Solar Energy Forecast for Mobile PV Applications

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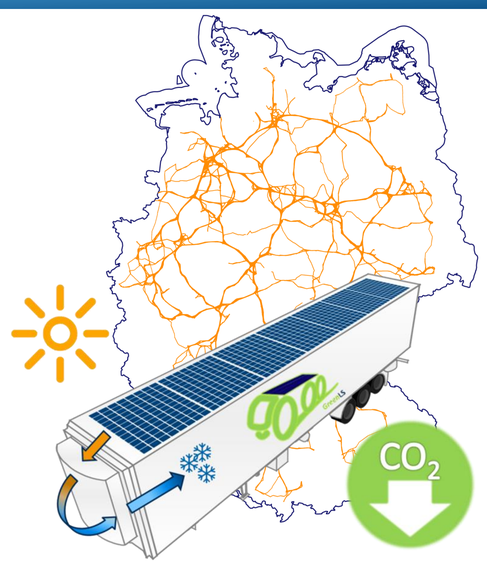
Motivation and Concept

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 can not be represented by a stationary profile.



The Concept:

Meteorological simulation
- Establish a suitable met. data grid
- An algorithm for the creation of a met. profile along a track

Specifics of moving PV installations
- Identify temperature evolution on insulated back
- Estimate head-wind benefit

Calculation of the potential
- PV simulation with python library pvlib
- Calculation of the energy yield

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	525600

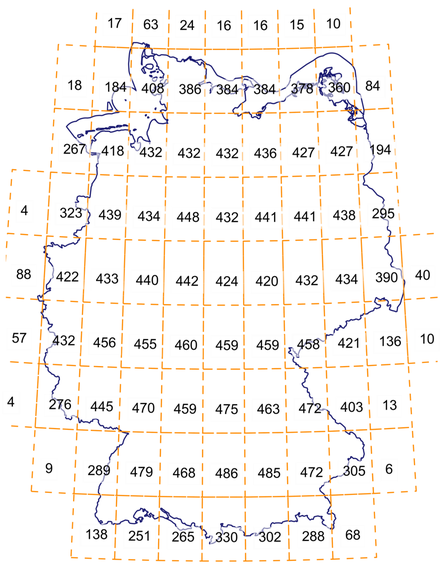


Fig. 1.: Container size and location incl. no. of datasets inside each container.

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.

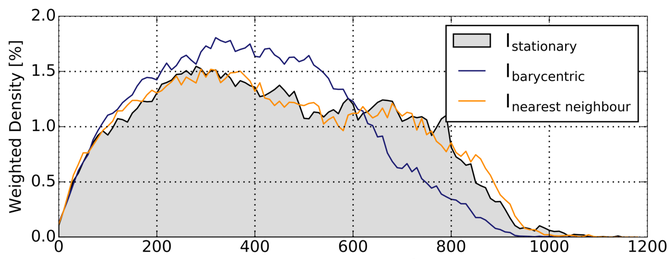


Fig. 2.: Annual irradiance distribution of a stationary dataset (grey area) and a track of the same area (interpolated: blue, nearest neighbour: orange).

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 .

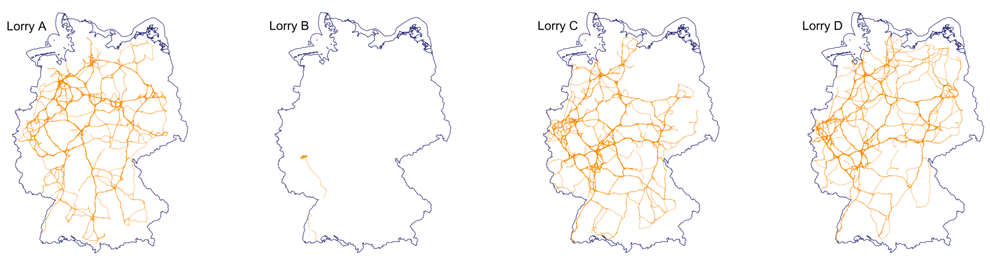


Fig. 3.: Annual track profiles of four operating lorries from „Uhlhorn Logistik“ which were used as showcases for the algorithm

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).

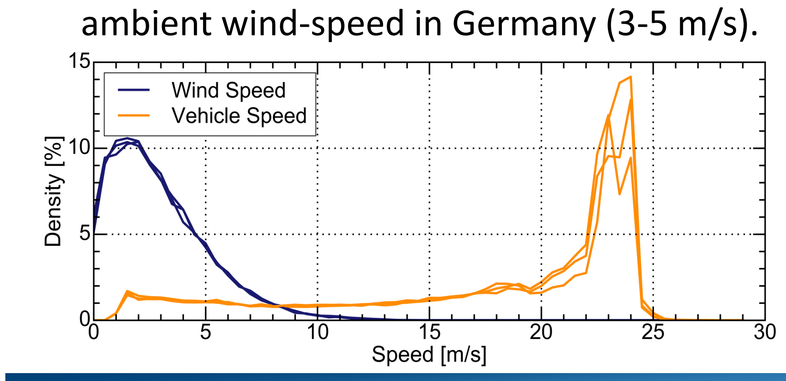


Fig. 4.: Annual distribution of ambient wind and vehicle speed of 3 trucks operating in Germany.

Wind Chill Effect on Solar Modules

- Module temperature depends on:
  - Irradiance (G)
  - Wind speed (FF)
  - Ambient Temperature (T_a)
  - Mounting Parameter (a, b)
- Cell and module temperatures have a serious impact in the module efficiency depending on the cell material and technology.

$$T_m = G \cdot e^{a+b \cdot FF} + T_a$$

Eq. 1.: Module temperature

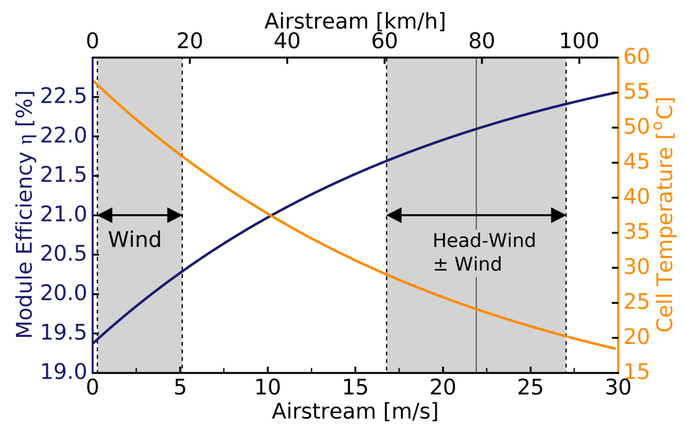


Fig. 5.: Simulated cell temperature and efficiency (T_a = 5°C, G = 1000W/m²) for a crystalline silicon cell with insulated back. Median wind speed and median vehicle-speed ± real wind are indicated in grey.

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

	Only wind in kWh/a	Incl. head wind in kWh/a	ΔE in kWh/a	ΔE in %	hours
Whole profile	6946	7021	75	1.1	8668.4
Driving hours	1904	1979	75	3.8	1848.3

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.