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VERSITÄT

# PV and Wind Power - Complementary Technologies

DLR

Ann-Katrin Gerlach, Daniel Stetter
and Christian Breyer

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# PV and Wind power – Future Technologies

**Often mentioned statement:**

**"Too much PV and Wind power are a danger for the grid stability."**

**Why?**

**→ Fluctuating energy forms.**

**What consequences?**

**→ PV and Wind power industries – competitors.**

**True?**

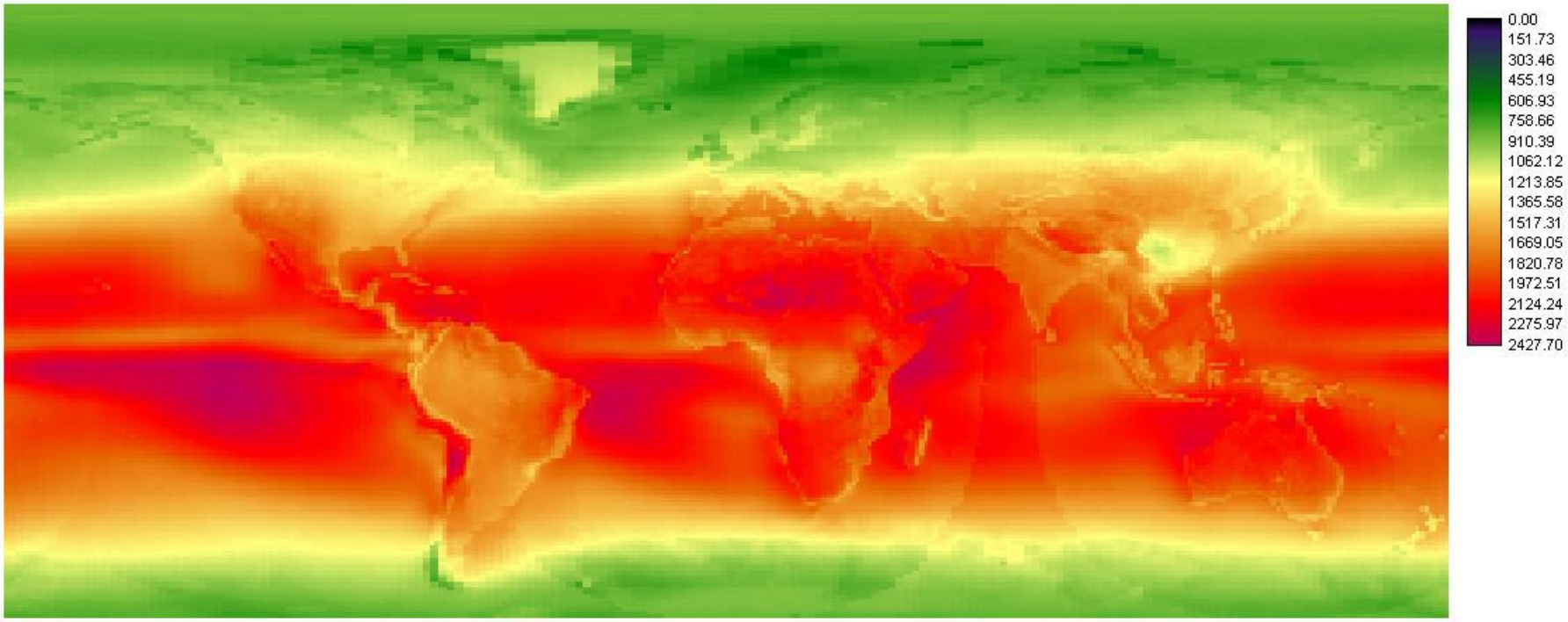
**→ Depending on interaction between solar and wind resources.**

# Outline

- Resource Availability
- Feed-in Power potential
- Full Load Hours of PV and Wind Power
- Overlap of PV and Wind Power
- Critical Overlap
- Conclusions

# Resource Availability - PV

## Global Horizontal Irradiance (GHI)



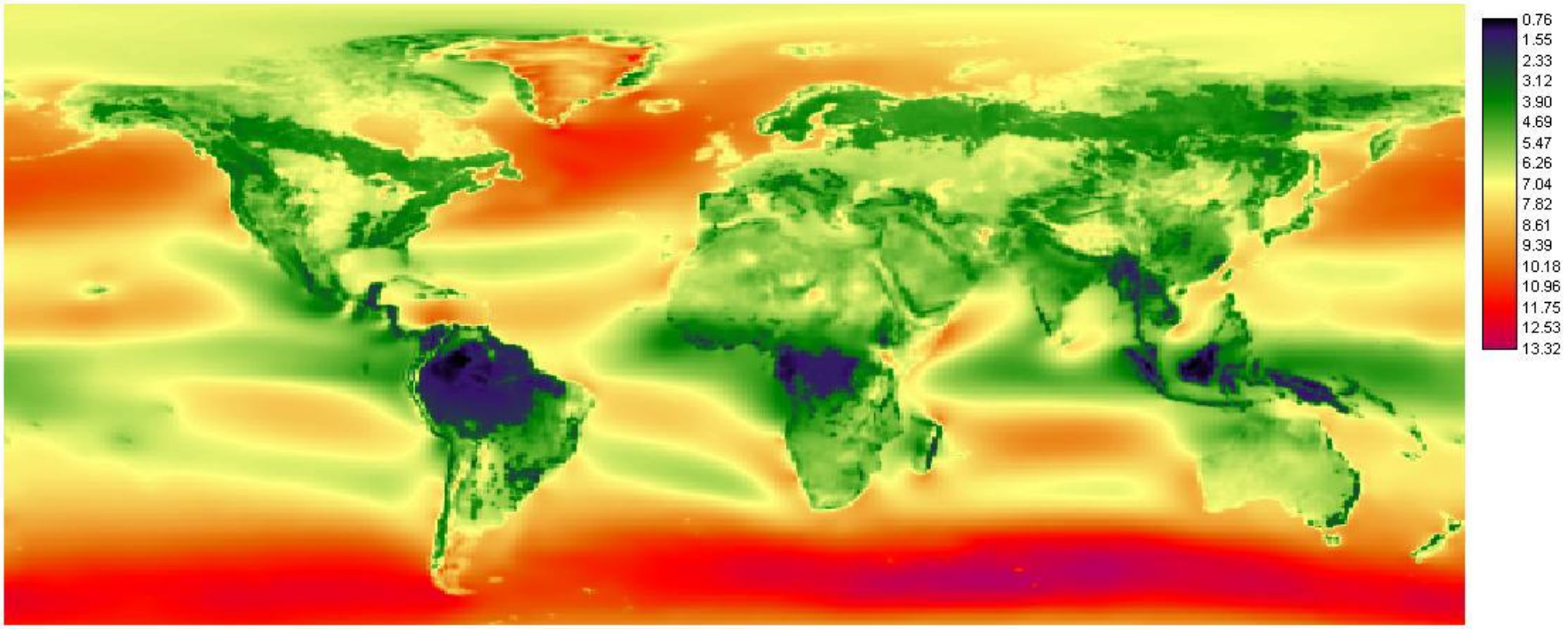

Annual long-term average in kWh / year

NASA data: 0.45°x0.45°, hourly, 22 years

based on these data:
**Modeling of 1 GW PV power plant**

# Resource Availability - Wind

## Wind Speeds




Annual long-term average in m / s

NASA data: 0.45°x0.45°, hourly, 22 years

based on these data:
**Modeling of 1 GW Wind power plant**

# Feed-in Power Potential

**Data:** NASA Surface Meteorology and Solar Energy SSE Release 6.0

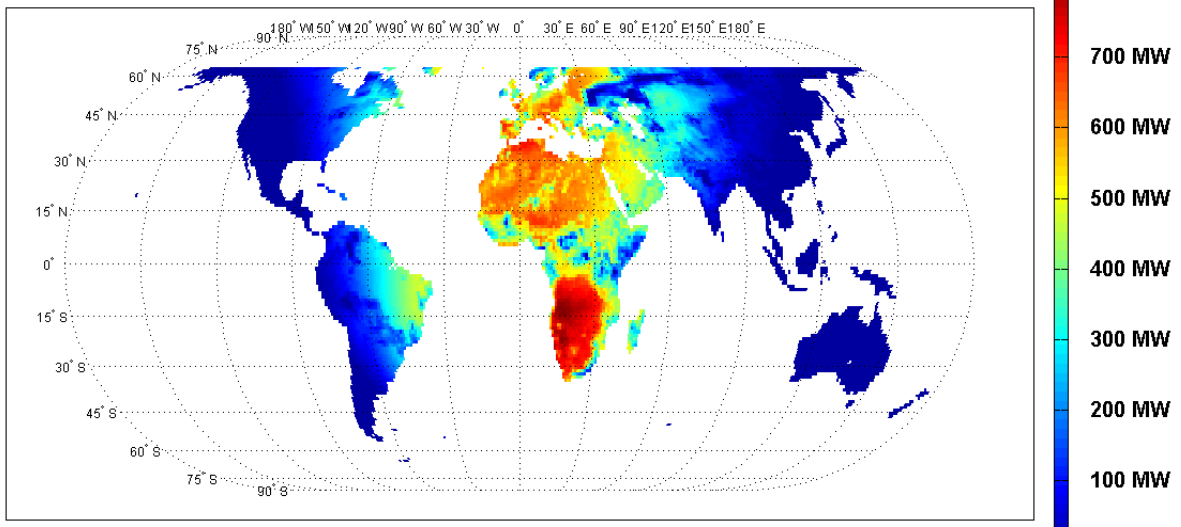
22 years, 1 h time-resolved and 1° spatially-resolved

**PV:** modeling of 1 GW power plant (optimally tilted, dependent on temperatur and irradiation , c-Si Module, central inverter)

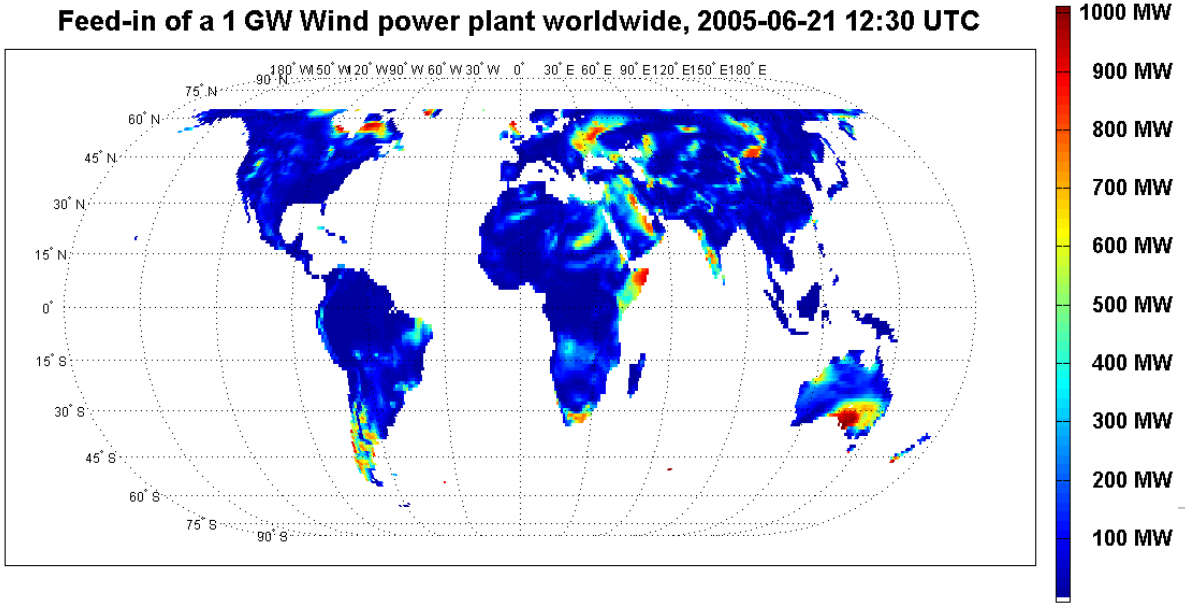
**Wind:** modeling of 1 GW power plant (7.5 MW E-126 with 150 m hub height)

source: Gerlach A.-K., Breyer Ch., et al., 2011. PV and Wind Power – Complementary Technologies, 26th PVSEC, Hamburg

Feed-in of a 1 GW PV power plant worldwide, 2005-06-21 12:30 UTC

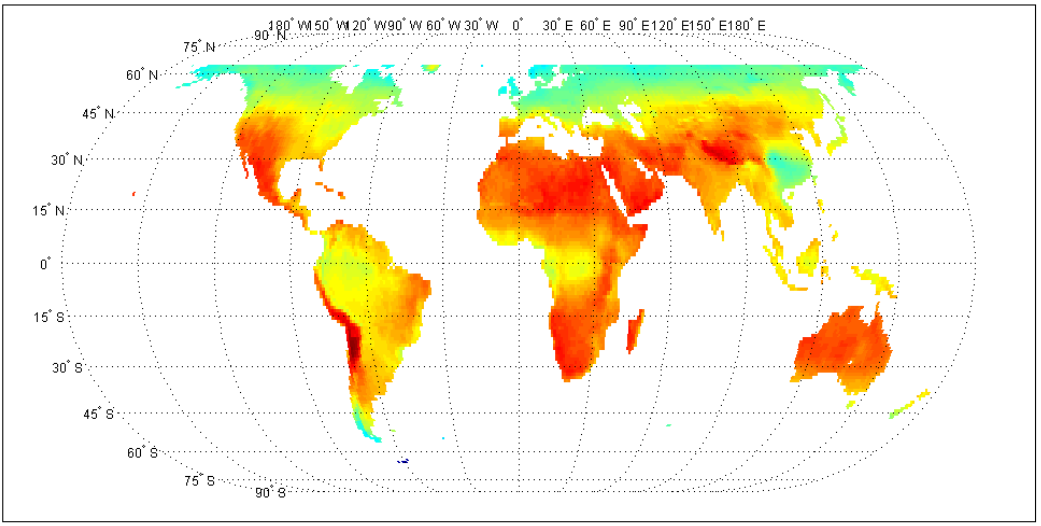


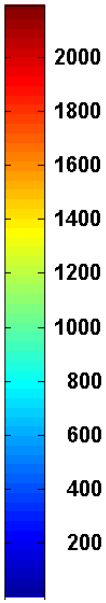

Feed-in of a 1 GW Wind power plant worldwide, 2005-06-21 12:30 UTC



# Full Load Hours of PV and Wind Power

**Full load hours PV worldwide, 2005**

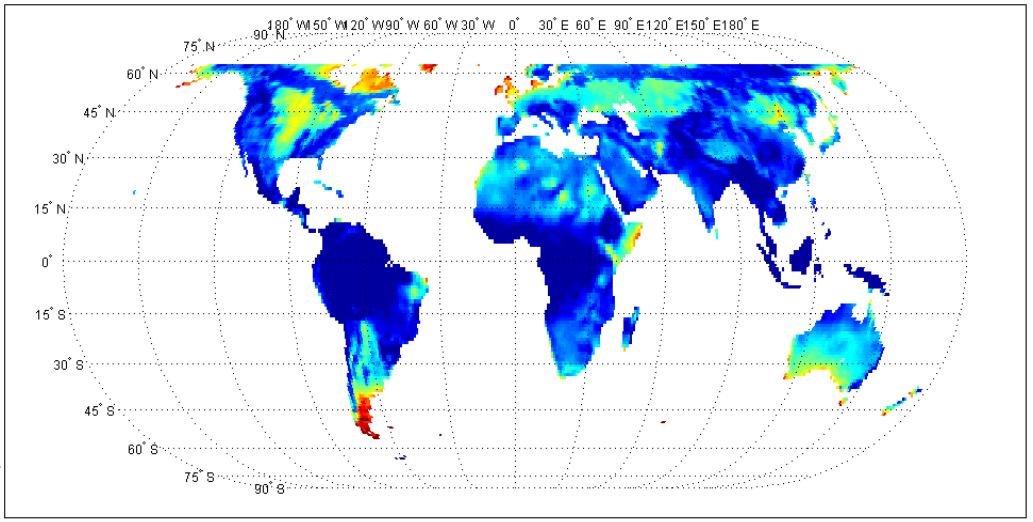


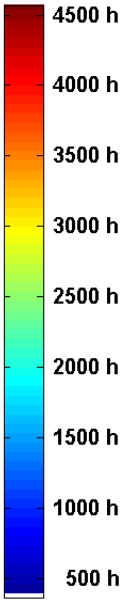




| Technical Potential | | PV [TW] | Wind [TW] |
|---|---|---|---|
| Weingart | 1978 | > 100 | - |
| WBGU | 2003 | infinite | 90 |
| Greenpeace | 2008 | 150 | 35 |
| Sawin and Moomaw | 2008 | 145 | 55 |
| Lu et al. | 2009 | - | 80 - 150 |
| Jacobson and Delucchi | 2009 | 580 | 40 - 85 |
| WBGU | 2011 | 8900 | 54 |
| IPCC SRREN | 2011 | 120000 | 190 |
| Current Global Energy Demand | | | |
| including waste of heat | [TW] | 17.0 | |
| direct energy demand | [TW] | 11.5 | |

$$FLh_{PV} = \left(\sum_{i=1}^{8760} \left(P_{PV,i}\right)\right) \cdot 1GW^{-1}$$

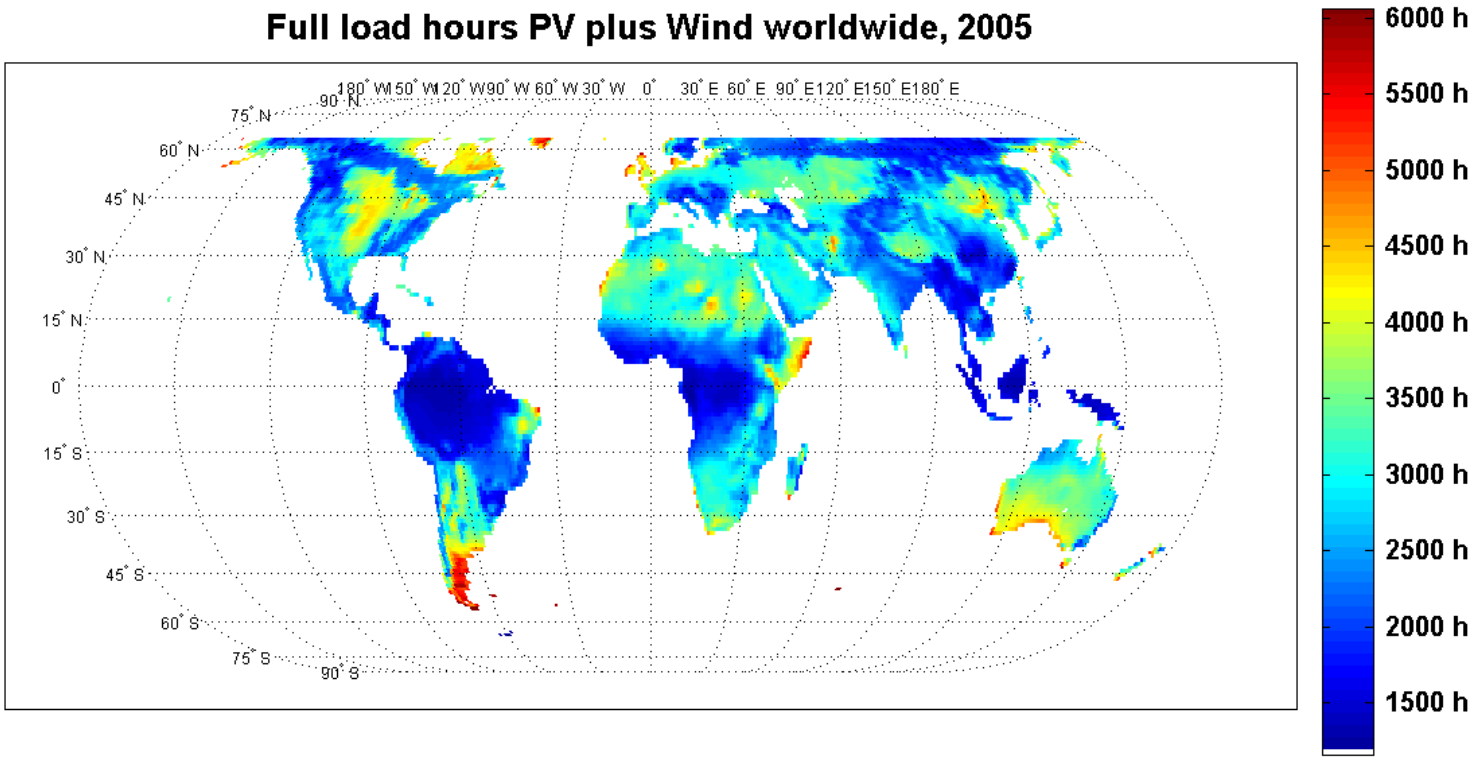
**Full load hours Wind worldwide, 2005**




$$FLh_{Wind} = \left(\sum_{i=1}^{8760} \left(P_{Wind,i}\right)\right) \cdot 1GW^{-1}$$

# Full Load Hours of PV and Wind Power

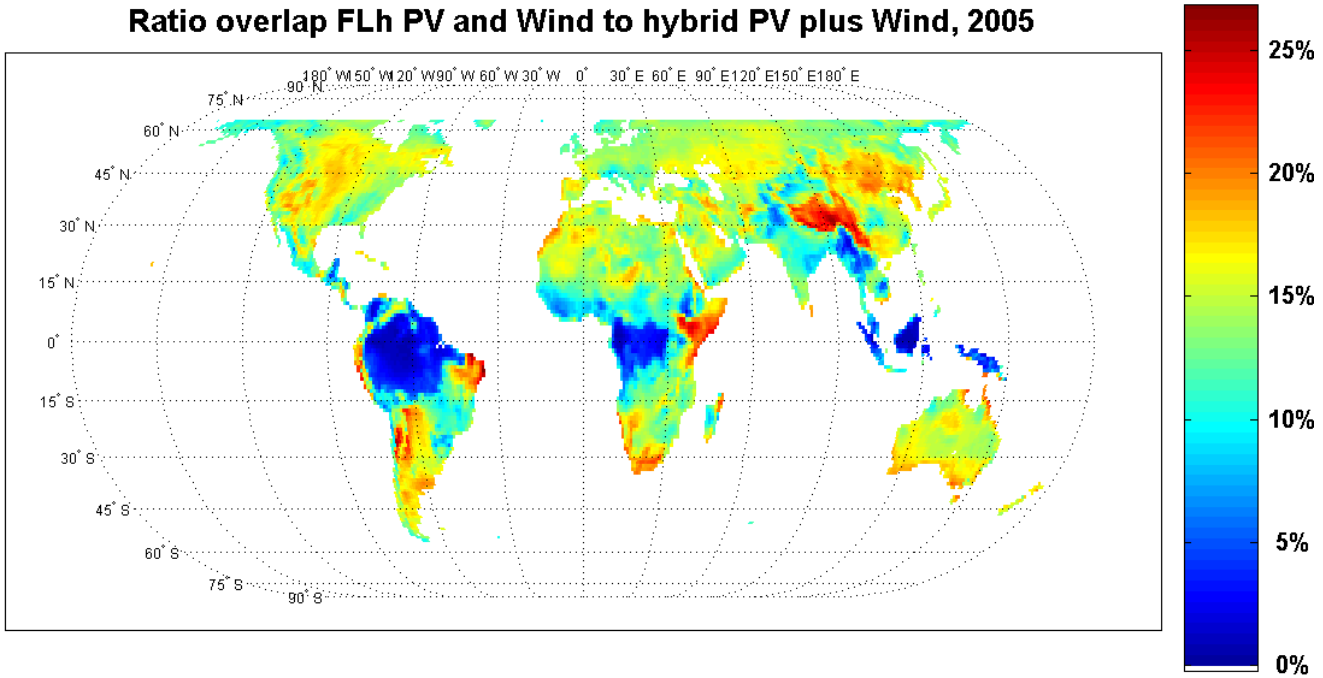



$$FLh_{PV,Wind} = FLh_{PV} + FLh_{Wind}$$

**Question:** How much of PV and Wind energy has been produced at the same time?

# Overlap of PV and Wind Power

**Overlap**
ranging between
**5 ... 25 %**
of total energy



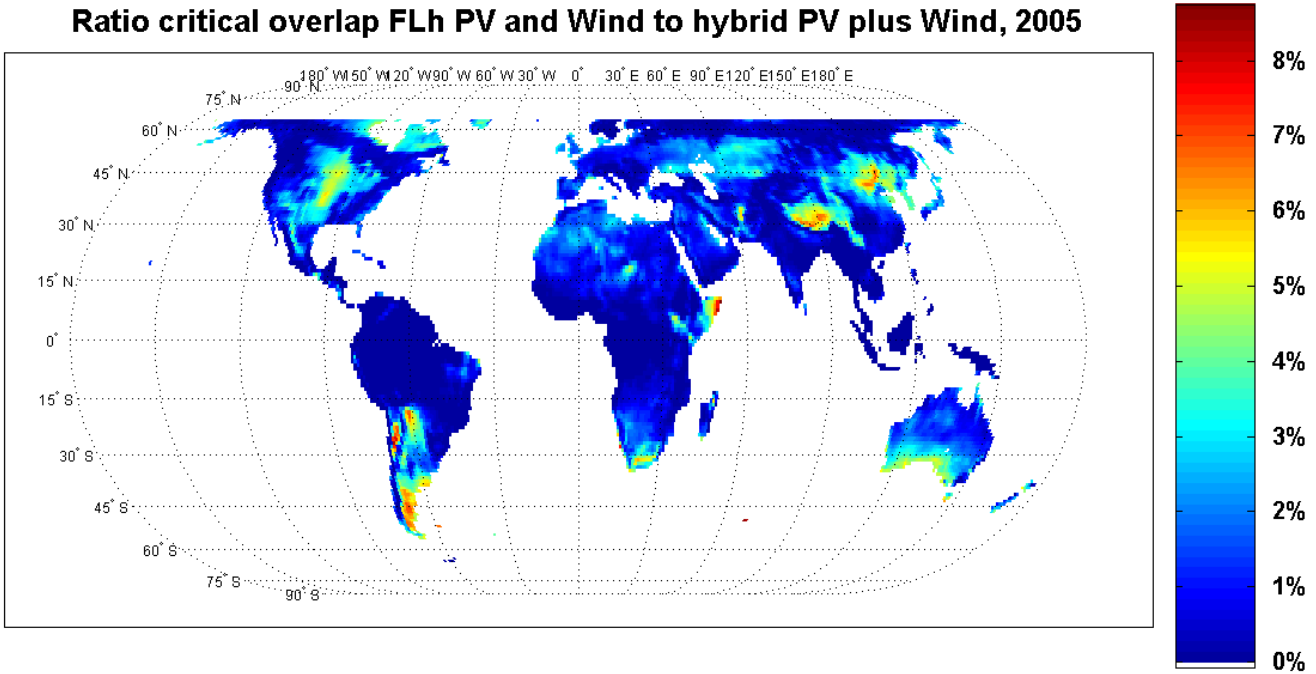

$$FLh_{OL} = \left( \sum_{i=1}^{8760} min\left(P_{PV,i}, P_{Wind,i}\right) \right) \cdot 1GW^{-1}$$

**Question:** How much of the overlap energy is critical?

# Critical Overlap of PV and Wind Power

**Critical Overlap**
**< 9 %**
of total energy

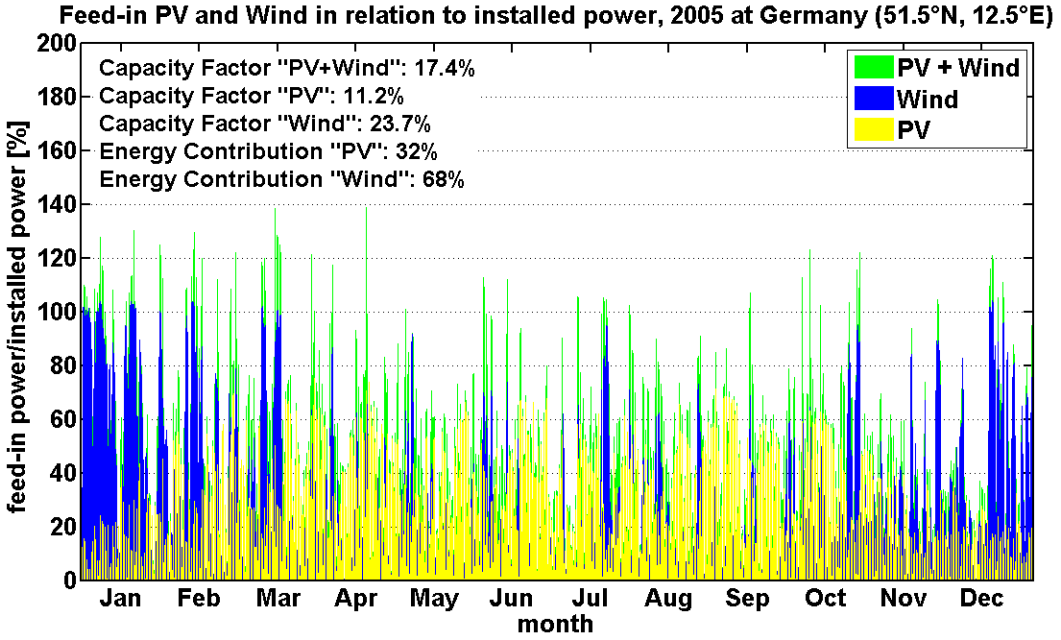
critical due to limitations in
- grid capacity,
- storage capacity,
- balancing systems,
- etc.




$$FLh_{COL} = \left( \sum_{\forall i \in \{(P_{PV,i}+P_{Wind,i})>1GW\}} P_{PV,i} + P_{Wind,i} - 1GW \right) \cdot 1GW^{-1}$$

→ in most parts of the world **only 1 – 3 %** of total energy production would be critical

# Example Coordinate Middle-East-Germany




**significant more detailed view on the time dependend structure of power feed-in for PV and Wind → possible for all coordinates**

**paper for Middle-East-Germany: www.reiner-lemoine-institut.de/literatur/veroeffentlichungen**

**"Gerlach A.-K. and Breyer Ch., 2012. PV und Windkraft: sich hervorragend ergänzende Energietechnologien am Beispiel Mitteldeutschlands, 27. Symposium Photovoltaische Solarenergie, Bad Staffelstein"**

# Conclusions

- PV and Wind power do complement each other very well
- PV and Wind power industries do not need to compete with each other

  → should cooperate
- PV and Wind power peaks are not a problem for the grid stability
- less storage capacity is needed if PV and Wind power plants are built

# Thanks for your attention.

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