Designing Solar and Biogas based Renewable Energy System on University Campus and its Impacts on Energy Cost after Renewable Energy Interconnection to the University Grid Network

By Ummay Habiba, Sujan Kumar Talukdar & Md. Rabiul Islam
Pabna University of Science & Technology, Bangladesh

Abstract - In Bangladesh power crisis is one of the great problems. The whole of the probable sector is affected by it. The effects of power crisis is destroyed our economic growth. The total development of a country’s depends on the power generation. On the other hand when the load shedding is occurred, then the students of the university are basically affected, then they do not attain their lesson attentively and study their lesson attentively. Even they do not able to complete their laboratory works, complete their thesis and their class notes and so on. But, there is a huge opportunity to back up the load shedding using Solar and Biogas energy. This paper presents a design and analysis of Solar based power plant using sunlight and Biogas based plant using Human and Kitchen waste of the University for Load shedding Backup and the cost analysis results that, the system is economically feasible for University campus.

Keywords : solar power, biogas energy, renewable energy, university campus, load-shedding back up, economical system.

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Keywords: solar power, biogas energy, renewable energy, university campus, load-shedding back up, economical system.

1. INTRODUCTION

Bangladesh is endowed with plentiful supply of renewable source of energy [1]. Out of various renewable sources solar, wind, biomass can be effectively used in Bangladesh. Renewable energy practices in Bangladesh are [2]-

- Solar energy
- Biomass energy
- Wind energy
- Hydro power energy

Wind & Hydro power have a limited scope of success in Bangladesh, but could solar & biogas provides a viable solution to our existing energy problems [3].

Solar power is not new in Bangladesh. Since, 1996 different companies have tried to market solar energy systems to the public [4]. Yet in a technologically backward country like Bangladesh the idea took a fair while to gestate. Solar and biogas energy is a renewable energy without causing pollution to the environment. Grameen Shakti and few other companies are working to provide solar biogas energy to the villages in Bangladesh. The Government of Bangladesh is working to provide more energy to its people to accelerate economic growth, social development and reduce poverty [5]. On one hand, government is working to promote the use of renewable energy technologies. On the other hand, the government works with industry public sector power utilities and private households to increase the use of energy efficient appliance and production processes and promote energy generation. Renewable energy and energy efficiency is a priority area of Bangladeshi–German development co-operation [6].

II. LITERATURE REVIEW

Sun is the richest source of energies like light and heat. Huge amount of energies are available for us to take and make big impact on our electricity requirements [7]. Our sun throws as much amount of energy on earth in one day which is equivalent to the energy requirement for the entire year. Sun surface is about 109 times bigger than surface of the earth [8]. It takes millions of years for energy generated from the center of the sun to reach to the surface of the sun [9]. Our mother earth is about 149.63 * 106 kilometers away from the sun, and light takes about 8 minutes and 31 seconds to reach to the surface of the earth. Light from the sun travels 186,262 miles per second to reach to earth [10] [11]. Energy emitted from the sun which reaches earth is in massive amount and can be extremely dangerous for mankind on earth if direct exposure is made.
a) Solar Energy

Solar electricity is the energy which is extracted by Sun using solar power plants.

i. Photovoltaic or Solar Cell

It is possible to convert solar energy directly into electrical energy by means of silicon wafer photovoltaic cells, also called solar cells, without any intermediate thermodynamic cycle [12]. The solar cell operates on the principle of photovoltaic effect, which is a process of generating an EMF as a result of the absorption of ionizing radiation. Thus a solar cell is a transducer, which converts the sun’s radiant energy directly into electrical energy.

ii. Storage Device

The electricity produced by the PV modules is stored in batteries for later use when there is no sun [13]. Charge controllers regulate the rate of flow of electricity from the modules to the battery or the loads or to both simultaneously. It keeps the battery from overcharging or overloading thus prolonging its life.

iii. Inverters

The inverter converts the DC electricity produced by the solar modules into alternating current (AC) since most electrical appliances and equipment run on AC electricity [14].

b) Biogas Energy

Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic (without air) conditions [15]. The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of microorganisms which degrade organic material and return the decomposition products to the environment. In this process biogas is generated, a source of renewable energy.

i. Hydraulic Retention Time (HRT)

The retention time is the theoretical time that a particle or volume of liquid added to a digester would remain in the digester [16]. It is calculated as the volume of the digester divided by the volume of slurry added per day and it is expressed as days. The solids retention time (SRT) represents the average time that the solids remain in the system. The solids retention time can be determined by dividing the weight of volatile solids in the system by the weight per unit time of volatile solids leaving the system. The hydraulic retention time (HRT) is equal to the solids retention time in completely mixed non-recycled digester systems.

ii. Total Solid (TS)

The amount of solid material without considering the liquid part is termed as Total Solid (TS) [16]. Total solid is the material unit that indicates the production rate of Biogas. The favourable total solid value for smooth fermentation is 8%.

iii. Fresh Discharge

Fresh discharge is the total amount of manure including moisture content directly obtained from the cow, chicken, human etc. [16].

iv. Liquid Part

Liquid part is the amount of water to be added with fresh discharge to make the TS value is 8% [16].

III. Research Methodology

We have designed a biogas plant with respect to human and kitchen waste of four hostel and a dormitory at a university campus and according to area of roof space of a academic building and four hostel, & We are establishing a solar panel which act as an ideal model for reducing load shedding and at the absence of load shedding it will provide electricity at national grid.
The conversion of sunlight into electricity is defined as the solar power. It has done with the help of directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). CSP use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic Cell converts light into electric current using the photoelectric effect which is the basic principle of solar power generation.

IV. Solar Panel & Biogas Plant

The determination of Solar panel requirements and the composition of Biogas are provided below.

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Load Emergency KW</th>
<th>Quantity of Light KW</th>
<th>Rating per light (Watt)</th>
<th>Quantity of Fan</th>
<th>Rating of Fan (Watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student hostel 1,2,3,4</td>
<td>22.82</td>
<td>992</td>
<td>23</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Teacher Dormitory</td>
<td>11.60</td>
<td>200</td>
<td>23</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Academic Building</td>
<td>7.615</td>
<td>115</td>
<td>23</td>
<td>71</td>
<td>70</td>
</tr>
<tr>
<td>Server</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Composition of Biogas based Plant

The average composition of biogas is shown in table with respect to percentage 55%-75% biogas is methane gas.

<table>
<thead>
<tr>
<th>Matter</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (CH₄)</td>
<td>55-75</td>
</tr>
<tr>
<td>Carbon-dioxide (CO₂)</td>
<td>25-45</td>
</tr>
<tr>
<td>Carbon mono-oxide (CO)</td>
<td>0-0.3</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>1-5</td>
</tr>
<tr>
<td>Hydrogen sulphide (H₂S)</td>
<td>0.1-0.5</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>0.1-0.8</td>
</tr>
</tbody>
</table>

V. Calculation of Digester Volume

a) Calculation of Digester Volume for Hostel from Human Waste

Digester volume for student hostel-1:

Let, HRT = 40 day (for temperature 30° C).

We know, From every person 0.5 Kg waste is obtained per day.

Total discharge for human waste = (496×0.5) Kg = 248 Kg.

TS of fresh discharge = (248×0.2) = 49.6 Kg.

To make the TS value of 8% for favourable condition we have to mix some additional water with fresh discharge. The required water added can be calculated by the following way.

8 Kg solid equivalent of influent.

49.6 Kg solid equivalent = \( \frac{100 \times 49.6}{8} \) Kg = 620 Kg.

Working volume of digester = \( Q \times HRT = 620 \times 40 = 24.8 \ m³ \).

From geometrical assumption, \( V_\text{ps} + V_\text{i} = 80\% \) of \( V \)

or, \( 24.8 = 0.8 \times V \)

or, \( V = \frac{24.8}{0.8} = 31 \ m³ \)

Similarly, For hostel 2, \( V = 31 \ m³ \)

& For hostel 3, \( V = 31 \ m³ \)

& For hostel 4, \( V = 31 \ m³ \)

Parameter of digester volume for hostel 1 from human waste:

Since, \( V = 31 \ m³ \)

\( D = 1.3078 \ V^{(1/3)} \)

Or, \( D = 4.10 \ m \)

Again, \( V_\text{c} = (3.14 \times D^2 \times H)/4 = (3.14 \times 4.10^2 \times 0.5)/4 = 6.6 \ m³ \)

Here, \( H = 0.5 \)m(Calculated).

Then, \( f_1 = D/5 = 4.10/5 = 0.82 \ m \)

\( f_2 = D/8 = 4.10/8 = 0.50 \ m \)

\( V_\text{i} = 0.0827 D^3 = 0.0827 \times 4.10^3 = 5.60 \ m³ \)

\( V_\text{c} = 0.05 V = 0.05 \times 31 = 1.55 \ m³ \)

Respectively, we can find these data’s for Student Hall-02, 03 & 04.
Figure 3: Design of Digester Volume of Student Hall 1, 2, 3 & 4

b) Calculation of Digester Volume for Kitchen

Digester volume for kitchen:

Let, HRT = 40 day (for temperature = 30° C).

We know, From every household 0.10 Kg waste is obtained per day.

Total discharge for kitchen waste = 2184 × 0.10 Kg = 218.40 Kg.

TS of fresh discharge = (218.40 × 0.52) = 113.568 Kg.

To make the TS value of 8% for favourable condition, we have to mix some additional water with fresh discharge. The required water to add can be calculated by the following way.

8 Kg solid equivalent of influent.

26.624 Kg solid equivalent = \( \frac{100 \times 113.568}{8} \) Kg = 1416.60 Kg.

Working volume of digester = \( Q \times HRT = 1416.60 \times 40 = 56.784 \text{m}^3 \).

From geometrical assumption,

\( V_{gs} + V_1 = 80\% \) of \( V \)

or, \( 56.784 = 0.8 \times V \)

or, \( V = \frac{56.784}{0.8} = 70.98 \text{ m}^3 = 71 \text{ m}^3 \)

Parameter of digester volume for Kitchen:

Figure 4: Design of digester volume for Kitchen waste

Since, \( V = 71 \text{ m}^3 \).

\( D = 1.3078 \times V^{\frac{1}{3}} \)

Or, \( D = 5.42 \text{ m} \)

Again, \( V_3 = (3.14 \times D^2 \times H)/4 = (3.14 \times 5.42^2 \times 1.13)/4 = 25.85 \text{ m}^3 \)

Here, \( H = 1.13 \text{m} \) (Calculated).

Then, \( f_1 = D/5 = 5.42/5 = 1.08 \text{ m} \)

\( f_2 = D/8 = 5.42/8 = 0.68 \text{ m} \)

\( V_1 = 0.0827 \times D^3 = 0.0827 \times 5.42^3 = 13.17 \text{ m}^3 \)

\( V_c = 0.05 \times V = 3.55 \text{ m}^3 \)

c) Calculation of Digester Volume of Teacher’s Dormitory

Digester volume for teacher’s Dormitory:

Let, HRT = 40 day (for temperature 30° C).

We know, From every person 0.5 Kg waste is obtained per day.

Total discharge for human waste = (200 × 0.5) Kg = 100 Kg.

TS of fresh discharge = (100 × 0.2) = 20 Kg.

To make the TS value of 8% for favourable condition we have to mix some additional water with fresh discharge. The required water to added can be calculated by the following way.

8 Kg solid equivalent of influent.

6 Kg solid equivalent = \( \frac{100 \times 20}{8} \) Kg = 250 Kg.

Working volume of digester = \( Q \times HRT = 250 \times 40 = 10.00 \text{ m}^3 \).
Figure 5: Design of digester volume of Teachers’ Dormitory

From geometrical assumption,

\[ V_{gs} + V_f = 80\% \text{ of } V \]

or, \[ 10.00 = 0.80 \times V \]

or, \[ V = \frac{10.00}{0.80} = 12 \text{ m}^3. \]

**d) Parameter of Digester Volume for Teachers’ Dormitory**

Since, \( V = 12.50 \text{ m}^3 \)

Then, \( D = 1.3078 \times V^{1/3} \)

or, \( D = 3 \text{ m} \)

Again,

\[ V_1 = (3.14 \times D^2 \times H)/4 = (3.14 \times 3^2 \times 0.20)/4 = 1.40 \text{ m}^3 \]

Here, \( H = 0.20 \text{ m} \) (Calculated).

Then, \( f_1 = D/5 = 3/5 = 0.60 \text{ m} \)

\( f_2 = D/8 = 3/8 = 0.375 \text{ m} \)

\( V_2 = 0.0827 D^3 = 0.0827 \times 3^3 = 2.23 \text{ m}^3 \)

\( V_c = 0.05 \text{ V} = 0.05 \times 12.50 \text{ m}^3 = 0.62 \text{ m}^3 \)

**VI. Electricity Generation Capacity & Load Distributions**

The total generation capacity from human waste, kitchen waste and solar energy is given in the table-2 shown in below.

<table>
<thead>
<tr>
<th>Position</th>
<th>Type</th>
<th>Waste Type</th>
<th>Power (KW)</th>
<th>Volume and Roof space respectively of Biogas and Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student hostel 1,2,3,4</td>
<td>AC</td>
<td>Human</td>
<td>8.54*4 = 34.16</td>
<td>31m of each Digester</td>
</tr>
<tr>
<td>Teachers Dormitory</td>
<td>AC</td>
<td>Human</td>
<td>3.41</td>
<td>12m of Digester</td>
</tr>
<tr>
<td>Student hostel 1,2,3,4 &amp; Teacher’s Dormitory</td>
<td>AC</td>
<td>Kitchen</td>
<td>50.29</td>
<td>71m</td>
</tr>
<tr>
<td>Student hostel 1,2,3,4</td>
<td>DC</td>
<td>Solar energy</td>
<td>54*4 = 216</td>
<td>4000 sq. ft. of each Hostel</td>
</tr>
<tr>
<td>Academic Building</td>
<td>DC</td>
<td>Solar energy</td>
<td>67</td>
<td>5000 sq. ft.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>370.86</strong></td>
<td></td>
</tr>
</tbody>
</table>

The important loads are listed as the table-3 as shown. Now, the distributions of the loads are given below:

- **Load-1**: Teacher’s room (60) = 60 × (23(Light) + 70(Fan)) = 5.58 KW
- **Load-2**: Chairman Room (11) = 11 × (23(Light) + 70(Fan)) = 1.00KW (Approximately)
- **Load-3**: Server = 15 KW
- **Load-4**: Classroom (22) = 22 × (2×23(Light)) = 1KW
- **Load-5**: Student Hostel 1,2,3,4 and teacher’s dormitory: For student hostel 1,2,3,4 = 992*23 (light) = 22.80 KW. For Teachers dormitory = (200*23(light) + 100*70(fan)) = 11.60 KW, Teachers Dormitory+ Hostel = 11.60+22.80 = 34.40 KW.
The duration of the operation of the loads are shown in the table-4 in below.

Table 4: Operation time of loads based on priority of loads

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>00:00 – 06:00</th>
<th>06:00 – 08:00</th>
<th>08:00 – 14:00</th>
<th>14:00 – 18:00</th>
<th>18:00 – 24:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running Load</td>
<td>Load1 Load1</td>
<td>Load</td>
<td>Load Load2</td>
<td>Load Load3</td>
<td>Load Load5</td>
</tr>
<tr>
<td>Load3 Load3</td>
<td>Load2 Load3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load5 Load4</td>
<td>Load</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Load (KW)</td>
<td>49.40 KW</td>
<td>15 KW</td>
<td>22.58 KW</td>
<td>22.58 KW</td>
<td>55.98 KW</td>
</tr>
</tbody>
</table>

VII. Cost Benefit Analysis & Savings

Since, 1 Unit = 1 KWh = 5 Taka

From the time duration table:

- In time (00:00-06:00) = 49.4×8×5=1482 Taka
- In time (06:00-08:00) = 15×2×5 = 150 Taka
- In time (08:00-14:00) = 22.58×6×5 = 677.40 Taka
- In time (14:00-18:00) = 22.58×4×5 = 451.60 Taka
- In time (18:00-24:00) = 55.98×6×5 = 1679.40 Taka

The total per month savings = 1482*30 + 150*30 + 677.40*30 + 451.60*30 + 1679.40*30 = 1,33,212 Taka.

Figure 3: Distribution of Renewable energy

Table 5: Total demand of load on University campus

<table>
<thead>
<tr>
<th>Building name</th>
<th>Load in KW</th>
<th>Quantity of light</th>
<th>Rating per light (watt)</th>
<th>Quantity of fan</th>
<th>Rating per fan (watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student hostel 1,2,3,4</td>
<td>92.256</td>
<td>992</td>
<td>23</td>
<td>992</td>
<td>70</td>
</tr>
<tr>
<td>Teachers dormitory</td>
<td>11.6</td>
<td>200</td>
<td>23</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Academic building</td>
<td>115.32</td>
<td>1240</td>
<td>23</td>
<td>1240</td>
<td>70</td>
</tr>
<tr>
<td>Server</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Load A**: Teacher’s room (60) = 60*(23(light) + 70(fan)) = 5.58 KW
- **Load B**: Chairman Room (11) = 11*(23(light) + 70(fan)) = 1.00 KW
- **Load C**: Server = 25 KW
- **Load D**: Classroom (22) = 22*(3*23(light) + 3*70(fan)) = 7.678 KW
- **Load E**: Student hostel 1,2,3,4 & teacher’s dormitory:
  - Student hostel 1, 2, 3, 4 = 992*(23(light) + 70(fan)) = 92.256 KW
  - Teacher’s dormitory = 200*23(light) + 100*70(fan) = 11.6 KW
  - Student hostel 1,2,3,4 + Teacher’s dormitory = 92.256 + 11.6 = 103.856 KW
Table 6: Time Duration Table

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>00:00 – 06:00</th>
<th>06:00 – 08:00</th>
<th>08:00 – 14:00</th>
<th>14:00 – 18:00</th>
<th>18:00 – 24:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load A</td>
<td>Load A</td>
<td>Load A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load B</td>
<td>Load B</td>
<td>Load B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load C</td>
<td>Load C</td>
<td>Load C</td>
<td>Load C</td>
<td>Load C</td>
<td>Load C</td>
</tr>
<tr>
<td>Load D</td>
<td>Load D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Load E</td>
</tr>
<tr>
<td>Total Load (KW)</td>
<td>128.856</td>
<td>25</td>
<td>39.258</td>
<td>9.258</td>
<td>135.436</td>
</tr>
</tbody>
</table>

Figure 4: Distribution of Renewable energy assuming no load-shedding

Table 7: Cost Analysis during on no load-shedding

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Load in KW (from renewable energy)</th>
<th>Load in KW (from BPDB)</th>
<th>Total cost (from renewable energy) in Taka</th>
<th>Total cost (from BPDB) in Taka</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00-06:00</td>
<td>49.4</td>
<td>79.456</td>
<td>49.40<em>6</em>5=1482</td>
<td>79.456<em>6</em>5=2383.68</td>
</tr>
<tr>
<td>06:00-08:00</td>
<td>15.0</td>
<td>10.000</td>
<td>15<em>2</em>5=150</td>
<td>10<em>2</em>5=100</td>
</tr>
<tr>
<td>08:00-14:00</td>
<td>22.58</td>
<td>16.678</td>
<td>22.58<em>6</em>5=677.4</td>
<td>16.678<em>6</em>5=500.34</td>
</tr>
<tr>
<td>14:00-18:00</td>
<td>22.58</td>
<td>16.678</td>
<td>22.58<em>4</em>5=451.6</td>
<td>16.678<em>4</em>5=333.56</td>
</tr>
<tr>
<td>18:00-24:00</td>
<td>55.98</td>
<td>79.456</td>
<td>55.98<em>6</em>5=1679</td>
<td>79.456<em>6</em>5=2383.68</td>
</tr>
<tr>
<td></td>
<td>Total cost= 4440 TK/Day</td>
<td>Total cost= 5701.26 TK/Day</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Total cost = 4440 Taka (R.E) + 5701.26 Taka (BPDB) = 10141.26 Taka. Total per month cost = 10141.26*30 = 304,237.8 Taka.

From renewable energy,

Per month cost = per month saving = 4430*30 = 133,200 Taka.

Assumption of load shedding period: During the load shedding period, only the emergency load is connected:

<table>
<thead>
<tr>
<th>Load shedding period</th>
<th>Demand (KW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 am–12 pm</td>
<td>22.58</td>
</tr>
<tr>
<td>03 pm–04 pm</td>
<td>22.58</td>
</tr>
<tr>
<td>07 pm–09 pm</td>
<td>55.98</td>
</tr>
</tbody>
</table>

During on load shedding, Total per day cost = (22.56*2*5 + 55.98*2*5) Taka = 785 Taka. Per month saving = 785*30 Taka = 23568 Taka. During the load shedding time, total saving per month on a University campus = (133200-23568) Taka = 109632 Taka.

During load shedding, only the emergency load is connected:

$\begin{align*}
\text{Total cost} &= 4440 \text{ Taka (R.E)} + 5701.26 \text{ Taka (BPDB)} \\
&= 10141.26 \text{ Taka. Total per month cost} \\
&= 10141.26 \times 30 = 304,237.8 \text{ Taka. From renewable energy,} \\
\text{Per month cost} &= \text{per month saving} = 4430 \times 30 \\
&= 133,200 \text{ Taka.}
\end{align*}$

Assumption of load shedding period: During the load shedding period, only the emergency load is connected:

<table>
<thead>
<tr>
<th>Load shedding period</th>
<th>Demand (KW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 am–12 pm</td>
<td>22.58</td>
</tr>
<tr>
<td>03 pm–04 pm</td>
<td>22.58</td>
</tr>
<tr>
<td>07 pm–09 pm</td>
<td>55.98</td>
</tr>
</tbody>
</table>

During on load shedding, Total per day cost = (22.56*2*5 + 55.98*2*5) Taka = 785 Taka. Per month saving = 785*30 Taka = 23568 Taka. During the load shedding time, total saving per month on a University campus = (133200-23568) Taka = 109632 Taka.

IX. Acknowledgment

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References


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