



Data monitoring & analytics for better PV
performance and grid integration

Pearl PV Workshop organized by WG5

12th of January, 2021

Impact of performance and degradation on PV plants profitability

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INSTITUTE**

Becquerel Institute

Empowering Companies to Embrace the Solar-PV driven Energy Revolution

www.becquerelinstitute.eu

Becquerel Institute at a glance

Privately-owned Belgian company founded in 2014, providing a hybrid service of high-quality consultancy and non-for-profit research, focused on the role of solar PV in the energy revolution

Applied Research



Support the PV ecosystem

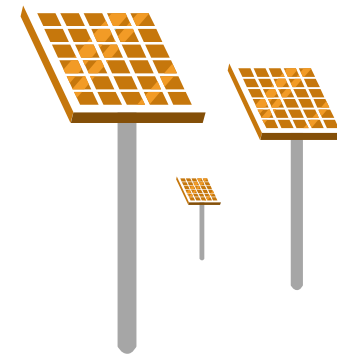


Operational Advisory Services



Table of content

- 1 Degradation rates and performance ratio : **influencing factors**
- 2 Degradation rates and performance ratio : **state of the art**
- 3 Degradation rates and performance ratio : **impact on profitability**
- 4 **Conclusions**



Impacting factors on PV degradation and performances

🌞 Degradation rate

Module-level degradation is caused among other by :

- delamination,
- backsheet adhesion loss,
- junction box failure,
- frame breakage,
- cell cracks,
- potential induced degradation,
- high ambient and cell temperature, and
- cell hot spots

System-level degradation is caused among other by :

- problems with the balance of system (trackers, inverters, wiring, fuses, and breakers)
- the growth of vegetation that contributes to increased shading over time.

🌞 Performance ratio

Environmental factors

- Temperature of the PV module
- Solar irradiation and power dissipation
- PV module in the shade or soiled

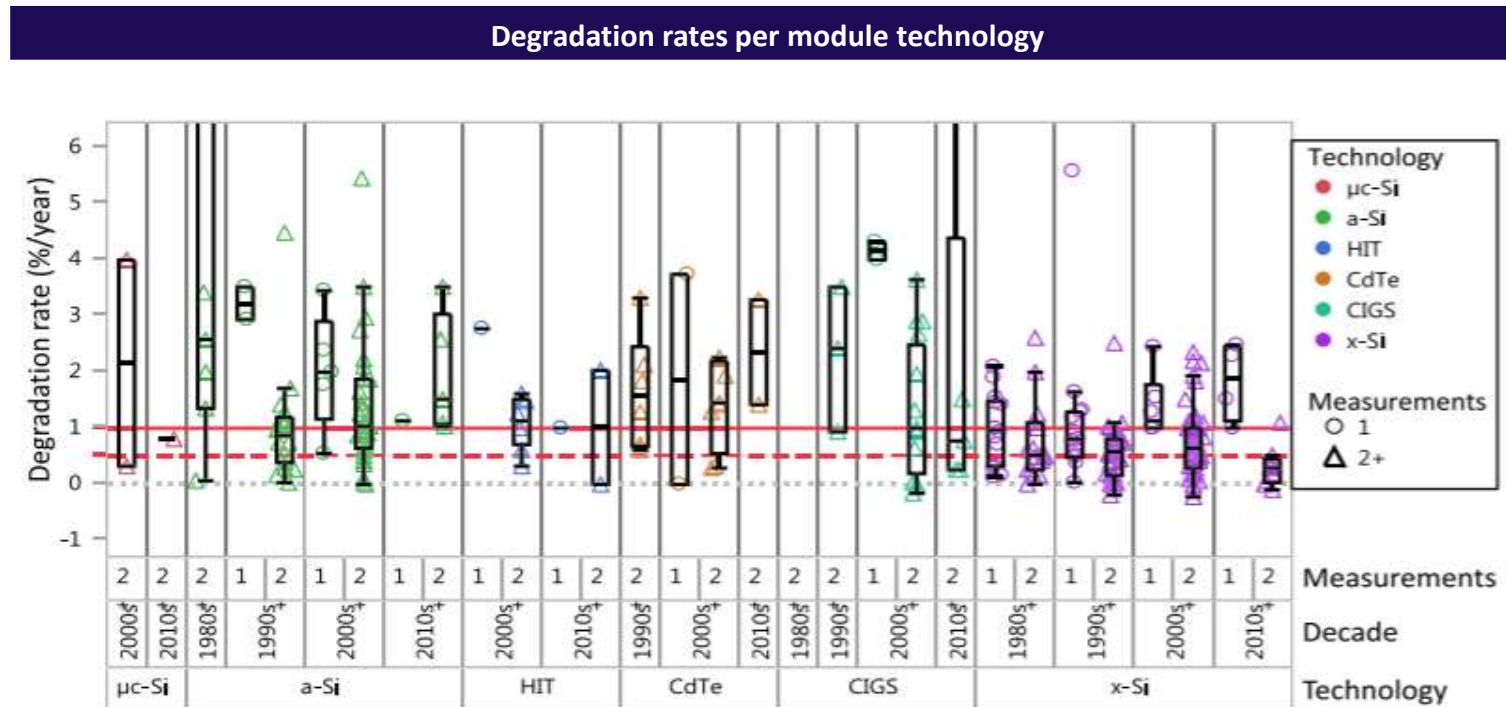
Other factors

- Conduction losses
- Efficiency factor of the PV modules
- Efficiency factor of the inverter

Source : System-level performance and degradation of 21 GWDC of utility-scale PV plants in the United States, 2020 (J. Renewable Sustainable Energy 12, 043501 (2020); <https://doi.org/10.1063/5.0004710>)

State of the art of PV degradation rates

Important differences exist depending on the considered PV technology

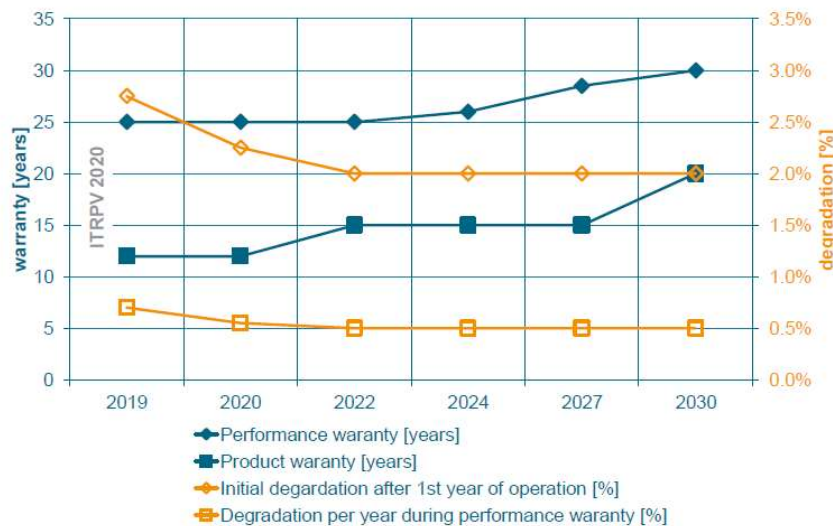


Source : NREL, Compendium of photovoltaic degradation rates, 2016

State of the art of PV degradation rates

Guaranteed degradation rates are converging towards 0,5% for c-Si modules

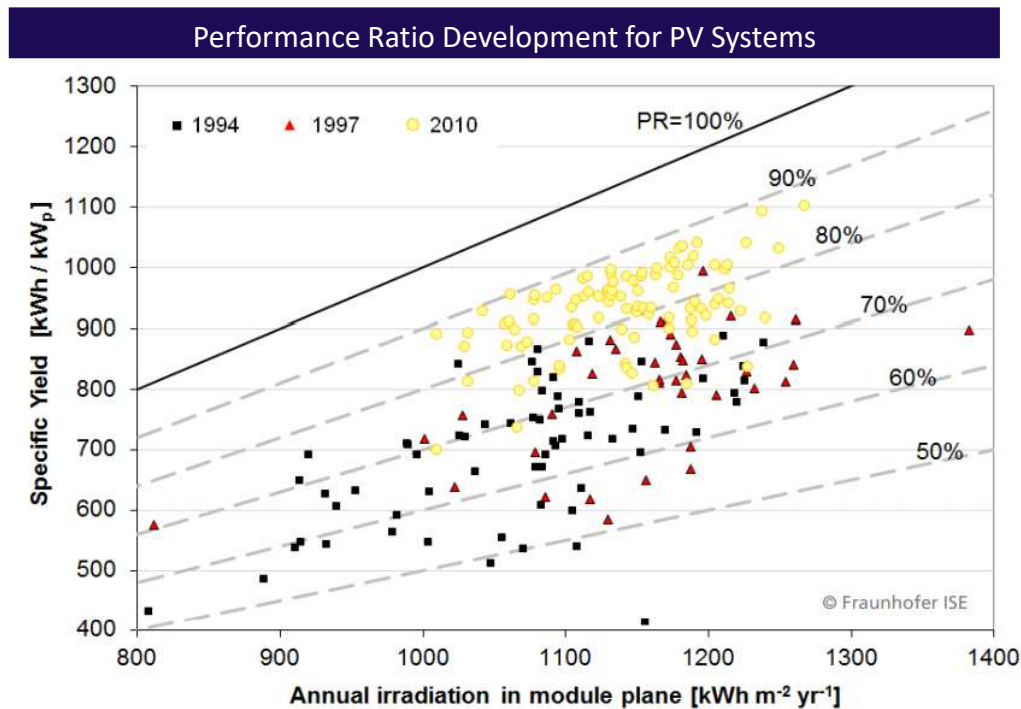
Warranty requirements & degradation for c-Si PV modules



- Improvements in terms of warranty period foreseen
- Guaranteed degradation rates are converging towards 2,0% for the first year of operation and 0,5%/a for the following years.
- These guaranteed degradation rates are usually used in profitability calculations

Source : ITRPV, Eleventh Edition, April 2020

State of the art of PV performance ratios



- In the 1990's, typical PR was around 70% but observed PR values ranged widely around that value
- In the 2010's, typical PR was around 80-90%, with a vast majority of observed PR falling in this interval.


Source : Performance ratio revisited: is PR>90% realistic? Nils H. Reich, Bjoern Mueller, Alfons Armbruster, Wilfried G. J. H. M. van Sark, Klaus Kiefer and Christian Reise, Paper presented at 26TH EU PVSEC, HAMBURG, GERMANY 2011

Improvements foreseen are also focusing on forecasts and monitoring quality


- Still ongoing research aiming at reducing degradation rates or increasing performance ratio
- The focus is put on how to improve the precision of degradation and performance **forecasts** for a given PV plant and their **monitoring** over the system's lifetime rather than to decrease degradation rates and increase performance ratio of PV systems.

Impact of degradation and performance on PV profitability

Base cases




PV technology : Mono c-Si PERC
Installed capacity : 50 MWp
System lifetime : 30 years




CAPEX : 0,6 €/Wp




OPEX : 12 €/kWp.a



Share of equity : 20%
Cost of equity : 6%
Interest rate : 3%



Initial performance ratio : **0,80**



Degradation rate (year 1) : **1,8%**
Degradation rate (year 1+) : **0,5%**

GERMANY

Yearly irradiation :
1300 kWh/m²

Feed-in premium :
0,06 €/kWh / 20 years

Selling on the wholesale market :
0,035 €/kWh / last 10 years



Net Present Value :
3 038 149 €



LCOE :
53,2 €/MWh

SPAIN

Yearly irradiation :
2100 kWh/m²

Selling on the wholesale market :
0,035 €/kWh / 30 years



Net Present Value :
901 177 €

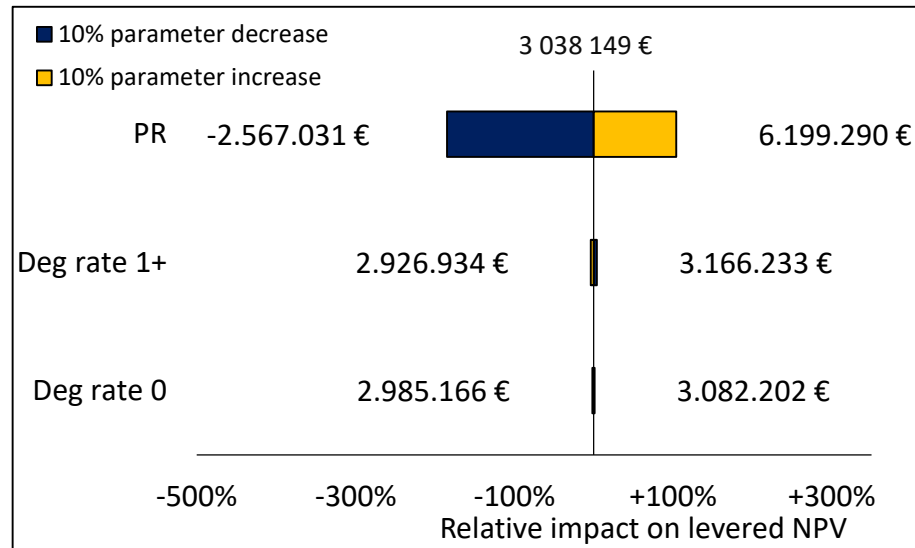


LCOE :
33 €/MWh

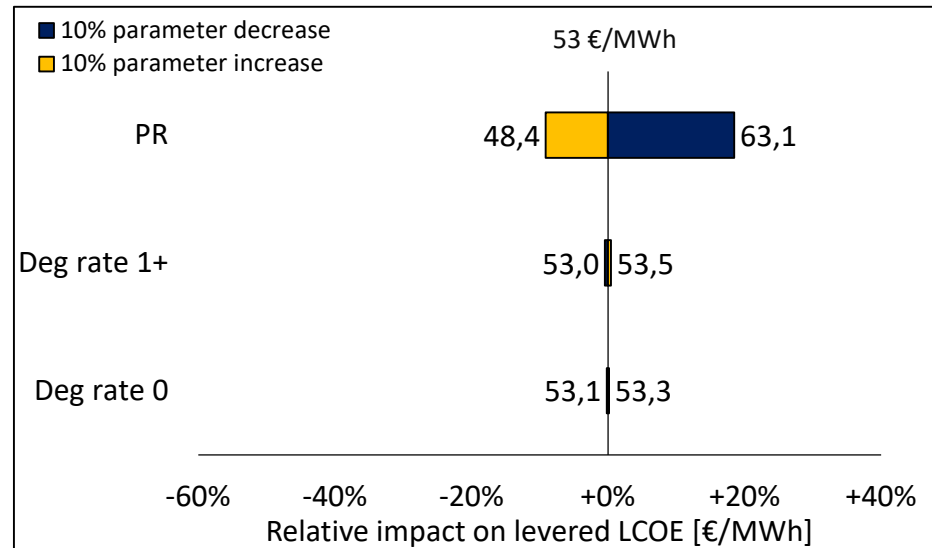
Impact of degradation and performance on PV profitability

Sensitivity analysis for the German case

Impact of PR and degradation rate 10% variations on NPV



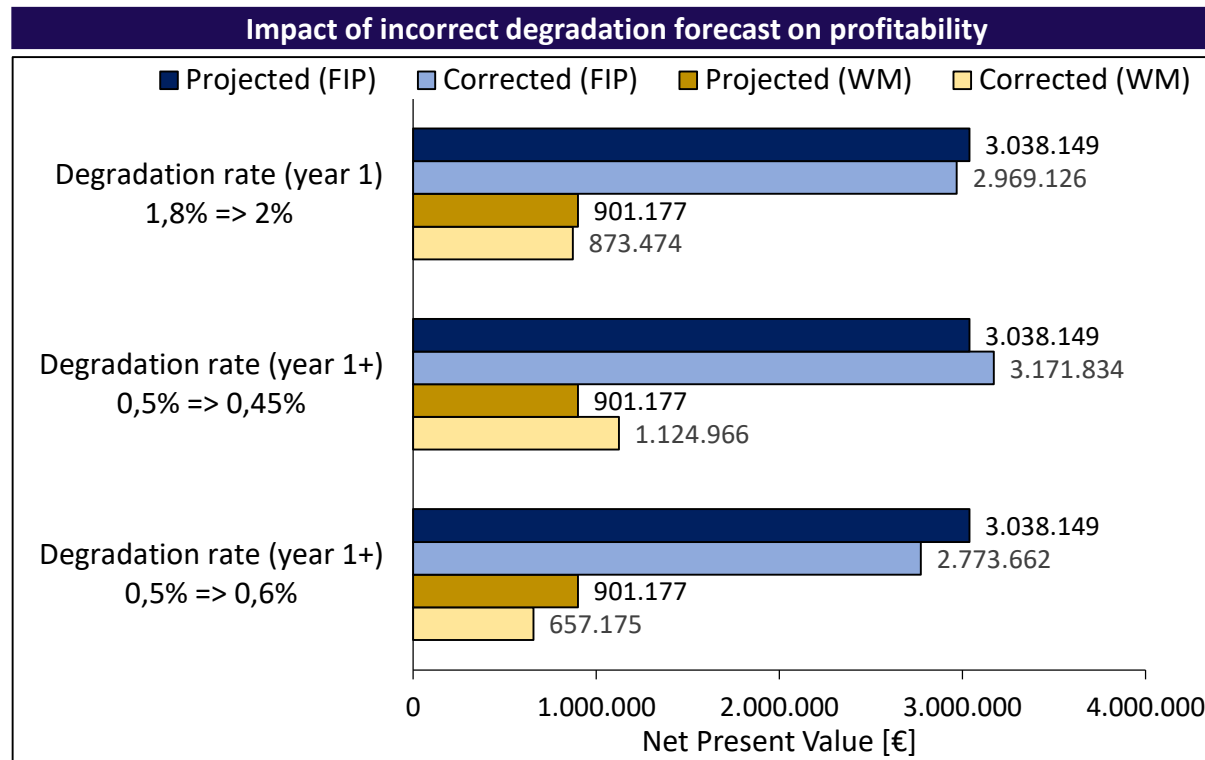
Impact of PR and degradation rate 10% variations on LCOE



- When considering -10%/+10% variations of the degradation rates and the performance ratio, the latter appears as the most influential parameter

A 10% increase of the performance ratio can allow a doubling of the NPV and a 10% decrease of the LCOE

Impact of degradation on PV profitability

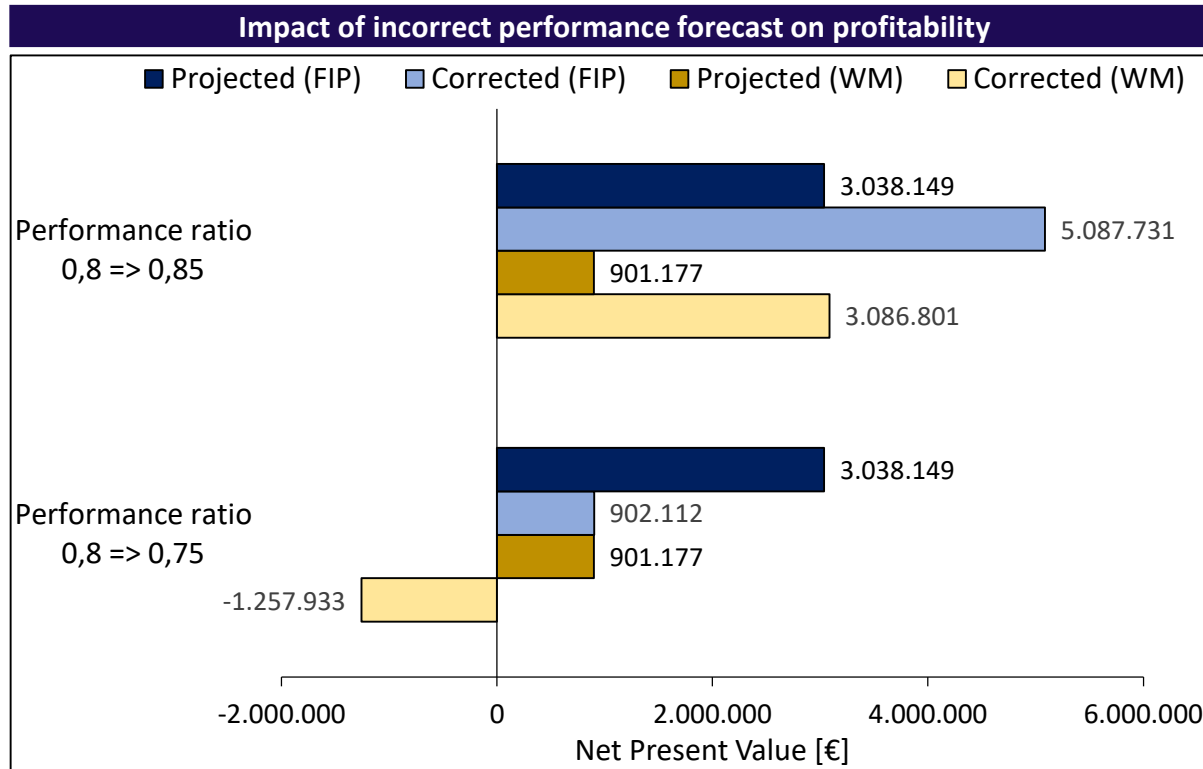


FIP = Business model based on a feed-in premium

WM = Business model based on the selling on the wholesale market

In particular when the business case considered is based on the selling on the wholesale market, wrongly projected degradation rates can significantly impact the profitability.

Impact of performance on PV profitability



FIP = Business model based on a feed-in premium

WM = Business model based on the selling on the wholesale market

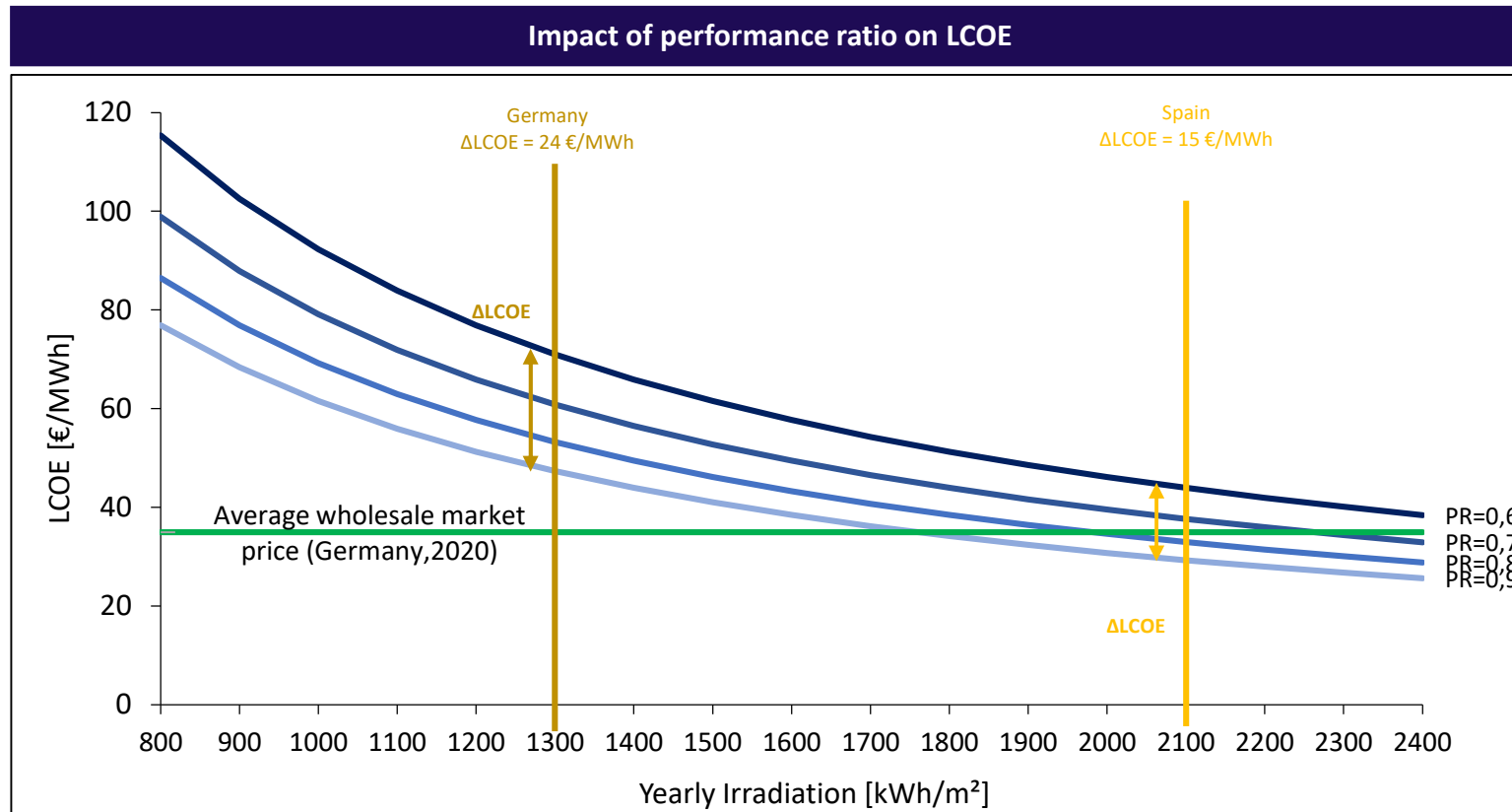
- Performance ratio variations can significantly impact the NPV.

PR decrease \approx unforeseen soiling effects

PR increase \approx use of n-type modules allowing lower temperature losses

- In particular when the business case considered is based on the selling on the wholesale market, such an error could lead to an unexpected negative NPV.

Impact of performance ratio on LCOE



- The impact of PR variations on the LCOE is important, in particular:
 - In locations with lower irradiances
 - When a business model based on the selling on the wholesale market is considered

Conclusions

- **LATEST IMPROVEMENTS** which allowed an overall degradation rates decreasing and performance ratio increasing have greatly **benefitted to PV profitability**
- **FORECASTING PRECISELY** the degradation and performance ratio of a PV system is of great importance:
 - To elaborate a **robust business model** :
 - *Underestimating the degradation rate by an absolute 0,1% can lead to a NPV decrease of 10% to 30% compared to forecasts*
 - *Overestimating the performance ratio by absolute 5% can lead to a NPV decrease of 70% to 240% compared to forecasts*
 - To **increase investors' trust**, thus avoiding a cost of capital increase which is one of the most influential parameters in profitability assessment
- **MONITORING** the degradations of a PV system over its lifetime allows to detect any failures and defaults which if not detected could rapidly ruin the business model
- Overall, these aspects are even **more important** :
 - For business models based on the **selling on the wholesale market only**
 - In geographic locations with **lower irradiances levels**.



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