GREEN MOSQUES INITIATIVE

Empowering Community-Led Sustainable Solutions

AUTHORS

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As an alliance-led initiative, Ummah for Earth is working to empower Muslim communities - especially those at the front lines of the climate crisis, to take more initiative and lead the way towards a green and just transition to a sustainable world.

As we endeavour to amplify Muslim voices within the broader climate movement, we also seek opportunities to demonstrate the value of promoting and enabling community-led solutions. Solutions and initiatives that can serve as an example to others around the world, and catalyse the changes we are all working to manifest.

This report shows the potential that the Ummah has to be part of the solution not only through the direct environmental benefits of ‘greening’ these Mosques but also because of their potential to influence people as centres of culture, spirituality and community life. They are an expression of the willingness of Muslims and religious leaders to be part of the climate solution!

The report represents the first step of a journey of a thousand miles. It began with a big idea and some questions: what if all mosques in the world were equipped with solar energy systems? How could that be achieved? What impact would it have on the communities these centres of worship serve? How will it help mitigate the effects of climate change?

With these questions in mind, we took the first step by selecting ten mosques from around the world that can serve as examples, and commissioned a detailed technical analysis of the feasibility and impact of installing solar energy systems at the sites. The report was developed by a team from the Issam Fares Institute for Public Policy and International Affairs at the American University of Beirut, in collaboration with The Lebanese Foundation for Renewable Energy and the National Council for Scientific Research.

Just days before the publication and release of this report, we are excited to see the Glasgow Central Mosque in Scotland leading the way by installing a solar system after receiving a generous grant from Islamic Relief, a member of the Ummah for Earth alliance.

Our hope is for this report to be an inspiration, and for this initiative to instigate a domino effect of green mosques. Grand ideas can be turned into physical realities, especially when we can muster our collective passion, solidarity and conviction to achieve them.

Ghiwa Nakat
Executive Director, Greenpeace Middle East and North Africa
Executive Summary
This report studies the potential social, environmental and financial impact of installing PV systems at 10 major mosques around the world.
The adjacent map shows the 10 mosques which have been studied.
### Technical Findings

Comparing power output and annual electricity production

<table>
<thead>
<tr>
<th>Mosque</th>
<th>Power (kW)</th>
<th>AEP (MWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NABAWI MOSQUE</td>
<td>3169</td>
<td>191.1</td>
</tr>
<tr>
<td>GLASGOW MOSQUE</td>
<td>227</td>
<td>91.4</td>
</tr>
<tr>
<td>AL AZHAR MOSQUE</td>
<td>599</td>
<td>63.7</td>
</tr>
<tr>
<td>GRAND JAMIA MOSQUE</td>
<td>1019</td>
<td>1441</td>
</tr>
<tr>
<td>ISTIQLAL MOSQUE</td>
<td>3925</td>
<td>5612</td>
</tr>
<tr>
<td>MOSQUE OF ALGIERS</td>
<td>78.7</td>
<td>144</td>
</tr>
<tr>
<td>NIZAMIYEH MOSQUE</td>
<td>2634</td>
<td>4564</td>
</tr>
<tr>
<td>AL HARAM MOSQUE</td>
<td>960</td>
<td>1532</td>
</tr>
<tr>
<td>UMMAYED MOSQUE</td>
<td>729</td>
<td>1057</td>
</tr>
<tr>
<td>HASSAN II MOSQUE</td>
<td>729</td>
<td>1057</td>
</tr>
</tbody>
</table>
# Economic Findings

Internal rate of return Vs Payback and Benefits: Costs ratio

## Financial Viability

<table>
<thead>
<tr>
<th>Location</th>
<th>IRR (%)</th>
<th>Payback</th>
<th>B-C Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>NABAWI MOSQUE</td>
<td>13.9</td>
<td>8</td>
<td>1.5</td>
</tr>
<tr>
<td>GLASGOW MOSQUE</td>
<td>21.3</td>
<td>5.2</td>
<td>2.3</td>
</tr>
<tr>
<td>AL AZHAR MOSQUE</td>
<td>11.2</td>
<td>9.8</td>
<td>1.2</td>
</tr>
<tr>
<td>GRAND JAMIA MOSQUE</td>
<td>22.2</td>
<td>2.4</td>
<td>1.2</td>
</tr>
<tr>
<td>ISTIQLAL MOSQUE</td>
<td>11.2</td>
<td>9.8</td>
<td>1.2</td>
</tr>
<tr>
<td>MOSQUE OF ALGIERS</td>
<td>26.9</td>
<td>0.44</td>
<td>1.4</td>
</tr>
<tr>
<td>NIZAMIYEH MOSQUE</td>
<td>13.4</td>
<td>8.3</td>
<td>1.4</td>
</tr>
<tr>
<td>AL HARAM MOSQUE</td>
<td>12.1</td>
<td>9.1</td>
<td>1.3</td>
</tr>
<tr>
<td>UMMAYED MOSQUE</td>
<td>41.7</td>
<td>2.6</td>
<td>4.6</td>
</tr>
<tr>
<td>HASSAN II MOSQUE</td>
<td>18</td>
<td>6.2</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Note: IRR (%), Payback, and B-C Ratio represent the Internal Rate of Return, Payback Period, and Benefit-Cost Ratio respectively.
<table>
<thead>
<tr>
<th>Mosque</th>
<th>ANNUAL SAVINGS ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NABAWI MOSQUE</td>
<td>$395,420</td>
</tr>
<tr>
<td>GLASGOW MOSQUE</td>
<td>$43,630</td>
</tr>
<tr>
<td>AL AZHAR MOSQUE</td>
<td>$60,710</td>
</tr>
<tr>
<td>GRAND JAMIA MOSQUE</td>
<td>$89,140</td>
</tr>
<tr>
<td>ISTIQLAL MOSQUE</td>
<td>$103,710</td>
</tr>
<tr>
<td>MOSQUE OF ALGIESI</td>
<td>$145,750</td>
</tr>
<tr>
<td>NIZAMIYEH MOSQUE</td>
<td>$288,420</td>
</tr>
<tr>
<td>AL HARAM MOSQUE</td>
<td>$373,200</td>
</tr>
<tr>
<td>UMMAYED MOSQUE</td>
<td>$9,493</td>
</tr>
<tr>
<td>HASSAN II MOSQUE</td>
<td>$117,410</td>
</tr>
</tbody>
</table>
AVERAGE EMPLOYMENT OVER LIFE OF FACILITY

Social Findings

Total number of jobs created ranges between 93 & 153
Environmental Findings

A total annual reduction of 12025 tonnes of CO2

Equivalent to

2203 cars and light trucks not used per year

5,166,844 Liters of gasoline not consumed

1107 Hectares of forest absorbing carbon
<table>
<thead>
<tr>
<th>Mosque</th>
<th>Percentage</th>
<th>COVERAGE OF MOSQUES’ ENERGY DEMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nabawi mosque</td>
<td>53%</td>
<td></td>
</tr>
<tr>
<td>Glasgow mosque</td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>Al-Azhar mosque</td>
<td>79%</td>
<td></td>
</tr>
<tr>
<td>Grand Jamia mosque</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>Istiqlal mosque</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>Mosque of Algiers</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Nizamiyah mosque</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td>Al-Haram mosque</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>Ummayed mosque</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>HASSAN II mosque</td>
<td>32%</td>
<td></td>
</tr>
</tbody>
</table>

Equivalent to:
- 6548 Households reducing energy by 100%.
- 37980 persons reducing energy by 100%.
Introduction and Methodology
Converting these mosques to full or partial solar power can have a real and measurable impact on greenhouse gas emissions, as well as viable financial and social benefits.

These mosques can serve as examples for the communities around them and others all over the world, to inspire the adoption of sustainable solutions and transition away from the need for energy production based on fossil fuels.
In order to conduct a reliable and accurate study for calculating the potential of a PV system on the Mosque’s rooftops, and determine the economic and social benefits, a group of software were used. Each one has its own mission (see the adjacent text):

<table>
<thead>
<tr>
<th>Software Used</th>
<th>Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ArcMap: for mapping and modelling</td>
<td></td>
</tr>
<tr>
<td>2. Sketchup: 3D modelling</td>
<td></td>
</tr>
<tr>
<td>3. PVsyst: PV design for small areas</td>
<td></td>
</tr>
<tr>
<td>4. RETScreen: for economic and environmental studies</td>
<td></td>
</tr>
</tbody>
</table>
01 Solar Energy Assessment
Determination of the available solar energy which depends on the location

02 Solar Site Assessment
Determination of the suitable and available area for installing PV system through mapping and modelling

03 Design of PV System
Simulation and detailed design of PV system using energy software.

04 Economic & Environment studies
Determination of CO2 emissions and economic feasibility study
1-Al Nabawi Mosque
This mosque is located in Madina, Saudi Arabia. (24°28'13.1"N 39°36'36.9"E)

The optimal tilt angle of PV module is 25° and azimuth is south facing.

Source: Global Solar Atlas
Preliminary Solar Energy Assessment

Average hourly profiles for each month
Total photovoltaic power output (Wh)

The figures show the hourly and monthly operation of 1 kWp PV system installed at Al Madina town. We can conclude that the energy production is approximately constant throughout the year, with high potential of solar energy.

Data source: Global Solar Atlas

Total Photovoltaic Power Output per year
= 1824 kWh/kWp
The adjacent map shows the land use type at radius 2 km from the mosque. Al Nabawi mosque is located in a high density urban area with a few green areas.

To the west of the mosque, a mountain is located (yellow) which can be a suitable location for installing PV system. (The slope and aspect of mountain must be checked.)

To the east of the mosque, there is a cemetery with area 177,000 m² which can be used for installing PV system at a height of 5m from the ground. In addition to some open plots (yellow) with a total area of 1,088,000 m² which also can suitable locations for installing PV systems.
Preliminary Solar Site Assessment

- Total area of the plot where the mosque is located is around 440,000 m², of which mosque's building around 95,000 m².

- The mosque includes automatic umbrellas that open in morning and close in evening. Their total area around 140,000 m².

- PV system can be installed at the rooftop of the mosque and at the yard to the west of the mosque.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: **95,900 m²**
- Total area available for installing a PV system is: **35,020 m²**
The PV Design of Mosque’s Rooftop Solar System Parameters

**PV Module**
- **Model:** LR5-72 HPH 540 M
- **Manufacturer:** Longi Solar
- **Nominal PV Power (kWp):** 3169
- **Total Number of modules:** 5868 (18 in series, 326 in Parallel)
- **Total Area of Modules (m^2):** 15,000
- **Total Number of Sheds:** 6035

**Inverter**
- **Model:** CORE-1000.0-TL
- **Manufacturer:** ABB
- **Nominal Inverter Power (kWac):** 3000 (3 inverters each 1000 kW)

**System Production**
- **Total Produced Energy (MWh/year):** 6190
- **System Performance Ratio (%):** 76

**System Cost**
- **$3,169,000**
Economic Benefits

- Total Initial Cost = $3,169,000
  (Considering 1000 $ /KWp - Ref: RETScreen)

- O&M Cost = $31,690/yr
  (Considering 10 $ /KWp/yr - Ref: RETScreen)

- Savings = $395,420/yr
  (0.069$/kWh in Saudi Arabia – Ref: Global Petrol Prices)

- NPV = $1,497,073

- IRR = 13.9%

- Simple payback = 8 yr

- Benefit-Cost Ratio = 1.5
Potential Jobs Created

Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.

According to RETScreen software, the GHG emission for 1 kWh is 0.556 kgCO2/kWh. Referring to the energy produced by PV system which is around 6.19 GWh, the gross annual GHG emission reduction CO2 is 3199 TCO2/yr would be equivalent to:

- 586 cars and light trucks not used per year
- 1,374,646 Liters of gasoline not consumed
- 1435 citizens reducing energy by 100%
- 1103 Tonnes of waste recycled
- 294 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

54%

Equivalent to

4314 kWh/yr

1435 Citizens

The yearly average consumption of a religious building is 120 kWh/m²

Source: RETScreen
2- Glasgow Central Mosque
This mosque is located in Glasgow, Scotland. (55°51'07.6"N 4°15'07.4"W)

The optimal tilt angle of PV module is 38° and azimuth is south facing.

This mosque has already been partially equipped with solar energy.

Source: Global Solar Atlas
The figures show the hourly and monthly operation of a 1 kWp PV system installed at Glasgow. We can conclude that the energy production ranges between 22 kWh/yr and 118 kWh/yr, with low potential of solar energy.

Data source: Global Solar Atlas
The adjacent map shows the land use type at radius 2 km from the mosque. Glasgow mosque is located in a high density urban area with medium distribution of green areas.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: **3,600 m²**
- Total Area available for installing PV system is: **3,030 m²**
## PV Design of Mosque’s Rooftop

<table>
<thead>
<tr>
<th>Solar System Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV Module</strong></td>
</tr>
<tr>
<td>Model: LR5-72 HPH 550 M</td>
</tr>
<tr>
<td>Manufacturer</td>
</tr>
<tr>
<td>Nominal PV Power (kWp)</td>
</tr>
<tr>
<td>Total Number of modules</td>
</tr>
<tr>
<td>Total Area of Modules (m^2)</td>
</tr>
<tr>
<td>Total Number of Sheds</td>
</tr>
<tr>
<td><strong>Inverter</strong></td>
</tr>
<tr>
<td>Model: SUN-2000</td>
</tr>
<tr>
<td>Manufacturer</td>
</tr>
<tr>
<td>Nominal Inverter Power (kWac)</td>
</tr>
<tr>
<td><strong>System Production</strong></td>
</tr>
<tr>
<td>Total Produced Energy (MWh/year)</td>
</tr>
<tr>
<td>System Performance Ratio (%)</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
</tr>
<tr>
<td>$227,000</td>
</tr>
</tbody>
</table>
Economic Benefits

- Total Initial Cost = $227,000  
  (Considering 1000 $ /KWP - Ref: RETScreen)

- O&M Cost = $2,270/yr  
  (Considering 10 $ /KWP/yr - Ref: RETScreen)

- Savings = $43,630/yr  
  (0.24$/kWh in UK - Ref: Global Petrol Prices)

- NPV = $287,600

- IRR = 21.3%

- Simple payback = 5.2 yr

- Benefit-Cost Ratio = 2.3
Potential Jobs Created

Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.

According to RETScreen software, the GHG emission for 1 kWh is 0.245 kgCO2/kWh. Referring to the energy produced by PV system which is around 0.191 GWh, the gross annual GHG emission reduction CO2 is 43.5 tCO2/yr would be equivalent to:

- 8 cars and light trucks not used per year
- 18,680 Liters of gasoline not consumed
- 41 Households reducing energy by 100%
- 15 Tonnes of waste recycled
- 4 Hectares of forest absorbing carbon
The yearly average consumption of a religious building is 120 kWh/m².

Additional Benefits

Coverage of Energy Demand

43%

Equivalent to

1985 kWh/yr

= 4648 kWh/yr

96 Citizens

41 Households

Source: RETScreen
3- Al Azhar Mosque
This mosque is located in Cairo, Egypt. (30°02'46.0"N 31°15'44.8"E)

The optimal tilt angle of PV module is 26° and azimuth is south facing.

Source: Global Solar Atlas
The figures show the hourly and monthly operation of 1 kWp PV system installed at Cairo. We can conclude that the energy production ranges between 115 kWh/yr and 167 kWh/yr, with high potential for solar energy production.

Data source: Global Solar Atlas
The adjacent map shows the land use type at radius 2 km from the mosque. Al Azhar mosque is located in a high density urban area with a few green plots.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: 9,700 m²
- Total area available for installing PV system is: 8,510 m²
## PV Design of Mosque’s Rooftop

### Solar System Parameters

<table>
<thead>
<tr>
<th><strong>PV Module</strong></th>
<th><strong>Model:</strong> LR5-72 HPH 540 M</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>Longi Solar</td>
</tr>
<tr>
<td><strong>Nominal PV Power (kWp)</strong></td>
<td>599</td>
</tr>
<tr>
<td><strong>Total Number of modules</strong></td>
<td>1110</td>
</tr>
<tr>
<td><strong>Total Area of Modules (m²)</strong></td>
<td>2837</td>
</tr>
<tr>
<td><strong>Total Number of Sheds</strong></td>
<td>1110</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Inverter</strong></th>
<th><strong>Model:</strong> PVMC-45-0540</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>LTI REEnergy</td>
</tr>
<tr>
<td><strong>Nominal Inverter Power (kWac)</strong></td>
<td>540</td>
</tr>
</tbody>
</table>

### System Production

| **Total Produced Energy (MWh/year)** | 914                        |
| **System Performance Ratio (%)**    | 74                         |

### System Cost

| **System Cost** | $599,000                     |
Economic Benefits

- Total Initial Cost = $599,000
  (Considering 1000 $ /KWp - Ref: RETScreen)

- O&M Cost = $5,990/yr
  (Considering 10 $ /KWp/yr - Ref: RETScreen)

- Savings = $60,710/yr
  (0.073$/kWh in Egypt – Ref: Global Petrol Prices)

- NPV = $118,500

- IRR = 11.2%

- Simple payback = 9.8 yr

- Benefit-Cost Ratio = 1.2
Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW

According to RETScreen software, the GHG emission for 1 kWh is 0.522 kgCO2/kWh. Referring to the energy produced by PV system which is around 0.914 GWh, the gross annual GHG emission reduction CO2 is 444 tCO2/yr would be equivalent to:

- 81 cars and light trucks not used per year
- 190,593 Liters of gasoline not consumed
- 377 Households reducing energy by 100%
- 153 Tonnes of waste recycled
- 41 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

Equivalent to

605 kWh/yr

1510 Citizens

= 377 Households

The yearly average consumption of a religious building is 120 kWh/m².
4- Grand Jamia Mosque
This mosque is located in Lahore, Pakistan. (31°22'08.4"N 74°11'07.6"E)

The optimal tilt angle of PV module is 28° and azimuth is south facing.

Source: Global Solar Atlas
The figures show the hourly and monthly operation of a 1 kWp PV system installed at the city of Lahore. We can conclude that the energy production ranges between 93 kWh/yr and 143 kWh/yr, with moderate potential of solar energy.

Data source: Global Solar Atlas
The adjacent map shows the land use at radius 2 km from the mosque. Grand Jamia mosque is located in a high density urban area with large green areas in the vicinity.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: **7,930 m²**
- Total area available for installing a PV system is: **5,430 m²**
**PV Design of Mosque’s Rooftop**

**Solar System Parameters**

<table>
<thead>
<tr>
<th><strong>PV Module</strong></th>
<th><strong>Model:</strong> LR5-72 HPH 550 M</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>Longi Solar</td>
</tr>
<tr>
<td><strong>Nominal PV Power (kWp)</strong></td>
<td>446</td>
</tr>
<tr>
<td><strong>Total Number of modules</strong></td>
<td>825</td>
</tr>
<tr>
<td><strong>Total Area of Modules (m^2)</strong></td>
<td>2109</td>
</tr>
<tr>
<td><strong>Total Number of Sheds</strong></td>
<td>825</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Inverter</strong></th>
<th><strong>Model:</strong> Ingecon Sun 400TL M320 DC Indoor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>Ingeteam</td>
</tr>
<tr>
<td><strong>Nominal Inverter Power (kWac)</strong></td>
<td>408</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>System Production</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Produced Energy (MWh/year)</strong></td>
<td>637</td>
</tr>
<tr>
<td><strong>System Performance Ratio (%)</strong></td>
<td>80</td>
</tr>
</tbody>
</table>

| **System Cost** | $446,000 |
Economic Benefits

- Total Initial Cost = $446,000
  (Considering 1000 $ /KWp - Ref: RETScreen)
- O&M Cost = $4,460/yr
  (Considering 10 $ /KWp/yr - Ref: RETScreen)
- Savings = $89,140/yr
  (0.147$/kWh in Pakistan– Ref: Global Petrol Prices)
- NPV = $606,000
- IRR = 22.2%
- Simple payback = 5 yr
- Benefit-Cost Ratio = 2.4
Potential Jobs Created


Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.
Environmental Benefits

According to RETScreen software, the GHG emission for 1 kWh is 0.421 kgCO2/kWh. Referring to the energy produced by PV system which is around 0.637 GWh, the gross annual GHG emission reduction CO2 is 249 tCO2/yr would be equivalent to:

- **OR**
  - 46 and light trucks not used per year
  - 107,181 Liters of gasoline not consumed
  - 327 Households reducing energy by 100%
  - 86 Tonnes of waste recycled
  - 22.9 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

67%

Equivalent to

183 kWh/yr

3481 Citizens

327 Households

The yearly average consumption of a religious building is 120 kWh/m²

Source: RETScreen
5- Istiqlal Mosque
This mosque is located in Jakarta, Indonesia. (6°10'14.5"S 106°49'52.9"E)

The optimal tilt angle of PV module is 9° and azimuth is north facing.

Source: Global Solar Atlas
The figures show the hourly and monthly operation of 1 kWp PV system installed in Jakarta. We can conclude that the energy production ranges between 82 kWh/yr and 129 kWh/yr, with moderate potential for solar energy production.

Data source: Global Solar Atlas
The adjacent map shows the land use type at radius 2 km from the mosque. Istiqlal mosque is located in a high density urban area with some green areas in the vicinity.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: **20,200 m²**
- Total area available for installing a PV system is: **14,600 m²**
**PV Design of Mosque’s Rooftop**

<table>
<thead>
<tr>
<th>Solar System Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV Module</strong></td>
<td></td>
</tr>
<tr>
<td>Model: LR5-72 HPH 550 M</td>
<td></td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Longi Solar</td>
</tr>
<tr>
<td>Nominal PV Power (kWp)</td>
<td>1019</td>
</tr>
<tr>
<td>Total Number of modules</td>
<td>1853 (17 in series , 109 in Parallel)</td>
</tr>
<tr>
<td>Total Area of Modules (m^2)</td>
<td>4736</td>
</tr>
<tr>
<td>Total Number of Sheds</td>
<td>1858</td>
</tr>
<tr>
<td><strong>Inverter</strong></td>
<td></td>
</tr>
<tr>
<td>Model: ULTRA-700.0-TL</td>
<td></td>
</tr>
<tr>
<td>Manufacturer</td>
<td>ABB</td>
</tr>
<tr>
<td>Nominal Inverter Power (kWac)</td>
<td>1000</td>
</tr>
<tr>
<td><strong>System Production</strong></td>
<td></td>
</tr>
<tr>
<td>Total Produced Energy (MWh/year)</td>
<td>1441</td>
</tr>
<tr>
<td>System Performance Ratio (%)</td>
<td>80</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
<td>$1,019,000</td>
</tr>
</tbody>
</table>
Economic Benefits

- Total Initial Cost = $1,019,000
  (Considering 1000 $ /KWp - Ref: RETScreen)
- O&M Cost = $10,190/yr
  (Considering 10 $ /KWp/yr - Ref: RETScreen)
- Savings = $103,710/yr
  (0.079$/kWh in Indonesia– Ref: Global Petrol Prices)
- NPV = $204,500
- IRR = 11.2%
- Simple payback = 9.8 yr
- Benefit-Cost Ratio = 1.2
Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.
Environmental Benefits

According to RETScreen software, the GHG emission for 1 kWh is 0.819 kgCO2/kWh. Referring to the energy produced by PV system which is around 1.44 GWh, the gross annual GHG emission reduction CO2 is 1098 tCO2/yr which would be equivalent to:

- 201 cars and light trucks not used per year
- 471,568 Liters of gasoline not consumed
- 977 Households reducing energy by 100%
- 378 Tonnes of waste recycled
- 101 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

60%

Equivalent to

257 kWh/yr

5607 Citizens

977 Households

The yearly average consumption of a religious building is 120 kWh/m²

Source: RETScreen
6- Great Mosque of Algiers
This mosque is located in Mohammadia, Algeria. (36°44′05.9″N 3°08′24.4″E)

The optimal tilt angle of PV module is 30° and azimuth is south facing.
Preliminary Solar Energy Assessment

Average hourly profiles for each month
Total photovoltaic power output [Wh]

Monthly Averages
Total photovoltaic power output [kWh]

The figures show the hourly and monthly operation of 1 kWp PV system installed at Mohammadia town. We can conclude that the energy production ranges between 88 kWh/yr and 159 kWh/yr, with Moderate potential of solar energy.

Data source: Global Solar Atlas

Total Photovoltaic Power Output per year
= 1515 kWh/kWp
The adjacent map shows the land use type at radius 2 km from the mosque. Great mosque is located in a high dense urban coastal area with a few green areas.
• The rooftop area of the mosque is: 71,850 m²

• Total area available for installing PV system is: 60,440 m²
# PV Design of Mosque’s Rooftop

<table>
<thead>
<tr>
<th>Solar System Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV Module</strong></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>LR5-72 HPH 550 M</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Longi Solar</td>
</tr>
<tr>
<td>Nominal PV Power (kWp)</td>
<td>3925</td>
</tr>
<tr>
<td>Total Number of modules</td>
<td>7136 (16 in series, 446 in Parallel)</td>
</tr>
<tr>
<td>Total Area of Modules (m²)</td>
<td>18240</td>
</tr>
<tr>
<td>Total Number of Sheds</td>
<td>7138</td>
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<tr>
<td><strong>Inverter</strong></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>PVS800-57-0875Kw-B</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>ABB</td>
</tr>
<tr>
<td>Nominal Inverter Power (kWac)</td>
<td>3500 (4 inverters each 875)</td>
</tr>
<tr>
<td><strong>System Production</strong></td>
<td></td>
</tr>
<tr>
<td>Total Produced Energy (MWh/year)</td>
<td>5612</td>
</tr>
<tr>
<td>System Performance Ratio (%)</td>
<td>76</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
<td>$3,925,000</td>
</tr>
</tbody>
</table>
Economic Benefits

- **Total Initial Cost = $3,925,000**
  (Considering 1000 $ /KWP - Ref: RETScreen)

- **O&M Cost = $39,250/yr**
  (Considering 10 $ /KWP/yr - Ref: RETScreen)

- **Savings = $145,750/yr**
  (0.033$/kWh in Algeria– Ref: Global Petrol Prices)

- **IRR = 1.4%**

- **Simple payback = 26.9 yr**

- **Benefit-Cost Ratio = 0.44**
Potential Jobs Created

Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.

Environmental Benefits

According to RETScreen software, the GHG emission for 1 kWh is 0.542 kgCO2/kWh. Referring to the energy produced by PV system which is around 5.6 GWh, the gross annual GHG emission reduction CO2 is 2829 tCO2/yr which would be equivalent to:

- 518 cars and light trucks not used per year
- 1,215,378 Liters of gasoline not consumed
- 2818 Households reducing energy by 100%
- 975 Tonnes of waste recycled
- 260 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

65%

Equivalent to

323 kWh/yr

17,375 Citizens

2,824 Households

Source: RETScreen

The yearly average consumption of religious building is 120 kWh/m²
7- Nizamiyeh Mosque
This mosque is located in Midrand, South Africa. (26°00'50.4"S 28°07'46.9"E)

The optimal tilt angle of PV module is 29° and azimuth is north facing.

Source: Global Solar Atlas
Preliminary Solar Energy Assessment

Average hourly profiles for each month
Total photovoltaic power output [Wh]

Total Photovoltaic Power Output per year = 1738 kWh/kWp

Monthly Averages
Total photovoltaic power output [kWh]

The figures show the hourly and monthly operation of 1 kWp PV system installed in Midrand. We can conclude that the energy production ranges between 126 kWh/yr and 162 kWh/yr, with High potential of solar energy.

Data source: Global Solar Atlas
The adjacent map shows the land use type at radius 2 km from the mosque. Nizamiye mosque is located in a high density urban area with a large green areas and natural lands.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: \(3,330\) m\(^2\)
- Total area available for installing PV system is: \(1,110\) m\(^2\)
PV Design of Mosque’s Rooftop

<table>
<thead>
<tr>
<th>Solar System Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV Module</strong></td>
</tr>
<tr>
<td>Model: LR5-72 HPH 550 M</td>
</tr>
<tr>
<td>Manufacturer</td>
</tr>
<tr>
<td>Nominal PV Power (kWp)</td>
</tr>
<tr>
<td>Total Number of modules</td>
</tr>
<tr>
<td>Total Area of Modules (m^2)</td>
</tr>
<tr>
<td>Total Number of Sheds</td>
</tr>
<tr>
<td><strong>Inverter</strong></td>
</tr>
<tr>
<td>Model: PVM2-45-075-TT</td>
</tr>
<tr>
<td>Manufacturer</td>
</tr>
<tr>
<td>Nominal Inverter Power (kWac)</td>
</tr>
<tr>
<td><strong>System Production</strong></td>
</tr>
<tr>
<td>Total Produced Energy (MWh/year)</td>
</tr>
<tr>
<td>System Performance Ratio (%)</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
</tr>
<tr>
<td>$78,700</td>
</tr>
</tbody>
</table>
**Economic Benefits**

- **Total Initial Cost = $78,700**
  (Considering 1000 $ /KWp - Ref: RETScreen)

- **O&M Cost = $787/yr**
  (Considering 10 $ /KWp/yr - Ref: RETScreen)

- **Savings = $9,493/yr**
  (0.071$/kWh in South Africa– Ref: Global Petrol Prices)

- **NPV = $33,300**

- **IRR = 13.4%**

- **Simple payback = 8.3 yr**

- **Benefit-Cost Ratio = 1.4**
Potential Jobs Created


Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.
According to RETScreen software, the GHG emission for 1 kWh is 0.958 kgCO2/kWh. Referring to the energy produced by PV system which is around 0.144 GWh, the gross annual GHG emission reduction CO2 is 128 tCO2/yr which would be equivalent to:

- 55,181 Liters of gasoline not consumed
- 24 and light trucks not used per year
- 51 Households reducing energy by 100%
- 44 Tonnes of waste recycled
- 12 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

- **36%**

Equivalent to

- **164 kWh/yr**
- **878 Citizens**
- **51 Households**
- **2083 kWh/yr**

The yearly average consumption of a religious building is **120 kWh/m²**.

Source: RETScreen
8- Al Haram Mosque
This mosque is located in Mecca, Saudi Arabia. \((21^\circ25'17.9''N ~ 39^\circ49'34.2''E)\)

The optimal tilt angle of PV module is 22° and azimuth is south facing.

Source: Global Solar Atlas
Preliminary Solar Energy Assessment

Average hourly profiles for each month
Total photovoltaic power output [Wh]

Total Photovoltaic Power Output per year
= 1726 kWh/kWp

Monthly Averages
Total photovoltaic power output [kWh]

The figures show the hourly and monthly operation of 1 kWp PV system installed at Mecca. We can conclude that the energy production ranges between 131 kWh/yr and 161 kWh/yr, with high potential of solar energy.

Data source: Global Solar Atlas
The adjacent map shows the land use type at radius 2 km from the mosque. Al Haram mosque is located in a high density urban area with a few green areas and surrounded by mountains.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: **164,000 m²**
- Total Area available for installing PV system is: **32,260 m²**
**PV Design of Mosque’s Rooftop**

### Solar System Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>PV Module</strong></td>
<td>Model: LR5-72 HPH 540 M</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Longi Solar</td>
</tr>
<tr>
<td>Nominal PV Power (kWp)</td>
<td>2634</td>
</tr>
<tr>
<td>Total Number of modules</td>
<td>4878 (18 in series, 271 in Parallel)</td>
</tr>
<tr>
<td>Total Area of Modules (m²)</td>
<td>12468</td>
</tr>
<tr>
<td>Total Number of Sheds</td>
<td>4878</td>
</tr>
<tr>
<td><strong>Inverter</strong></td>
<td>Model: FreeSun FS1130 HES 330V</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Power Electronics</td>
</tr>
<tr>
<td>Nominal Inverter Power (kWac)</td>
<td>2260 (2 inverters each 1130)</td>
</tr>
<tr>
<td><strong>System Production</strong></td>
<td></td>
</tr>
<tr>
<td>Total Produced Energy (MWh/year)</td>
<td>4564</td>
</tr>
<tr>
<td>System Performance Ratio (%)</td>
<td>73</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
<td>$2,634,000</td>
</tr>
</tbody>
</table>
Economic Benefits

- **Total Initial Cost = $2,634,000**
  (Considering 1000 $ /KWp - Ref: RETScreen)

- **O&M Cost = $26,340/yr**
  (Considering 10 $ /KWp/yr - Ref: RETScreen)

- **Savings = $288,420/yr**
  (0.069$/kWh in Saudi Arabia – Ref: Global Petrol Prices)

- **NPV = $769,000**

- **IRR = 12.1%**

- **Simple payback = 9.1 yr**

- **Benefit-Cost Ratio = 1.3**
Potential Jobs Created

Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.

According to RETScreen software, the GHG emission for 1 kWh is 0.556 kgCO2/kWh. Referring to the energy produced by PV system which is around 4.564 GWh, the gross annual GHG emission reduction CO2 is 2359 tCO2/yr which would be equivalent to:

- 432 cars and light trucks not used per year
- 1,013,458 Liters of gasoline not consumed
- 1058 Citizens reducing energy by 100%
- 813 Tonnes of waste recycled
- 217 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

23%

Equivalent to

4314 kWh/yr

1058 Citizens

The yearly average consumption of a religious building is 120 kWh/m²

Source: RETScreen
9- Ummayeed Mosque
This mosque is located in Damascus, Syria. (33°30'40.6"N 36°18'25.9"E)

The optimal tilt angle of PV module is 29° and azimuth is south facing.

Source: Global Solar Atlas
The figures show the hourly and monthly operation of a 1 kWp PV system installed in Damascus. We can conclude that the energy production ranges between 110 kWh/yr and 178 kWh/yr, with high potential of solar energy. Data source: Global Solar Atlas.
The adjacent map shows the land use type at radius 2 km from the mosque. Umayyad mosque is located in a high dense urban area with a few green areas.
Preliminary Solar Site Assessment

- The rooftop area of the mosque is: $8,790 \, m^2$
- Total area available for installing PV system is: $6,730 \, m^2$
## PV Design of Mosque’s Rooftop

### Solar System Parameters

<table>
<thead>
<tr>
<th>Component</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV Module</strong></td>
<td>Model: LR5-72 HPH 550 M</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Longi Solar</td>
</tr>
<tr>
<td>Nominal PV Power</td>
<td>960 kWp</td>
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<tr>
<td>Total Number of modules</td>
<td>1746 (18 in series, 97 in Parallel)</td>
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<tr>
<td>Total Area of Modules</td>
<td>4463 m²</td>
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<tr>
<td>Total Number of Sheds</td>
<td>1749</td>
</tr>
<tr>
<td><strong>Inverter</strong></td>
<td>Model: RPS 1040 Master-Slave</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Bonfiglioli Vectron</td>
</tr>
<tr>
<td>Nominal Inverter Power</td>
<td>917 kWac</td>
</tr>
<tr>
<td><strong>System Production</strong></td>
<td></td>
</tr>
<tr>
<td>Total Produced Energy (MWh/year)</td>
<td>1532</td>
</tr>
<tr>
<td>System Performance Ratio</td>
<td>71 (%)</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
<td>$960,000</td>
</tr>
</tbody>
</table>
**Economic Benefits**

- **Total Initial Cost** = $960,000  
  (Considering 1000 $ /Kwp - Ref: RETScreen)

- **O&M Cost** = $9,600/yr  
  (Considering 10 $ /Kwp/yr - Ref: RETScreen)

- **Savings** = $373,200/yr  
  (0.25$/kWh in Syria, Reference: Assumption)

- **NPV** = $3,444,000

- **IRR** = 41.7%

- **Simple payback** = 2.6 yr

- **Benefit-Cost Ratio** = 4.6
Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW.
Environmental Benefits

According to RETScreen software, the GHG emission for 1 kWh is 0.707 kgCO2/kWh. Referring to the energy produced by PV system which is around 1.532 GWh, the gross annual GHG emission reduction CO2 is 1008 tCO2/yr which would be equivalent to:

185 and light trucks not used per year
432,935 Liters of gasoline not consumed
310 Households reducing energy by 100%
347 Tonnes of waste recycled
93 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

100% + 694 Citizens = 2226 Citizens = 310 Households

Equivalent to 688 kWh/yr

4943 kWh/yr

Source: RETScreen

The yearly average consumption of religious building is 120 kWh/m²
10- Hassan II Mosque
This mosque is located in Casablanca, Morocco. (33°36’27.9”N 7°38’01.3”W)

The optimal tilt angle of PV module is 29° and azimuth is south facing.

Source: Global Solar Atlas
The figures show the hourly and monthly operation of 1 kWp PV system installed in the city of Casablanca. We can conclude that the energy production ranges between 103 kWh/yr and 157 kWh/yr, with high potential of solar energy. Data source: Global Solar Atlas.
The adjacent map shows the land use type at radius 2 km from the mosque. Hassan II mosque is located in a coastal high density urban area with a few green areas.
Preliminary Solar Site Assessment

• The rooftop area of the mosque is: **27,800 m^2**

• Total area available for installing PV system is: **10,560 m^2**
## Solar System Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>PV Module</strong></td>
<td>Model: LR5-72 HPH 540 M</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Longi Solar</td>
</tr>
<tr>
<td>Nominal PV Power (kWp)</td>
<td>729</td>
</tr>
<tr>
<td>Total Number of modules</td>
<td>1350 (18 in series , 75 in Parallel)</td>
</tr>
<tr>
<td>Total Area of Modules (m²)</td>
<td>3451</td>
</tr>
<tr>
<td>Total Number of Sheds</td>
<td>1350</td>
</tr>
<tr>
<td><strong>Inverter</strong></td>
<td>Model: SUNWAY TG750 1000V TE - 320 OD</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Santerno</td>
</tr>
<tr>
<td>Nominal Inverter Power (kWac)</td>
<td>665</td>
</tr>
<tr>
<td><strong>System Production</strong></td>
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</tr>
<tr>
<td>Total Produced Energy ( MWh/year)</td>
<td>1057</td>
</tr>
<tr>
<td>System Performance Ratio (%)</td>
<td>70</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
<td>$729,000</td>
</tr>
</tbody>
</table>
**Economic Benefits**

- **Total Initial Cost** = $729,000  
  (Considering 1000 $ /Kwp - Ref: RETScreen)

- **O&M Cost** = $7,290/yr  
  (Considering 10 $ /Kwp/yr - Ref: RETScreen)

- **Savings** = $117,410/yr  
  (0.118$/kWh in Morocco– Ref: Global Petrol Prices)

- **NPV** = $656,500

- **IRR** = 18%

- **Simple payback** = 6.2 yr

- **Benefit-Cost Ratio** = 1.9
Potential Jobs Created

Average employment (jobs per megawatt of solar photovoltaic system) over life of facility including manufacturing, construction, installation and operation & maintenance ranges between 6.96 and 11.01 per MW

According to RETScreen software, the GHG emission for 1 kWh is 0.680 kgCO2/kWh. Referring to the energy produced by PV system which is around 1.057 GWh, the gross annual GHG emission reduction CO2 is 668 tCO2/yr which would be equivalent to:

122 and light trucks not used per year
287,224 Liters of gasoline not consumed
810 Households reducing energy by 100%
231 Tonnes of waste recycled
62 Hectares of forest absorbing carbon
Additional Benefits

Coverage of Energy Demand

32%

Equivalent to

245 kWh/yr

4314 Citizens = 810 Households

The yearly average consumption of a religious building is 120 kWh/m²
Conclusion: The Result of 10 Mosques Going Solar

- 22.3 GWh/yr of annual energy production
- Reduces 
  - 12025 TCO₂/yr
  - Equivalent to:
  - 5,166,844 Liters of gasoline not consumed
  - 2203 cars and light trucks not used per year
  - Protection of 1107 hectares of forest absorbing carbon
  - 37980 persons reducing energy by 100%

New jobs created: Between 93 - 153