“光伏电站系统效率及评价交流会”
如何评价光伏系统效率?
HOW TO EVALUATE PV SYSTEM PERFORMANCE ?

Jefferson Bor, Project Manager
Group PV Power Plants
薄中南
光伏电站組 – 項目經理

第三届光伏电站设计与设备选型研讨会
28.Jan.2018

Fraunhofer ISE

议程
AGENDA

- 弗朗霍夫太阳能研究所对光伏系统评价概念
  - 关注系统预期值和实测值
- 建模& 测试
  - 需要什么样的条件来支持这样的评价方式?

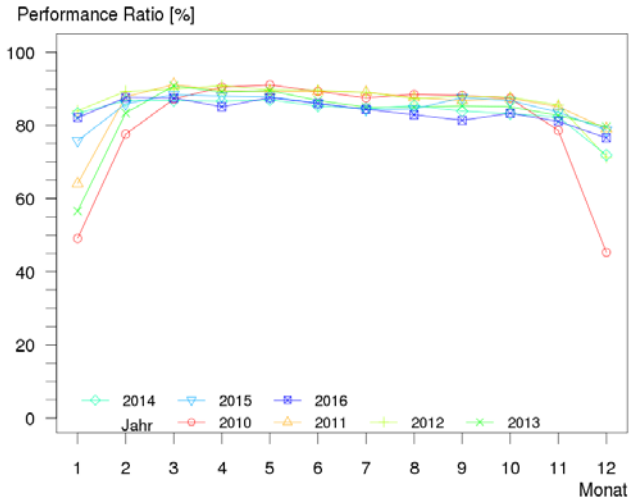
- Fraunhofer ISE Concept for evaluating the quality of PV power plant
  - Focus on expectation and actual value
- Modeling & Measurement
  - What requirements must be meet to support the evaluation?

弗朗霍夫评价系统概念
Fraunhofer Evaluation Concept

- 單一的標準有其限制

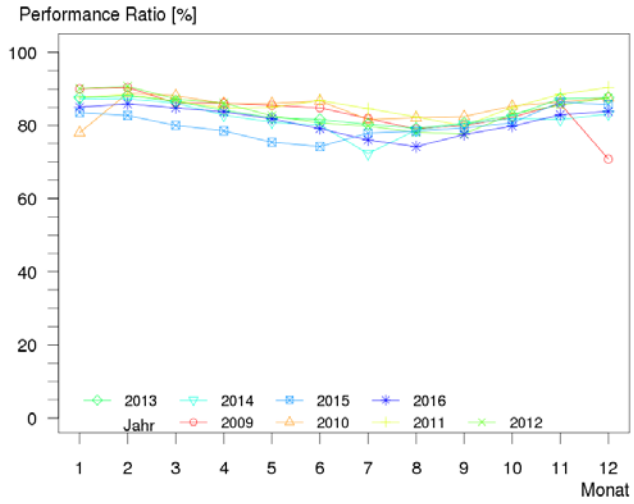
电站A

2016 PR: 84.3%



电站B

2016 PR: 80.4%

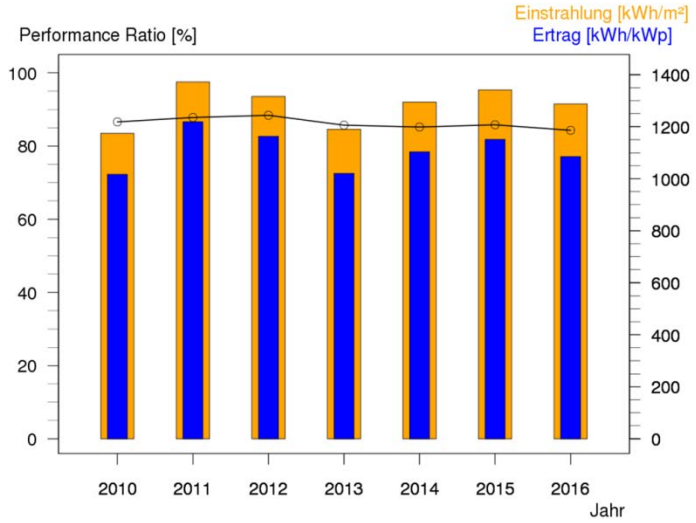


弗朗霍夫评价系统概念
Fraunhofer Evaluation Concept

- 單一的標準有其限制

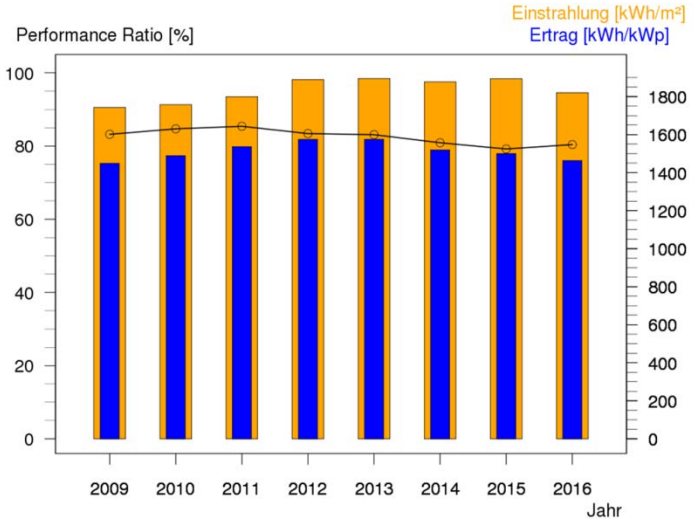
电站A

2016 功率比: 1085 kWh/kWp



电站B

2016功率比: 1464 kWh/kWp



弗朗霍夫评价系统概念
Fraunhofer Evaluation Concept

- 单一的标准有其限制
- 定量的标准可能不足以统一地评价各种系统
  - 不同气候带
  - 不同的支架系统 (固定, 季调, 平单轴, 斜单轴, 双轴, 鳞片 ...)
  - 不同的组件类型 (单晶, 多晶, 薄膜, 异质结, 双面, 双波...)
  - 不同的系统衰减速率
  - ...

着重于的"**相对比较**"的评价方式: 系统是否达到**自身**应有的效能

横向的比较: 预测值 vs 实测值

纵向的比较: 理论衰减值vs 实际衰减值

评价电站质量 Evaluation of Quality of PV Power Plant

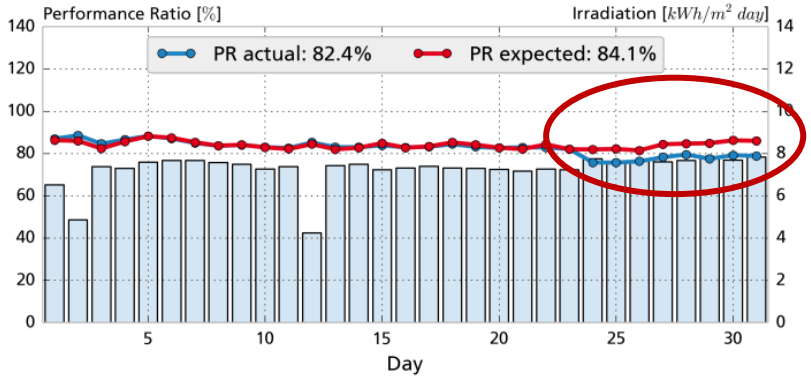
系统效能 System Performance

预期 vs. 真实

$$\text{预期PR} = \frac{\text{预期发电量} / \text{装机容量}}{\text{辐照量(组件平面)} / 1000W/m^2} \quad \text{vs.} \quad \text{真实PR} = \frac{\text{真实发电量} / \text{装机容量}}{\text{辐照量(组件平面)} / 1000W/m^2}$$

效率警报!

Alarm!



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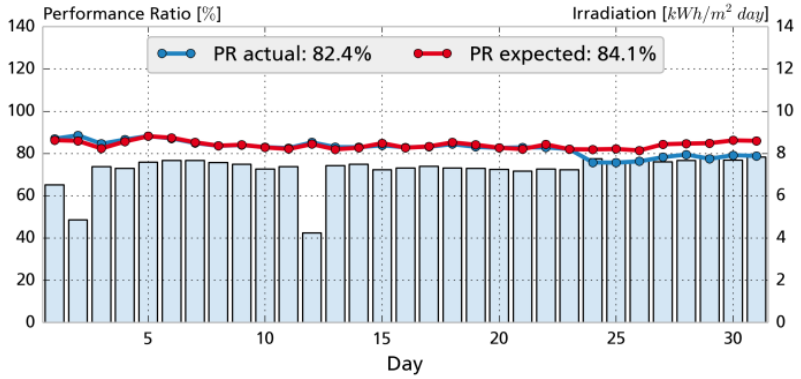
评价电站质量 Evaluation of Quality of PV Power Plant

系统效能 System Performance

模型 Modeling

预期 vs. 真实

$$\text{预期PR} = \frac{\text{预期发电量} / \text{装机容量}}{\text{辐照量(組件平面)} / 1000W/m^2} \quad \text{vs.} \quad \text{真实PR} = \frac{\text{真实发电量} / \text{装机容量}}{\text{辐照量(組件平面)} / 1000W/m^2}$$



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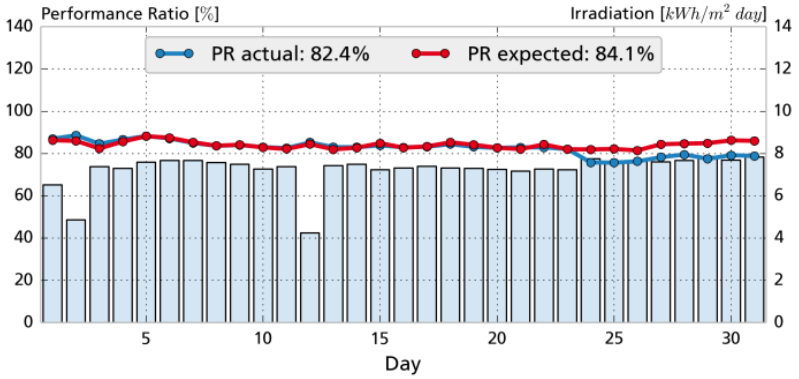
評價電站質量 Evaluation of Quality of PV Power Plant

系統效能 System Performance

预期 vs. 真实

$$\text{预期PR} = \frac{\text{预期发电量} / \text{装机容量}}{\text{辐照量(组件平面)} / 1000W/m^2} \quad \text{vs.} \quad \text{真实PR} = \frac{\text{真实发电量} / \text{装机容量}}{\text{辐照量(组件平面)} / 1000W/m^2}$$

- 虽不影响比较两者，辐照量测精度与准确性仍至关重要
  - 准确计算系统效率, PR
  - 确保辐照数据库
  - 修正与比对卫星资料



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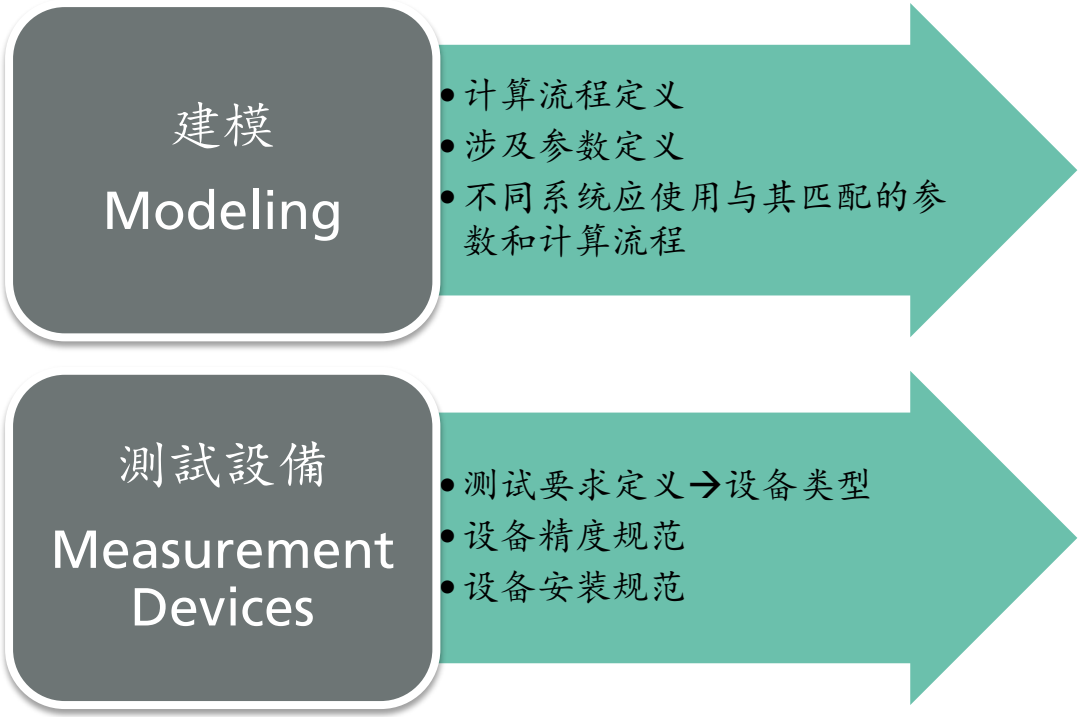
评价电站质量 Evaluation of Quality of PV Power Plant

评价标准的目标 The Goal of Evaluation



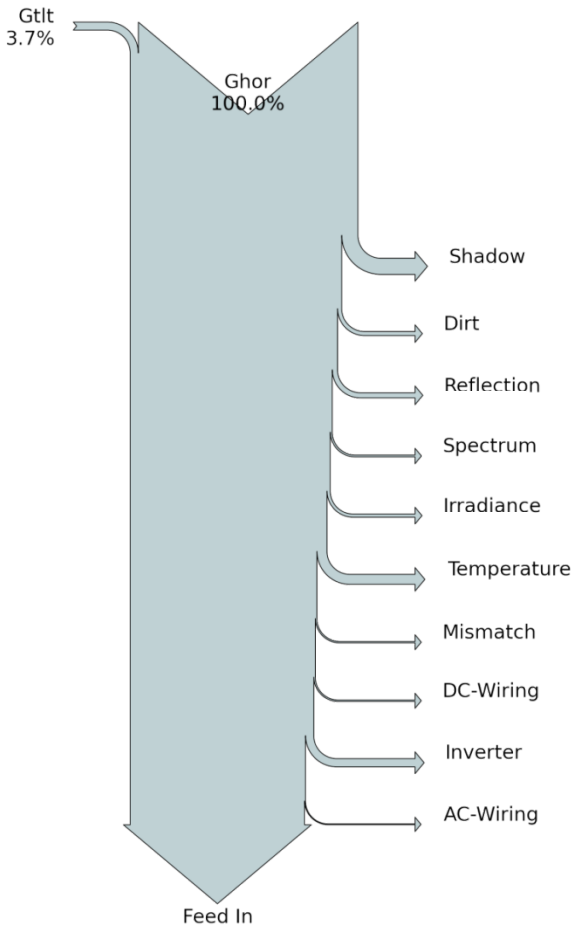
预测值或实测值如不准确，

我们如何“评价”系统效能？

If the predicted or measured value is not correct, how can we „evaluate“ the performance?

评价电站质量 Evaluation of Quality of PV Power Plant

模型中的不同系统 - 例子1 Different System in Modeling-Example 1



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评价电站质量 Evaluation of Quality of PV Power Plant

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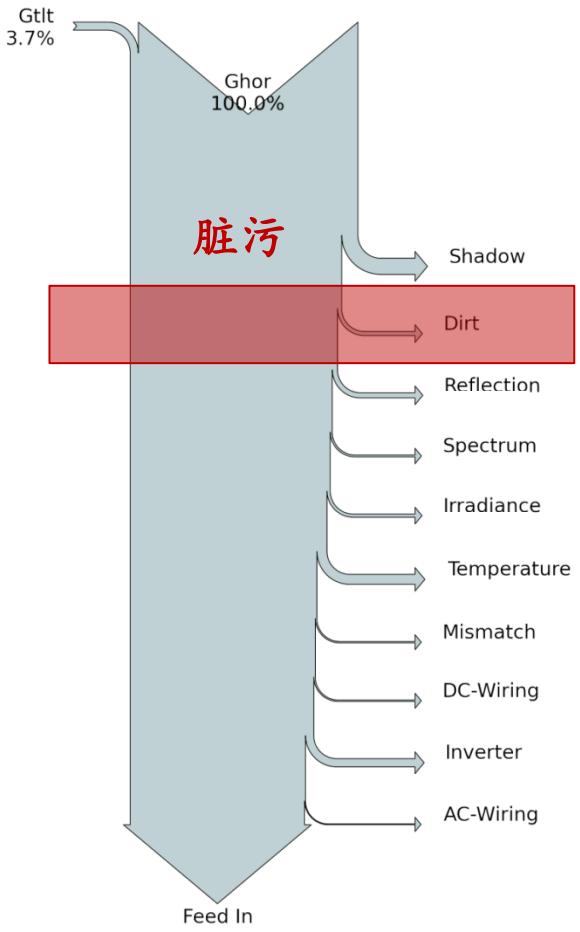

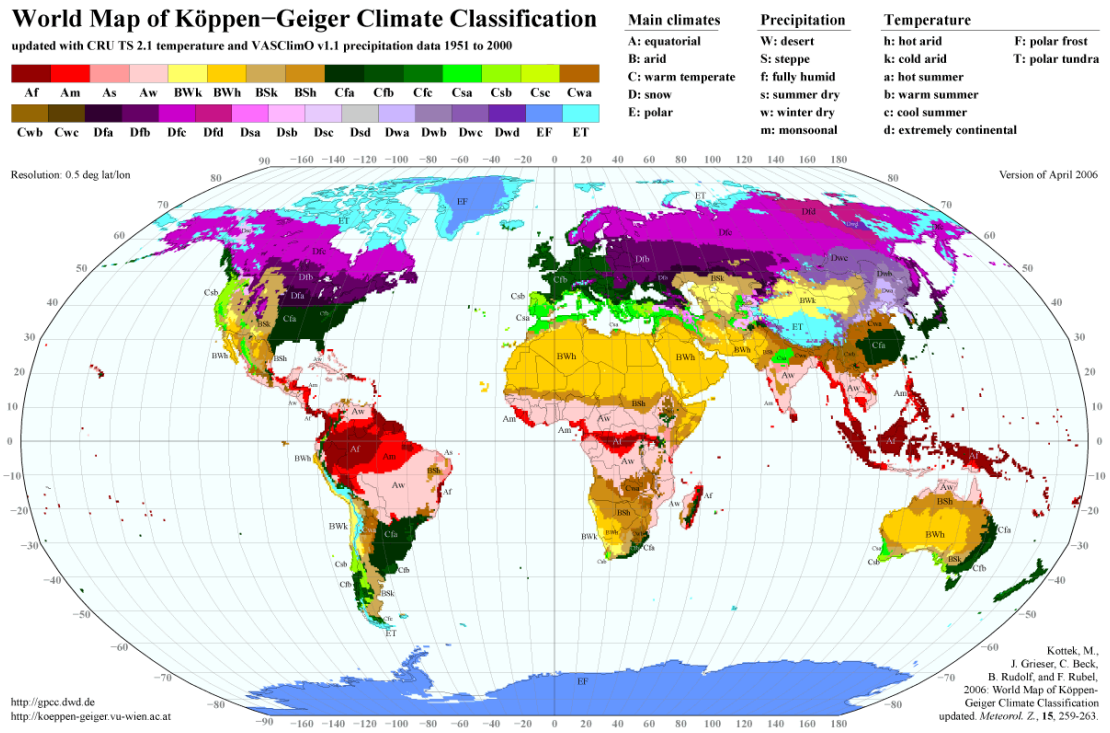

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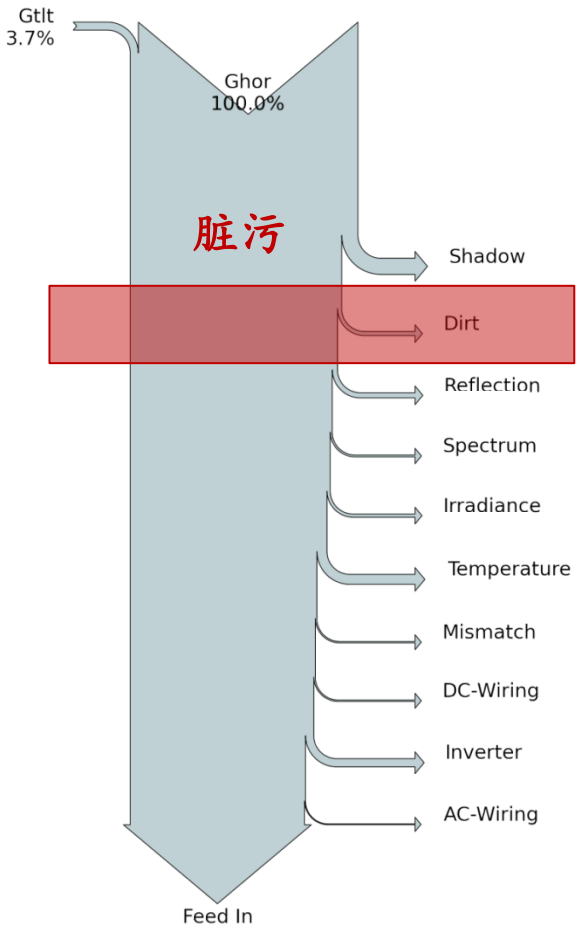
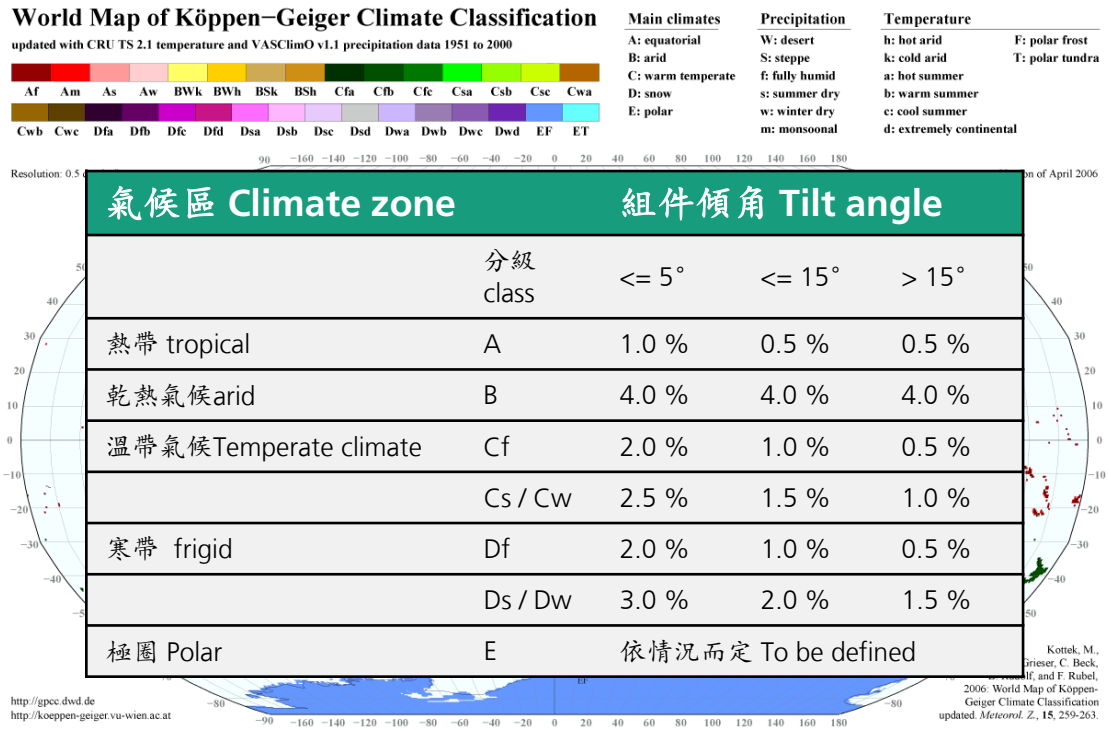
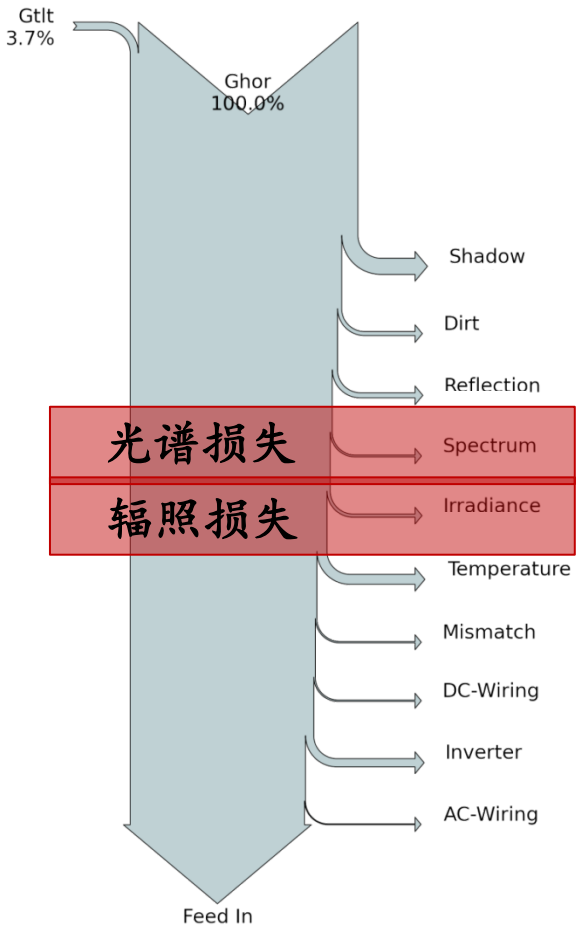




氣候區 Climate zone		組件傾角 Tilt angle		
	分級 class	<= 5°	<= 15°	> 15°
熱帶 tropical	A	1.0 %	0.5 %	0.5 %
乾熱氣候arid	B	4.0 %	4.0 %	4.0 %
溫帶氣候Temperate climate	Cf	2.0 %	1.0 %	0.5 %
	Cs / Cw	2.5 %	1.5 %	1.0 %
寒帶 frigid	Df	2.0 %	1.0 %	0.5 %
	Ds / Dw	3.0 %	2.0 %	1.5 %
極圈 Polar	E	依情況而定 To be defined		

评价电站质量 Evaluation of Quality of PV Power Plant

模型中的不同系统 - 例子2 Different System in Modeling-Example 2



光谱损失

- Mono-Si , Poly-Si: 1,0%
- First Solar CdTe: 2,0%

辐照损失

辐照度 W/m2	相对效率-单晶 %	相对效率-多晶 %
1000	100.00	100.00
800	99.80	100.13
600	99.71	100.06
400	99.50	99.40
200	97.64	96.26

评价电站质量 Evaluation of Quality of PV Power Plant

测试设备精度规范 Regulation for Measurement Devices

测试设备	参数	精度要求
辐照仪 Pyranometer	ISO Classification	Secondary Standard
	Sensitivity	20 µV/W/m²
	Response time	< 5 s
	Irradiance range	0 to 4 000 W/m²
	Non linearity	< 0.2% (100 to 1 000 W/m²)
	Zero offset a (unventilated)	< 7 W/m²
	Operating temperature	-40° to +80° C
风速风向传感器 Wind sensor	Wind speed range	0 to 50 m/s
	Wind speed accuracy	0.5 m/s
	Wind direction accuracy	3°
温度湿度传感器 Temperature and humidity sensor	Measurement Range (temperature)	-40 ° C to +60 ° C
	Accuracy (temperature)	± 0,1°C @ 23°C ± 5°C
	Measurement range (hygrometer)	0 to 100% RH, non-condensing
	Accuracy (hygrometer)	≤3% RH (0-100% RH)
	Temperature dependence (hygrometer)	max ±0.05% RH/° C
	Other	With radiation shield

弗朗霍夫 – VDE 认证标准
Fraunhofer – VDE Verification Standard

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VDE Quality Tested
PV Power Plant
Concept & Design
Safety
Performance
ID. 49000000

模型和设备验证
Model Validation

- 辐照数据与环境数据纪录最低不应低于每一小时一组数据
- 在相同时间范围内，现有数据采集设备的数据平均值不应与参考设备(由弗朗霍夫指导安装)的平均值有3%以上的误差
- 辐朗霍夫 “Zenit”模拟模型应作为产能与PR预测值依据

系统效能评价
Performance Evaluation

- 根据IEC 61724 计算系统真实产能与RR
- 在相同时间范围内，上述计算之PR值不应与基于Zenit模型预测的PR值相差超过3%
- 具体对于衡量该误差的时间范围则必须依据系统条件在项目中定义

弗朗霍夫评价系统概念Fraunhofer Evaluation Concept

优点与缺点 Pros and Cons

优点

- 评价的核心为基于真实情况预测下的质量保证
  - 了解电站的真相！
- 对于电站的质量控管有长期的附加加值
- 模型能够随着数据累积不断改进加强预测能力

缺点

- 建模的复杂性与知识产权保护有赖高度的专业与经验
- 各项参数的定义必须经过长期的研究
- 公平性
- 系统内部各种影响因速彼此间的交互关系很难量化

→ 此评价方式较不易整合为标准化使用

感谢您的参与!
Thank you for your Attention!

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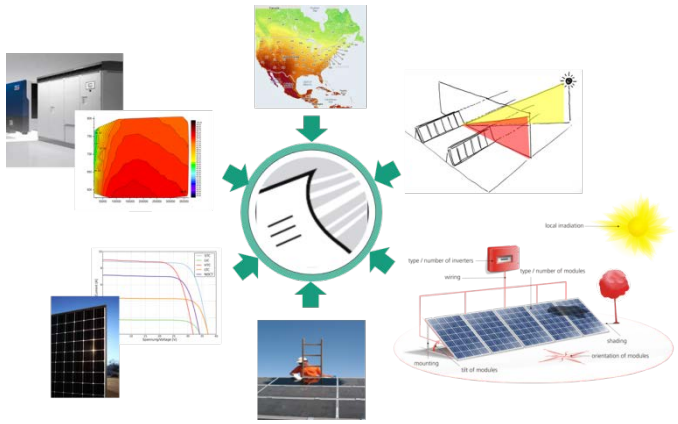
評價電站的基礎
構成要素

電站模型	衛星數據	運維數據	監測數據
Plant model	Satellite	O&M	Monitoring



模擬參數

- 輻照度與環境溫度
- 組件, 電子設備參數
- 髒汙率
- 系統不匹配
- 系統錯誤率
- 維修斷電
- 限電
- …

評價電站的基礎
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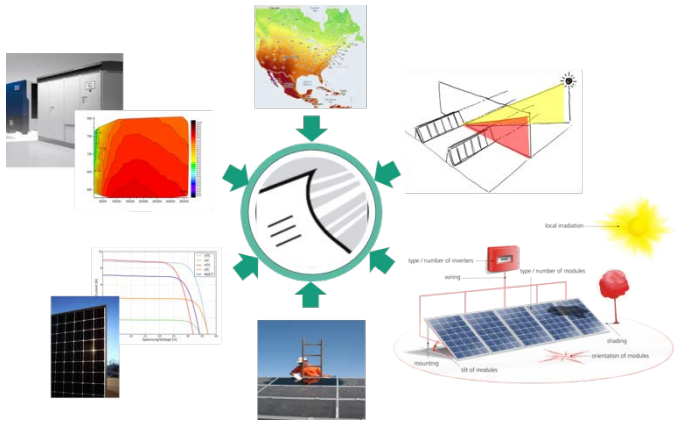


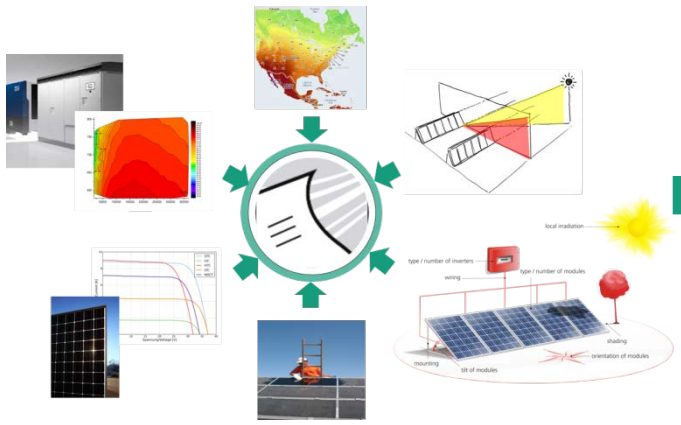
模擬參數

- 輻照度與環境溫度?
- 組件, 電子設備參數?
- 髒汙率?
- 系統不匹配?
- 系統錯誤率?
- 維修斷電?
- 限電?
- …

高不確定度!

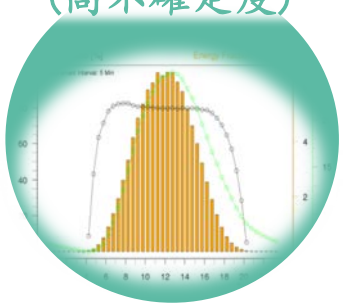
評價電站的基礎
構成要素

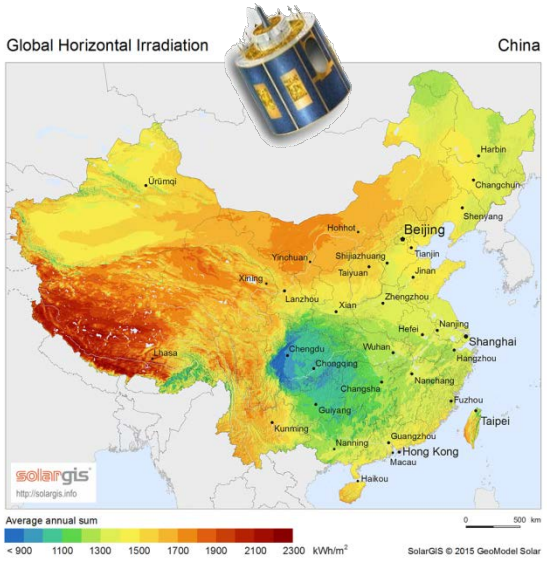
電站模型	衛星數據	運維數據	監測數據
Plant model	Satellite	O&M	Monitoring



理論產能

（高不確定度）





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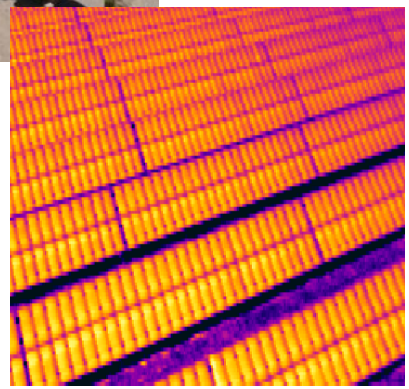
評價電站的基礎
構成要素

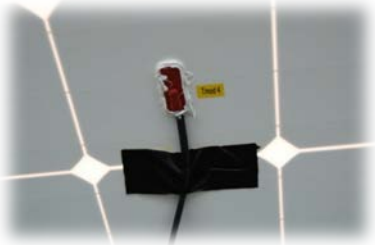
電站模型	衛星數據	運維數據	監測數據
Plant model	Satellite	O&M	Monitoring

- **紀錄**實際電站發電數據
- **修正**模型中系統參數



〈模型優化〉

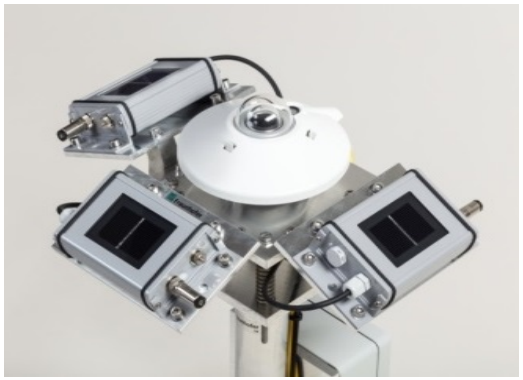
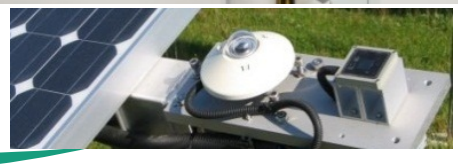
評價電站的基礎
構成要素


電站模型	衛星數據	運維數據	監測數據
Plant model	Satellite	O&M	Monitoring

- **紀錄**實際輻照與環境數據
- **修正**模型中環境參數

〈模型再優化〉

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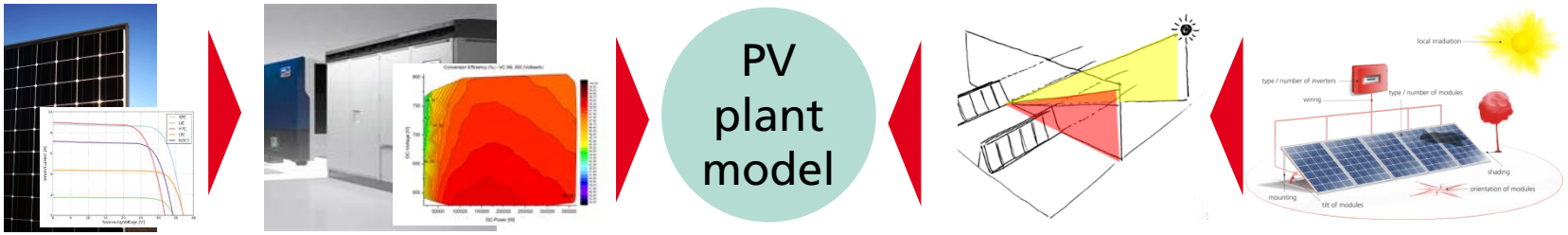
Testing during Final Acceptance Test

Short-term Performance Check of the PV Plant

Independent performance verification in 3 steps:

1: Model of the plant as built



module and inverter characteristics
e.g. temperature and irradiance dependence, efficiency

plant construction
e.g. orientation, tilt, shading and wiring losses

2: Validation of PV plant monitoring sensors (Irradiance and temperature)

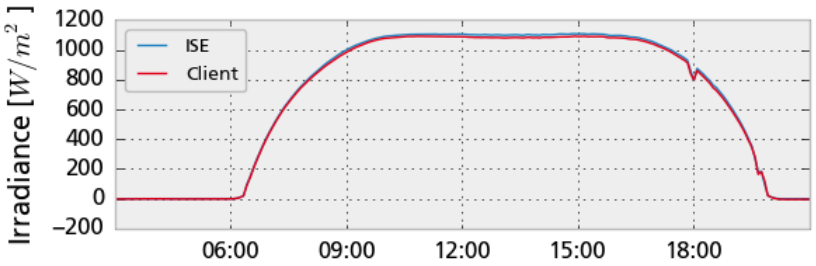


Fig. 1: Measured irradiance of ISE (red) and client (blue) sensor

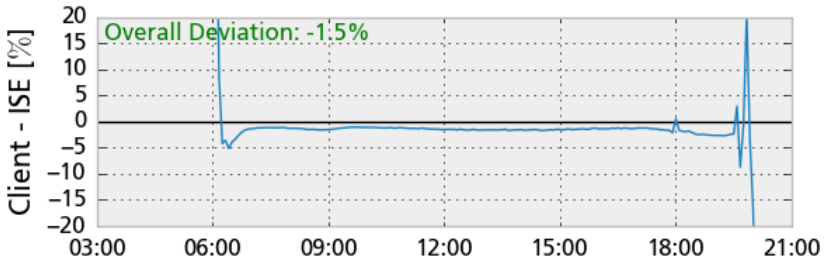


Fig. 2: Comparison of ISE and client pyranometer values

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Testing during Final Acceptance Test
Short-term Performance Check

3: Plant performance: modelled vs. measured data

on-site measured irradiance and temperature data

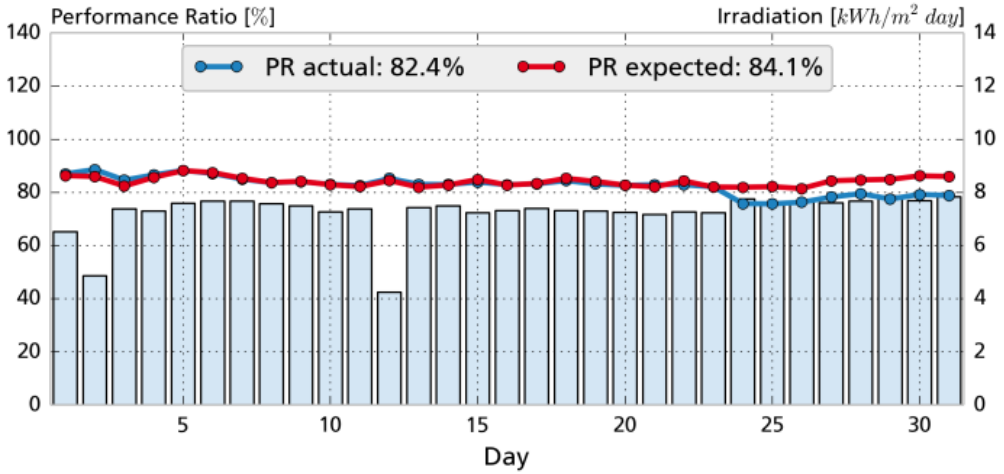
PV plant model

modelled PR

measured PR

PR

comparison and results



- Comparison of actual (measured) and expected (modelled) PR

单位发电成本和质量保证
Levelized costs of energy and quality

$$LCOE = \frac{\text{cost of produced electric energy}}{\text{produced electric energy}} = \frac{I_0 + C_0 \sum_{t=1}^{n} \frac{(1+i)^t}{(1+r)^t}}{R_P \cdot \eta_{STC} \cdot E_y \sum_{t=1}^{n} \frac{(1+d)^t}{(1+r)^t}}$$

LCOE	单位发电成本	Levelized cost of energy
I_0	初始投资	initial investment for power plant
C_0	年运维成本	annual operation & maintenance cost
n	生命周期	service life
i	通膨率	annual inflation rate
r	贴现率	annual discount rate
R_P	初始PR值	initial Performance Ratio of power plant
η_{STC}	初始组件效率(STC)	initial module efficiency (STC)
E_Y	组件平面年辐照量	yearly sum of energy irradiated on module plane
d	年衰减率	annual degradation rate

quality sensitive

和质量密切相关参数

商用电站质量保证 Quality Assurance for utility scale PV plants

测试数据和预测对比 Measured compared to predicted PR and yield

对比结果 Result

- 预测PR结果和实际测量值高度吻合

  On average very good agreement of measured and predicted PR

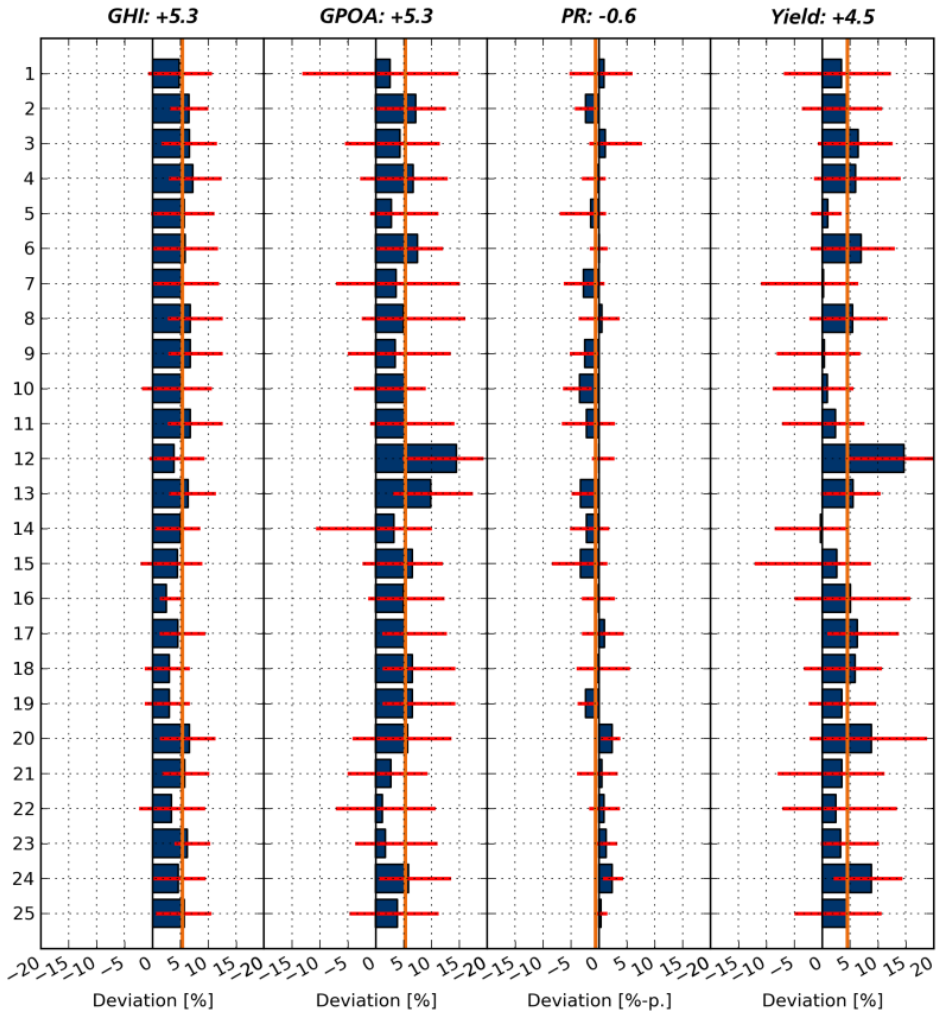
- 辐照值和产能普遍高于预测值

  Irradiation and yield remarkably higher than predicted

对比基础 Basis

- 25座电站及其5年高精测量数据

  25 PV Plants with 5 years highly accurate data



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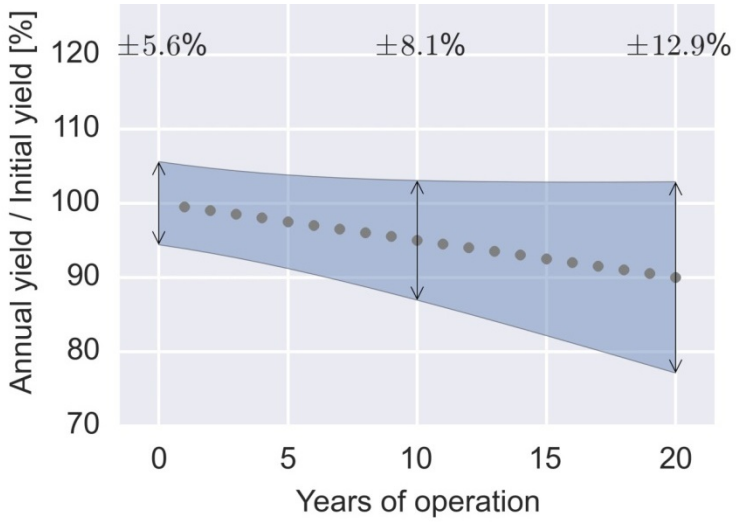
如何降低不确定度与投资风险?
How to reduce uncertainty and financial risk?

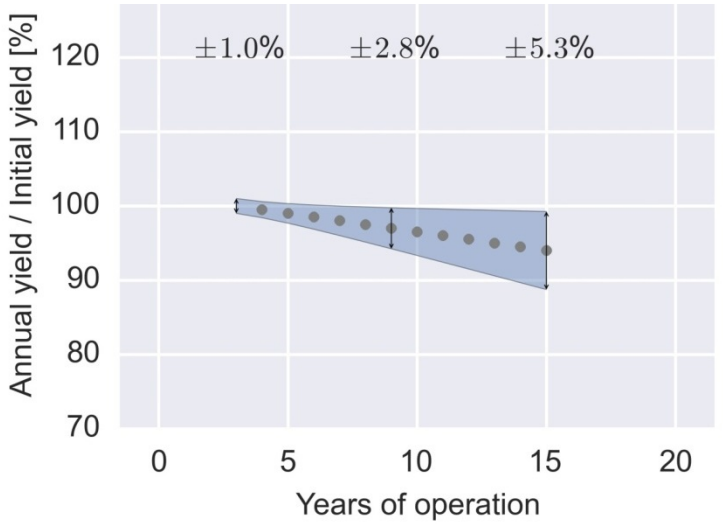
- 分析不确定度与风险应透过以下方式降低: Uncertainty and risk can be lowered by
  - 电站投资组合 — PV plant portfolio
  - 调整投资期限 — Adjusted investment period
  - 实验室测试与现场检测 — Laboratory and on-site testing

[1] B.Müller et al. „Investment risks of utility-scale PV: Opportunities and limitations of risk mitigation strategies toreduce uncertainties of energy yield predictions", *42. IEEE PV Specialists Conference, New Orleans (2015)*

单体电站20年预测不确定度变化
20-year prediction for individual plant



投资组合与调整期限后结果
Portfolio and adjusted investment period



系统模拟与测试 Modelling and Testing on System Level

电站初期/短期性能确保 short-term performance check

电站性能: 模拟分析 vs. 测量数据
Plant performance: modelled vs. measured data

现场辐照与温度测试设备
on-site measured irradiance and temperature data

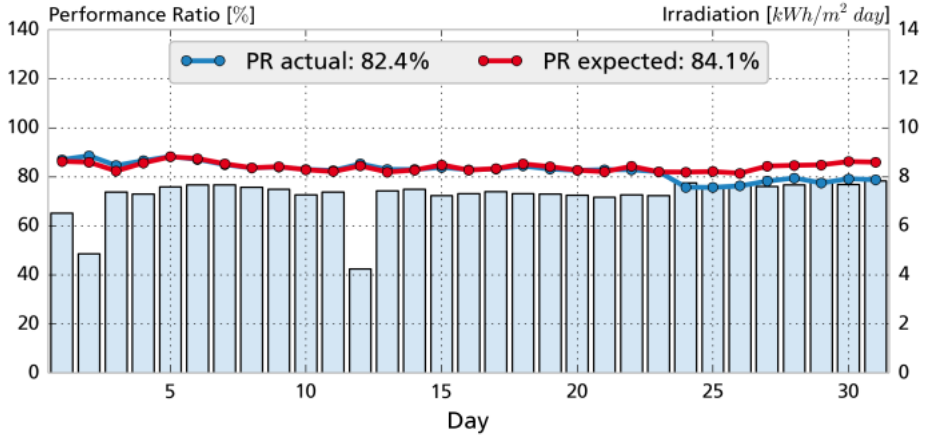
电站模型
PV plant model

模拟的PR
modelled PR

量测的PR
measured PR

PR

comparison and results



- 比较实际(测量)与理想(模拟)值之间的差异

  Comparison of actual (measured) and expected (modelled) PR

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