco” without affecting its correct operation.

According to the WWEA (World Wind Energy Association) by each new MW installed 20 jobs in direct form and 160 jobs of indirect way are created [7], this allows to infer that the installation of the Wind Farms that were developed in the Province of Neuquén will produce 1000 positions of direct way between professionals, technicians and described and not described manual labor. This means positive an environmental aspect due to the generation of local manual labor.

References

The Potential of Renewable Hydrogen Production in Pakistan

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Abstract

Pakistan’s population and economy are growing at a rapid pace and so are the energy needs. In order to reduce the dependency of fossil fuels, Renewable technologies need to be developed and introduced at an even pace. Hydrogen is being propagated as fuel for future. Pakistan, already a net energy importer, has to join the Hydrogen economy based on Renewable Hydrogen.

According to the Pakistan Energy Yearbook, natural gas is currently the country’s largest energy source, making up almost 50 percent of Pakistan’s energy mix in FY 2007/2008 as depicted in Figure 2 [3].

1. Introduction

The total recoverable reserves of crude oil in Pakistan as of 1st January 2009 have been estimated at 313 million barrels. The average crude oil production during July-March 2008-09 was 66532 barrels per day as compared to 70166 barrels per day during the corresponding period last year showing a negative growth of 5.2 percent.

In the wake of rising oil consumption and flat oil production coupled with 1.947% population growth [1] and projected demand of 400,000 bpd by year 2010, the gap between Oil production and consumption is a wedge, widening along the timeline. Figure 1 shows the oil production and consumption for years 2005-2018.

1.1. Pakistan-Present Energy profile

Pakistan had 19,575 MW of installed electric generating capacity in 2008. Conventional thermal plants using oil, natural gas, and coal account for about 66 percent of Pakistan’s capacity, with hydroelectricity making up 32 percent and nuclear 2 percent [4]. In
2003, the Pakistani government created the Alternative Energy Development Board (AEDB) with the primary objective to help Pakistan achieve a 10 percent renewable energy share in the country’s energy mix. In 2006 the Pakistani government estimated that by 2010, Pakistan will have to increase its generating capacity by more than 50 percent to meet increasing demand. [5]

In Pakistan 83.1% of all electricity users are residential consumers [6] whereas 72% of Final Energy Consumption is taken up by Industrial and Transport sector as shown in Figure 3.

Planning Division of Pakistan assumed a GDP growth rate of 7.4% as depicted in Figure 4. Projected indigenous energy supply and deficits corresponding to the 6.5% GDP growth rate are summarized in Figure 5.

Production of oil and gas in the country is expected to improve slightly in the near term but decline in the long run, given the current onshore exploration activities and resource outlook, and a low likelihood of a major offshore discovery. The energy deficit which stands at 15 MTOE or 28% of the energy demand presently will increase to 122 MTOE by 2025, corresponding to 62% of the demand, detailed below (Table 1) [7].

<table>
<thead>
<tr>
<th>Resource</th>
<th>FY 05</th>
<th>FY 15</th>
<th>FY 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Indigenous Supply</td>
<td>39</td>
<td>61</td>
<td>75</td>
</tr>
<tr>
<td>Total Energy Requirement</td>
<td>54</td>
<td>110</td>
<td>198</td>
</tr>
<tr>
<td>Deficit</td>
<td>15</td>
<td>50</td>
<td>122</td>
</tr>
<tr>
<td>Deficit as % Energy</td>
<td>28</td>
<td>45</td>
<td>62</td>
</tr>
<tr>
<td>Requirement</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This outlook clearly indicates a need to place development of the indigenous resource base on a high priority, followed by long-term arrangements to acquire energy from external sources that are affordable and reliable. Thus any energy planning efforts are to be targeted at Industrial, residential and transport sector and through Renewable Resources.

1.2. Hydrogen-Fuelling the Future

Hydrogen has moved farther from its conventional role as an additive in oil refineries and in various other chemical/fertilizer production processes, to attain a new role as a fuel in transport and stationary power. Hydrogen is being assigned a lead in addressing climate change concerns to provide a carbon-free energy system, while at the same time offering prospects in reducing dependence on fossil fuels.

Hydrogen is the primary input to the emerging fuel cell applications, that has only water and oxygen depleted air as exhaust products. Fuel cells thus hold the key to a non-polluting energy system that is more reliable and secure. Fuel cells are being developed for a range of various stationary as well as mobile applications.

Natural gas is the main source of hydrogen followed by other fossil fuels. However any sustainable energy system that is Hydrogen-based must exclude fossil fuels to fully be able to exploit the system’s carbon mitigation and pollution free potential.

However, with the advancement in Hydrogen technologies as fuel cells and electrolyzers through mass
production and research, renewable hydrogen is likely to be more competitive. Also hydrogen costs and stocks would be relatively stable, as opposed to the ever fluctuating oil market. Hence environmental advocates and states have one long term aim—a clean energy system that is based on hydrogen produced from renewable resources.[8]

1.3. Renewable Potential

This study identifies the locations of R3 (Renewable Resource Rich) areas of Pakistan with solar and wind in focus. This is followed by an assessment of hydrogen producing potential through various technologies at each of the R3 areas. The hydrogen output and its electricity generating potential are then compared with the power generation of WAPDA (Water and Power Development Authority).

2. Hydrogen Production Methods

The important aspect of the hydrogen economy is the production of hydrogen and the total energy consumed and CO₂ emitted in the process. Current world hydrogen production is approximately 50 million tons per year, which is equivalent to only 2% of world energy demand. Hydrogen can be produced from a diversity of energy resources using a variety of process technologies. A brief summary is provided in Figure 5 [10].

Transition to the Hydrogen Economy is based on Hydrogen production, which is eventually purported to replace fossil fuels, envisioned for its pro-environment reduced harmful emissions. Hydrogen in its pure form can be used in fuel cells and hydrogen combustion engines to cleanly release its stored energy.

Production of Hydrogen fuel requires it to be in its diatomic form. Hydrogen can be produced from a variety
of feed stocks, however carbon based feedstock like methane, coal and biomass contain carbon and hence would release carbon mono-oxide or carbon dioxide as a byproduct of the process. Hydrogen production from water is the only carbon-free process, provided carbon based fuel is not used to produce energy necessary to split water.

Depletion of fossil fuels along with its harmful environmental effects such as climate change and acid rain have led to the emergence of Hydrogen Energy technologies. Hydrogen though being widely recognized as one of the important future energy carriers and its demand is expected to increase as fuel cell technologies become cheaper, however hydrogen hardly exists naturally. Presently, two basic technologies are widely used for hydrogen generation:
- Reformation of natural gas
- Electrolysis

Hydrogen Economy faces a number of technical and economical challenges, the main being with the renewable hydrogen technologies, where major breakthroughs are needed. Fortunately renewable supplies are unlimited and potentially available in many different forms. Practical ways are however required to exploit them as efficiently and cheaply as possible on a global scale [9,11,12].

Sustainable energy supplies are based on renewable resources, of which solar and wind are identified as the most common and available resource all over the world. These are conceptually evaluated below.

### 3. Resource Assessment

Solar and wind energy can be harnessed to provide clean electricity to hydrogen-generating electrolyzers. In this way, hydrogen production can be a pathway for using renewable domestic energy sources to contribute directly to reducing greenhouse gases and reliance on imported transportation fuels. Hydrogen is produced via electrolysis by passing electricity through two electrodes in water. The water molecule is split and produces oxygen gas at the anode and hydrogen gas at the cathode via the following reaction:

\[ \text{H}_2\text{O} \rightarrow \frac{1}{2} \text{O}_2 + \text{H}_2 \]

#### 3.1. Solar Hydrogen

Figure 6 describes the Solar-Hydrogen concept. Solar panels collect the radiation from sun and supply electric power to the electrolyser. Electrolysis generates hydrogen which is sent to storage and oxygen is vented as a by-product. Hydrogen can then be used in any fuel cell application that is represented by a load.

Solar energy may be employed to generate hydrogen from water. There are several ways in which this may be accomplished, as summarized in Figure 7.
3.1.1. Photovoltaic Cells

Photovoltaic cells or “Solar cells” are the most common route for the conversion of solar energy to electricity. The technology though expensive in the foreseeable future has promising prospects keeping in view the dramatic improvement in the efficiency-to-cost ratio of these cells. The objective of low-cost solar cells have moved from mono-crystalline to multi crystalline and onward to organic polymer based photovoltaics (OPVs) that have special attributes, besides being attractive for cheap scalable power generation:

- Ability to be formed in larger sheets of solar cells
- High optical absorption coefficient
- Ecological and environmental benefits

The main disadvantages are its poor solar conversion efficiency and sensitivity of polymers to oxygen and water vapor that lead to lower performance and instability.

3.1.2. Solar Thermal Process

In this process the dissociation of water into Hydrogen and Oxygen is achieved by focusing the Sun’s rays from a large number (upto thousands) of individual mirrors onto a thermal receiver placed on top of a “solar tower”. Commonwealth Scientific and Industrial Research Organisation (CSIRO) has constructed one such tower in Australia. The key challenges are:

- To reduce the dissociation temperature of water with the help of new catalysts.
- Improved means of separation of two gases to prevent their recombination.

Licht [13] has proposed the use of dielectric filters to separate the radiation received by the solar tower into an infrared component to heat pressurized water to at least 300o C and an optical/ultraviolet component to generate electricity through PV (or photo electrochemical) cells. This electricity would then be used for high temperature steam electrolysis. This solar to hydrogen conversion process has a potential of achieving 20% overall efficiency. This concept is illustrated schematically in Figure 8.

3.1.3. Photo-Electrochemical Cells

Apart from Photovoltaic (PV) cells are another class of device - based on ‘photo-electrochemical’ reactions, which take place at light-sensitive electrodes. DC electricity generated (via dye-sensitized solar cells) can then be used to electrolyze water (as with PV cells). Alternatively, “photolysis” may be employed that illuminates an electrode to reduce water directly to hydrogen.

3.1.3.1. Dye-sensitized Solar Cells

Dye-sensitized solar cell (DSSC) (also known as a ‘Gratzel cell’ after the pioneer of the technology) is being used to improve the solar conversion efficiency by means of a subterfuge. A dye, usually ruthenium-based, is adsorbed on the surface of highly porous Titania, where it acts as an electron-transfer sensitizer. The coated titania then serves as the negative electrode in a photo-electrochemical cell. The dye-coated electrode is then assembled into a cell with a counter electrode, also made from conducting glass, and the intervening space is filled with electrolyte and the mediator (typically, the iodide_triiodide couple, I-I3-, dissolved in acetonitrile or some other organic solvent). A small amount of platinum is deposited on the counter electrode to catalyze reduction of the mediator.

The titania layer with a very high surface-to-volume ratio, results in light absorption that is 1000 times greater than for a dye monolayer on a non-porous, solid surface. Hence, the light-harvesting ability of a dye when adsorbed on a mesoporous film is greatly increased and results in an enhanced cell efficiency.
3.1.3.2. Direct Hydrogen Production

Photo-electrochemical (PEC) reactions may be employed to decompose water to hydrogen by combining a photovoltaic system and an electrolyzer into a single monolithic device. Resultant system has a higher overall system efficiency and a lower capital cost compared with a separated one, with the following advantages:

(i) the semiconductor immersed in an electrolyte forms the junction for charge separation of photo generated electrons;
(ii) the electrolyte is conformable and forms a strain-free junction; and
(iii) the direct conversion of light into hydrogen forms a wireless system without a separate electrolyzer.

3.1.3.3. Tandem Cells

A tandem cell can be developed to improve the efficiency of DSSCs, in several possible configurations. Besides the multi-junction design described above another is a series combination of a hydrogen PEC cell with a DSSC as shown in Figure 9. The photoactive electrode (e.g., TiO₂, WO₃ or Fe₂O₃) in the front cell absorbs the high-energy ultraviolet and blue light in sunlight to liberate oxygen, while radiation of longer wavelength in the green-to-red region of the spectrum passes to, and is absorbed by, the DSSC. The resulting boost in flow of electrons is then fed back to a counter electrode in the PEC cell to produce hydrogen. Photon-to-hydrogen efficiencies of up to 12% have been achieved with such a configuration.

\[ 2H_2O + 2hv \rightarrow 4H^+ + 4e^- + O_2 \]

Along with adenosine 50-triphosphate (ATP), NADPH is an important intermediary in the photosynthetic fixation of carbon dioxide. The protons and electrons react with carbon dioxide via these two mediators to produce sugars. The overall photo-biochemical process taking place in green plants is represented by:

\[ nCO_2 + 2nH_2O + ATP + NADPH \rightarrow n(CH_2O)nH_2O + nO_2 \]

3.1.3.4. Photo-biochemical Cells

Tandem cells and photosynthesis are parallel in nature as two photo systems connected in series are in process. First, light absorbed by chlorophyll acts as a mediator to oxidize water to oxygen, while in the second, electrons reduce the organic compound nicotinamide adenine dinucleotide phosphate (NADP) to a state generally designated NADPH.

Hawaii National Energy Institute has proposed one such system shown schematically in Figure 10. The main components are the following:

(i) production of algal biomass in an open pond;
(ii) an algal settling (harvesting) tank for activating the hydrogenase enzyme;
(iii) a fermentation tank for dark production of about one-third of the hydrogen [note: the tanks in (ii) and (iii) are combined in Figure 10];
(iv) a photo-bioreactor for completion of the hydrogen production from stored carbohydrates;
(v) a gas-separation unit (carbon dioxide from hydrogen); and
(vi) Treatment, storage and other support systems (not shown in Figure 10).

With the exception of PV cells, all solar-based water splitting methods discussed are still under development and a valid assessment...
about its benefits is quite difficult. Photovoltaic electricity is yet unaffordable, nor is the hydrogen as a fuel. However studies are underway to assess the potential available for its long term implementation as and when cheap technologies find its way into commercial applications.

3.2. Wind Hydrogen

Wind hydrogen is essentially the generation of hydrogen by electrolysis where in the electricity supplied is derived from wind turbines. Conceptually it is very promising as both the processes are renewable and nonpolluting.

Wind power penetration in the electrical grids has increased significantly and is still expanding even without the adoption of any appropriate energy storage technique, which would solve many problems, associated with the unstable performance of wind energy systems. Wind farms (WFs) may use some part of their energy production for storage by balancing their load with respect to the current wind conditions and the energy demand of the grid for on-site hydrogen production and distribution.

Schematic Wind Hydrogen concept is elaborated in Figure 11.

Solar radiation transmitted to the earth surface result in different thermal conditions causing wind movements. Kinetic energy of the wind is converted into mechanical work which in turn drives an electrical generator for the production of electricity. A group of these Wind Turbine generators including the auxiliary equipment, constitute a Wind Farm (WF).

WIND-HYDROGEN SYSTEM CONCEPT

Figure 11. [14]
Governments all over the world are supporting wind generated electricity toward a policy of reducing green house gas emissions, in terms of subsidies as well as concessions in the energy market for renewable energy sources [15]. Wind energy is now a recognized mature technology verified by its accelerated growth over the past decade.

Wind energy systems are termed 'grid connected' or 'stand alone', when connected in an energy transmission system or if operated as an independent power plant. Grid connected WFs may be on- or off-shore, ranging in varied capacities. Stand alone systems may provide for electricity in direct use or may feed a cluster of batteries in low demand periods.

### 3.3. Wind power for electrolysis

Wind potential of particular site is the first step towards the estimation of its electrical energy yield. Wind speed distribution expressed as a histogram is the key factor in determination of energy production. It is convenient to calculate these magnitudes in per hour units to obtain the results in commonly used units of energy. Equation (1) describes how the annual energy production from a wind turbine can be estimated at the generator output.

\[
WEY = \sum_{\theta=ci}^{co} (P_{\theta} \times \Delta H_{\theta})
\]

For each wind speed value \(v\) from the cut-in \(ci\) to the cut-out \(co\) phase of the WTG, the product of its corresponding power output \(P_{\theta}\) multiplied by the time \(\Delta H_{\theta}\) during which value \(v\) appears in a year is calculated. The sum of these products gives the annual energy production \(WEY\).

The electrolyser for hydrogen production is determined separately for each category of wind energy system. Currently the stand alone system integrated with an electrolyzer is the most commonly evaluated application. Electrolyser may be PEM or an alkaline type. The produced hydrogen is stored in a tank at the output pressure of electrolyser or compressed in a compressor at high pressure. A metal hydride device can also be used as a storage medium depending upon the load consumption of the system.

### 3.4. Solar Resource

Pakistan's area is about 800,000 sq. km; more than half of which is very sunny, as well as sparsely populated. Considering the area, which also has abundant water (River Indus, see map at Figure 12), along with high insolation and low-cloudiness, the potentially useable area for generating solar-hydrogen in Pakistan would exceed ~150,000 sq. km. Rough calculations show that less than 2% of this area could house more than 100 such plants (Solar Thermal) of 200 MW each, producing more than 20 GW, with ample prospects for growth [16].

Lutfi and Veziroglu [17] have proposed and analyzed a solar-hydrogen system for Pakistan; however the present study completely translates the solar potential available anywhere in Pakistan into hydrogen, with the help of NASA’s 10 year solar data [18]. Insolation Data is presented as “Monthly Averaged Clear Sky Insolation Incident on a Horizontal Surface (kWh/m\(^2\)/day)” at Annex ‘B’. Data has been obtained from Atmospheric Science Data Centre of NASA Surface meteorology and Solar Energy. The data is averaged on a 10 year record and tabulated according to Latitude/Longitude. Areas have also been identified along with the Insolation values.

#### 3.4.1. Data Inferences:

Average insolation was observed to range from 5-7 kWh/m\(^2\)/day, whereas about 30% area of Pakistan has insolation greater than 6 kWh/m\(^2\)/day, with the remaining ranging from 5-6 kWh/ m\(^2\)/day.
3.4.2. Calculation Methodology

Renewable Hydrogen Potential was calculated as per Administrative divisions (districts), province wise as below:

Average power per capita was taken as 48.4 watts based on population of 157,935,000 [19] and Total annual electricity consumption of 67,060,000 MWh/yr [3].

\[ P = \frac{E \times 1,000}{365.25 \times 24} \]  \hspace{1cm} (2)

\[ P = 48.4 \times \text{district population} \]  \hspace{1cm} (3)

Where

\( P = \) Power
\( E = \) Electricity Consumption in MWh/year

Solar PV system is considered to estimate power output and resulting Hydrogen generation. 6.4 acres of land (equivalent to 0.0259 sq km, refer to equation 4) is required for generating 1000 kW [20], thus land required for generating power for the population calculated in equation (3) results for each district.

Area of the district gives complete photovoltaic generation from its land by Equation (4)

\[ P_G = \frac{A}{0.0259} \]  \hspace{1cm} (4)

Where

\( P_G = \) Generation capacity (in kW)
\( A = \) Area in sq.km

The calculations are based on following assumptions:

a. Max of 5 sun hours daily
b. 52.3 kWh are required for 1 kg of Hydrogen
c. 39.41 kWh are obtained from 1 kg of hydrogen
d. Land area = 6.4 acres per 1000kW

Area required as a percentage of total land, for electric power demand for each province is reproduced below as Table 5:

Thus 0.45% of total land can fulfill the electric power requirement of the entire country. Connected Excel SPREAD sheets for each province are attached as Annex ‘A’, that translate into 3542 sq km (highlighted as yellow in Excel Sheets) that can provide for photovoltaic power generation. Total theoretical generation capacity amounts to 1.16x1011 kWh from complete land area.

3.4.3. Solar Hydrogen Production

Here an estimate is made of the hydrogen that can be produced by electrolysis followed by an estimation of the Electricity generation capacity of the produced hydrogen. Electrolysis is also connected with loss, so the hydrogen that is produced contains less energy than the amount of electricity used in the production. 52.3 kWh are needed to produce 1 kg of hydrogen, while that the energy content of hydrogen is only 39.41 kWh/kg (Higher Heating Value) [21]. Solar Hydrogen output,
based on 52.3 kWh for producing 1 kg of hydrogen, for each province in kilotonnes is given in Table 6. Similarly power output from resultant hydrogen @ 39.41 kWh/kg gives the kWh potential (Table 6):

<table>
<thead>
<tr>
<th>Province/Region</th>
<th>Kilotonnes of Solar Hydrogen</th>
<th>kWh potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Balochistan</td>
<td>1281</td>
<td>5.05E+10</td>
</tr>
<tr>
<td>2. Kashmir</td>
<td>49</td>
<td>1.93E+09</td>
</tr>
<tr>
<td>3. Northern Areas</td>
<td>258</td>
<td>1.01E+10</td>
</tr>
<tr>
<td>4. NWFP &amp; FATA</td>
<td>100</td>
<td>3.96E+09</td>
</tr>
<tr>
<td>5. Punjab</td>
<td>758</td>
<td>2.98E+10</td>
</tr>
<tr>
<td>6. Sindh</td>
<td>500</td>
<td>1.96E+10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2746</strong></td>
<td><strong>1.16E+11</strong></td>
</tr>
</tbody>
</table>

The above values can be used to assess the weekly/monthly or yearly potential for each area/location. The areas rich in solar resource are identified from the values attached as Annex ‘A’. District wise, Solar PV generation capacity is compared with the requirement (as described above) in Table 6. This indicates 0.117% of the total area that can fulfill the entire electrical energy needs (excluding the distribution, transmission losses etc).

In terms of land use for solar generation of hydrogen, 0.45% of the total land area if dedicated for solar hydrogen is sufficient for fulfilling the electrical energy requirements.

### 3.5. Wind Resource

Wind power potential in Pakistan is moderate, however yet it is the most promising renewable resource for power generation [16]. U.K. Mirza et al. have recommended wind as a long-term measure for envisaged road map to hydrogen economy. The current experience with wind technologies show that hydrogen may provide a much needed solution for managing intermittent nature of wind energy [22, 23].

### 3.6. Potential

Ahmed, Ahmad and Akhter have already identified the coastal areas and mountains as most suitable for wind energy utilization. Pasni and Jivani have been recommended as the most prospective sites for use with a 4 kW and 20 kW wind machines. The locations of Karachi and Ormara can utilize wind power throughout the year using 4 kW wind machines only [24].

This study is based on Ten year monthly data retrieved from Atmospheric Science Data Centre of NASA Surface meteorology and Solar Energy. The data is presented at Annex ‘B’ as “Averaged Wind Speed At 50 m Above the Surface of the Earth for Terrain Similar to Airports in m/s”. Mapping carried out by the author, with the help of NASA data reveals the wind class distribution and potential availability (in MW) as per Table 7 below:
Calculations are based on following assumptions:
Installed capacity per km$^2 = 5$ MW
Total land area of Pakistan = 877,525 km$^2$
Only land area included in calculations [25]

1.2 MW Vensys 62 already installed at Jhimpir, Thatta, Sindh by Zorlu Enerji Pakistan Limited [26] has been assumed for the calculation purposes. Detailed specifications are given in Table 9 below:

### Table 9: Vensys 62 Specifications [26]

<table>
<thead>
<tr>
<th>Power</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>1,200 kW</td>
</tr>
<tr>
<td>Cut-in wind speed</td>
<td>3 m/s</td>
</tr>
<tr>
<td>Rated wind speed</td>
<td>13.5 m/s</td>
</tr>
<tr>
<td>Cut-out wind speed</td>
<td>25 m/s</td>
</tr>
<tr>
<td>Survival wind speed</td>
<td>59.5 m/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rotor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>62 m</td>
</tr>
<tr>
<td>Swept area</td>
<td>3,019 m$^2$</td>
</tr>
<tr>
<td>Speed range</td>
<td>10-20 r/min</td>
</tr>
</tbody>
</table>

The 2.354 x 10$^5$ MW assessed potential from Fair to excellent wind resources mentioned at Table 5 translate into 45,017 tonnes of hydrogen, based on 52.3 kWh/kg of electrical input [21]. This when converted into electricity results into an yearly availability of 6.475 x 10$^{11}$ kWh. (Assuming 39.41 kWh from one kg of hydrogen). The calculations are summarized in Table 10:

### Table 10: Electrical potential from Wind generated Hydrogen

<table>
<thead>
<tr>
<th>MW potential</th>
<th>10 hr</th>
<th>52.3 kWh/kg</th>
<th>Electricity generation potential</th>
<th>Yearly potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>87752.5</td>
<td>87752</td>
<td>16778680.69</td>
<td>661247805.9</td>
<td>2.41355E+11</td>
</tr>
<tr>
<td>60812</td>
<td>608120</td>
<td>11627533.46</td>
<td>458241093.7</td>
<td>1.67258E+11</td>
</tr>
<tr>
<td>86875</td>
<td>868750</td>
<td>16610898.66</td>
<td>654635516.3</td>
<td>3.28942E+11</td>
</tr>
<tr>
<td>235439.5</td>
<td>45017112.81</td>
<td></td>
<td></td>
<td>6.7555E+11</td>
</tr>
</tbody>
</table>

The wind energy data provide an estimate of hydrogen potential from wind, based on wind sites that are categorized as Class 3 or better. With current technology, Class 4 and greater are considered economically viable, but for this study, Class 3 is expected to be viable in the near future and is included [26]. For Area wise details of wind speed, please refer to Annex “B”. The analysis used updated wind resource data that were available for several locations.

### 3.6.1. Major wind resource areas identified are:

#### 3.6.1.1. Southeastern Pakistan especially
- Hyderabad to Gharo region in southern Indus Valley
- Coastal areas south of Karachi
- Hills and ridges between Karachi and Hyderabad

#### 3.6.1.2. Northern Indus Valley especially
- Hills and ridges in northern Punjab
- Ridges and wind corridors near Mardan and Islamabad

#### 3.6.1.3. Southwestern Pakistan especially
- Near Nokkundi and hills and ridges in the Chagai area
- Makran area hills and ridges

#### 3.6.1.4. Central Pakistan especially
- Wind corridors and ridges near Quetta
- Hills near Gendari
- Elevated mountain summits and ridge crests especially in northern Pakistan
4. Discussion

Renewable Energy Technologies and resources have continuously been under research and discussion in Pakistan, however Renewable Hydrogen is still in infancy. Solar and wind resource potential have amply been studied and researched. MA Sheikh [27] has presented a review about conventional and Renewable energy scenario of the country in quantitative terms of supply and generation. Main emphasis has been given on presentation of Data about Renewable Energy installations in the country. Harijan K et al. [28] concludes that at most of the locations in the coastal areas of Pakistan especially in Sindh province, wind power is competitive to conventional grid connected thermal power, even without considering the externalities. Ullah et al. [29] has investigated wind power production potential of sites in South East Pakistan. Keti Bandar has been found to be Class 4 wind power site and suggests its suitability for wind farms and small, stand alone systems.

Various researchers have studied and recommended site specific proposals. In this regard Cholistan Desert has been selected for solar energy conversion processes by Sukhera [30], while Syed et al. [31] has selected Quetta as the highest solar radiation receiving city in Pakistan. Mirza UK et al. [32] has discussed the status and outlook of solar energy use in Pakistan. In this regard the role of R&D organizations in promotion of solar energy technologies and a brief description of projects have been made. Nasir and Raza [33] in [34] have assessed new and Renewable resource potential at four provincial capitals in terms of Solar and Wind resource.

Lutfi and Veziroglu [17] have recommended a Solar-Hydrogen System for Pakistan while UK Mirza et al. [35] have outlined a path for Hydrogen Economy in Pakistan. Uqaili MA et al. [36] has assessed the Hydrogen production from Wind Energy in Sindh. As discussed above, efforts have been underway to assess potential at selected locations and without establishing a link with the overall energy mix of the country. In order to realize a greater share of Renewable Energy in the broader Energy Mix, a bigger picture needs to be painted considering the potential anywhere and everywhere. The potential then has to be evaluated for realizing in terms of availability of energy to the end user, keeping in view the existing Energy infrastructure. Authors of this article, during the course of research have felt that a Birdseye view of the complete country is required to be pictured to identify the potential at various locations, followed by an optimization exercise to refine the options for Site specific Renewable Hydrogen production pertaining to each resource.

Conclusions and Recommendations

The study identifies the Hydrogen generation potential at R3 (Renewable Resource Rich) areas pertaining to Solar and Wind Resource. It has been found that whereas the region is quite rich in solar potential all along the 800,000 sq km stretch from the Northern mountainous region to the Southern coastline touching the Arabian Gulf, the realization is promising. Keeping in view the Energy gap (oil production and consumption) a fraction of the total potential if realized can fulfill the energy requirement. The data amply demonstrates the potential for each sub divisible area and can be employed for energy planning in future.

Wind resource, although limited with just 9% of the area with good to excellent wind availability, yet has tremendous potential for growth. Hydrogen Economy may be a distant future reality; however as a first step towards the Hydrogen pathways already identified elsewhere, it is imperative that Sustainable generation of Hydrogen for Pakistan must be appraised realistically. As imported fossil fuels form a major portion of Pakistan's Energy mix, hence the foreseeable Hydrogen-based Energy Infrastructure should preclude any of the existing fossil fuels. Focus in this study has therefore been on indigenous and sustainable supply of hydrogen, amounting to several thousand tonnes of hydrogen that can generate appreciable amounts of electricity.

Economic competitiveness, storage options and delivery & distribution are some of the other challenges that are to be addressed for effective headway towards the Hydrogen Economy. Following recommendations are suggested:
- Ambitious targets for Government sponsored “Stand-alone Renewable Energy” projects for rural areas.
- Cluster mushrooming of micro Renewable Energy projects all over the country, to enhance public confidence in Renewable Energy technologies.
- Sustained efforts for development of Renewable resources at National level.
- Duty-free import of elements/items pertaining to “Renewable Energy projects” such as small wind turbines, solar panels etc.
- Private entrepreneurs be encouraged for Renewable energy based generation of power and its linkage with the national grid. This will help in growth of industry based on RE technologies.
- Promotion of R&D in Hydrogen based projects in universities and increased level of public awareness and investment.
- Demonstration projects may be pursued with international organizations such as ICHET under the umbrella of UNIDO.
- Industries already producing hydrogen gas such as Oil Refineries, Food processing units be encouraged to integrate Fuel cell applications and vehicles in their premises.
- Government owned organizations such as Railways, Postal services and Ministries holding a huge fleet of vehicles may enter into an agreement with Hydrogen producing industry for running of fuel cell cars.
- Evolution of a Hydrogen Pathway and its modeling for future scenarios in collaboration with countries already making headway in Hydrogen Technologies.
- Timeline must be defined to correlate with gradual phasing out of fossil fuels, along with the contribution of Hydrogen and/or of other Renewable resources in the country's Energy Mix.
- Technocrats and Universities must be integrated with the “Energy modeling” process rather than confining the process to conventional, non-technical public representatives heading the Energy Ministry.
- Energy issues and decisions on its far-sighted development must not be handled as a political matter. Constitutional protection is ensued to keep the investors in RE technologies.

References


[34] Sahir MH et al, Assessment of new and renewable energy resources potential and identification of barriers to their significant utilization in Pakistan, Renewable and Sustainable Energy Reviews 12 (2009) 290-298.


1. Introduction

Pakistan, despite being a solar-rich country, faces the acute challenges of energy deficit. The country is running out of conventional energy sources very rapidly [1]. The current energy scenario reveals small share of renewable energy sources and utilization of alternative energy utilization approaches. Therefore it is crucial to devise a diverse energy strategy based on diminishing dependence on vulnerable energy supply channels and explores sustainable energy resources such as renewables [2]. Moreover, major electricity generation sources are conventional such as oil, gas, hydel and nuclear, and the share of renewable energy is less than 1% despite the fact that solar potential as compared to conventional energy resource. Pakistan spend 3 billion US dollars every year to import oil with annual growth rate of 1% [3]. Electricity generation by fuel source is illustrated in Figure 1.

![Figure 1](image)

The utilization of indigenous solar energy sources can lead to the path of sustainable energy development processes in remote areas. Installation of solar powered plants in coastal areas is a viable option for electricity generation at potentially low average cost and emissions [5]. The coastal belt of Pakistan extends to 1046 sq. km. Of this 930 km is from the Karachi to Gwader region in the
province of Baluchistan. The coastal areas of Pakistan has a population of about 10 million people [6]. Most of the areas in Pakistan receive intense solar radiation on largely-uninhabited land with little or no agricultural potential and, consequently, a low opportunity cost of utilization [5]. Solar energy can be utilized to meet the electricity and freshwater needs of coastal and adjacent village communities. The energy scarcity and costs can also be brought down by utilization of solar energy by local production of solar cells and by economies of scale. Concerted efforts are also made by the government for PV modules production with an expected capacity of 3MW/year are [7].

Moreover, it is well established that PV is a cost-effective technology, as its maintenance costs are negligible compared with fuels systems, and enjoys a long life, usually 20-30 years, which make them more reliable and attractive than fossil fuel systems [8, 9]. An important aspect of solar PV generation is the self-contained nature, which facilitates the process of energy generation in remote places, without incurring the expenditures on transmission systems, and eliminates transmission losses. Not much basic infrastructure is required for the development of these self-contained energy systems.

2. Methodologies

Solar photovoltaic cells powered electricity and desalination methods are used for the production of freshwater and electricity. Seawater can be pumped from sea to desalination plants at these coastal sites. Solar powered reverse osmosis process can produce one ton of freshwater from the average amount of solar energy i.e. 5 kWh falling on 1m$^2$ area [10]. By this way enough electricity for desalination process can be generated, as the land spaces are available around the costs at small or no cost. The large land spaces around the coastal areas can be utilized for installation of the solar panels. It can resolve the issues of land cost, which is considered a major cost item besides the cost of solar cells. The power produced from solar photovoltaic can be utilized for electricity generation and conversion of seawater to freshwater. Besides solar panels coal powered oxy-fuel combustion power plants can be installed to reduce solar panel costs. A substantial amount of fossil fuels can be saved and the resulting environmental emissions can be avoided if solar photovoltaic power generation is utilized in the industry and for power generation.

An important aspect of coastal solarisation process is its self-contained nature of solar energy generation system, which makes these systems free from transmission losses, theft and transmission line investment. The use of photovoltaic solar panels, can play a vital role by decentralizing electricity generation as well as eliminating the needs for transmission and distribution [1]. Large terrestrial photovoltaic power stations, about 100 MW capacity operate as stand-alone in the United States [11]. Solar PV stand alone micro projects along coasts could be planned instead of initiating any mega/macro PV project on commercial scale in a bid to attain self sufficiency and supply of basic amenities to communities living in vicinity of the costal areas. [4].

Another reason to propose solar option for the production of freshwater and electricity in coastal areas is the one time capital cost on installation of solar panels and zero fuel cost of solar electricity. According to figures, Ghazi Barotha Dam cost Rs. 118 million per MW (US$ 2.2 billion for 1400 MW) in comparison to solar thermal power system costing Rs. 70 million per MW due to saving in construction costs [12]. PV cells are usually sold in Pakistan at the rate of $ 7 per watt along with storage batteries, that is $70 million for a 10 MW plant, converters, and installation charges [13]. Concerted efforts have been made for increase in the efficiency of solar cell. Pakistan Council for Renewable Energy Technologies (PCRET) have achieved 13% efficiencies on 4 in. round plainer solar cell with single layer antirefection coating [14].

3. Viability of solar electricity

Pakistan is a solar-rich country, and is bestowed with high solar insolation and long sunny days most of the year. Pakistan is located in the sunny belt to take advantage of solar energy technologies [1, 9, 15, 16]. On average Pakistan receives 7-8 hours sunshine and solar radiation 5-8 kWh/m2/day over more than 95% of its area with 85% persistence factor [1, 4, 17]. Since photovoltaic electricity generation capacity is measured in square meters or kilometres, therefore it is assumed that half the coastal land, i.e. 523 square kilometres is available for its utilization. If 10% solar electricity utilization targets are set every year in the costal areas, especially in costal belt, it can produce huge amount of electricity. The amount of electricity production by 10% solar utilization in Pakistan is in Figure 2.
The annual mean values of insolation lie between 16.0-21.0 MJ/m$^2$/day with 19.0 MJ/m$^2$/day over most parts of the country [9, 18]. The greatest value of 15.5 MJ m$^2$/d occurs along the coastline of Baluchistan and the central part of Sind in the month of January, revealed in the January map of typical winter distribution of daily global insolation [19]. The south-western province of Baluchistan is particularly rich in solar energy [20] with an average daily global insolation of 19-20 MJ/m$^2$ a day (1.93-2.03 MWh per m$^2$ in a year) and annual mean sunshine duration of 8-8.5 hours. Such conditions are ideal for photovoltaic (PV) and other solar energy applications. The Energy Information Administration describes the daily solar energy potential for Pakistan as 5.3 KWh per m$^2$ (1.93 MWh per m$^2$ annually) [20].

Solar electricity costs are also optimized with the passage of time. The factory prices for single and polycrystalline silicon modules have decreased to US$2.90, and amorphous silicon modules are reportedly being sold at prices of $2.00-3.00 per watt, with the result that solar powered electricity costs in Pakistan are US $0.20 [7]. Moreover, the levelised cost of producing electricity from a 10 MW solar PV plant comes to 27.2 cents/kWh [13]. Intensive efforts are made for the local production of solar cells on economies of scale. National Institute of Silicon Technology, Pakistan has a capacity of assembling and manufacturing 3 million solar cells [21]. National Engineering and Science Commission (NESCOM) and Solar Energy Centre (SEC) are engaged on production of photovoltaic panels and designing of solar thermal appliances, respectively. Almost all the villages in and around the coastal belt can be electrified and freshwater can be made available through coastal solarisation development process.

The self-contained solar power generation systems are economical choice for Pakistan in terms of optimization of line losses and transmission line expenses. The current losses in the power generation system in Pakistan are 24% of the total power generated [8, 22]. These include losses incurred during transmission and distribution as well as due to theft. Pakistan suffers from a massive electricity shortage. The high electricity demand can be also being stabilized due to increase electricity generation capacity of coastal solarisation process. Solar photovoltaic is also a feasible option for Pakistan as these systems are free of fuel costs, maintenance costs, and are free from environmental emissions. Solar energy is a renewable form of energy that does not have any direct environmental impacts [15].

4. Prospects of freshwater production

Demand of freshwater is on rise in Pakistan due to high increase in population. Pakistan is one of the countries classified by United Nations Environment Program (UNEP) through its OCA/PAC regional seas program, as being particularly vulnerable to the effects of sea level rise [15]. The residents of coastal areas use saline water jeopardizing their health due to unavailability of freshwater in these areas. The development in the coastal areas is not possible without exploring new sources of fresh water such as desalination of seawater [23]. Moreover, freshwater supply levels in Baluchistan are not up to the mark. Most of the coastal areas are dry, and have low annual rainfall ratio. The goal of supplying freshwater to coastal communities and adjacent rural areas could not have been attained so far due to resource immobilization.

Solar desalination is an accepted method for converting brackish or saline water for drinking purposes. The option of Solar Photovoltaic (SPV) powered water pumps is also possible, because of the availability of average daily solar radiation greater than 3.5 kW/m$^2$ on a horizontal surface [24]. Pakistan Council of Scientific and Industrial Research (PCSIR) have already installed solar desalination plants at different locations. Freshwater production at the coastal and its adjacent areas is the most important factor for the sustainable development of the people living in and around these areas, to raise their standard of life or to increase their per capita energy consumption. The use of seawater on large scale may also lessen the vulnerability of seawater rise, which is rising gradually due to global warming process.
There is huge potential of freshwater at these coastal areas due to easy availability of input raw material of seawater and solar electricity. Seawater can be made available to the potential deserts by pumping it from sea, which can be desalinated to get freshwater. Therefore the amount of freshwater to be produced in the coasts if entire costal area of is utilized at 10% expansion each year is depicted in Figure 3.

Desalination of seawater is a feasible method for the sustainable development and management of freshwater resources in coastal and adjacent rural areas of Pakistan. Karachi nuclear power plant (KANUPP) is already operating a Sea Water Reverse Osmosis (SWRO) plant to meet its operating requirements [23]. The amount of freshwater produced every 10% costal land, as projected in figure 3 is considerable and leads to the development of costal areas and adjacent rural areas.

5. Results and discussion

The costal areas in Pakistan are lagging behind the developmental process due to lack of development initiatives. The arid and semi-arid areas of Baluchistan and Sindh have meagre surface flows and the people have to depend on underground porous and permeable rock reservoir [25]. Coastal (arid and semi arid) are particularly suitable for solar/wind combined system because of their high proportion of cloudless days [18]. The Baluchistan coastline extends over 750 kms from Hub, to the Gawadar bay. Karachi, Ormara, Jawani and Pasni are the potential coastal sites. The geographical view of the coastal sites is depicted in Figure 4.

Despite the exploration programme for supply of freshwater to these costal areas there is no substantial progress in power and water sector. Most of the groundwater is highly saline, and rainfall is the only source of freshwater source. The gravity of the situation can be realized from the fact that rainfall is the only source of freshwater source in deserts, which occurs mostly during monsoon from July to September [27]. The standard of life is poor due to lack of water storage facilities. The groundwater is mostly saline and unfit for human and livestock drinking [28]. Since on average 5 kWh power can be produced by 1 m² solar panel per day in most of the areas, it can be presumed that 1 kilometre square coastal land can produce 5 MW electricity and 833 tonnes of freshwater per kilometre square per day. Therefore million of tonnes of freshwater and mega watts electricity can be generated if the whole coastal belt is utilized. The availability of freshwater and electricity can change the fate of these coastal communities thereby increasing their standard of living.

6. Suggestions and recommendations

- Increase in the utilization of solar energy for the production of freshwater and electricity in the coasts.

- Survey of all the coastal areas for development coastal plans in respective areas.

- Establishment of coastal development authorities to cater the construction of solar energy power and desalination plants in these areas on national, provincial and regional levels the coastal development projects.

- Feasibility studies of all costal areas for the development of coastal development projects.
- Allocation of funds in the development budgets for the supply of solar powered freshwater and electricity in coastal areas.
- Carrying out environmental assessment for estimation of environmental costs saving due to solar powered processes.
- Indigenous production of high efficiency solar cells and to benefit from the economies of scale.

- Intensive monitoring of coastal development plans at implementation stage to make them successful.
- Launching pilot coastal development projects.
- Further research on coastal solarisation for better outputs and less costs.

Conclusions

Coastal Development Authority can be established to initiate the process of electricity generation and freshwater production over all the coastal areas. The developed methodology can be implemented in the coastal areas of Karachi, Gawadar, Pasni, and Jawani for the supply of electricity and freshwater to the communities living in and around these coasts. The proposed costal development process may change the fate of the costal communities and would provide them the basic necessities of life. The development process could enhance the national electricity and freshwater capacity and contribute to diminishing the dependence on fossil-fuelled economies. A fascinating aspect of desert development model is the development of indigenous renewable energy sources for the supply of freshwater and electricity in deserts. The ongoing process can promote sustainable activities in the coasts, creation of commercial activities and is accompanied with environmental and economical changes.

Acknowledgement

Special thanks are offered to Prof. Ali. Sayigh for his encouragement and Prof. Yang Zhang for his guidance for to publish the research paper.

References


Abstract

In this research, the effects of different cultivation sizes (0.1 to 2, 2.1 to 5 hectares, and over 5 hectares) on indices of energy such as energy ratio (ER), energy productivity (EP), and net energy gain (NEG) for irrigated wheat crop of production year 2008-2009 in Silakhore plain located in west of Iran, have been studied. Considering the size of statistical population, size of samples were determined through Cochrane procedure, and hence 150 questionnaires were distributed among irrigated wheat crop producers. The data obtained were analyzed, based on completely randomized design. Results showed the ER of irrigated wheat (grain + straw) as whole, and for grain, and for straw separately to be 3.95, 2.74, and 1.2 respectively. Analysis of variance of variables under surveillance (energy indices) against different cultivation sizes showed that for the plain under study the cultivation area sizes of 0.1 up to 2 hectares can be recommended, if the whole crop is to be harvested and used.

Keywords: Cultivation size, Energy productivity, Energy ratio, Net energy gain, Iran.

1. Introduction

Role of energy on development and performance of agricultural sector is undeniable. Nowadays the main effort in the world is to decrease and minimize energy consumption in performing of different processes (Sabzvari, 2009). Although the agricultural sector of Iran has lower share of energy consumption in comparison with industrial sector, but with a brief scrutiny, it will be found that input rates of energies in this sector are very high and considerable. Unfortunately, because of abundance and availability of relatively cheap energy, no appreciable attention is paid for its utilization, and optimization of its consumption in Iran (Mohammadian, 2007).

Since application of any technology in agriculture is dependant on energy resources, therefore surveillance of energy cycle as a suitable index for understanding technological transformation is necessary. This subject is of especial importance in evaluating the trends of technological changes in agriculture. Other advantage is that, through this surveillance different forms of energy inputs, such as land, water, and labor force which are used in different activities, can be evaluated (Koocheki, 1996).

Energy evaluation indices are as instruments which provide possibilities for comparison of systems and study of their elements. By studying of energy indices, different stages of crop production, and comparisons of energy efficiency on production of different crops with different procedures in many regions, can be surveyed (Pashaii, 2008).
In connection with land-size and its effects on costs and economic performance, different viewpoints have been expressed. Some believe that, smaller the farm size, its management will be more economical, its costs decrease, and economic yield of farm increases. Some researchers, in opposition, think that, in larger farms, use of large-sized machines in lower cost which is due to lower fixed costs per unit area, causes the final cost of produced crop to decrease and economic yield of farm to increase. There is a third group who reject both of above mentioned views, and believe in that, both of small and large sizes result in decreasing of economic yield. Therefore the highest productivity can be achieved only on a specific farm size, and so any changes towards either of smaller or larger sizes would decrease economic yield (Assuncao 2003, Koester 2003, Temel 2000).

This study has been done in Silakhore plain to recognize field-crop production patterns, and common practices, with the aim to determine share of each input for energy consumption, and to calculate energy indices, and as well to study the effect of different farm sizes (land sizes) on energy indices. For surveillance of energy circulation, wheat crop was selected among field crops, and due field investigations were carried out. After evaluation of obtained indices, some guidelines to improve utilization of energy resources, and power use are suggested for the region.

2. Materials and Methods

Geographic location of study was Silakhore plain (between townships of Broujerd and Dorood) in Lorestan province, west of Iran. Time span for data collecting was from late March till late July 2007. Statistical population was irrigated wheat growers of Silakhore plain. To obtain the statistical sample size, Cochrane equation is used as follows (Mansoorfar 1995, Cochrane 1997).

\[
 n = \frac{N(t,s)^2}{Nd^2 + (t.s)^2} 
\]  

(1)

Where; \( n \) = Size of sample, \( N \) = Acceptable confidence coefficient (on assumption of normality of cited property distribution, is obtained from students t distribution table), \( S^2 \) = Estimates of variance for cited property (\( S \) is standard deviation of cited property), and \( d \) desired probabilistic precision.

Since the value for variance of cited property among the above parameters is not foreknown, so a tentative small scale study was conducted to search for any probable deficiencies, and to estimate an approximation of cited property. After analysis of data on primary sampling and obtaining approximate values of statistics on cited property (farm size) within population, the size of main sample was calculated using Cochrane equation. The main sample size, for irrigated wheat growers, calculated to be 142 farmers. To increase the precision, number of farmers in the sample increased up to 150.

Considering; the informations gathered from Agricultural Jahad Organization of Lorestan province, and from its townships management offices in Broujerd and Dorood, and also by analyzing the data obtained from primary sample for irrigated wheat, different cultivation size ranges chosen (in three levels) were 0.1 up to 2, 2.1 up to 5, and 5.1 hectares and over. Based on above mentioned procedure, through random sampling and considering decent relations, questionnaires were distributed among wheat producers of Silakhore plain.

To calculate energy consumption during agricultural crop production process, all flow inputs, and also total produced main crop and byproducts should be evaluated at first stage. Then the rate of energy consumption can be calculated through multiplication of energy equivalent coefficients per unit input or output, by quantity of consumed input or produced output. Obviously in the studies, different coefficients, in accordance with prevailing conditions, are used, that some of which are referred to, in Table 1.

In addition to use of energy equivalents from Table 1, equation 2 is used for calculating of energy rate for manufacture and depreciation, and also equations 3 to 6 are used for fuel consumption. Energy consumption for irrigation has been calculated using equation 7.

Depth of wells, their water discharge rates, irrigation frequencies and time periods for irrigated wheat have been considered in calculation of water consumption per hectare of the crop. Indirect energy and consumed energy for trenching of canal network also included in the calculations.
**Equation (2)**

\[
\frac{\text{Machine Mass (kg)}}{\text{Estimate Life (hr)}} \times \frac{\text{Machine Operation (hr)}}{\text{Equivalent Energy of Manufacture / kg}}
\]

**Equation (3)**

\[
\text{Draw - bar Power (kW)} = \frac{\text{Draft (kN)} \times \text{Travel Speed (km/h)}}{3.6}
\]

**Equation (4)**

\[
\text{Traction and Transmission Coefficient (T & T)} = \frac{\text{Draw - bar Power}}{\text{P.T.O Power}}
\]

**Equation (5)**

\[
\text{Engine Load} = \frac{\text{P.T.O Power (Useful)}}{\text{P.T.O Power (Maximum)}}
\]

**Equation (6)**

\[
\text{Fuel Consumption (lit / h)} = \frac{\text{Useful P.T.O Power (kW)}}{\text{Value of Fuel Productivity (kWh / lit)}}
\]

**Equation (7)**

\[
E = \frac{\rho g h Q}{\varepsilon_1 \varepsilon_2}
\]

Where:

- **E** = Energy requirement for pumping (J/ha)
- **\(\rho\)** = Water density (1000 kg/m³)
- **g** = Acceleration of gravity (9.81 m/s²)
- **h** = Total dynamic head including friction losses (m)
- **Q** = Water consumption rate (m³/ha)
- **\(\varepsilon_1\)** = Pump efficiency which is a function of vertical elevation head, velocity, and discharge rate of water. Usually 0.7 to 0.9 is acceptable.
- **\(\varepsilon_2\)** = Efficiency of energy and power conversion, which for electric motors and for diesel engines can be in the range of 0.18 up to 0.22, and 0.25 up to 0.3 respectively.

ER, EP, and NEG were calculated for irrigated wheat using equations (8 to 10) as follows (Demircan 2006).

**Equation (8)**

\[
\text{ER} = \frac{\text{Output Energy}}{\text{Input Energy}}
\]

**Equation (9)**

\[
\text{EP} = \frac{\text{Crop Weight Yield}}{\text{Input Energy}}
\]

**Equation (10)**

\[
\text{NEG} = \text{Output Energy} - \text{Input Energy}
\]

Before proceeding to statistical analysis of quantitative data, which obtained from distributed questionnaires, tests for normality of data and their variance coordinations were done, and some appropriate modification was done where needed. Then for all quantified properties, variance analysis based on completely randomized design was carried out on three cultivation area sizes as treatments, and 40 to 60 farmers as replicates, using SPSS 16 software. Comparison of means between treatments at 5% probability level carried out by Tukey test, and results, have been indicated, together with relevant main means, or in figures, in the form of statistical rankings (a, b, c, ...etc). Figures have been drawn with aid of the EXCEL 2007 software.

**Results and discussion**

Total input energy to the system, and share of each input have been determined with regards to values of equivalent energies for; manufacture & depreciation of machinery, fuel consumption, seed & chemical fertilizers, irrigation, human power, and transportation.
As can be observed in Tables 2 and 3, the highest rate of energy consumption belongs to the input of seed, fertilizer & chemical toxins with 46.45 percent of total energy. The highest energy consumption for different cultivation sizes also belongs to same energy input. This input for cultivation size above 5 hectares is relatively higher than other area sizes. The reason for this may be related to higher consumption of fertilizers & chemical toxin in larger farms. According to the tables, input of fuel, irrigation, and transportation with 30.18, 18.27, and 1.1 percents respectively stand in subsequent rankings.

In case of irrigation, mean depth of wells in the region, discharge rate of each well, mean irrigation time period, and number of irrigations per season, estimated to be 62m, 20 lit/s, 7 hr, and 3 respectively. Considering energy consumption for canal ditching (917 MJ/ha), and also direct energy (2828 MJ/ha) & indirect energy (565.6 MJ/ha) for water pumping, the mean of total equivalent energy of irrigation in Silakhore plain calculated to be 4310.61 MJ/ha. Generally the irrigation energy increase with increase in area size. Since in some parts of Silakhore plain, water of canal network is used therefore the calculated water pumping energy is relatively lower, as compared to other research reports.

Highest fuel energy consumption belongs to area size group of 2.1 up to 5 hectares, and the lowest belong to 0.1 up to 2 hectares.

Finally cultivation area size of above 5 hectares had the highest share of total energy consumption rate (25078.81 MJ/ha), and area size group of 0.1 up to 2 hectares had the lowest rate (22134.15 MJ/ha).

As it can be seen from Tables 4 and 5, 70.32 per- cent of total equivalent energy belongs to grain, and 29.68 percent is that of the straw. Cultivated area above 5 hectares had the highest output energy of 72.1 GJ/ha, and area size category 0.1 to 2 hectares had the lowest rate (22134.15 MJ/ha).

As can be observed in Tables 2 and 3, the highest rate of energy consumption belongs to the input of seed, fertilizer & chemical toxins with 46.45 percent of total energy. The highest energy consumption for different cultivation sizes also belongs to same energy input. This input for cultivation size above 5 hectares is relatively higher than other area sizes. The reason for this may be related to higher consumption of fertilizers & chemical toxin in larger farms. According to the tables, input of fuel, irrigation, and transportation with 30.18, 18.27, and 1.1 percents respectively stand in subsequent rankings.

<table>
<thead>
<tr>
<th>TABLE 2. Mean energy of inputs, and percent share of each input within the total energy consumption per hectare of irrigated wheat production.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Machinery manufacture &amp; depreciation</td>
</tr>
<tr>
<td>Fuel consumption</td>
</tr>
<tr>
<td>Irrigation</td>
</tr>
<tr>
<td>Seed, fertilizer, and chemical toxins</td>
</tr>
<tr>
<td>Human power</td>
</tr>
<tr>
<td>Transportation</td>
</tr>
<tr>
<td>Total sum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 3. Share of each input within energy consumption rate per hectare of irrigated wheat crop for different cultivation sizes.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cultivation size (ha)</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Input</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Machinery manufacture &amp; depreciation</td>
</tr>
<tr>
<td>Fuel consumption</td>
</tr>
<tr>
<td>Seed, fertilizer, and chemical toxins</td>
</tr>
<tr>
<td>Irrigation</td>
</tr>
<tr>
<td>Human power</td>
</tr>
<tr>
<td>Transportation</td>
</tr>
<tr>
<td>Total sum</td>
</tr>
</tbody>
</table>

As can be observed in Tables 2 and 3, the highest rate of energy consumption belongs to the input of seed, fertilizer & chemical toxins with 46.45 percent of total energy. The highest energy consumption for different cultivation sizes also belongs to same energy input. This input for cultivation size above 5 hectares is relatively higher than other area sizes. The reason for this may be related to higher consumption of fertilizers & chemical toxin in larger farms. According to the tables, input of fuel, irrigation, and transportation with 30.18, 18.27, and 1.1 percents respectively stand in subsequent rankings.

<table>
<thead>
<tr>
<th>TABLE 4. Output energy per hectare of irrigated wheat.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Grain</td>
</tr>
<tr>
<td>Straw</td>
</tr>
<tr>
<td>total</td>
</tr>
</tbody>
</table>

As can be observed in Tables 2 and 3, the highest rate of energy consumption belongs to the input of seed, fertilizer & chemical toxins with 46.45 percent of total energy. The highest energy consumption for different cultivation sizes also belongs to same energy input. This input for cultivation size above 5 hectares is relatively higher than other area sizes. The reason for this may be related to higher consumption of fertilizers & chemical toxin in larger farms. According to the tables, input of fuel, irrigation, and transportation with 30.18, 18.27, and 1.1 percents respectively stand in subsequent rankings.
Highest energy output of straw (36.40 GJ/ha) belonged to cultivation size of 0.1 to 2 hectares, and the lowest (8.60 GJ/ha) to that of over 5 hectares. The reason for the highest share of straw energy in small-sized cultivation (0.1 to 2 ha) is that these farmers use the straw as a part of animal feed, but in contrast, some farmers of over 5 hectare cultivation size, leave the straw in farm during crop harvesting. Therefore output energy of straw within cultivation sizes of above 5 hectares is low.

Finally, total output energy (grain + straw) for cultivation area size of 0.1 to 2 hectares with 96.20 GJ/ha was the highest. The reason for this may be timely accomplishment of farming operations and use of manure in small farms in addition to straw utilization. Cultivation area sizes of 2.1 to 5, and over 5 hectares stand in subsequent ranking with outputs of 93.12, and 80.70 GJ/ha respectively.

Energy indices were calculated, based on results obtained from input and output energies, and shown in Table 6 energy ratio (ER) of output to total inputs (for grain plus straw) in Silakhore plain, as shown in the Table 6 was 3.95. As compared to other studies done in Ardabil (Shahin 2008), Maraghe (Mashhoody 2008), and Mahyar plain of Shahreza (Sadeghi 2009), where the ER for irrigated wheat were 3.13, 3.17, and 1.64 respectively, this study showed fairly good ER.

Results of variance analysis for; ER, EP, and NEG in different cultivation area sizes are given in Table 7. The table shows that; ER, EP, and NEG had no significant differences for different cultivation sizes on grain and or on straw separately, but on whole crop (grain + straw) these variables had significant differences at 1% probability level for different cultivation sizes.

Comparison of mean ER for different cultivation sizes (Figure 1) indicated no significant differences on grain, and or on straw as considered separately.

Mean ER of whole crop (grain + straw) for cultivation size of 0.1 to 2 hectares was 4.458 which had significant difference as compared to that of cultivation size over 5 hectares with ER of 3.244. Although cultivation area size of 2.1 to 5 hectares with ER of 3.91 showed no significant difference as compared to other cultivation sizes.

### Table 5. Output energy of different cultivation sizes in irrigated wheat crop production.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (kg/ha)</th>
<th>Energy equivalent (GJ/ha)</th>
<th>Percent of total energy equivalent</th>
<th>Yield (kg/ha)</th>
<th>Energy equivalent (GJ/ha)</th>
<th>Percent of total energy equivalent</th>
<th>Yield (kg/ha)</th>
<th>Energy equivalent (GJ/ha)</th>
<th>Percent of total energy equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain</td>
<td>4068.33</td>
<td>59.80</td>
<td>62.17</td>
<td>4258</td>
<td>62.59</td>
<td>67.22</td>
<td>4905</td>
<td>72.10</td>
<td>89.35</td>
</tr>
<tr>
<td>Straw</td>
<td>2911.67</td>
<td>36.40</td>
<td>37.83</td>
<td>2442</td>
<td>30.53</td>
<td>32.87</td>
<td>687.5</td>
<td>8.60</td>
<td>10.65</td>
</tr>
<tr>
<td>total</td>
<td>6980</td>
<td>96.20</td>
<td>100</td>
<td>6700</td>
<td>93.12</td>
<td>100</td>
<td>55.92</td>
<td>80.70</td>
<td>100</td>
</tr>
</tbody>
</table>

### Table 6. Energy indices per hectare of irrigated wheat cultivation.

<table>
<thead>
<tr>
<th>Index</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy ratio (ER) for grain</td>
<td>Dimensionless</td>
<td>2.743</td>
</tr>
<tr>
<td>Energy ratio (ER) for straw</td>
<td>Dimensionless</td>
<td>1.205</td>
</tr>
<tr>
<td>Energy ratio (ER) for (grain + straw)</td>
<td>Dimensionless</td>
<td>3.948</td>
</tr>
<tr>
<td>Energy productivity (EP) for grain</td>
<td>kg/MJ</td>
<td>0.1866</td>
</tr>
<tr>
<td>Energy productivity (EP) for straw</td>
<td>kg/MJ</td>
<td>0.0964</td>
</tr>
<tr>
<td>Energy productivity (EP) for (grain + straw)</td>
<td>kg/MJ</td>
<td>0.2830</td>
</tr>
<tr>
<td>Net energy gain (NEG) for grain</td>
<td>MJ/ha</td>
<td>40429.4</td>
</tr>
<tr>
<td>Net energy gain (NEG) for straw</td>
<td>MJ/ha</td>
<td>3440.8</td>
</tr>
<tr>
<td>Net energy gain (NEG) for (grain + straw)</td>
<td>MJ/ha</td>
<td>67454.4</td>
</tr>
</tbody>
</table>

### Table 7. Variance analysis of ER, EP, and NEG for three cultivation sizes.

<table>
<thead>
<tr>
<th>Source of variations</th>
<th>Degree of freedom (DF)</th>
<th>ER</th>
<th>Mean Squares (M.S)</th>
<th>NEG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grain</td>
<td>Straw</td>
<td>Grain + Straw</td>
</tr>
<tr>
<td>Cultivation size</td>
<td>2</td>
<td>0.951ns</td>
<td>0.049ns</td>
<td>17.783**</td>
</tr>
<tr>
<td>Error</td>
<td>147</td>
<td>0.749</td>
<td>0.014</td>
<td>2.328</td>
</tr>
<tr>
<td>C.V.</td>
<td>31.54</td>
<td>72.65</td>
<td>38.64</td>
<td>29.35</td>
</tr>
</tbody>
</table>

** significant at 1% probability level.
* significant at 5% probability level.
s Not significant
As it can be observed from Figure 2, comparison of mean EPs of whole crop (grain + straw) for different cultivation sizes, indicates that, the sizes of 0.1 to 2, and 2.1 to 5 hectares have significant difference with that of over 5 hectares. Highest mean EP of 0.32357 kg/MJ belongs to size of 0.1 to 2 hectares, and the lowest (0.22489 kg/MJ) to over 5 hectares. Lower EP for cultivation size of above 5 hectares may be related to uselessness of straw for some farmers.

Comparison of mean NEG of whole crop (grain + straw) between cultivation sizes of 0.1 to 2 hectares (74066 MJ/ha) and that of over 5 hectares (55618 MJ/ha) showed significant difference. However NEG of cultivation area size of 2.1 to 5 hectares (68989 MJ/ha) did not show significant difference with that of other area sizes (Figure 3).

Correlation coefficient of ER with EP and NEG for irrigated wheat obtained to be positive and significant at 1% probability level. Also correlation coefficients between EP and NEG estimated to be positive and significant at 1% probability level.

In case of whole crop (grain + straw) harvesting, the most appropriate cultivation area size of irrigated wheat for the region recommended to be 0.1 up to 2 hectares. However, should solely the grain yield targeted, the area size of over 5 hectares is advantageous.

I. Ranjbar, Y. Ajabshirchi, & A. Gobadifar / ISESCO Science and Technology Vision - Volume 6, Number 10 (November 2010) (8894)

Recommendations

The following items can be suggested to improve energy indices in Silakhore plain:

1- Determining appropriate rate of seeding
2- Determining appropriate rate of fertilizer application based on soil test results.
3- Management of irrigation practices and timely farm operations.

Acknowledgement

The authors are highly grateful to the University of Tabriz and as well to the Islamic Azad University, Takestan Branch, Iran, for giving all types of support in conducting this research.
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