FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE

Potential of PV on Trucks: A Field Study

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PV-Days 2017
Halle (Saale), 24.10.2017

www.ise.fraunhofer.de

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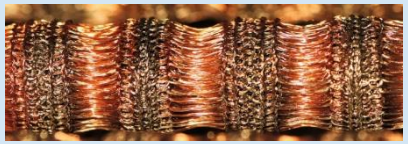
At a Glance

Institute Directors:
Prof. Dr. Hans-Martin Henning
Dr. Andreas Bett

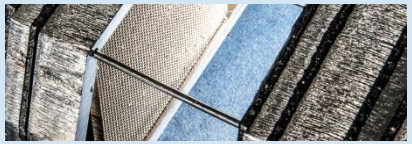
Staff:	ca. 1150
Budget 2016:	€ 81.2 million
Established:	1981

Photovoltaics

Solar Thermal Technology



Building Energy Technology



Hydrogen Technologies

Energy System Technology

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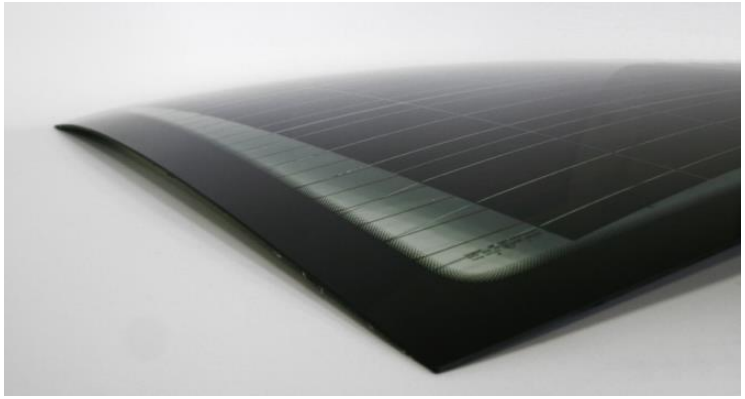
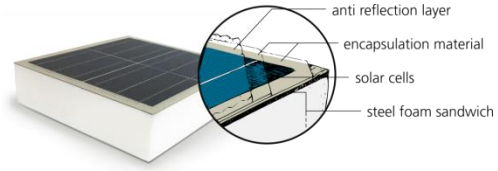
Module Technology at Fraunhofer ISE
Customized modules

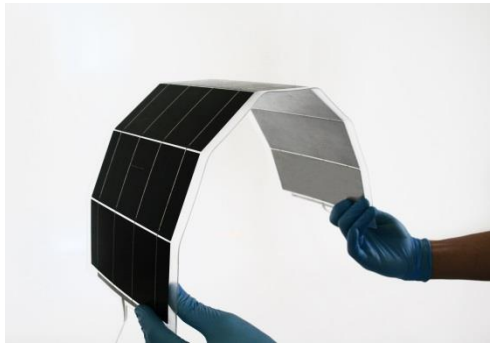
- Automotive applications
  - Design and Manufacturing process for 3D spherically shaped PV Modules
  - Cost efficient prototyping
  - Module power characterization and analysis
  - PV active thermal insulation panels for refrigerated trucks

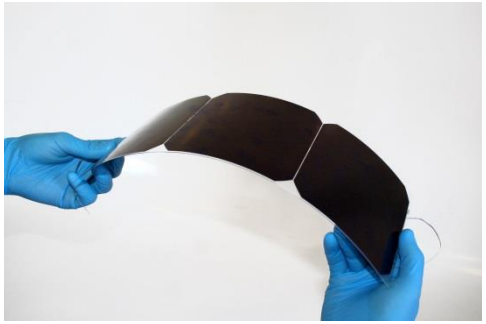


Module Technology at Fraunhofer ISE
Customized modules

- Automotive applications
- Light-weight modules
  - special applications with weight limitations
  - PV on composite substrates, excellent stiffness at minimal weight
  - Cost efficient prototyping
  - Module characterization and analysis
  - Substrate qualification and suitable manufacturing process development







Module Technology at Fraunhofer ISE

Morpho Butterfly Inspired Coloured BIPV Modules

- Colour induced efficiency reduction only 7% relative
- Large variety of colours possible
- Only module glass is modified
- ➔ Standard solar cells and lamination processes can be used

Demonstrator modules: 1.09 x 1.12 m^2

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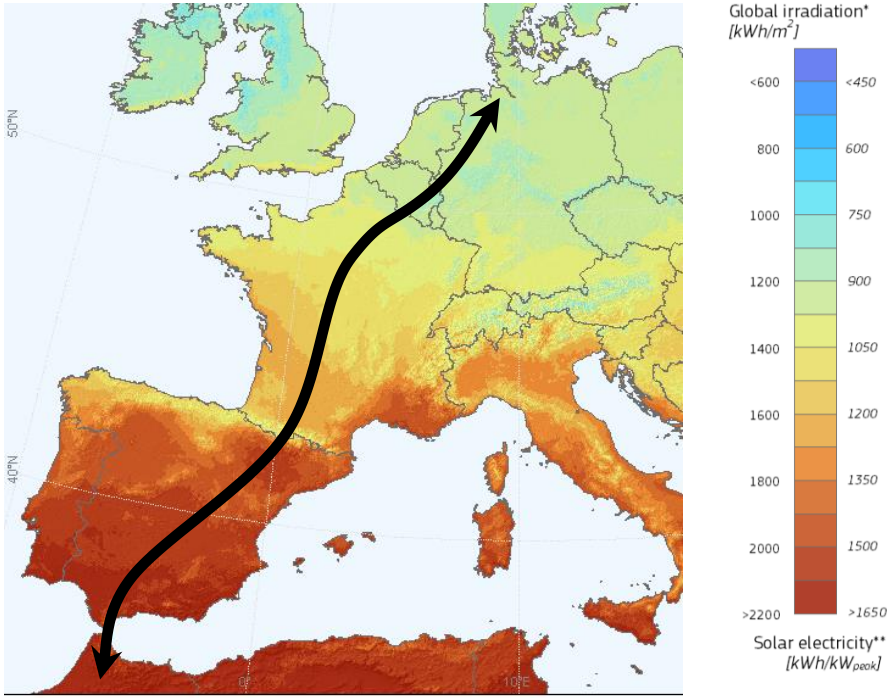
Motivation

Example: route of the prawns



Transport of prawns between northern Germany and Morocco

→ 50% of route at > 1400 kWh/m²a

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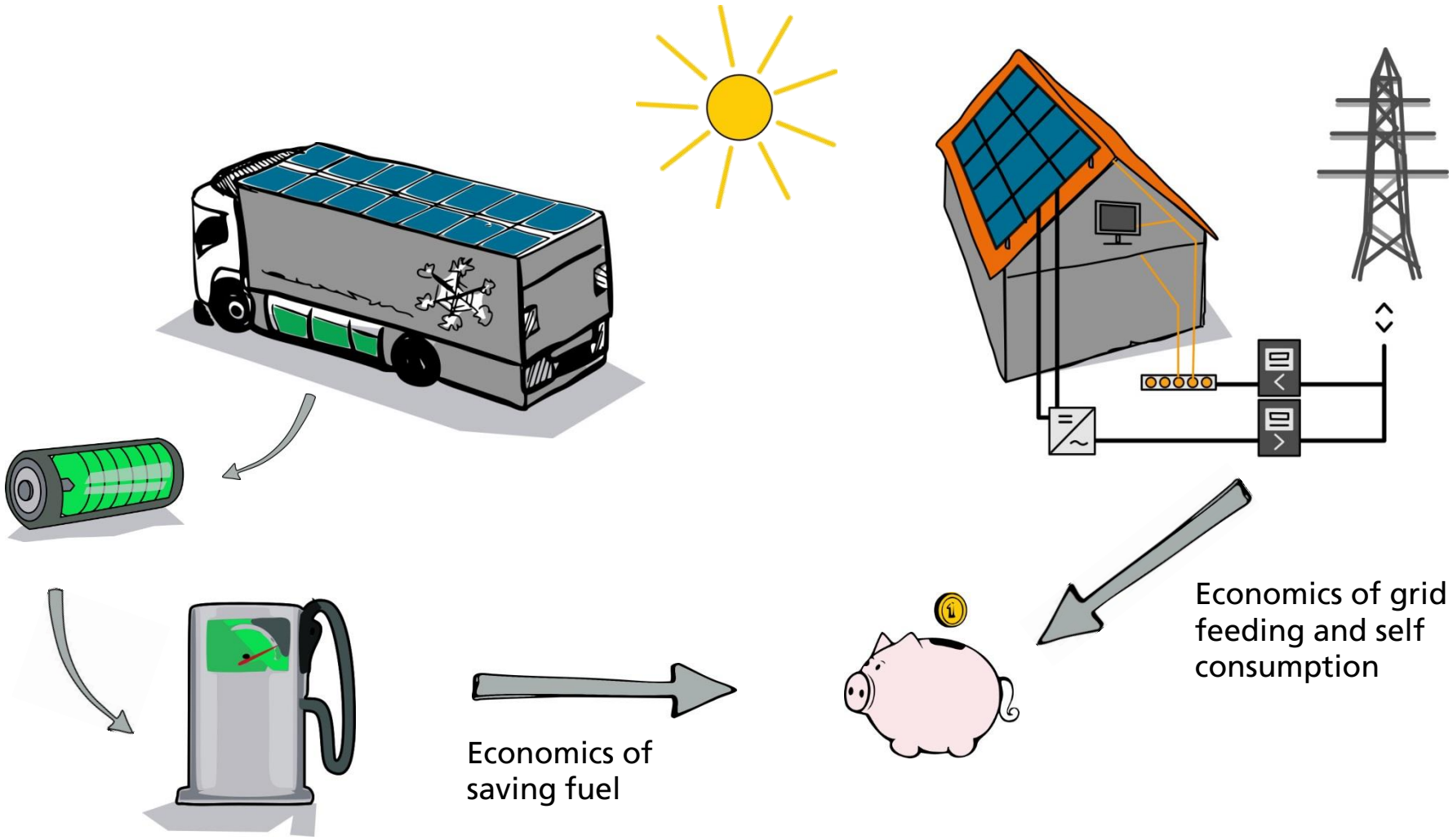
Motivation

PV on refrigerating trucks



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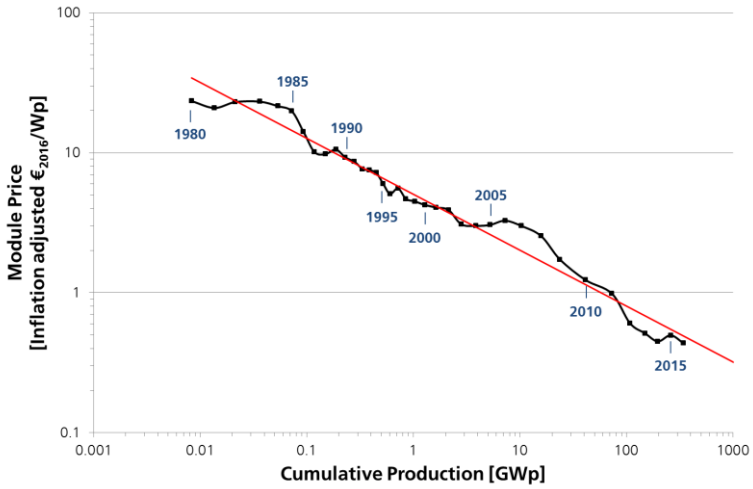
Motivation
Previous work

- PV on refrigerating trucks to save diesel



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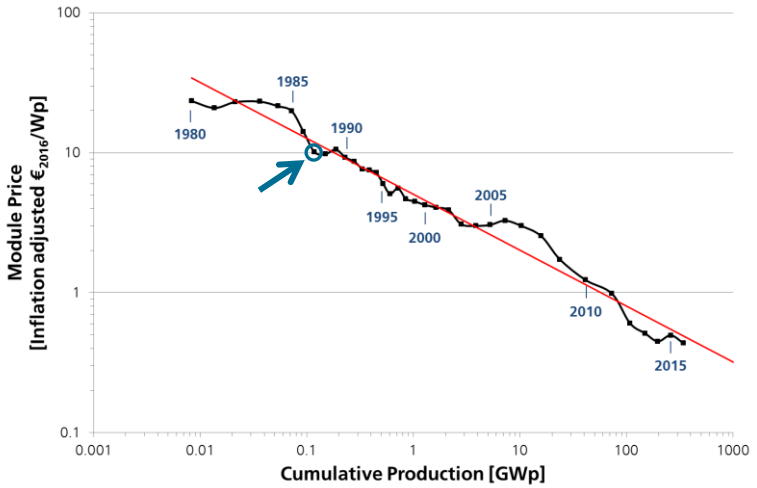
Motivation
Previous work

- PV on refrigerating trucks to save diesel
  - 1997: Sainsbury truck[1]

    → Calculated economic break even for PV+battery in UK ~15 yrs



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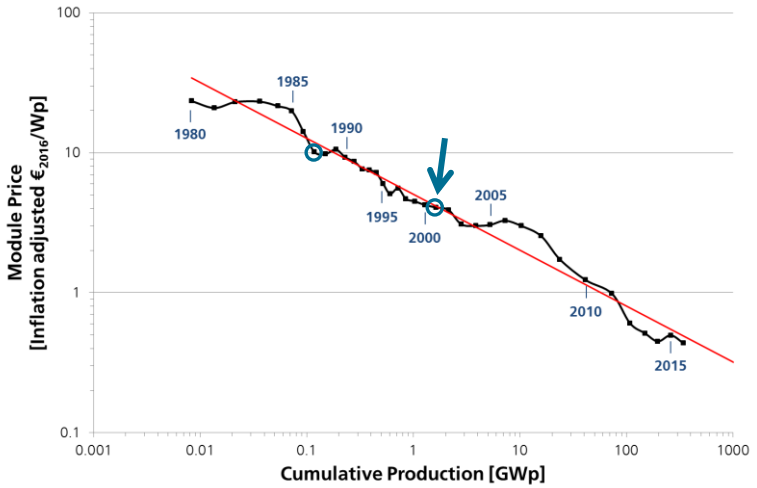
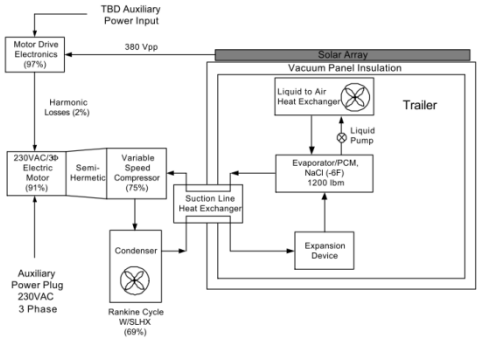
Motivation
Previous work

- PV on refrigerating trucks to save diesel
  - 1997: Sainsbury truck[1]
  - 2001: Sandia study[2]

    → Economic break even in US ~20 yrs @ 5$/$W_p$ module prize





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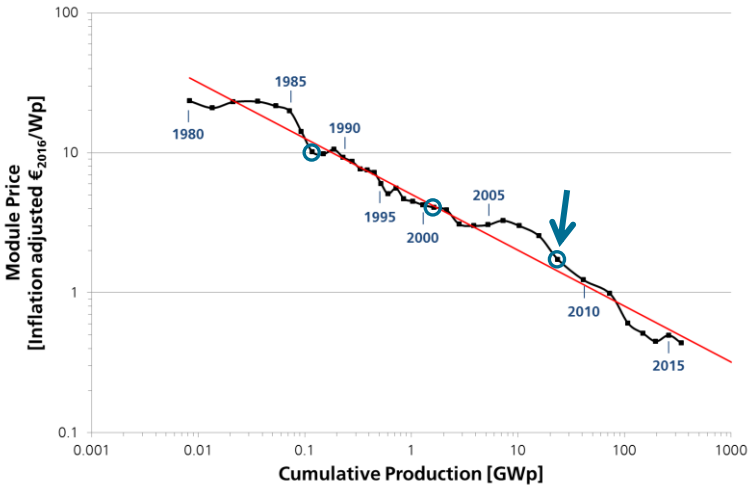
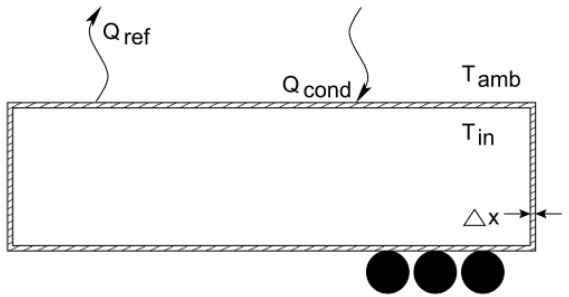
  - 1997: Sainsbury truck[1]
  - 2001: Sandia study[2]
  - 2009: ANU Study[3]

    → not economically feasible for Australia at Diesel prize level





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  - 1997: Sainsbury truck[1]
  - 2001: Sandia study[2]
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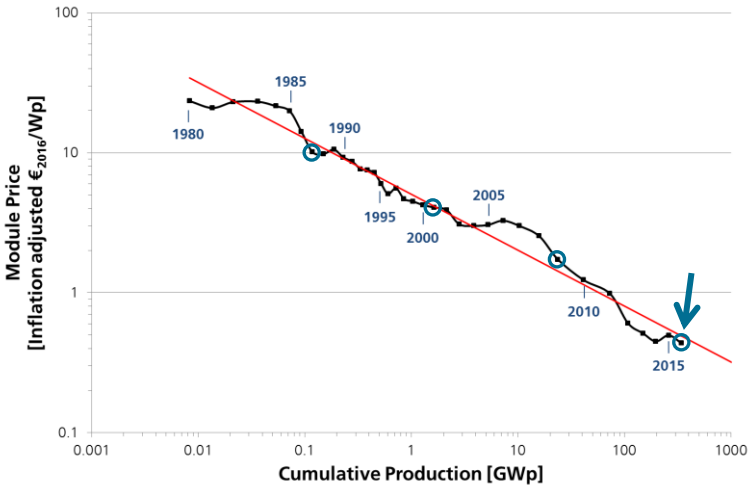
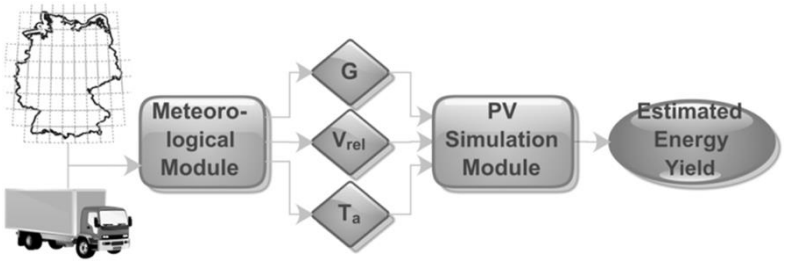
  - 2016: Next Energy study[4]
  - → simulation study yields diesel savings of 2000 L/a for cSi and 850 L/a for thin film PV





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[4] M. Kühnel et al., PROG PV (7), 2017, pp. 525–532

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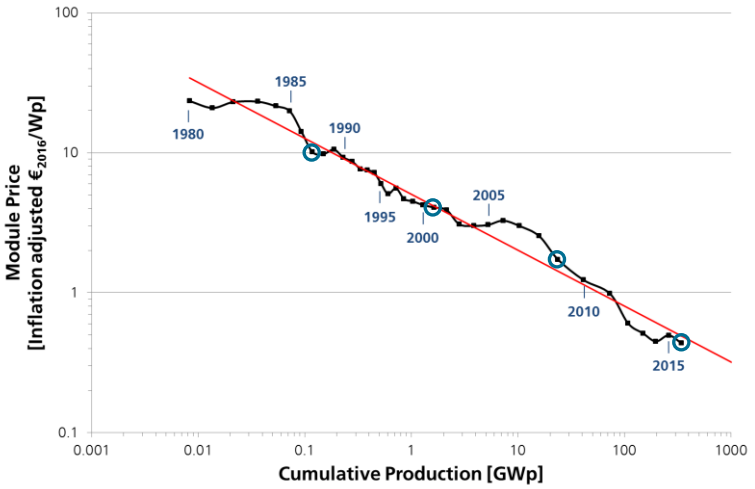

→ Outdated or modelled data
→ up-to-date verification by measuring operational yield needed

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Measurement campaign
PV yield assessment

- Record irradiance profiles for real transportation routes
- Verified yield models required for system design and economical evaluation

Housing of measurement electronics

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Measurement campaign
Data measured

- Measured data
  - GPS coordinates
  - Solar cell I_{SC}
  - Cell temperature T

- Calculation of
  - Status moving/stationary
  - Day/night
  - Irradiation G
  - Yield E for full roof coverage

$$G = \frac{I_{sc}}{I_{sc,STC}} \cdot G_{STC} \cdot \left(1 - (T_{cell} - 25°C) \cdot \beta\right)$$

$$P_{\mathrm{mod}} = G \cdot \eta_{\mathrm{mod}} \cdot \left(1 - (T_{cell} - 25°C) \cdot \alpha\right)$$

$$E = \sum_{1}^{n} P_{\mathrm{mod}} \cdot \Delta t$$

Measurement campaign
Trucks and routes

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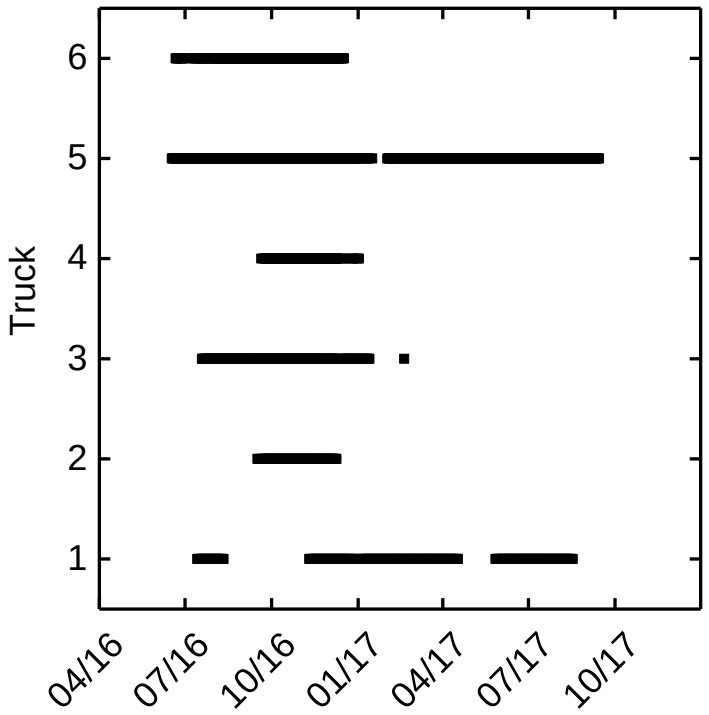
Measurement campaign
Results for 40t trailer

- Start of campaign June 2016
  - > 1 year
  - 3 months
  - Failures of electronics due to water ingress
  - Temporary failure of temperature sensor
- Incorrect data filtered for postprocessing



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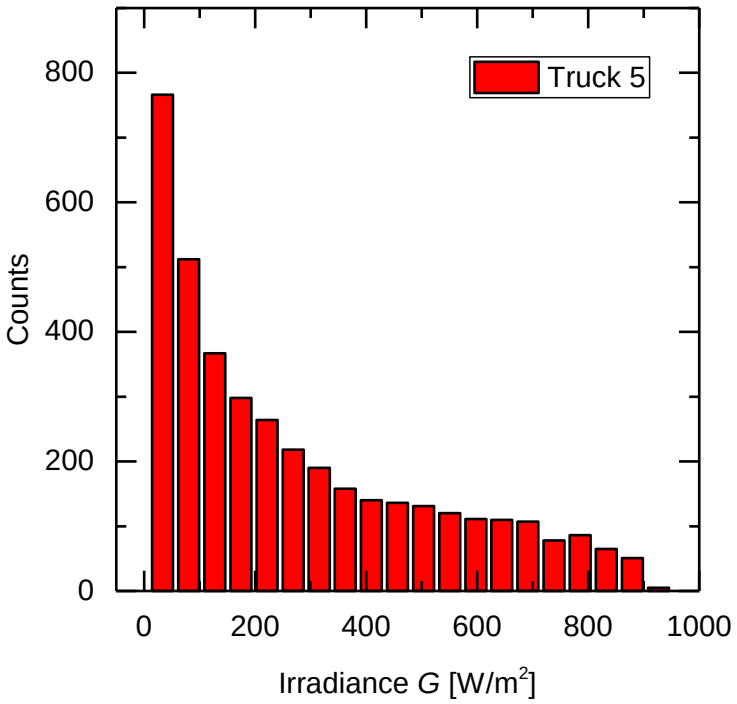
Measurement campaign
Irradiance levels and temperature effects

- Horizontal mounting leads to lower yield
- 50% of measured data < 200 W/m²
- Maximum irradiance 930 W/m²
- Angular effects included and sensor not cleaned



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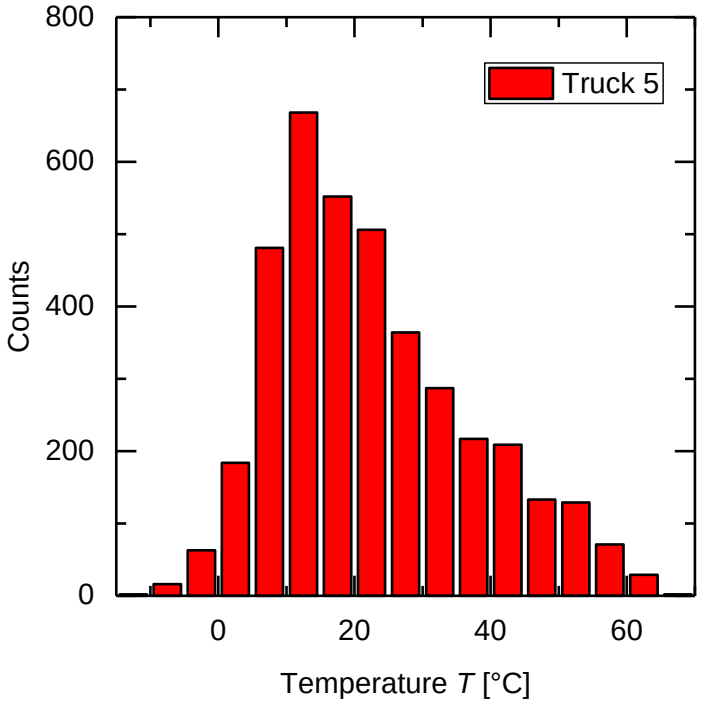
- Cell temperature range between -14°C and 66°C
- Average temperature 22°C



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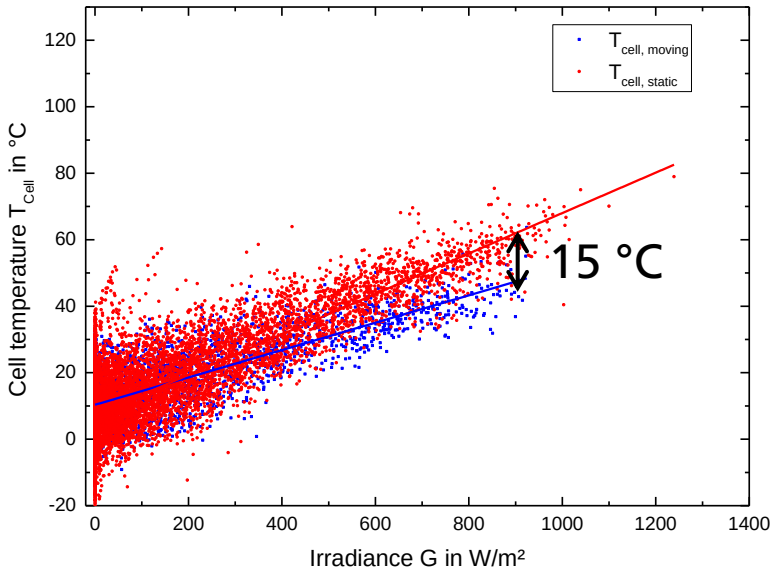
- Head wind cools cell temperature by ~15°C @ G > 800 W/m²



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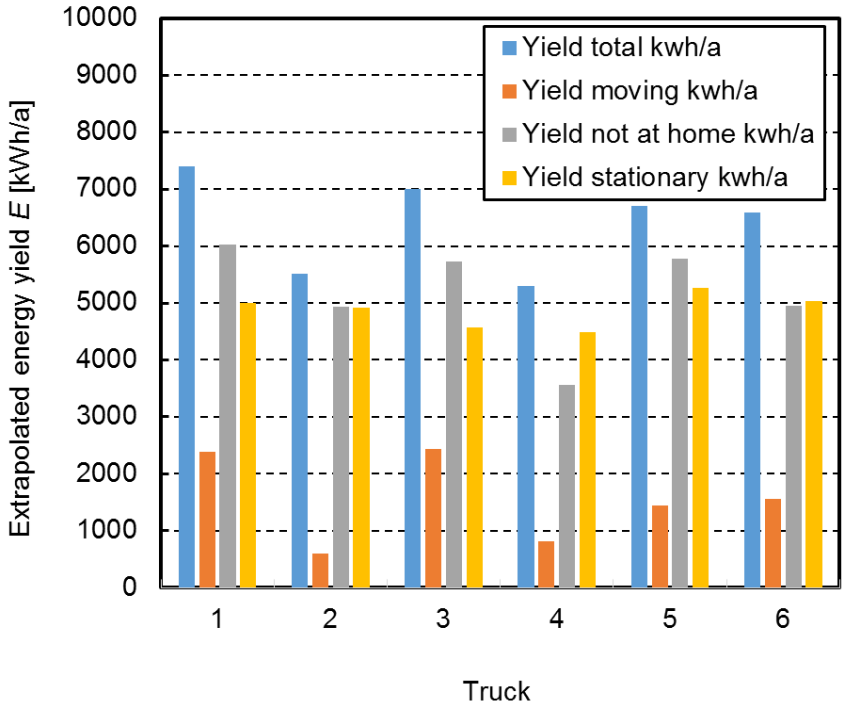
Measurement campaign
Annual yield

- Extrapolation of measured data
  - to 1 year for all trucks
  - based on monthly yield data of nearby location
- Grouping data into status
  - Total yield
  - Yield moving
  - Yield stationary
  - Yield not at home



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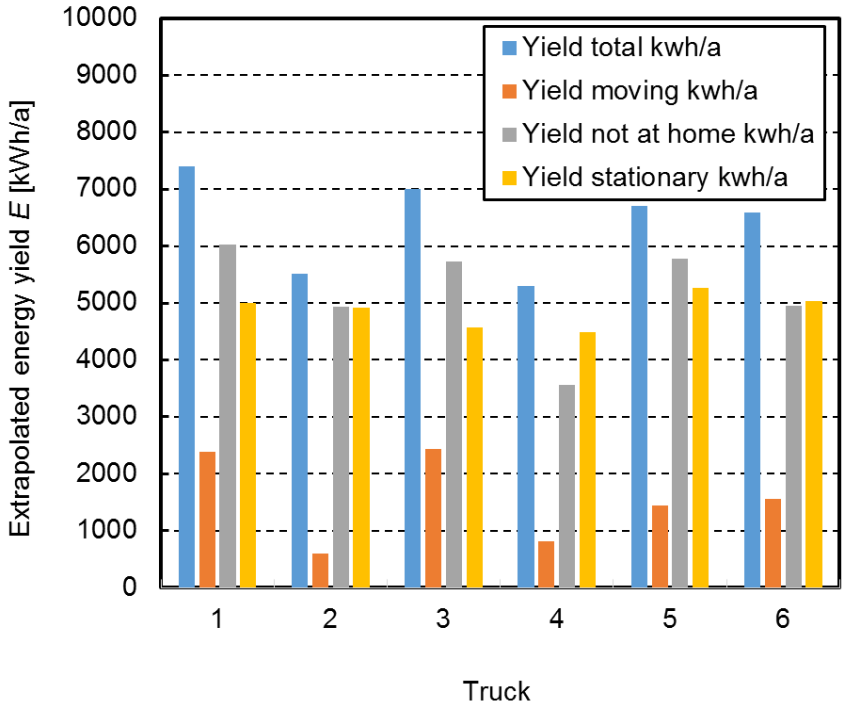

→ Yield between 7395 and 5297 kWh/a, in average 6421 kWh/a

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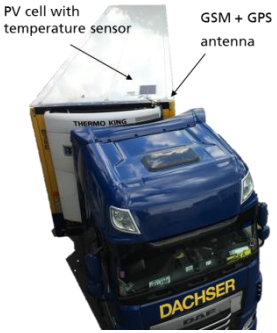
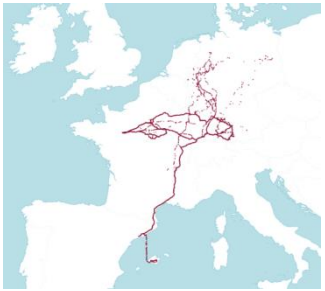
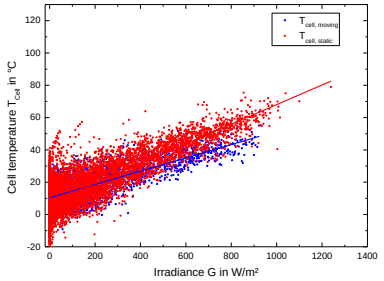
Conclusion

- Measurement campaign on 6 trucks in Europe and US
- Cell temperature range between -14°C and 66°C
- Head wind cooling ~15°C
- Annual yield
  - between 5297 and 7395 kWh/a in total
  - 11 – 35 % (Ø 23 %) during movement
- Diesel reduction
  - Yield equivalent to 1513 L and 2113 L
  - Next Energy study for Germany (2000 L) reasonable

→ Electricity usage and transport scenario highly decisive for PV on trucks







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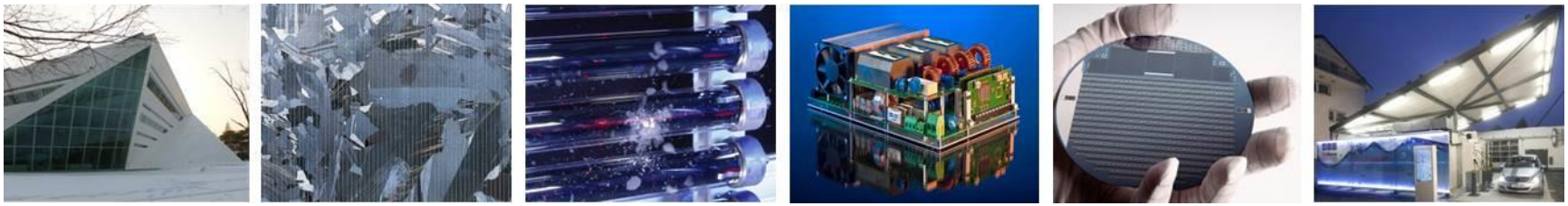

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