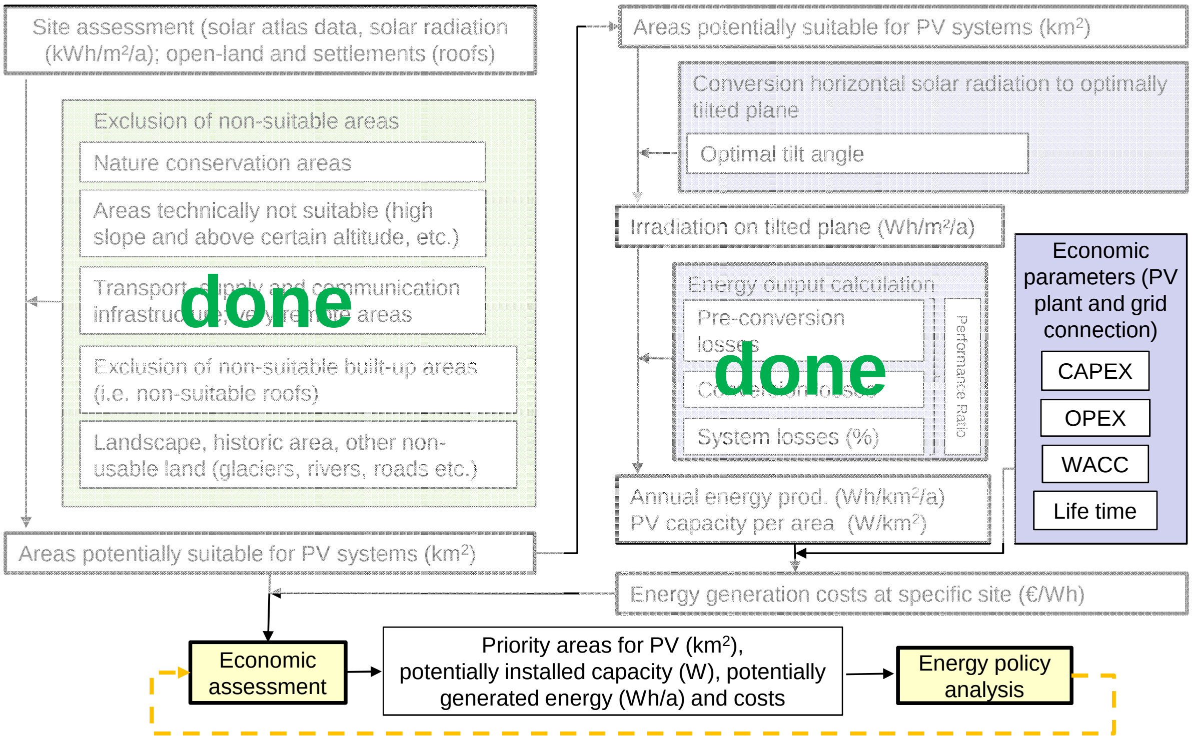
Session 4:
Economic assessment of PV and wind for energy planning

IRENA Global Atlas
Spatial planning techniques
2-day seminar

Central questions we want to answer

1. Once we know how much electricity can be produced in our country with given resources (technical potential), we will be able to **estimate their generation costs**
2. As all available data comes with uncertainties, we should know
   a. how **sensitive** results react on changing input parameters, and,
   b. what **socio-economic effect** highly uncertain input data could have.



CAPEX = Capital expenditure, OPEX = Operation expenditure, WACC = Weighted average cost of capital (debt, equity)

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1. LEVELIZED COST OF ELECTRICITY (LCOE)

Levelized Cost of Electricity (LCOE)

- Calculates the average cost per unit electricity. LCOE takes into account the time value of money (i.e. capital costs).

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{Q_{el}}{(1+i)^t}}$$

Where:

- LCOE: Average Cost of Electricity generation in $/unit electricity
- I_0: Investment costs in $
- A_t: Annual total costs in $ in each year t
- Q_{el}: Amount of electricity generated
- i: Discount interest rate in %
- n: useful economic life
- t: year during the useful life (1, 2, …n)

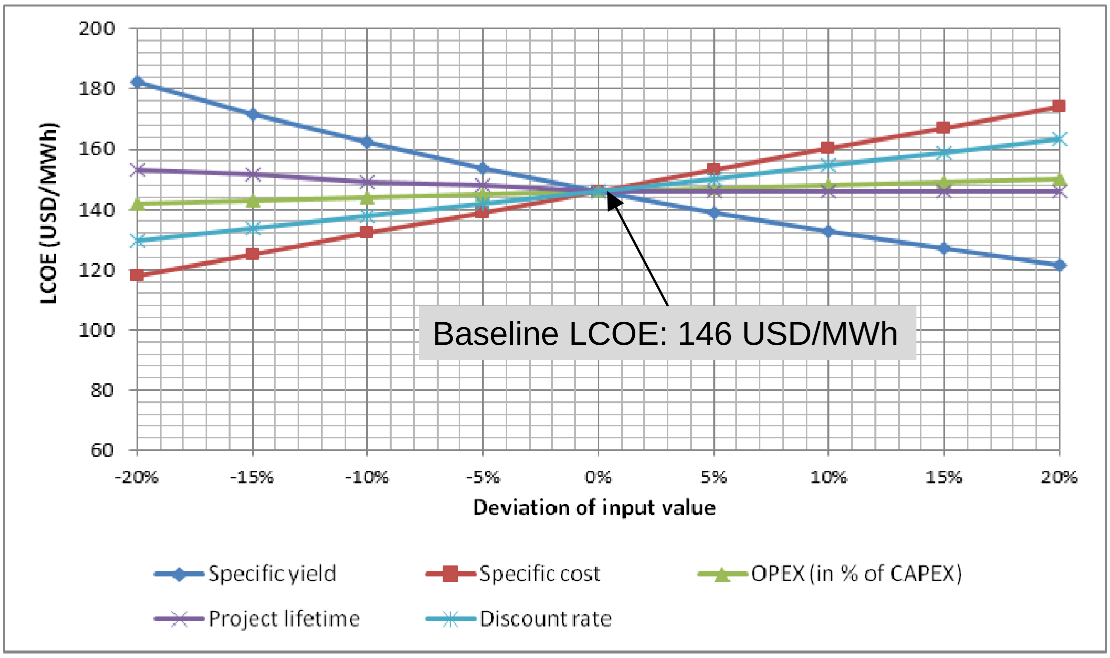
Worked example:

2. LCOE SENSITIVITY OF PV PROJECTS

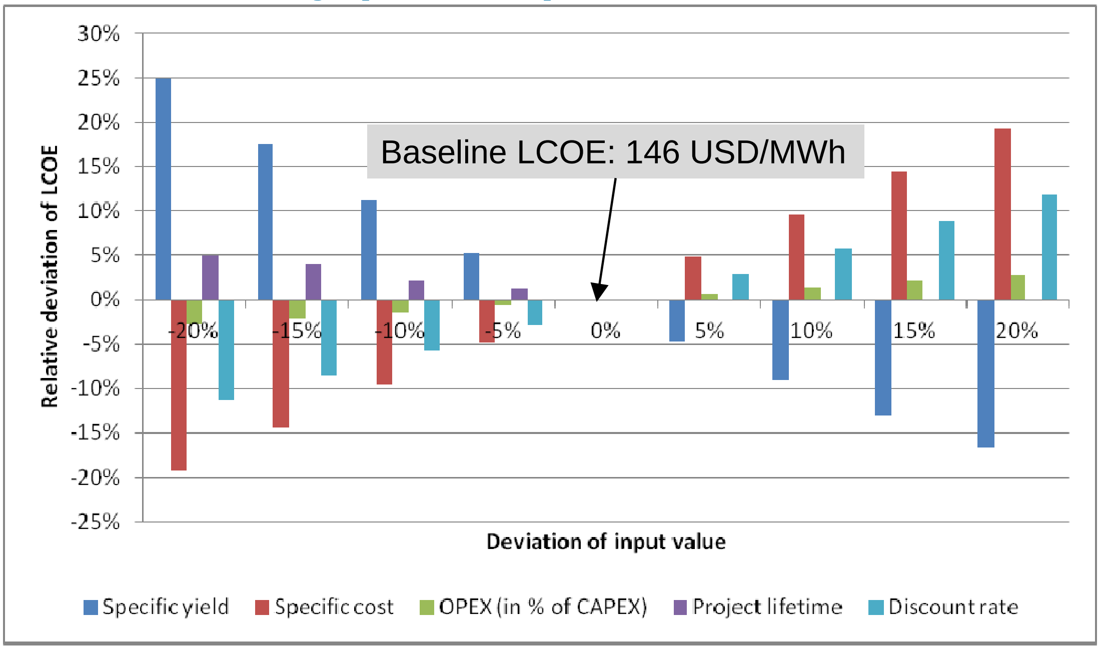
Worked example – Grid-tied PV in Pucallpa, Peru

• Project type:	Grid-tied
• Location at latitude:	10° South
• Reference irradiation (GHI):	2,050 kWh/m²/a
• Reference specific yield (P50):	1,580 MWh/MWp
• System size:	10 MWp
• Specific project CAPEX:	2.000.000 USD/MWp
• Project annual OPEX:	1.5% of project CAPEX
• Discount rate (WACC):	8%
• Project duration:	30 years
• Inverter replacements:	2
• Solar panel degradation:	0,7% p.a. (linear)

LCOE sensitivity (absolute)



LCOE sensitivity (relative)



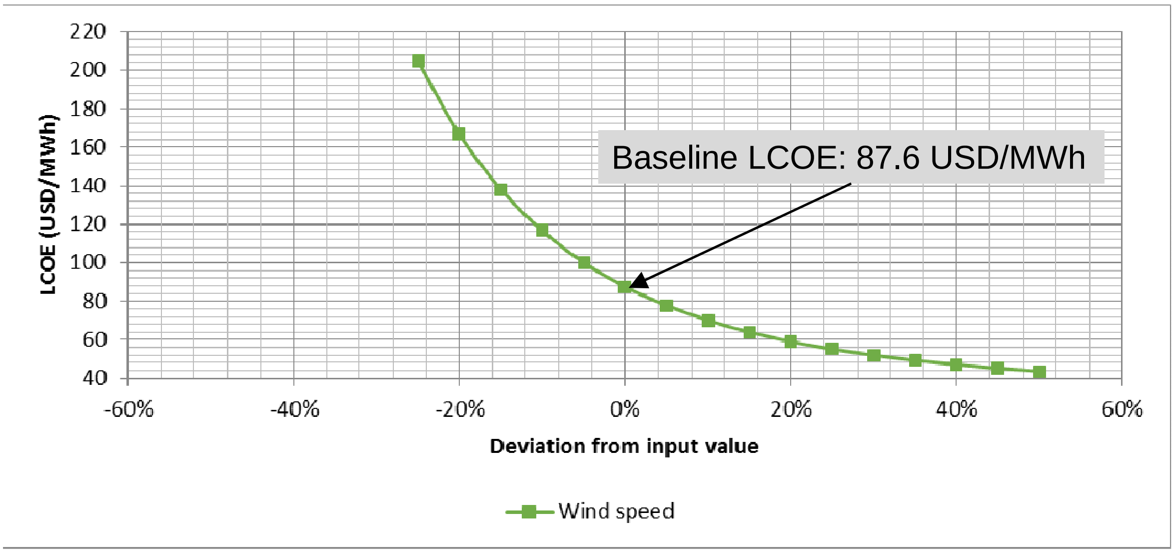
Worked example:

3. LCOE SENSITIVITY OF WIND PROJECTS

Worked example – Grid-tied wind project Egypt (variation A)

- Project type: Grid-tied wind
- Location: Peru / South of Lima
- Average wind speed @ 80m: 7.3 m/s
- Wind distribution, shape parameter: 3.5
- Wind distr., scale parameter: 8.11
- Technical availability: 97%
- Reference specific yield (P50): 3,202 MWh/MW (techn. availability considered)
- Capacity factor: 36.6%
- System size: 8 MW (4 turbines)
- Specific project CAPEX: 4.000.000 USD per turbine
- Project annual OPEX: 3.0% of project CAPEX
- Discount rate (WACC): 8%
- Project duration: 20 years

LCOE sensitivity (absolute) – Wind speed only



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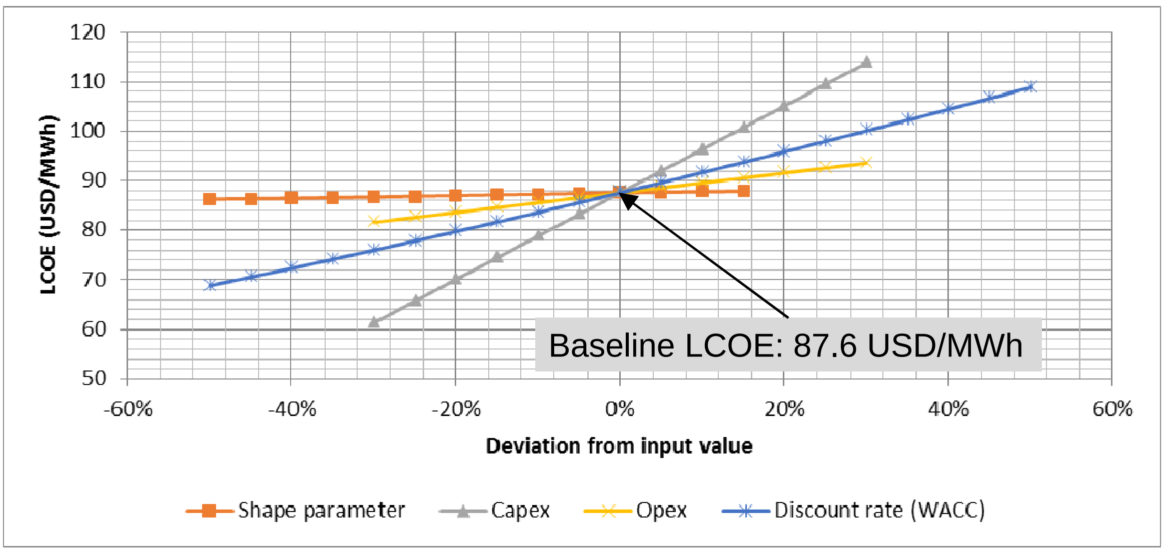
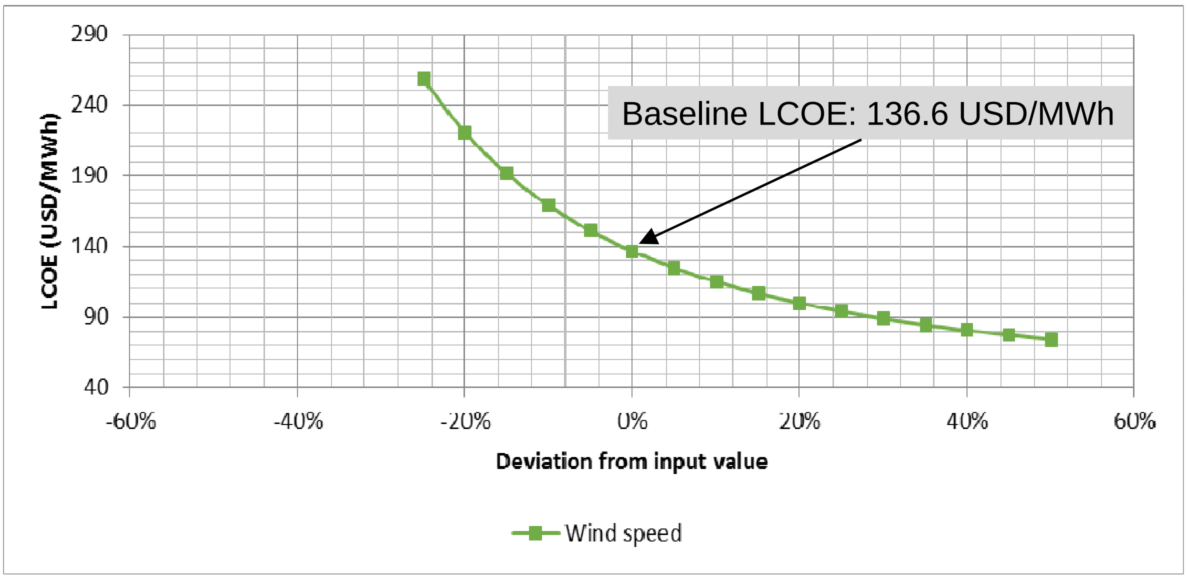
LCOE sensitivity (absolute) – other parameters



Worked example – variation B: lower wind speed & lower shape parameter

- Project type: Grid-tied wind
- Location: Peru / south of Lima
- Average wind speed @ 80m: ~~7.3 m/s~~ **5.5 m/s**
- Wind distribution, shape parameter: ~~3.5 m/s~~ **1.5 m/s**
- Wind distr., scale parameter: **6.11**
- Technical availability: 97%
- Reference specific yield (P50): 2,054 MWh/MW (techn. Availability considered)
- Capacity factor: 23.5%
- System size: 8 MWp (4 turbines)
- Specific project CAPEX: 4.000.000 USD per turbine
- Project annual OPEX: 3.0% of project CAPEX
- Discount rate (WACC): 8%
- Project duration: 20 years

LCOE sensitivity (absolute) – Wind speed only



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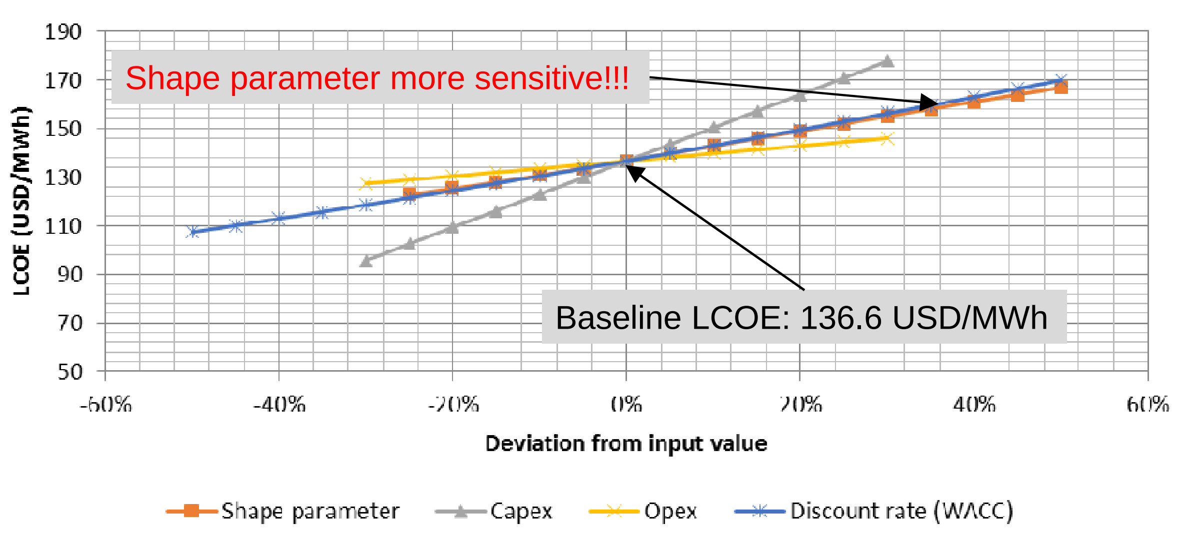
LCOE sensitivity (absolute) – other parameters



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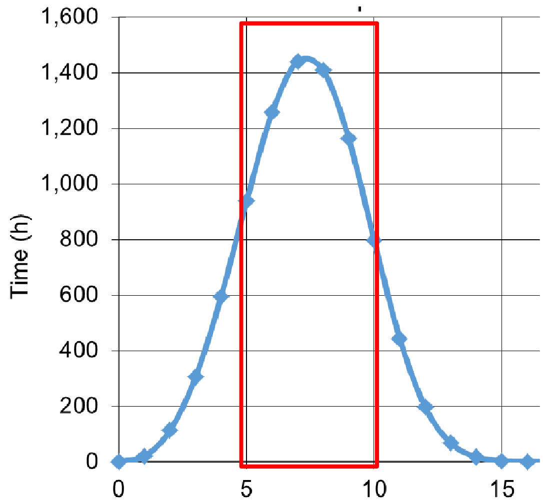
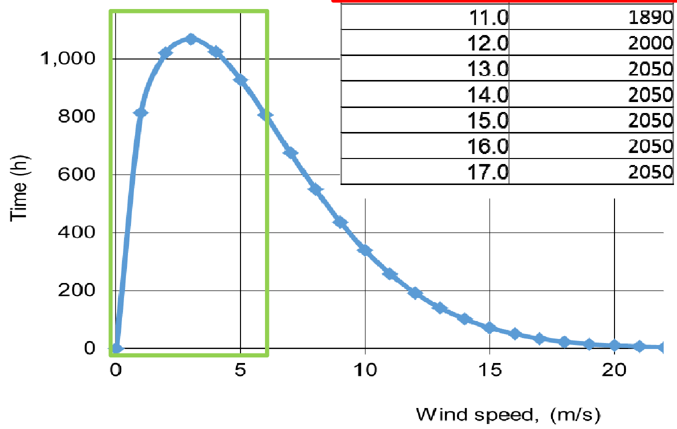
Conclusions on sensitivities and for scenario development

- Variations of the shape factor of the Weibull distribution of wind can have very different effects depending on the chosen scenario
  - In variation A (high wind, high shape factor), varying of the shape factor only had a **very little effect** on the LCOE.
  - In variation B (lower wind, lower shape factor), varying of the shape factor had a **considerable effect** on the LCOE.
  - **Reason**: The chosen wind turbine for the scenario has a power curve which operates better under weaker winds.
  - It is crucial for wind scenario developments, to chose appropriate turbines for sites with different wind speeds and wind speed distributions.

Comparison of Weibull curves for variations A (left) + B (right)

v_i (m/s)	Output power of E82-2000, (kW)
0.0	
1.0	0
2.0	3
3.0	25
4.0	82
5.0	174
6.0	321
7.0	532
8.0	815
9.0	1180
10.0	1612
11.0	1890
12.0	2000
13.0	2050
14.0	2050
15.0	2050
16.0	2050
17.0	2050





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Worked example:

4. EFFECTS OF DATA UNCERTAINTY ON THE LCOE OF PV

Why data quality is so important

- All data comes with **uncertainties**:
  - **Measurements** are always subject to deviations, and ,
  - **models** used for predictions can never simulate what happens in reality.
- It is obvious that the lower uncertainty is the more accurate predictions will be. This, in turn, will enable us to **make better estimates**.
- In the following, we will demonstrate how good data (i.e. data with low uncertainties) will potentially help **saving funds** for PV Power Purchase Agreements.

Uncertainty assumptions

- Low resolution NASA SSE data: +/- 13,7%
- Average Meteonorm 7 data: +/- 7,5%
- Best ground measurement at site: +/- 3,0%

- **Important note**: Besides uncertainty of irradiation data, there is also uncertainty within the simulation model and nameplate capacity. However, the latter are comparably small so that we will, to keep the example simple, only look at resource uncertainty. In real-life, when it comes to detailed project development, one should always ask the project developer to provide information about his uncertainty assumptions.

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Worked example – Grid-tied PV in Pucallpa, Peru

• Project type:	Grid-tied
• Location at latitude:	20° North
• Reference irradiation:	2050 kWh/m²/a
• Reference specific yield (P50):	1580 MWh/MWp
• System size:	10 MWp
• Specific project CAPEX:	2.000.000 USD/MWp
• Project annual OPEX:	1.5% of project CAPEX
• Discount rate (WACC):	8%
• Project duration:	30 years
• Inverter replacements:	2
• Solar panel degradation:	0,7% p.a. (linear)

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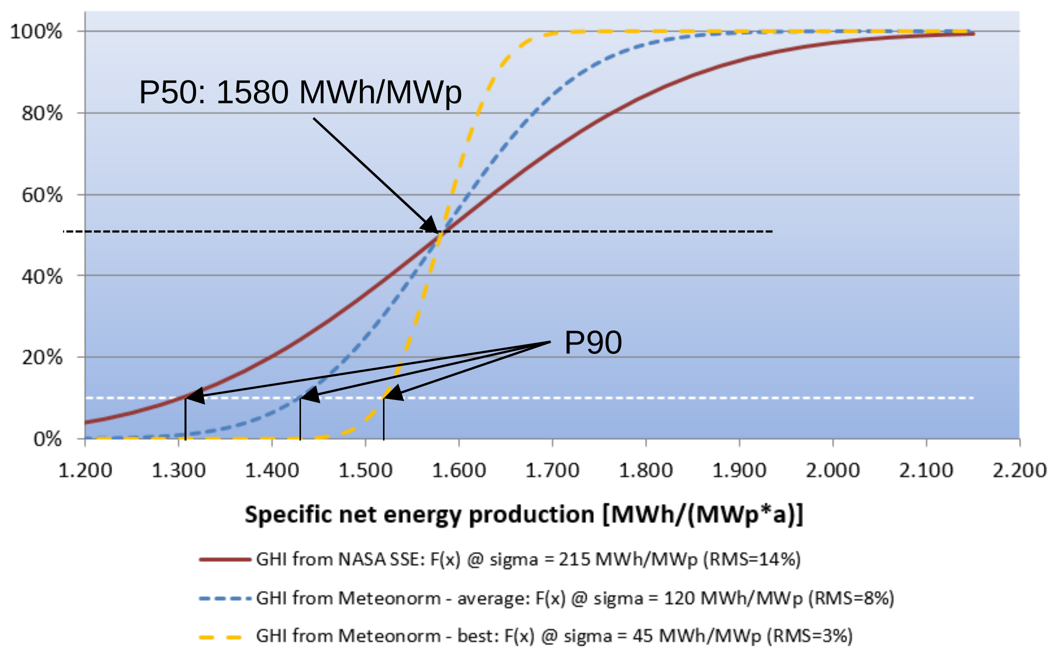
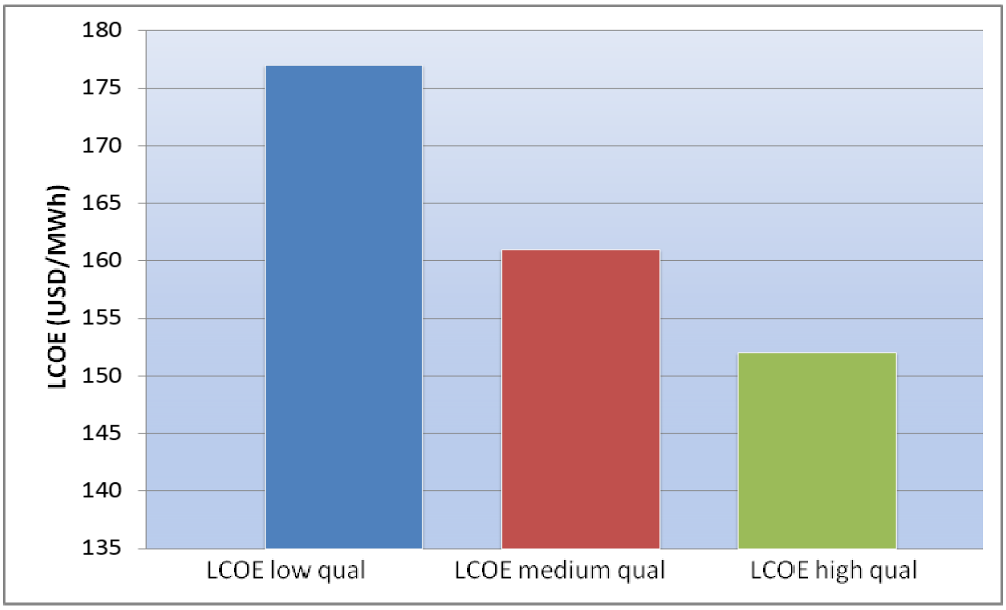
Exceedance probability



LCOE depends on quality of meteo data



LCOE is key factor for PPA tariff calculation

- Assuming a 10% premium on the LCOE as margin for IPP
  - Best case: 152 USD/MWh +10% = 167 USD/MWh
  - Worst case: 177 USD/MWh +10% = 195 USD/MWh
  - Delta: 28 USD/MWh (incl. 10% premium)

Country sets a 5% PV goal by 2020

• Sample:	Peru
• Total electricity demand 2010:	37 TWh (Source: Google Public Data)
• 5% of total:	1.85 TWh
• PPA tariff difference:	28 USD/MWh
• „Unnecessary“ payments in 2020:	1,850,000 MWh * 28 USD/MWh =51.8 Mio USD
• PV power needed:	1,200 MWp (with best P90 value)

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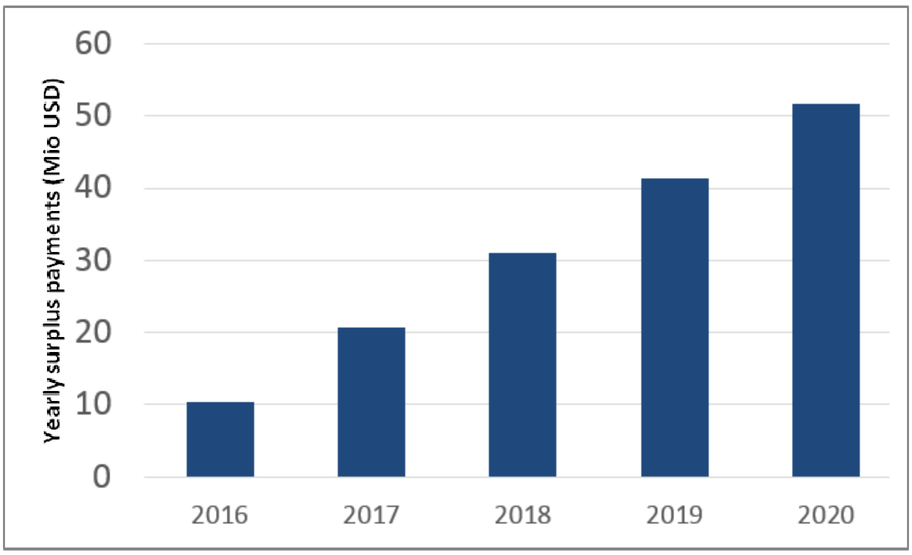
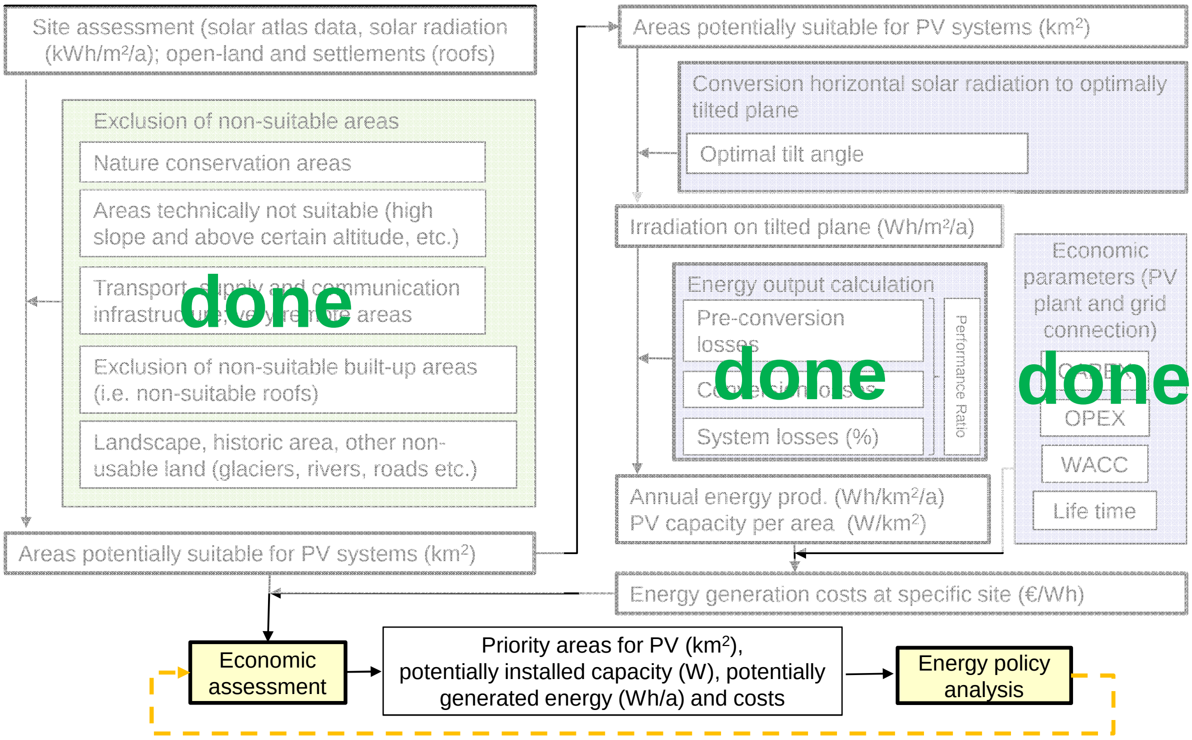
„Unnecessary“ payments due to inaccurate data

• PV power needed by 2020:	1,200 MWp (with best P90 value)
• **Avoidable payments:**	**155 Mio USD**





CAPEX = Capital expenditure, OPEX = Operation expenditure, WACC = Weighted average cost of capital (debt, equity)

Thank you very much for your attention!

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