Solar Energy Forecast for Mobile PV Applications

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Motivation and Concept

The Motivation:
For the reduction of fossil fuel consumption for cooling applications on the transport of perishable goods a sound business model is essential. The potential solar energy yield is the main argument for or against investment into solar cells.

The Problem:
Commercial software-solutions enable solar energy yield calculations for stationary constructions but not along a given track. Long-distance lorries operate in huge areas which cannot be represented by a stationary profile.

Database

Meteorological database
Stationary data of a typical meteorological year (TMY) from meteonorm
- Wind
- Ambient Temperature
- Global Horizontal Irradiance
- 5 km spatial resolution
- 1 Minute temporal resolution

Structure and Storage
Data format HDF5
No. container 83
Area covered per container 5.2’ x 5.2’
Overlap each side 0.1’
No. unique data frames 17916
Size 144 GB
No. columns per frame 7
No. rows per frame 825600

Irradiance Distribution Preservation

The sizing of electro technical installations depend on:
- Annual power distribution
- Depending on the irradiance distribution
- Estimated energy yield

The averaging effect of spatial interpolation alters the irradiance distribution in favor of median irradiances.

To preserve the power distribution averaging should be avoided.

Lorry Operating Profiles

To maintain the cold chain of perishable goods and frequency of drive and break times, lorries are equipped with a mechanic trip recorder or a digital recorder incl. positioning data.

Ambient Wind vs. Head Wind

Far-distance lorries operate mainly on highways with a mean driving speed of 80 km/h (~22 m/s).
The resulting mean head wind is much higher than the mean ambient wind-speed in Germany (3-5 m/s).

Wind Chill Effect on Solar Modules

Module temperature depends on:
- Irradiance (G)
- Wind speed (FF)
- Ambient Temperature (Ta)
- Mounting Parameter (a, b)

Cell and module temperatures have a serious impact in the module efficiency depending on the cell material and technology.

Fig. 4: Annual distribution of ambient wind and vehicle speed of 3 trucks operating in Germany.

Fig. 5: Simulated cell temperature and efficiency (Ta = 5°C, G = 1000W/m²) for a crystalline silicon cell with insulated back. Median wind speed and median vehicle-speed ± real wind are indicated in grey.

Calculated energy yield (E) considering only the ambient wind or both ambient wind speed and head wind

<table>
<thead>
<tr>
<th></th>
<th>Only wind in kWh/a</th>
<th>Incl. head wind in kWh/a</th>
<th>ΔE in kWh/a</th>
<th>ΔE in %</th>
<th>hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole profile</td>
<td>6946</td>
<td>7021</td>
<td>75</td>
<td>1.1</td>
<td>8668.4</td>
</tr>
<tr>
<td>Driving hours</td>
<td>1904</td>
<td>1979</td>
<td>75</td>
<td>3.8</td>
<td>1848.3</td>
</tr>
</tbody>
</table>

Conclusions

High temporal and spatial resolution is a necessity.
Depending on cell and mounting technology an energy yield of 7 MWh/a and lorry in Germany is possible.
Head wind can improve the annual efficiency of solar modules by up to 2.25 %.
To estimate the potential of vehicle integrated PV a good knowledge of the driving behavior and tracks is important.