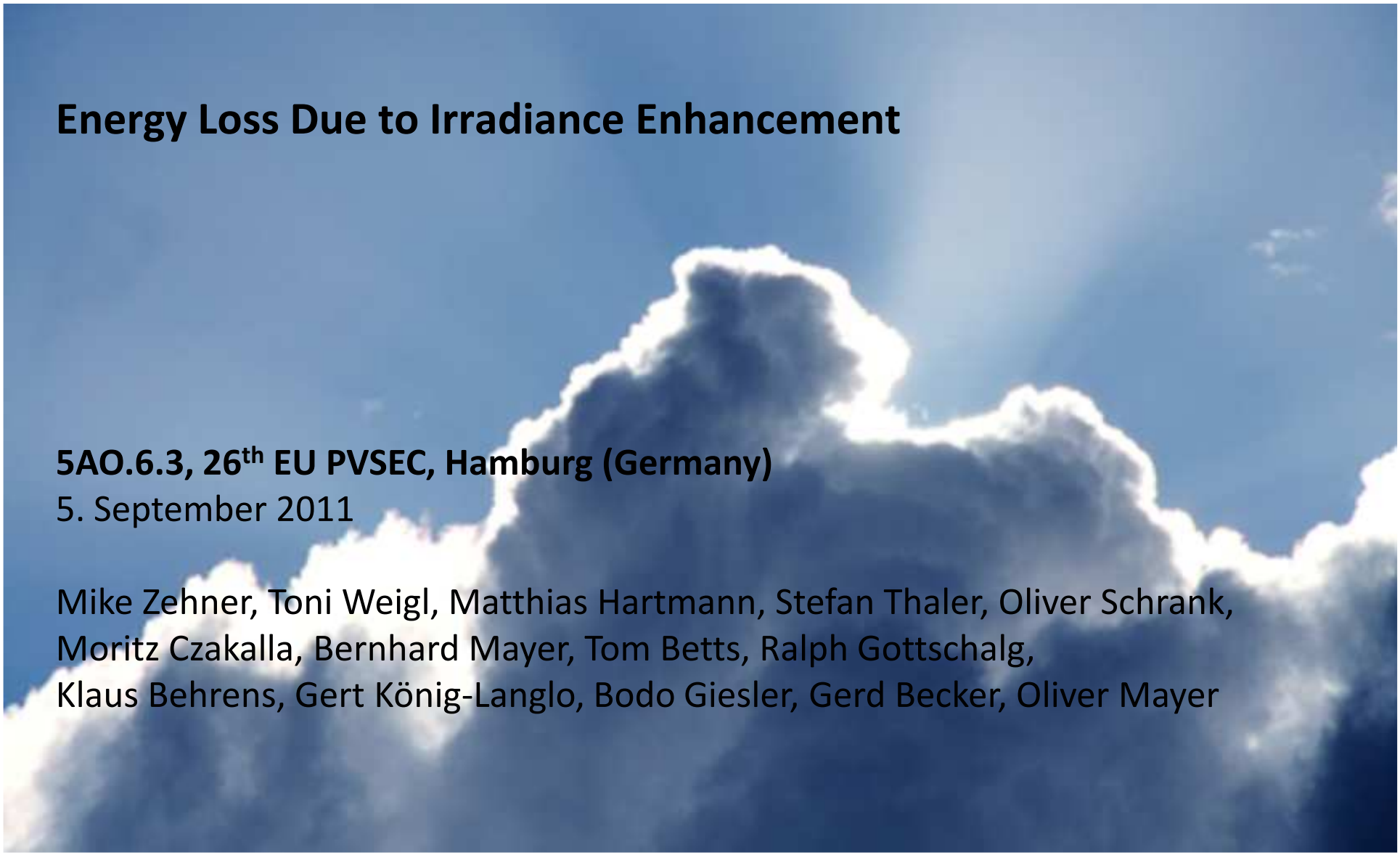


Energy Loss Due to Irradiance Enhancement

5AO.6.3, 26th EU PVSEC, Hamburg (Germany)
5. September 2011

Mike Zehner, Toni Weigl, Matthias Hartmann, Stefan Thaler, Oliver Schrank,
Moritz Czakalla, Bernhard Mayer, Tom Betts, Ralph Gottschalg,
Klaus Behrens, Gert König-Langlo, Bodo Giesler, Gerd Becker, Oliver Mayer

Survey on the Talk ‘Energy Loss Due to Irradiance Enhancement’

1) What is Irradiance Enhancement?
   Correlations and Profiles of the Effect

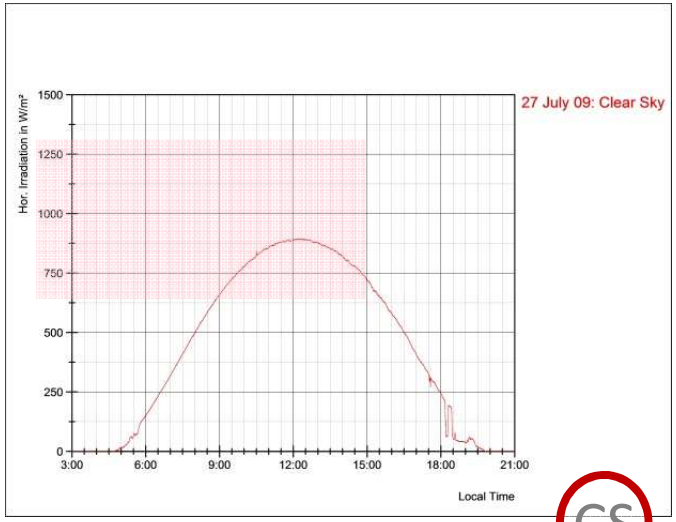
2) Improvements of the data base and
   Internationalisation

3) Relevance for PV-systems

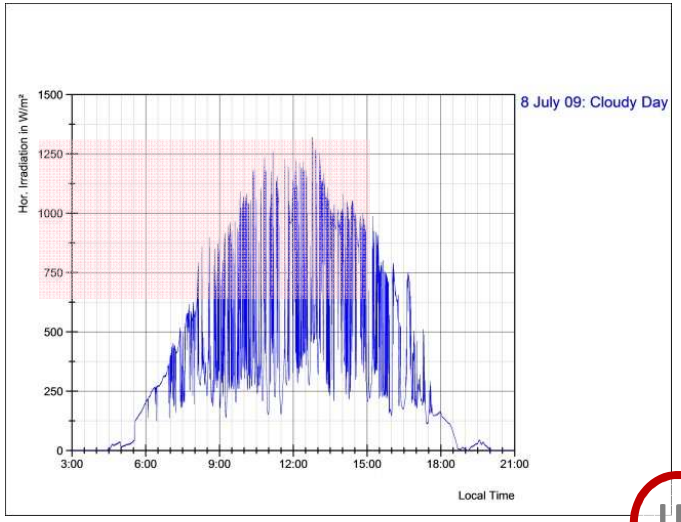
4) Wrap-up and next steps

Mike Zehner, Munich University of Applied Sciences, Work Group Degree Course Renewable Energies, mike.zehner@hm.edu

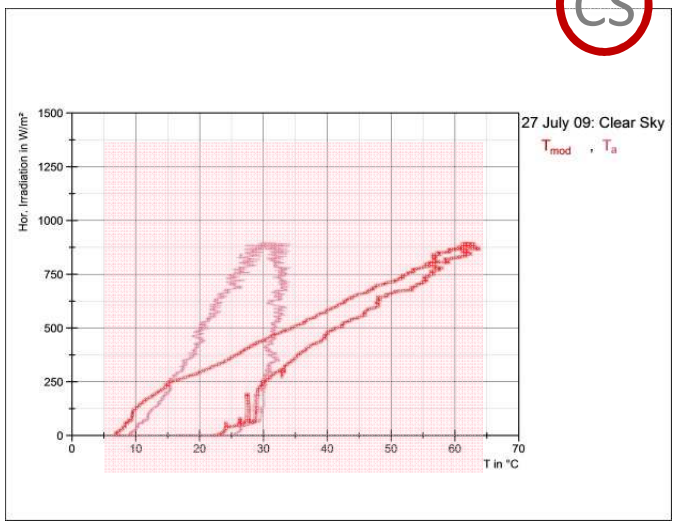
Clear Sky(1) Conditions on the Reference Day: 27 July 2009 versus Irradiance Enhancement(2) Conditions on the: 8 July 09

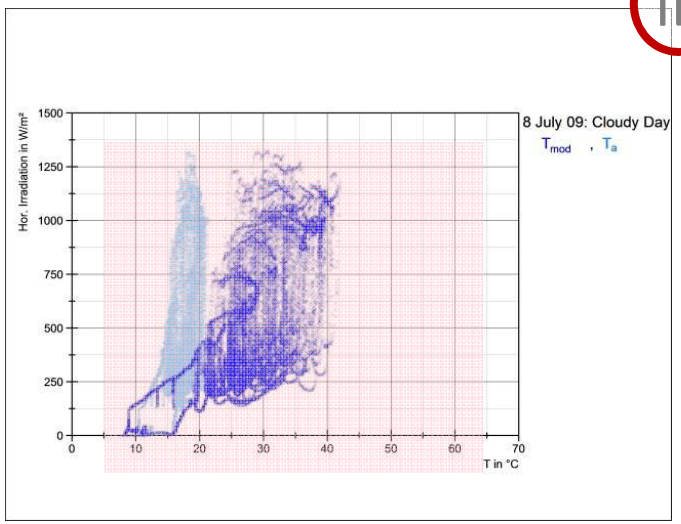


CS



IE





Weather Observation(3): 8 July 09

09:00

11:00

13:00

15:00

(1) CS: Clear Sky
(2) IE: Irradiance Enhancement
(3) Meteorological Institut of the LMU Munich

New Munich Trade Fair – global horizontal irradiance (CMP 21 from Kipp & Zonen)

‚Irradiance Enhancement' – Talk 5AO.6.3 at the 26th EU PVSEC, Hamburg (Germany), 5 September 2011

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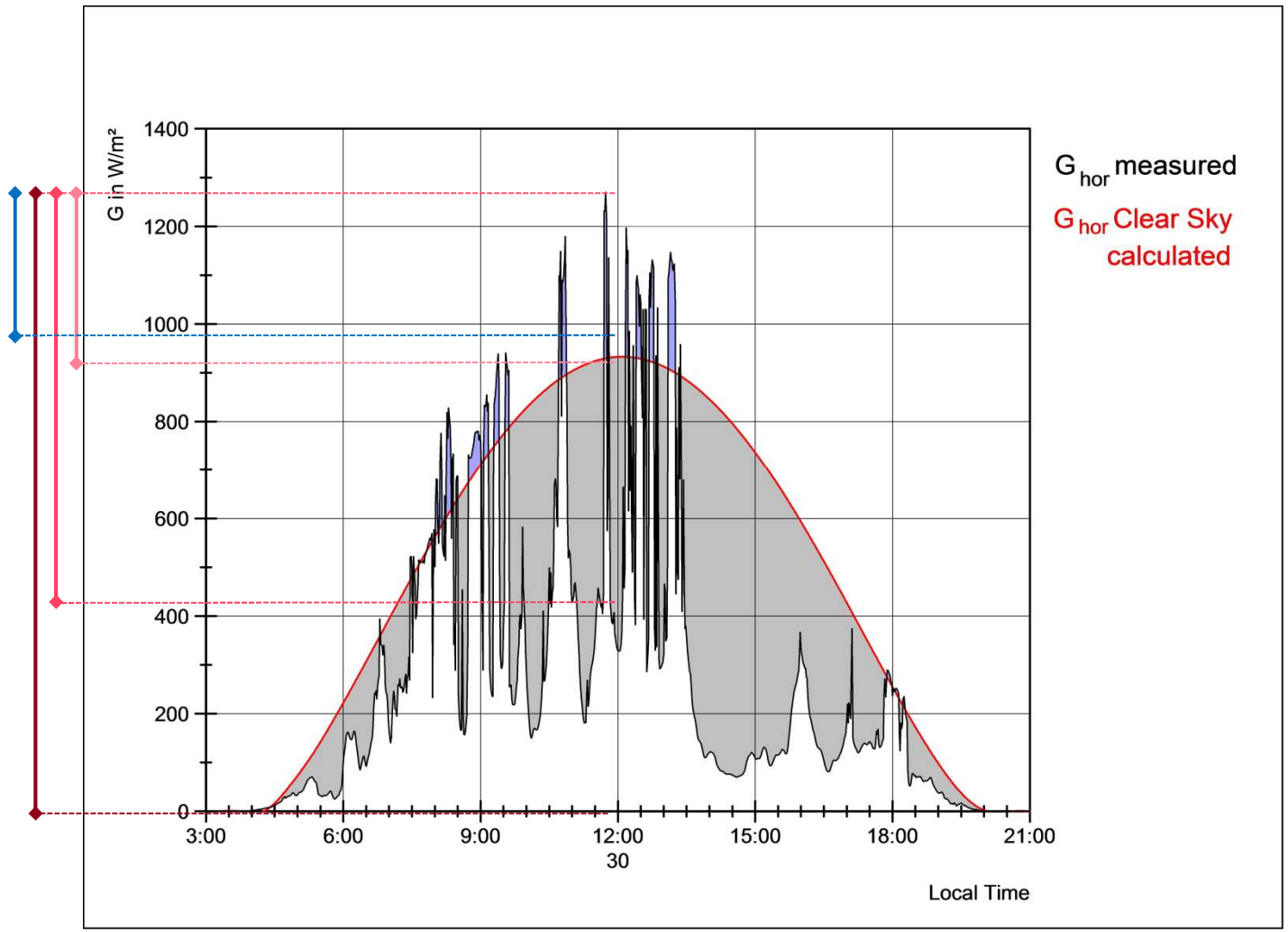
IE-Effect on the Reference Day: 30 May 2009



IE

In black: Measurement data of the New Munich Trade Fair www.sev-bayern.de

In red: libRadtran calculations www.libradtran.org

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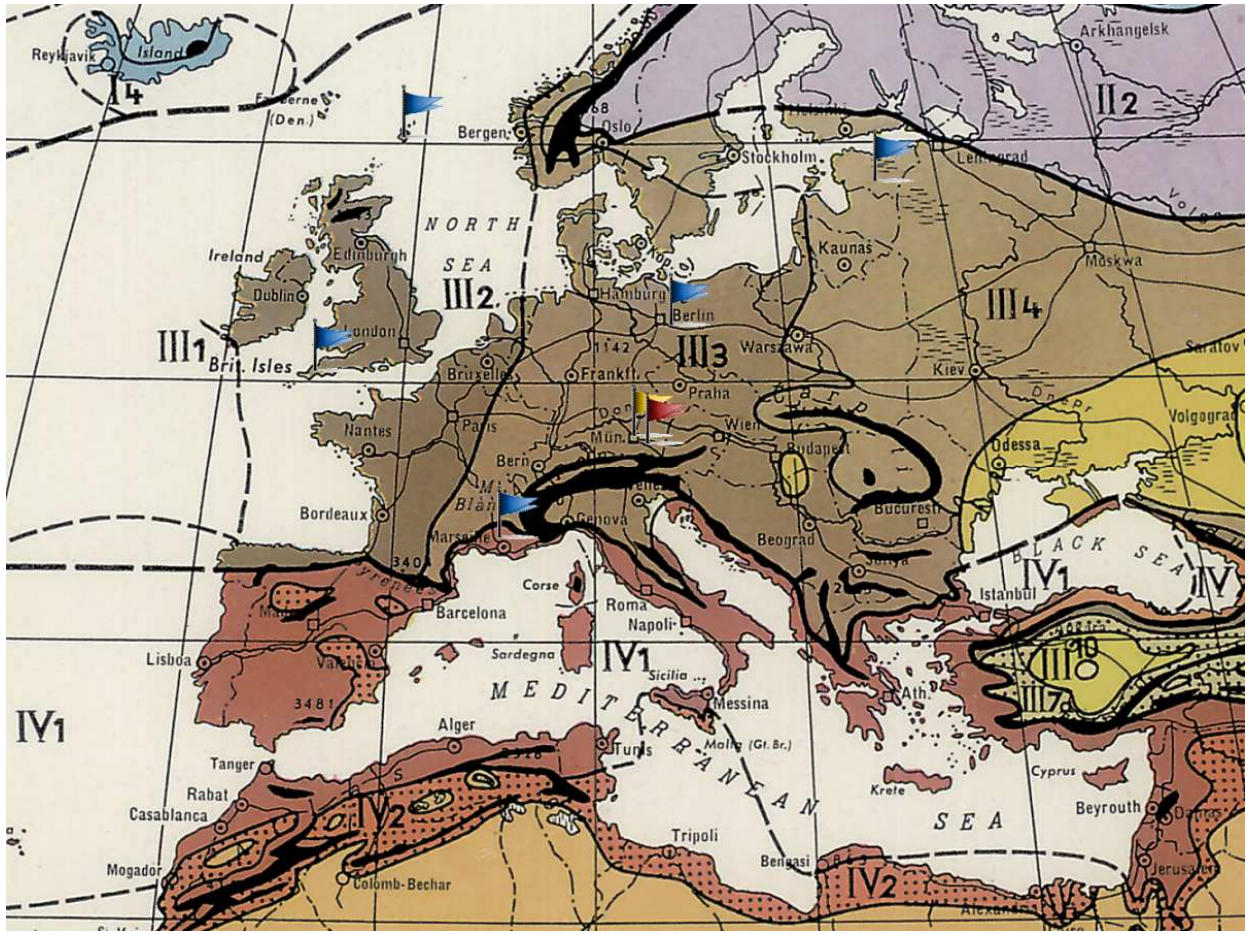
Data Mining - Baseline Surface Radiation Network (BSRN), Europe



Climatic Zones, Europe[1]

II-1 Maritime boreal climates

- Lerwick (GBR), SaR[2]: 1 min

III-2 Maritime climates with mild winters

- Camborne (GBR), SaR: 1 min

III-3 Submaritime climates

- OT Lindenberg (GER), SaR: 1 min
- Meteo Institute Munich (GER), SaR: 1 min
- New Munich Trade Fair (GER), SaR: 1 sec[3]

III-4 Subcontinental climates

- Toravere (EST), SaR: 1 min

IV-1 und IV-2 Mediterranean climates with humid winters and dry summers

- Carpentras (FRA), SaR: 1 min

1) Map 'The Seasonal Climates of the Earth' by C. Troll and KH. Paffen, Berlin 1964.
2) SaR: Sampling rate
3) Analysis of the measured values takes the sampling theorem into account

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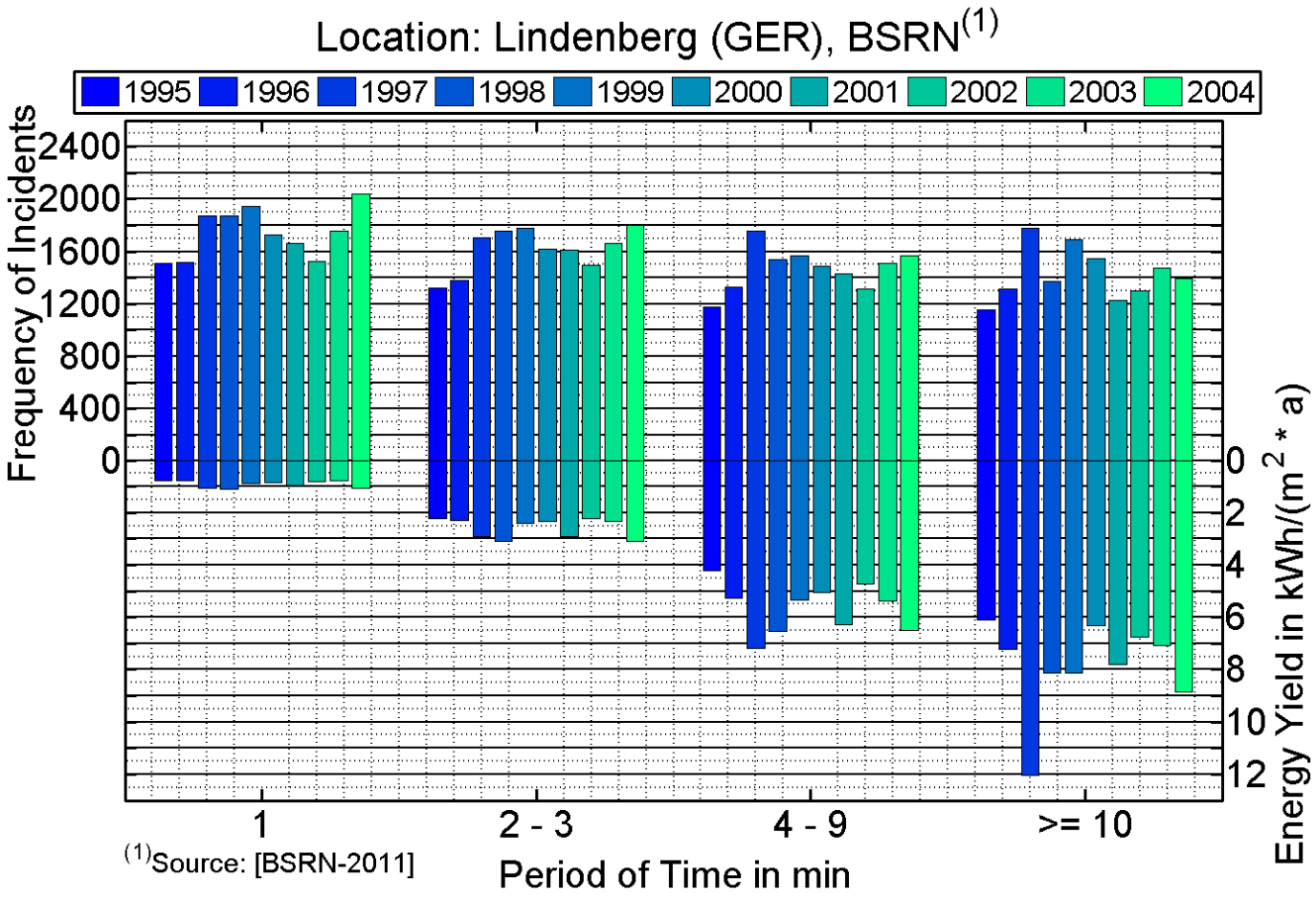
Gretchen Question: ‚Are we talking about relevant energy content?‘
Exemplary BSRN Site OT Lindenberg: IE Energy above CS



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Gretchen Question: ‚Are we talking about relevant energy content?‘ Exemplary BSRN Site OT Lindenberg: IE Energy above CS

Table 1: Final energy yield and energy due to IE incidents for the year (1995 – 2004, Lindenberg)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Ø
Final Yield in kWh/(m²a)	1061	1016	1132	1044	1114	1048	1029	1024	1191	1075	1074
IE Energy in kWh/(m²a)	237	254	375	277	278	233	273	229	270	294	272
in %	22.3	25.0	33.1	26.5	24.9	22.2	26.6	22.3	22.6	27.3	25.3
IE Energy above CS in kWh/(m²a)	13	16	23	19	17	15	18	15	16	20	17
in %	1.26	1.53	2.05	1.81	1.50	1.39	1.74	1.42	1.31	1.82	1.58

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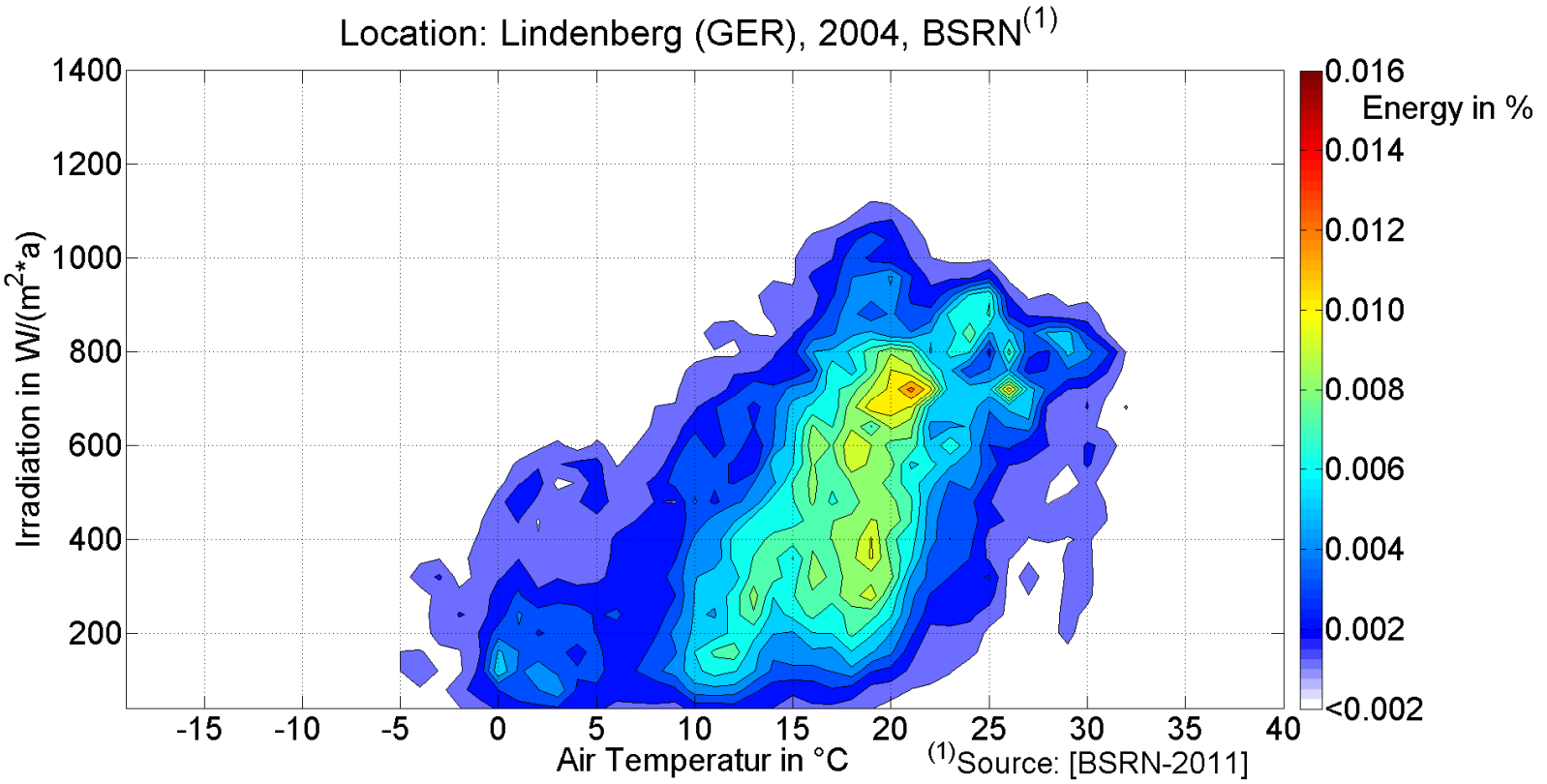
Site Assessment - OT Lindenberg: IE Energy in Absolute Values



Cf. Ralf Haselhuhn, www.dgs-berlin.de

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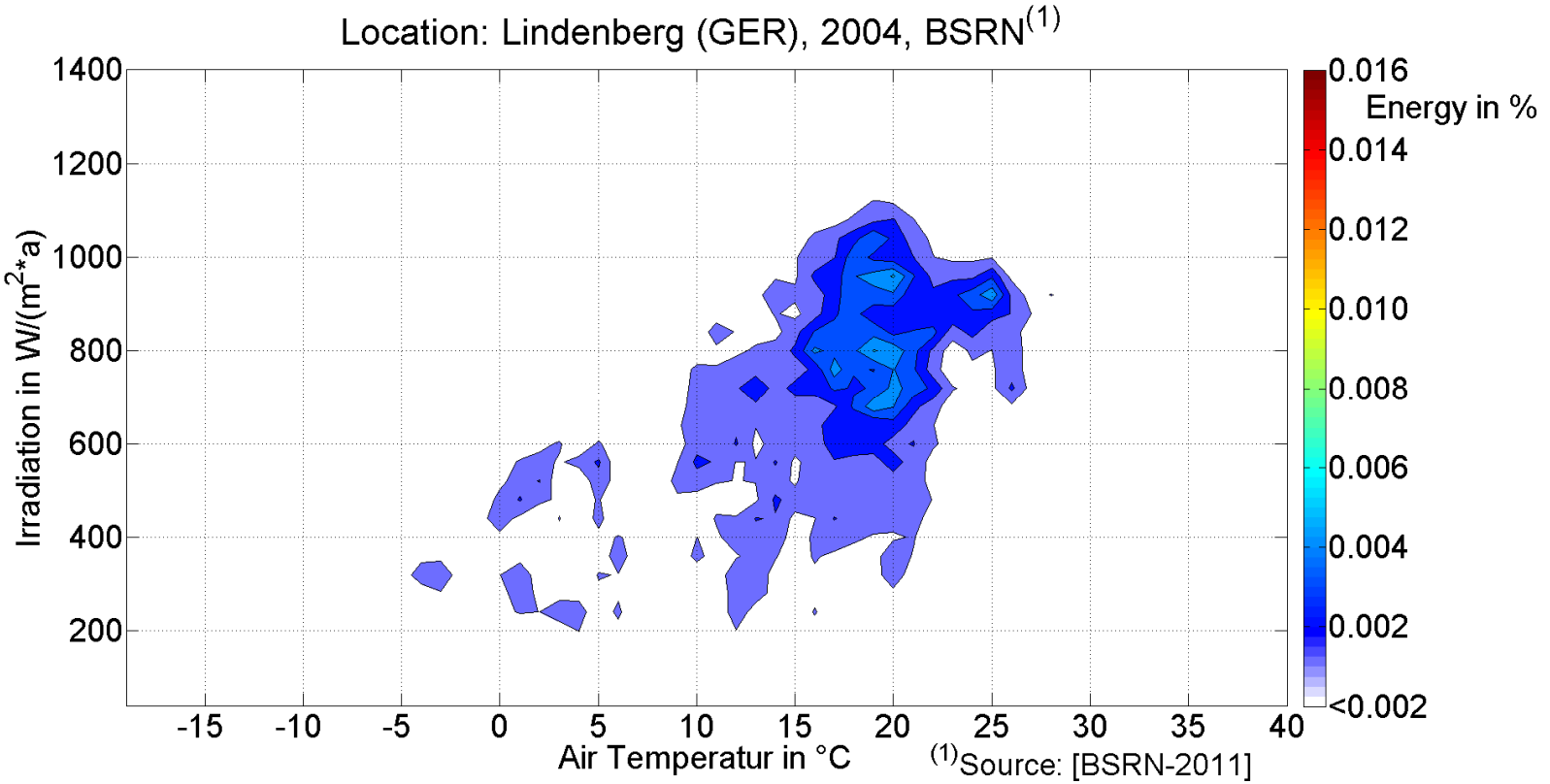
Site Assessment - OT Lindenberg: IE Energy in Absolute Values



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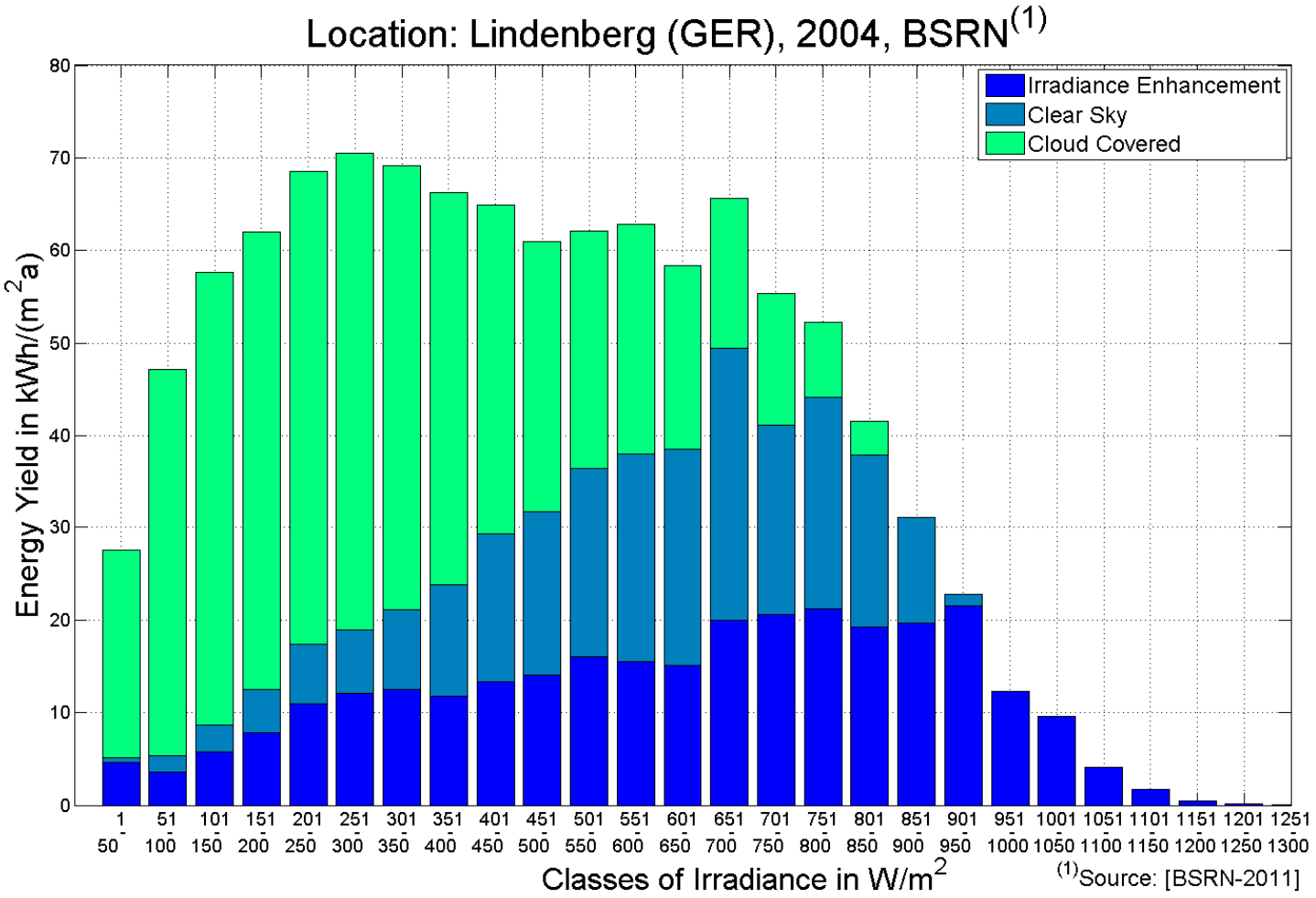
Site Assessment - OT Lindenberg: IE Energy in Absolute Values



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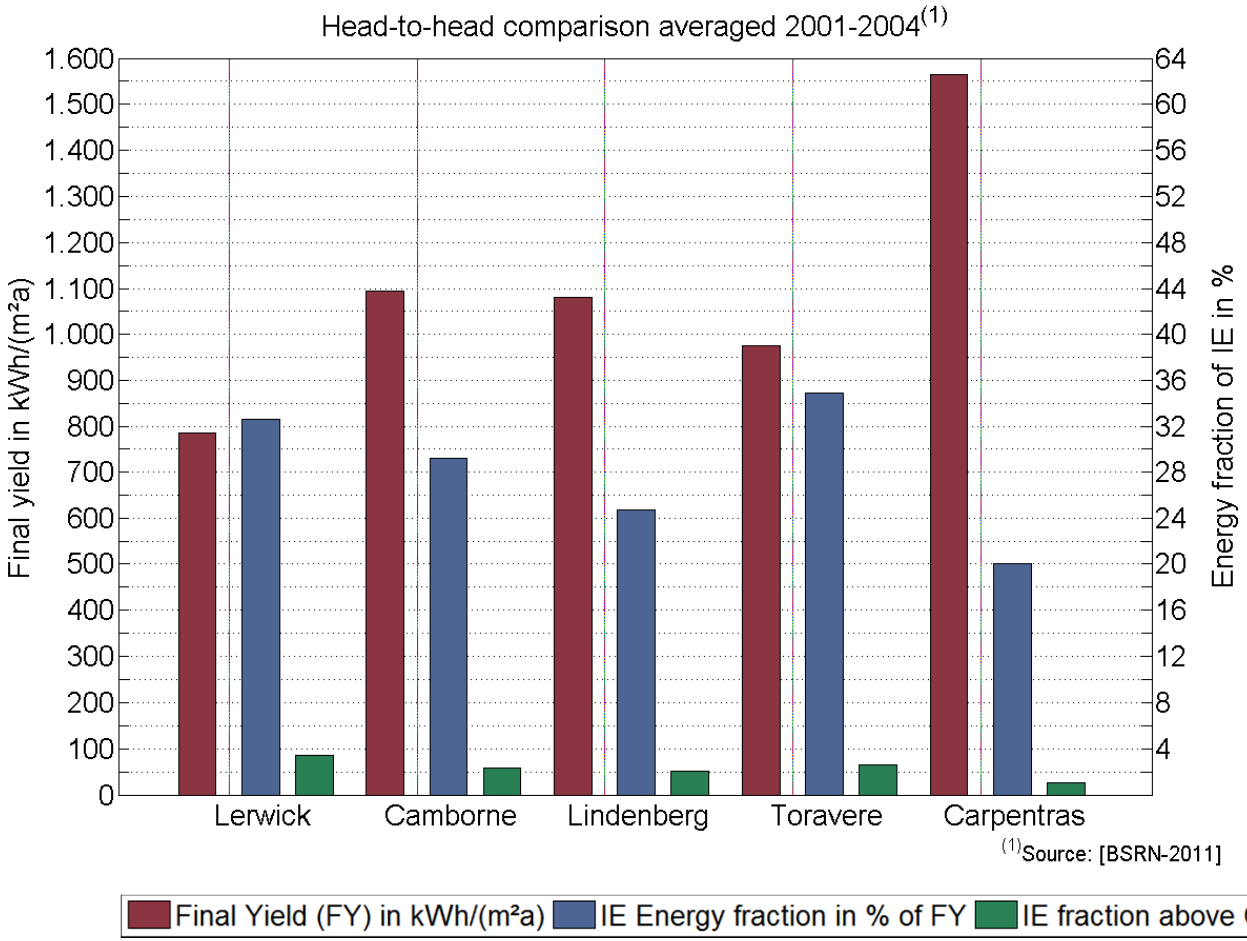
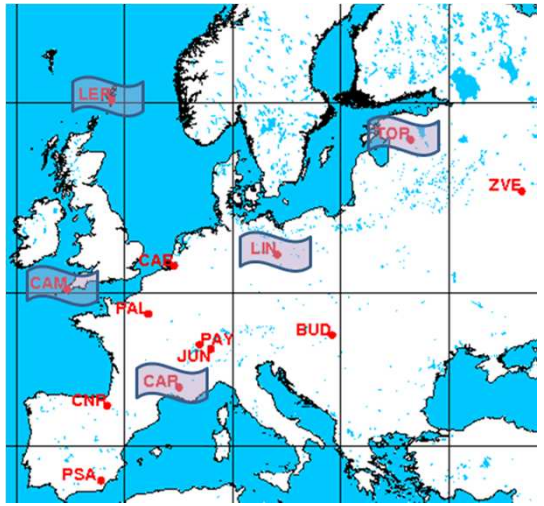
Site Assessment - 5 Representative European BSRN Locations





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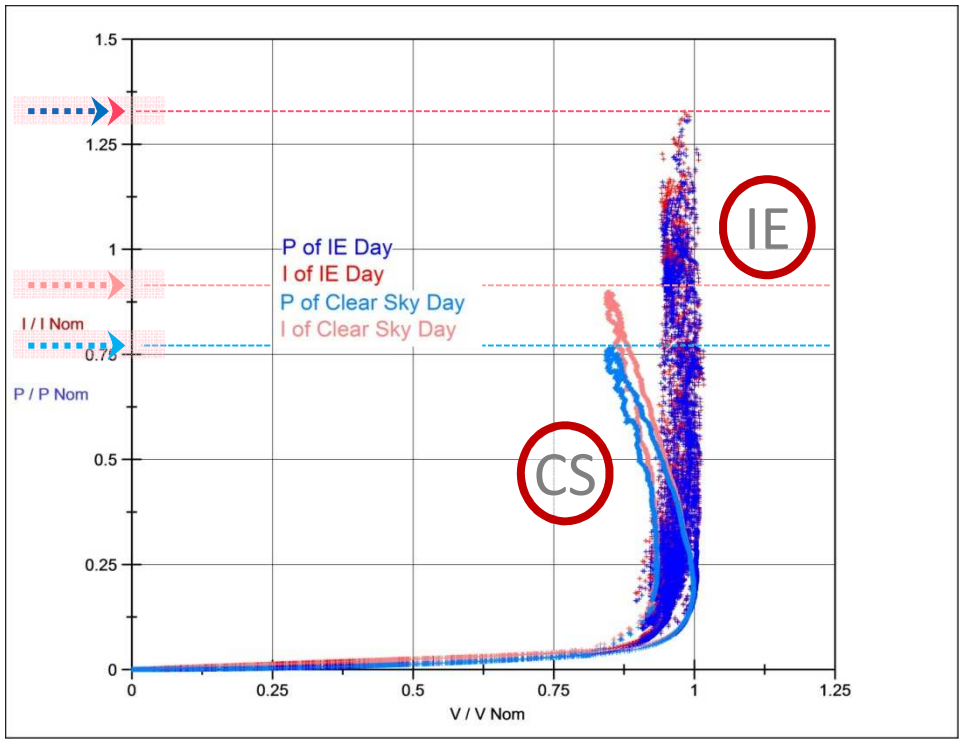
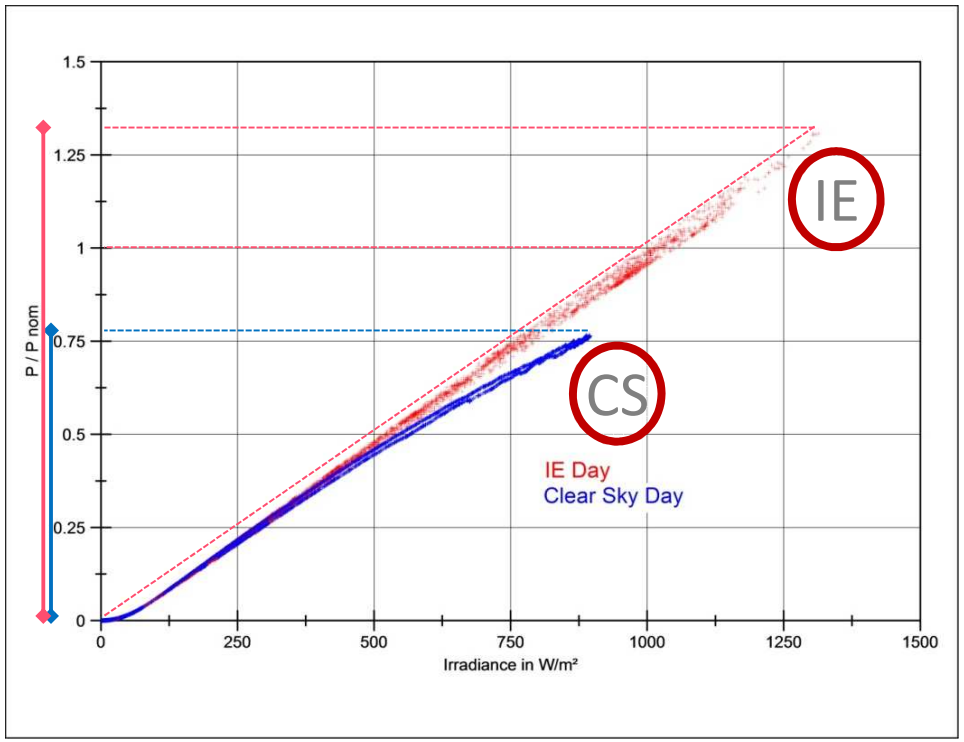
Modelled Operational Performance - Daily Profiles in Scatter Plots (2)
IE- and CS-Reference Days | Reference Module #1: Monocrystalline

MPP-Operating Points





Parameter Definitions
(1) Normalised DC current = $I_{DC.MPP}/I_{nom}$
(2) Normalised DC performance = $P_{DC.MPP}/P_{Nom}$

Software Modelling with
insel 8 – Release 8.01
Graphical programming language
www.insel.eu

‚Irradiance Enhancement' – Talk 5AO.6.3 at the 26th EU PVSEC, Hamburg (Germany), 5 September 2011

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Modelled Operational Performance - System Considerations

Initial Analysis on the System Response

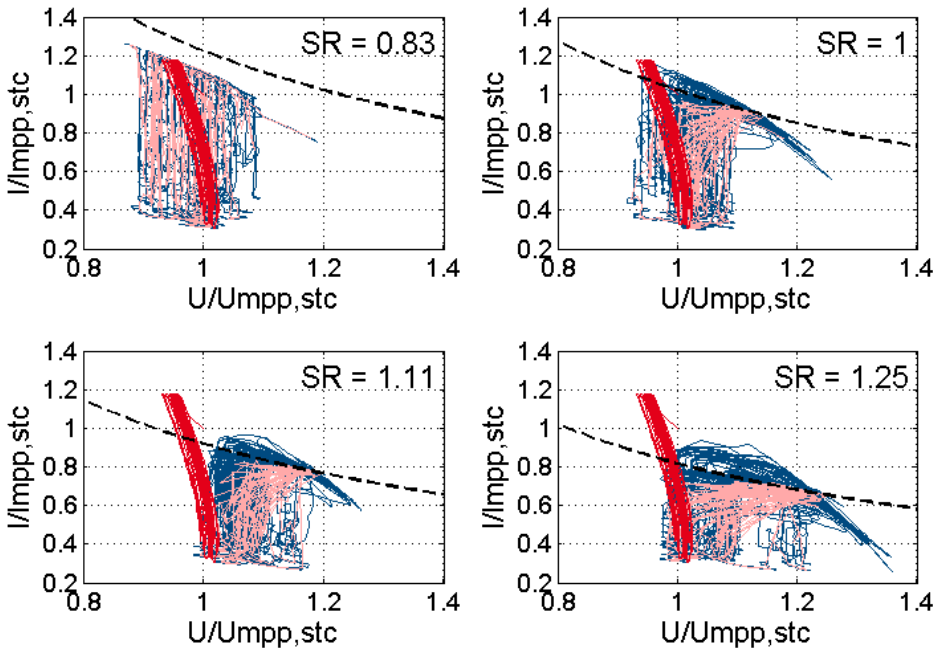
- Hardware modelling with a Solar Generator Simulator (SGS)
- 30 min IE Test Profile (rich in IE)
- Different modules / inverters - here: thin film modules with a transformerless inverter
- Sizing Ratio variations, here: SR = 0.83 | 1 | 1.11 | 1.25 (IE characteristics, interconnections)

» In dark red: target values of SGS

» In dark blue: inv response, SaR: 10 Hz

» In light red: inv response, SaR: 0,2 Hz

» Dotted line in black: power dissipation curve



(1) SGS: Solar Generator Simulator
(2) Parameter definition: Sizing Ratio: SR = $P_{PV\text{-}STC}/P_{INV\text{-}NP}$
(3) SaR: Sampling rate

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Wrap-Up and Next Steps

- CS days in July do **not** have the highest performance values
  STC conditions **are** visible operating points
- Lindenberg, energy yield above CS: 1.58 % | in total: 25.3 %
- Modules: 30 % more power than under STC
- Inverter: is current MPPT sufficient?
- System: cue IE-effect and Sizing Ratio (Poster **5BV.2.14**)

- IE - Effect > Understanding the effect
  - » Modelling of the radiative transfer
  - » Spatial dispersion and dynamics of enhancements
- IE - Sites > Geographical dispersion (North America / Pacific Area)
- IE - Systems > Data mining and modelling
  - » Adjustment of (site-specific) IE-test profiles
  - » Modelling with a solar generator simulator
  - » Modelling with the simulation language INSEL

23 MW PV Plant, »La Magascona«, Trujillo, Cáceres (Spain)

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Thanks to All Colleagues Involved in this Project

Toni Weigl, Matthias Hartmann, Stefan Thaler, Oliver Schrank, Moritz Czakalla, Bernhard Mayer, Tom Betts, Ralph Gottschalg, Klaus Behrens, Gert König-Langlo, Bodo Giesler, Gerd Becker, Oliver Mayer

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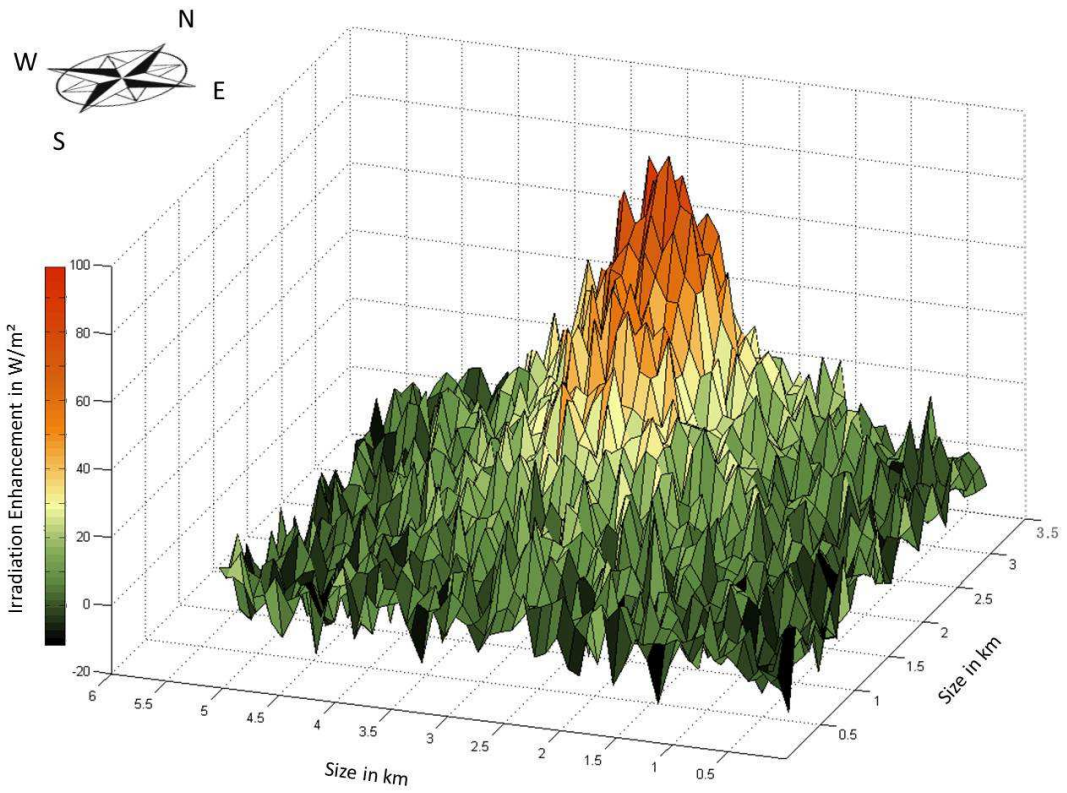
- Steve Ransome, Steve Ransome Consulting Ltd
- Werner Knaupp, PV-Plan



Thank you very much for your time, your interest and your attention.

Kick-Off for Questions …