Assessment of Solar Energy with Respect to Bihar: A Case Study

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ABSTRACT

A well-known statistical simulation method known as ARIMA was employed in this article to forecast the total daily solar energy output till the year 2040. The ARIMA model’s attractiveness resides in its simplicity, solar energy, which is created by sunshine, is a non-depleting renewable energy source that is unpolluting. The amount of solar energy that enters the earth every hour is sufficient to supply all of the energy needed for a year. In the modern period, we required electricity constantly. This solar energy is produced for use in commercial, industrial, and residential settings. It is simple to collect energy from direct sunshine. As a result, it is incredibly effective and does not pollute the environment. In this paper, we evaluated solar energy from sunlight and forecasted the sun radiation till 2040 through ARIMA Model. The model is created using sophisticated statistical approach. Error analysis is performed to demonstrate the effectiveness of the proposed method. The developed model’s accuracy can be improved in future research.

Key words: Arima, Forecast, Sunshine, Statistical approach.

Introduction

Regarding many domains, the term “energy” has several diverse meaning. We all rely heavily on energy to do our everyday tasks because it is the capacity to conduct work (Schlor, Hogler, et al., 2012). Energy cannot be generated or destroyed but can only be changed from one form to another, according to the rule of conservation of energy. Energy never runs out; it merely shifts from one form to another (Rashidi et al., 2012). Energy is inextricably related to the century’s economic progress and growth. The usage of energy has become a key component of current development programs that have prioritized rapid economic expansion (Khan et al., 2019). Most of the energy utilized for labour in many nations comes from non-renewable sources, such as gasoline, nuclear power, coal, and natural gas (Shrish Bajpai et al., 2016). Renewable resources have a nearly endless lifespan but have a finite amount of energy per unit. Biomass, Hydropower, Geothermal, Wind, and Solar are the five main categories of renewable energy sources. The majority of energy utilized for work in many nations comes from non-renewable energy sources, such as gasoline, nuclear energy, coal, natural gas, etc. (Shrish Bajpai et al., 2016). The average daily energy usage of a person in India is still only 18 kWh, according to data from 2020 on energy consumption (BP) and population (PRB). But with 77 kWh, China is already consuming more energy than the rest of the globe and will in a few decades use roughly the same amount as industrialized nations do. In 2020, the world’s population of around 7.7 billion people
consumed 71.4 GJ of primary energy per person. It indicates a 58 kWh daily primary energy usage average per person across the globe. The past 10 years are now more significant for the per-watt cost of solar energy devices due to the diminishing availability of renewable energy sources. It will undoubtedly become economically viable in better technology in terms of both price and applications in the upcoming years. The earth receives sunlight on a daily basis (around 1366W). This energy source can be used endlessly and is totally free. The primary advantage of solar energy over other conventional power sources is that it can be produced using the tiniest photovoltaic (PV) solar cells, which allow sunlight to be directly transformed into solar energy. Many research projects have been conducted to combine the Sun’s energy conversion process by creating solar cells, panels, and modules with high conversion rates. The greatest benefit of solar energy is that it is inexpensive, accessible to the general public, and abundant when compared to the cost of various fossil fuels and oils throughout the previous 10 years. Moreover, compared to traditional energy production technology, solar energy requires a lot less human costs. Any nation or state needs energy in order to prosper economically. The situation is the same in the state of Bihar in eastern India. The state has experienced encouraging growth in recent years and is poised to make major economic progress in the next years. At this point, Bihar needs to fullfill the power requirement with a strong political resolve in order to advance its progress. However, due to its position, climate, and geographical features, Bihar possesses a number of natural and strategic advantages. In the upcoming years, the state’s strong solar energy potential may serve as its primary energy source. Since Bihar is predominantly an agriculturally based state, it has a significant potential for creating agricultural waste that might serve as an excellent starting point for the production of energy. Additionally, the state’s northern regions have excellent potential for small-scale wind and hydropower. There are 45,098 villages in the 94,163 square kilometre state of Bihar, which has a population of 82.9 million. 12.6 million Households, or almost 89 percent of the population, live in rural areas. The State has a population density of 881 people per square kilometer, which is higher than the national average of 312. Bihar has several resources particularly fertile soils, favourable climate, and enough ground water for the cultivation of a wide range of crops. Bihar has experienced more growth in the past ten years as a result of these innate natural qualities and a strong political resolve. The post-bifurcation electricity availability situation in Bihar in 2000 became extremely precarious because major power facilities were located in the newly formed State of Jharkhand. Under the current context of constrained demand, the peak capacity of Bihar’s power system is approximately 1,500 MW, while the available capacity is approximately 950 MW. All consumer categories experience widespread power restriction as a result of the scenario. Currently, just 6% of homes and 50% of the communities in the country have access to electricity state. Demand for electricity is currently 95 units per person per year in Bihar (compared to 717 units nationally). In India, the annual growth rate of electricity is thought to be around 8%. Bihar’s estimated percentage is 14%. The projections are based on optimistic program acceleration for domestic household electrification, which results in a domestic consumption growth rate of 27% compounded annually. The energy requirement has been calculated to be 2.5 times greater than what it was in 2004-2005 for normal hours and peak load growth. Various periods of the year, scientists measure the amount of sunshine that strikes particular regions. The amount of sunshine that strikes areas with comparable climates and latitudes is then estimated. Total radiation on a horizontal surface or total radiation on a surface that tracks the sun are the two common ways that solar energy is measured. Kilowatt-hours per square meter (kWh/m²) are frequently used to express radiation statistics for solar electric (photovoltaic) systems. Watts per square meter (W/m²) can also be used to indicate direct estimations of solar energy. British thermal units per square foot (Btu/ft²) are the standard unit of measurement for radiation data for solar water heating and space heating systems. Efficiently and rapidly deliver your material based on the global distribution map annual solar radiation the average annually amount of PV energy that can be generated is 640-2400 kWh/m² depending on areas. The model is created using sophisticated statistical approach Time series approaches are highly studied in forecasting and are constantly being improved. ARIMA, which stands for Autoregressive Integrated Moving Average, is one of the most well-studied models in this field. The reasons for the popularity are the ease of installation and the usage of the well-known Box-Jenkins methodology. This
ease of use is due to the linear correlation assumption between past and present time series values.

**Bihar**

There are 45,098 villages in the 94,163 square kilometer state of Bihar, which has a population of 82.9 million. 12.6 million households, or almost 89 percent of the population, live in rural areas. Compared to the national average of 312 people per square kilometer, the State has a population density of 881 people. For the production of a wide range of crops, Bihar is blessed with a very fertile soil, favourable weather conditions, and ample groundwater. Due to these innate natural advantages and a strong political resolve, Bihar has experienced faster growth than the rest of the country during the past ten years. During the period 2000-2010, the state’s decadal growth rate was roughly 28.23%, compared to the national average of 21.54. However, about 95% of rural homes still rely on kerosene as a source of lighting, which is a large proportion when compared to that in metropolitan regions (40%) according to the 2001 census. In Bihar, which ranks second on the list of states with the least electrification after Jharkhand, transmission cables have still not reached 50% of the inhabited villages, according to the Rural Electrification Corporation Ltd. Report 2004.

**Materials and Methods**

- Autoregressive integrated moving average (ARIMA) models predict future values based on past values.

- ARIMA makes use of lagged moving averages to smooth time series data.
- Autoregressive models implicitly assume that the future will resemble the past.

**FLOWCHART OF ARIMA MODEL**

**Annual solar radiation forecasting using B-J methodology**

ADF in level form

<table>
<thead>
<tr>
<th>Test</th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.683357</td>
<td>0.0031</td>
</tr>
<tr>
<td>Test critical values:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% level</td>
<td>-4.226815</td>
<td></td>
</tr>
<tr>
<td>5% level</td>
<td>-3.536601</td>
<td></td>
</tr>
<tr>
<td>10% level</td>
<td>-3.200320</td>
<td></td>
</tr>
</tbody>
</table>


Here p-value is significant at 5 per cent.
This data set is stationary in level form. So here ARMA model is utilised for forecasting.

# Correlogram in level for identification of best ARMA (p, q) model.

The Correlogram suggest four ARMA model: ARMA (1, 1), (1, 2), (1, 3) and (1, 4). After estimating all this models we forecast the model with satisfying all the necessary criterion. We select one best model on the basis of higher R-square, lower Akaike
info criterion and lower Schwarz criterion.

# Result of ARMA (1, 1) estimates:
Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23  Time: 20:52
Sample: 1984 2021
Included observations: 38
Convergence achieved after 11 iterations
Coefficient covariance computed using outer product of gradients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>4.791128</td>
<td>0.243966</td>
<td>19.63850</td>
<td>0.0000</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.952984</td>
<td>0.075128</td>
<td>12.68482</td>
<td>0.0000</td>
</tr>
<tr>
<td>MA(1)</td>
<td>-0.501876</td>
<td>0.193038</td>
<td>-2.599882</td>
<td>0.0137</td>
</tr>
<tr>
<td>SIGMASQ</td>
<td>0.018697</td>
<td>0.004317</td>
<td>4.331515</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

R-squared | 0.556517 | Mean dependent var | 4.820263 |
Adjusted R-squared | 0.517386 | S.D. dependent var | 0.208086 |
S.E. of regression | 0.193038 | Akaike info criterion | -0.894732 |
Sum squared resid | 57.290000 | Schwarz criterion | -0.722355 |
Log likelihood | 20.99991 | Hannan-Quinn criter. | -0.834020 |
F-statistic | 14.22195 | Durbin-Watson stat | 1.732040 |
Prob(F-statistic) | 0.000004 |

# ARMA (1, 2) estimates:
Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23  Time: 20:54
Sample: 1984 2021
Included observations: 38
Convergence achieved after 21 iterations
Coefficient covariance computed using outer product of gradients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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</thead>
<tbody>
<tr>
<td>C</td>
<td>4.798315</td>
<td>0.139276</td>
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<td>AR(1)</td>
<td>0.857082</td>
<td>0.108750</td>
<td>7.881184</td>
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<tr>
<td>MA(2)</td>
<td>-0.284913</td>
<td>0.172559</td>
<td>-1.651100</td>
<td>0.1079</td>
</tr>
<tr>
<td>SIGMASQ</td>
<td>0.019445</td>
<td>0.004237</td>
<td>4.589569</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

R-squared | 0.555177 | Mean dependent var | 4.820263 |
Adjusted R-squared | 0.517386 | S.D. dependent var | 0.208086 |
S.E. of regression | 0.193038 | Akaike info criterion | -0.894732 |
Sum squared resid | 57.467000 | Schwarz criterion | -0.722355 |
Log likelihood | 20.43042 | Hannan-Quinn criter. | -0.834020 |
F-statistic | 13.23950 | Durbin-Watson stat | 1.732040 |
Prob(F-statistic) | 0.000007 |

# ARMA (1, 3) estimates:
Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23  Time: 20:56
Sample: 1984 2021
Included observations: 38
Convergence achieved after 18 iterations
Coefficient covariance computed using outer product of gradients
Coefficient covariance computed using outer product of gradients

# ARMA (1, 4) estimates:
Dependent Variable: ANNSR
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 09/03/23   Time: 20:58
Sample: 1984 2021
Included observations: 38
Convergence achieved after 16 iterations
Coefficient covariance computed using outer product of gradients
#### After comparing all these ARMA estimates.
We have ARMA (1, 3) estimates is best estimates. It’s all coefficients are statistically significant and higher R-square value. No we forecast on the bases of this model with satisfying all criterion.
# Stationarity of residual of ARMA (1, 3) estimates:
Residual are stationary. As all the p-value in the correlogram are insignificant, so we accept the null hypotheses and conclude that the residuals are white noise.

### Forecasted dataset are available in excelsheet
The graph above displays the shortwave downward irradiance (Kw-hr/m²/day) year over year.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
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<td>0.120341</td>
<td>39.87581</td>
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<td>AR(1)</td>
<td>0.631016</td>
<td>0.126498</td>
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<td>MA(3)</td>
<td>0.658308</td>
<td>0.257521</td>
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<td>SIGMASQ</td>
<td>0.016185</td>
<td>0.003362</td>
<td>4.813409</td>
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</table>

R-squared 0.61613  Mean dependent var 4.820263
Adjusted R-squared 0.582241  S.D. dependent var 0.208086
S.E. of regression 0.134495  Akaike info criterion -1.009013
Sum squared resid 0.615024  Schwarz criterion -0.836635
Log likelihood 23.17124  Hannan-Quinn criter. -0.947682
F-statistic 18.18927  Durbin-Watson stat 1.887188
Prob(F-statistic) 0.000000

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>AR(1)</td>
<td>0.694575</td>
<td>0.114548</td>
<td>6.063636</td>
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<tr>
<td>MA(4)</td>
<td>0.167035</td>
<td>0.182969</td>
<td>0.912918</td>
<td>0.3677</td>
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<tr>
<td>SIGMASQ</td>
<td>0.020166</td>
<td>0.005122</td>
<td>3.937203</td>
<td>0.0004</td>
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</tbody>
</table>

R-squared 0.521680  Mean dependent var 4.820263
Adjusted R-squared 0.479475  S.D. dependent var 0.208086
S.E. of regression 0.150129  Akaike info criterion -0.833026
Sum squared resid 0.766316  Schwarz criterion -0.660648
Log likelihood 19.82749  Hannan-Quinn criter. -0.771695
F-statistic 12.8609  Durbin-Watson stat 2.083802
Prob(F-statistic) 0.000013

# AR and MA roots are also within the range.
Now we can go for forecasting
# forecasted graph for ANNSR

<table>
<thead>
<tr>
<th>Autocorrelation</th>
<th>Partial Correlation</th>
<th>AC</th>
<th>PAC</th>
<th>Q-Stat</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0.032 0.032 0.0418</td>
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</tr>
<tr>
<td>2 -0.017 -0.018 0.0533</td>
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<tr>
<td>3 0.138 -0.137 0.8837 0.347</td>
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<tr>
<td>4 0.144 0.156 1.8144 0.404</td>
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<tr>
<td>5 0.098 0.086 2.2595 0.520</td>
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<tr>
<td>6 0.058 0.037 2.4221 0.659</td>
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<tr>
<td>7 0.050 0.041 2.5444 0.770</td>
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<tr>
<td>8 -0.021 -0.032 -0.065 -0.801</td>
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<tr>
<td>9 0.033 0.087 3.0203 0.883</td>
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<td>10 0.000 0.088 3.4638 0.902</td>
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<td>11 -0.068 -0.116 3.7234 0.929</td>
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<td>12 -0.235 -0.228 6.9456 0.731</td>
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<td>13 0.033 0.044 7.0106 0.798</td>
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<tr>
<td>14 -0.002 -0.087 7.0120 0.857</td>
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<tr>
<td>15 0.026 0.035 7.0653 0.899</td>
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<tr>
<td>16 0.087 0.188 7.5908 0.910</td>
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</tr>
</tbody>
</table>

Date: 09/03/23   Time: 21:04
Sample: 1984 2021
Included observations: 38
Q-statistic probabilities adjusted for 2 ARMA terms
The graph clearly demonstrates that the line of the

graph has no significant deviation. The information
regarding solar radiation till 2022 came from the
NASA website and from 2022 till 2040 we have fore-
casted the sun radiation through ARIMA Model.

Conclusion

After comparing all these ARMA estimates. We
have ARMA (1, 3) estimates is best estimates. Its all
coefficients are statistically significant and higher R-
square value. The potential for renewable energy
technology in rural Bihar is enormous. Numerous
devices used in the agriculture sector are powered
by non-renewable energy sources. In the same way
that we can power engines to pump water for irriga-
tion in fields using solar energy. There are numer-
ous pricey government programs for domestic pur-
poses that people should take advantage of and
employ to meet their everyday necessities by the
renewable energy sources, of energy. In Bihar, all
bachelor’s degrees should include a course on re-
newable energy technology and should include a
lesson on renewable energy as a subject. Promoting
and raising student understanding of the use of re-
newable resources should be required in all institu-
tions (Shrish Bajpai et al., 2016) for raising awareness
among Bihar’s rural population.

Conflict of interest

None
References


