Solar PV Quality Assurance

Smoothing the path for finance

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UL Solutions operates in more than **140** countries

500+ renewable energy experts

35+ years of experience in renewable energy

UL Solutions has assessed **100+** utility-scale solar project since 2013

HOMER Energy software is used in **190+** countries, with over **250,000** users

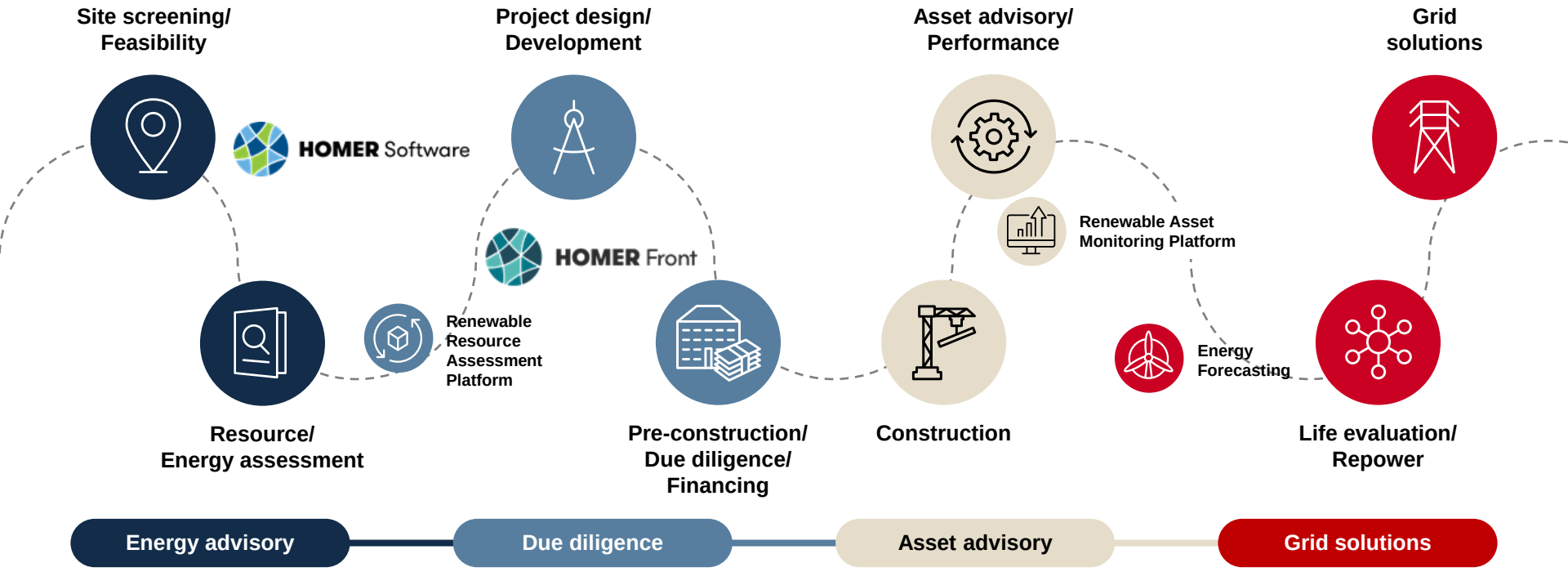
100+ PV product evaluations annually

100,000+ hybrid power projects modded since 2014

Forecast provider for **100+** gigawatts of installed renewable energy projects

Independent / owners engineer for **1,000+** wind and solar projects since 2012

UL Solutions advisory services across the renewable energy project life cycle



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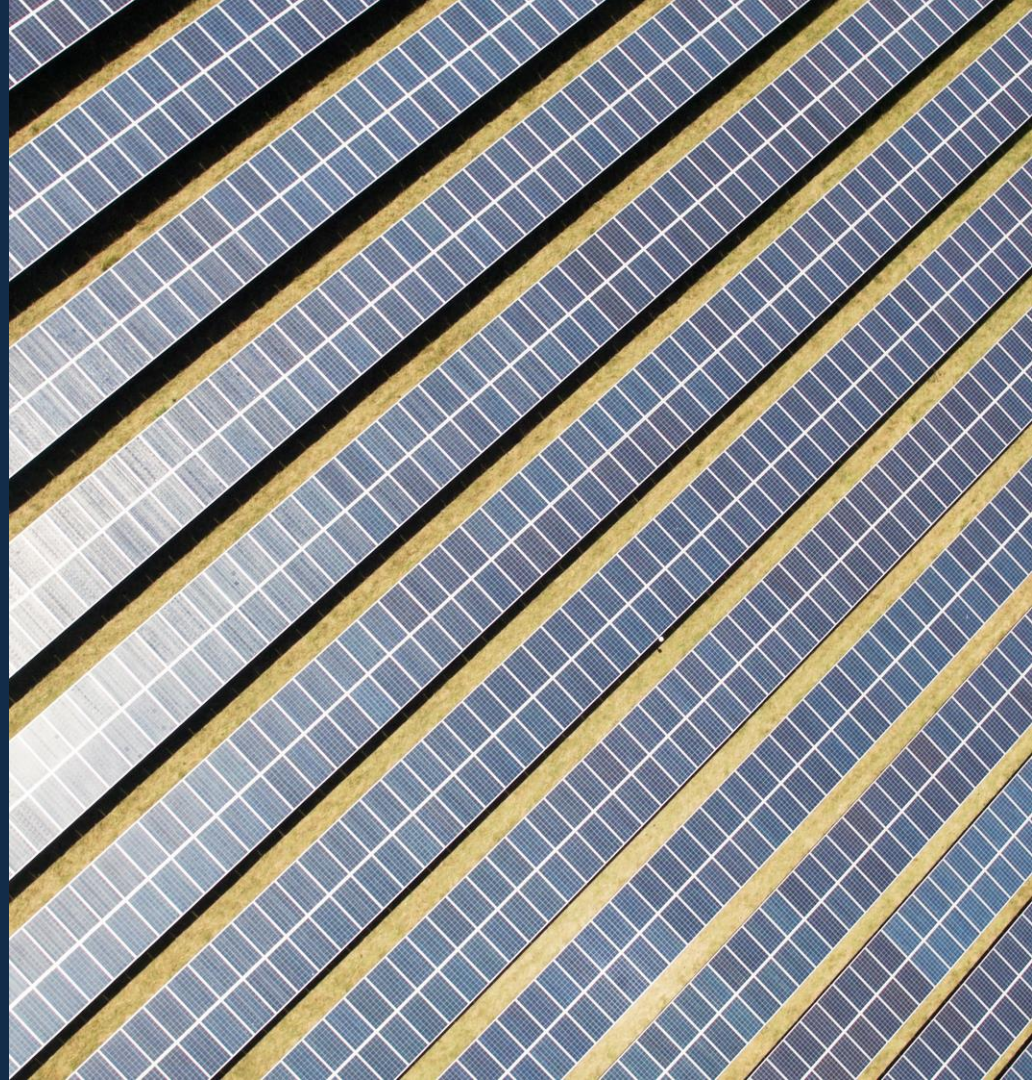
Agenda

- Market Context
- Quality Assurance as Key Driver
  - Technology
  - Contractual
  - Construction & implementation
- Conclusions



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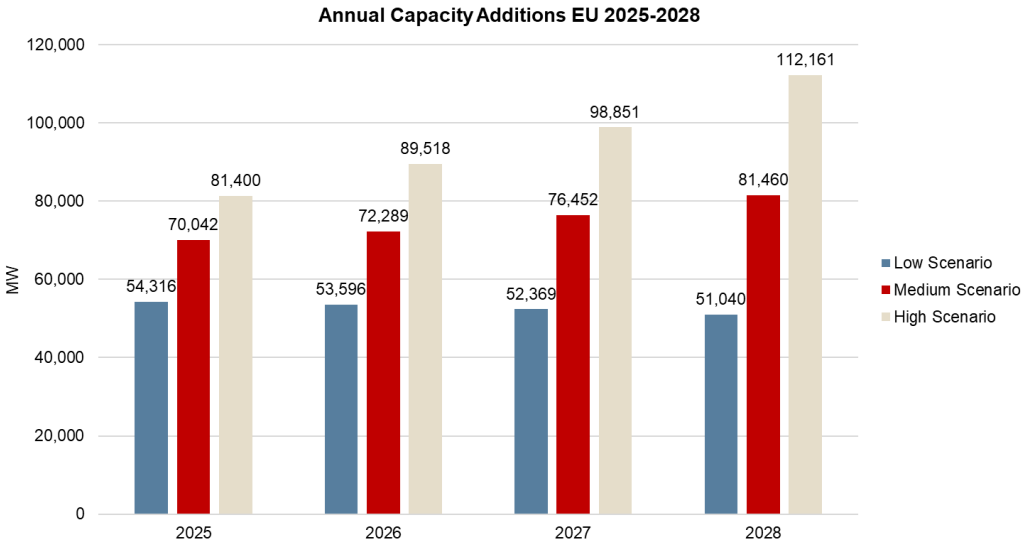
Market Context

- Germany, Spain, Italy, France and Poland are the top 5 countries in terms of new Solar PV Additions (2025-2028)
- 34% of the installed capacity in 2024 was on utility scale and this will grow to 45% by 2028
- CAGR for utility scale 21% (2024-2028) vs 15% CAGR on rooftop systems.



Source: Solar Power Europe (EU Market Outlook for Solar Power 2024-2028)

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CAPEX vs Quality

- CAPEX has decreased on a 10x scale over the last decade mainly due to price decreases on key components (PV modules, inverters, trackers)
- While other materials have not decreased at the same level, profit margins have been squeezed
- In some cases, Quality over the Project lifetime can be compromised
- It is key also to focus on OPEX (this will come with us for the Project lifetime!)
- Not sizing OPEX adequately can lead to decreased plant performance, and lowered profitability.

Source: IRENA, RENEWABLE POWER GENERATION COSTS IN 2023

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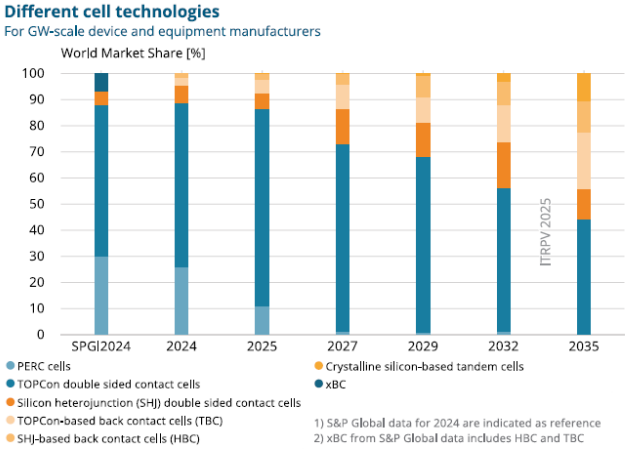
Quality Assurance Smoothing the Path for Financing

Risk mitigation during development

Development | Financing | Construction | Operation

Technology:

- Mono PERC technologies will be losing market presence towards TOPCon technologies.
- TOPCon technologies are claiming to have better efficiency, lower LID impact and better temperature coefficients. Manufacturers are offering better degradation conditions for those technologies.
- Low track record on operational assets at mass scale to date (UVID!)
- At high-level, UVID occurs when UV light exposure damages the deposited “tunnel oxide” dielectric passivation and ARC layers on the front and/or rear sides of a PV cell. When these layers are partly destructed by UV, electrons and holes start recombining at the front and rear surfaces of the PV cell at these atomic damage sites, leading to heat generation instead of electricity collection, and thereby lowering PV cell efficiency. Typically, this loss appears after the LID degradation and has been observed , ~1-16% power degradation (relative) in the equivalent of the first few years of outdoor operation.



Source: ITRPV 05/2025

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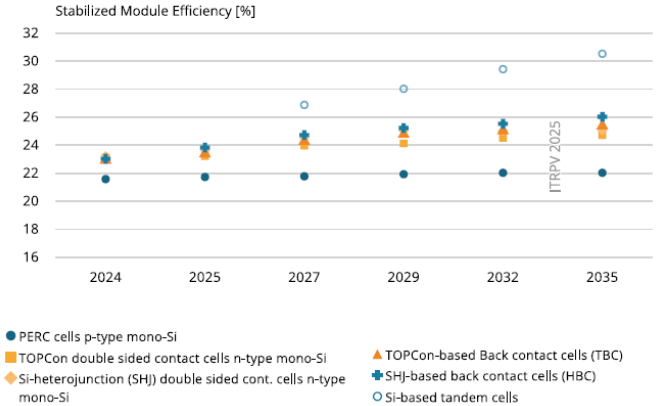
Risk mitigation during development

Development | Financing | Construction | Operation

- For a 50MWp Project in Spain with an average PPA price of 39EUR/MWh, this can represent a loss of income of roughly
  - 60kEUR/year,
  - Adding up to 1.2 MEUR in 20 years

Efficiency trend for c-Si modules in mass production



Source: ITRPV 05/2025

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Risk mitigation during development

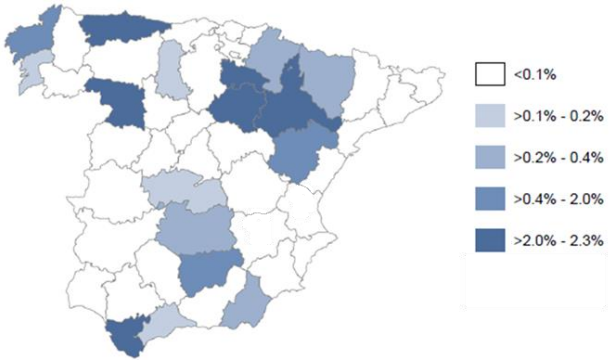
Development | Financing | Construction | Operation

Grid connection & curtailment risks

- Short-term risks (SRAP, “Sistema de reducción automática de potencia” in Spain)
- Long-term risks.

A 2.0% curtailment on the Project mentioned could represent a loss of revenue of 80kEUR/year on an asset (1.5 MUSD in 20 years).

It is key to determine the right project location, evaluating hybridization options (with BESS or wind) to maximize the utilization of the grid connection infrastructure and maximize Project returns.



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Risk mitigation pre-financing

- **Delays Liquidated Damages** are calculated as a fixed amount due per each day/week of delay on the deadline set for reaching the COD.
- The amount should exceed the potential loss of revenue suffered (as such delay may entail legal and financial costs).
- **Technical Delay Liquidate Damages** are linked to a failure to meet certain technical warranties such as PR during 24-month warranty period.
- In all cases those add typically p to 15-20% of the EPC contract value.

Contractual: Construction Agreements

- As margins are reduced, there is trend of moving away from EPC turn-key solutions, where provision of key components is a responsibility by the sponsor and a BOP provision is under a separate agreement.
  - Who takes overall responsibilities for achieving minimum performance levels (PR or peak power)
  - Responsibility for compliance with relevant grid regulatory framework
  - Guaranteed completion dates and LDs associated
  - Securities are standard in the form of advance payment bonds, performance bonds and warranty bonds, of 5-10 % of the contract price, to be delivered by the EPC service provider to secure the relevant payments of the relevant LDs or the performance of the relevant works.
  - Who holds overall liabilities ¿?
- Are shared interconnection infrastructures required? If so a SFA is key and terms, dates and provisions should be aligned with those under the construction agreements

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Risk mitigation pre-financing

Development | Financing | Construction | Operation

Contractual: Operation Agreements and OPEX provisions

- Typically, the industry has been pretty much CAPEX oriented, but OPEX is a key driver on ensuring the Quality on the Operation.
- Financing is typically structured between 10-15 years loan term and so the Lenders will focus on full coverage at least minimum during the loan term to minimize their exposure.
- Full scope O&M, tend to cover corrective maintenance or replacement of spare parts agreed between parties for the operation. Special attention to items that might not be included in the scope of services is key such as
  - Cost of additional cleanings
  - Vegetation cuts
  - Or replacement of certain key components
- MRA is sometimes considered to replace up to 60% of inverter costs at least twice for a 30 yr Project lifetime (impacting once during finance term).

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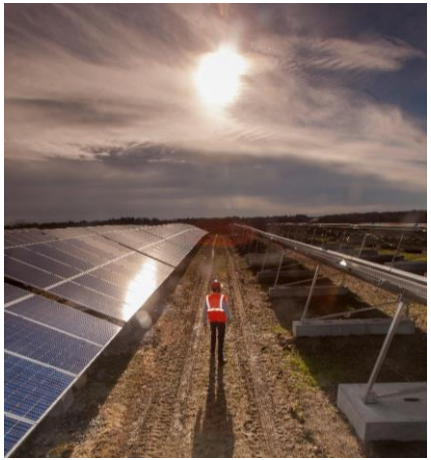
Risk mitigation post-financing

Development | Financing | Construction | Operation



Logistics:

Shipments of large components and access to the site. Damage, theft, etc. during shipping and / or installation

Delays:

Equipment delivery, environmental, administrative, third parties, force majeure, tests, etc.

Scope contract execution:

Requirements (PPA and connection). Scope not considered (EPC)

Construction Monitoring:

Periodic reports to certify work done and payment milestones

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Risk mitigation post-financing

- Postponing drainage works to focus on activities which have direct impact on electricity generation is a common practice, but there is a “price” for that.
- In cases contingencies have risen between 2.0-5.0% of the EPC works for remedy actions to conclude construction works as expected.
- **This can lead to additional costs of 1.0 – 1.9 MUSD on a 50MWp Project**




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Risk mitigation post-financing

- Thorough commissioning of the facility ensuring proper tracker operation
- The importance of vegetation and soling control prior to commissioning activities (and key during operation!)
- Transformer tests & MV cable short-circuit (common rework examples aside)
- Curtailment scenarios commonly appear after energization (impact on performance tests)
- Utility delays on substation and shared facilities commissioning can jeopardize Project deadlines and trigger the activation of Delay LDs.




Conclusions

- The pressure in CAPEX/OPEX should not compromise Project Quality
- There is always an engineering solution for not compromising the Quality and the return of the investment
- The sooner the better!
  - Proper technology selection
  - Right coverage under contractual terms
  - Proper deployment and construction
- By applying those best practices, we can ensure minimum impact on contingencies and loss of performance that can lead to 2.0-3.0 MEUR savings on a state-of-the-art 50MWp Project south of Europe.

Questions

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Thank you

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