The Impact of Performance Degradation Curves on The Profitability Of Solar PV Projects

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Outline

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2. Methodology & caveats
3. Results
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Motivation & Introduction

Business plans (BP) generally make several assumptions about the long-term performance of solar projects:

1. The plant degradation is equated to a degradation of the solar modules;
2. A linear degradation is assumed for modules with a constant performance loss rate (PLR) of -0.5%/y (REFERENCE).

Degradation curves are frequently non-linear. This technical knowledge is however neglected by the financial world.

In ths work:

1. We investigate that impact that **non linear-degradation curves or higher PLRs** have on the profitability of multi mega-watt (MW+) merchant projects developed in different sites in Europe.
2. We model two revamping scenarios and asses wheteher these interventions are economically viable.

Methodology

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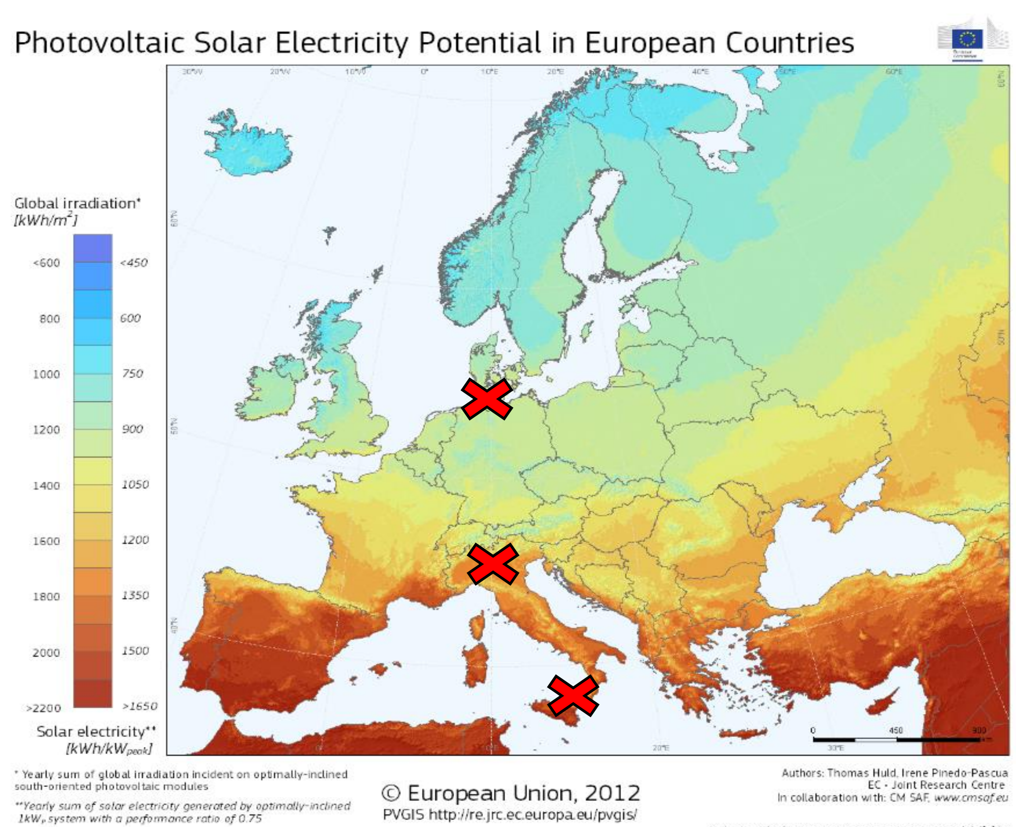
We use «state-of-art» BPs for multi-MW (50 MW) merchants projects realized in Italy at the end of 2021:

1. The electricty is sold at wholesale electricity prices;
2. 3 different locations are investigated: Siracusa (37°N), Milan (45°N), Hamburg (53°N);
3. We assume that project structure costs are the same for all locations (Italy, Germany);
4. We use the **unleveraged-equity-IRR** (Interest Return Rate) or **project-IRR** as main metric

   >> project are initially screened adopting this metric (even when later resorting to debt) ;
5. We *stress-test* the BP using different degradation curves and rates.



Source:
PV-GIS JRC-EC

BP - Assumptions

General			**CAPEX**	
Years in operation [y]	30	**a**	HW, permitting, EPC [k€/MW_p]	550
Installed capacity [MWp]	50	**b**	Of which module costs (included in previous line) [k€/MWp]	(200)
Module degradation rate [%/y]	**-0.5**	**c**	Project acquisition & development [k€/MW_p]	40
Inflation rate [%]	1	**d**	Grid-connection costs [k€/MW_p]	40
		e	**Total CAPEX [k€/MW_p]**	**630**
COGS (including Opex) & tax			**Pricing assumptions**	
O&M [k€/MW_p·y]	6	**a**	Spot electricity price [€/MWh]	50
Insurance [k€/MW_p·y] (*)	3	**b**	Wholesale electricity price [€/MWh]	47
Lease [k€/MWp·y]	0.6			
Corporate tax rate [%]	28.8			

HW includes: modules, inverters, transformers, cabling, mounting structures;

O&M includes: repair and service; EPC = Engineering, Procurement and Construction

(*) the insurance covers extreme weather events and vandalism, not underperforming solar modules covered by manufacturers warranties.

Caveats

To answer our primary **research question,** we make several assumptions....

(«how are BPs impacted by different degradation curves and rates?»)

TEMPORAL SCOPE

1. These numbers (2021) are presently outdated by the current economical situation: hardware costs & inflation are higher as well as the selling price of electricity;
2. This is a transient situation. We are confident that most parameters will go back to these numbers in a few years;

GEOGRAPHICAL SCOPE

1. We apply our analysis to 3 sites in Europe with a different availability of solar resources;
2. Thus under the assumptions that the same numbers can be used in different countries (Italy, Germany)

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Degradation curves

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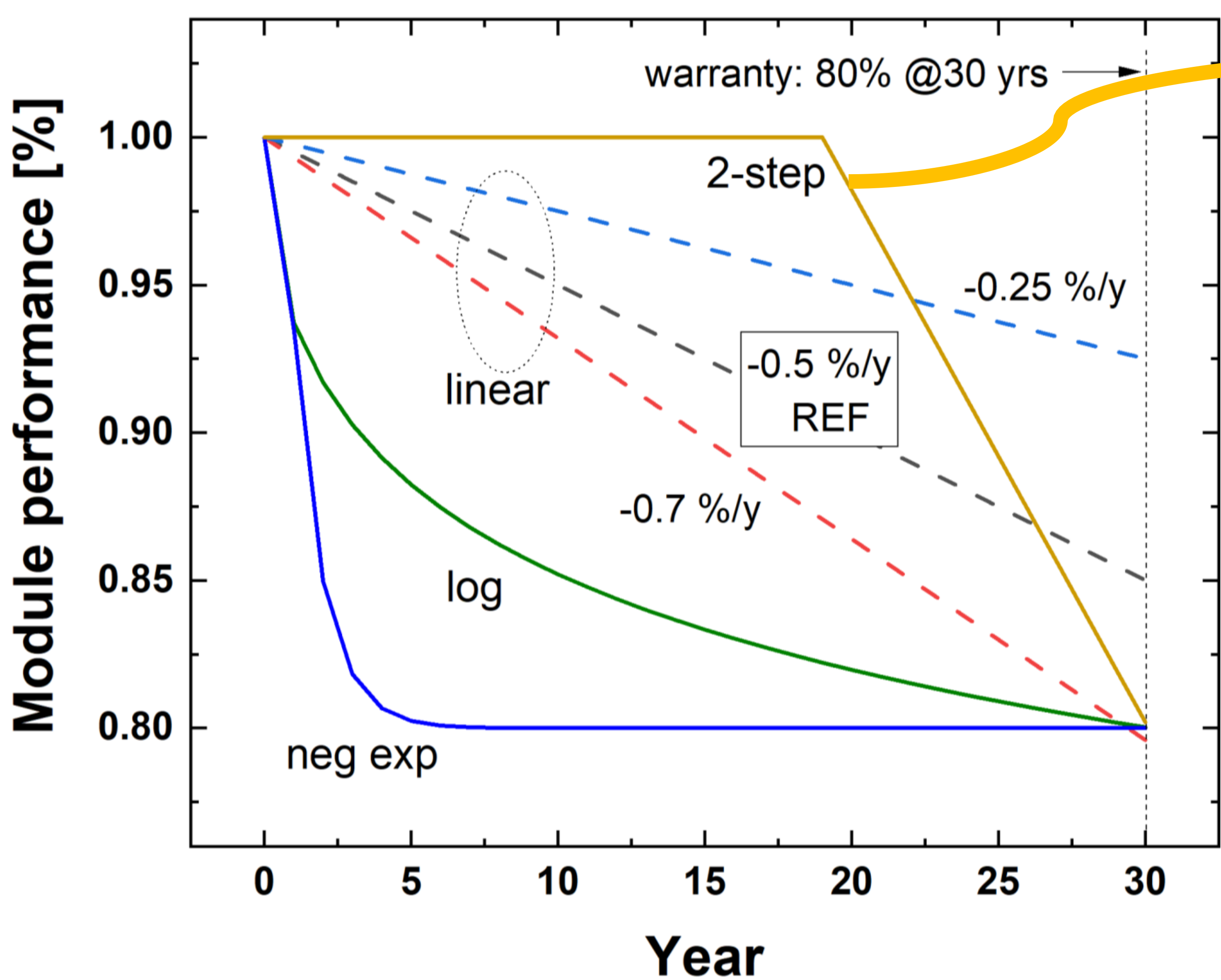
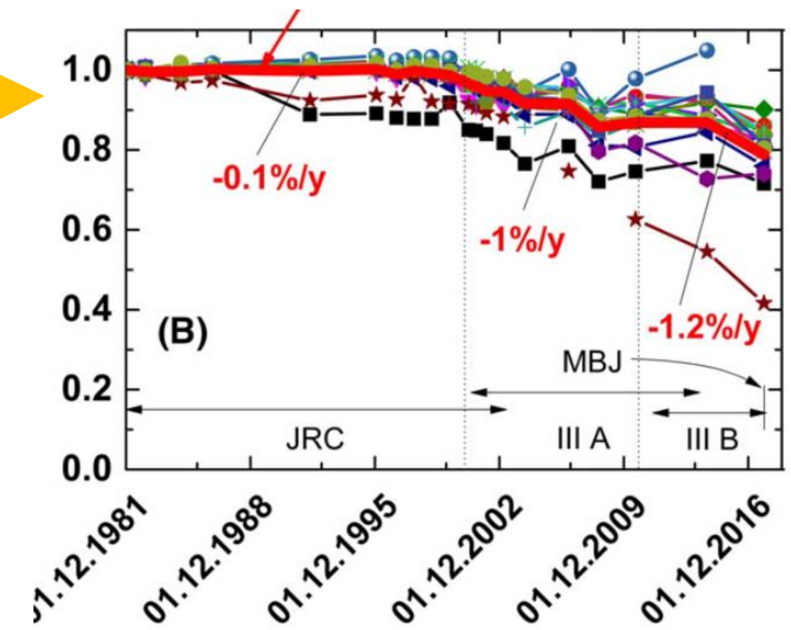




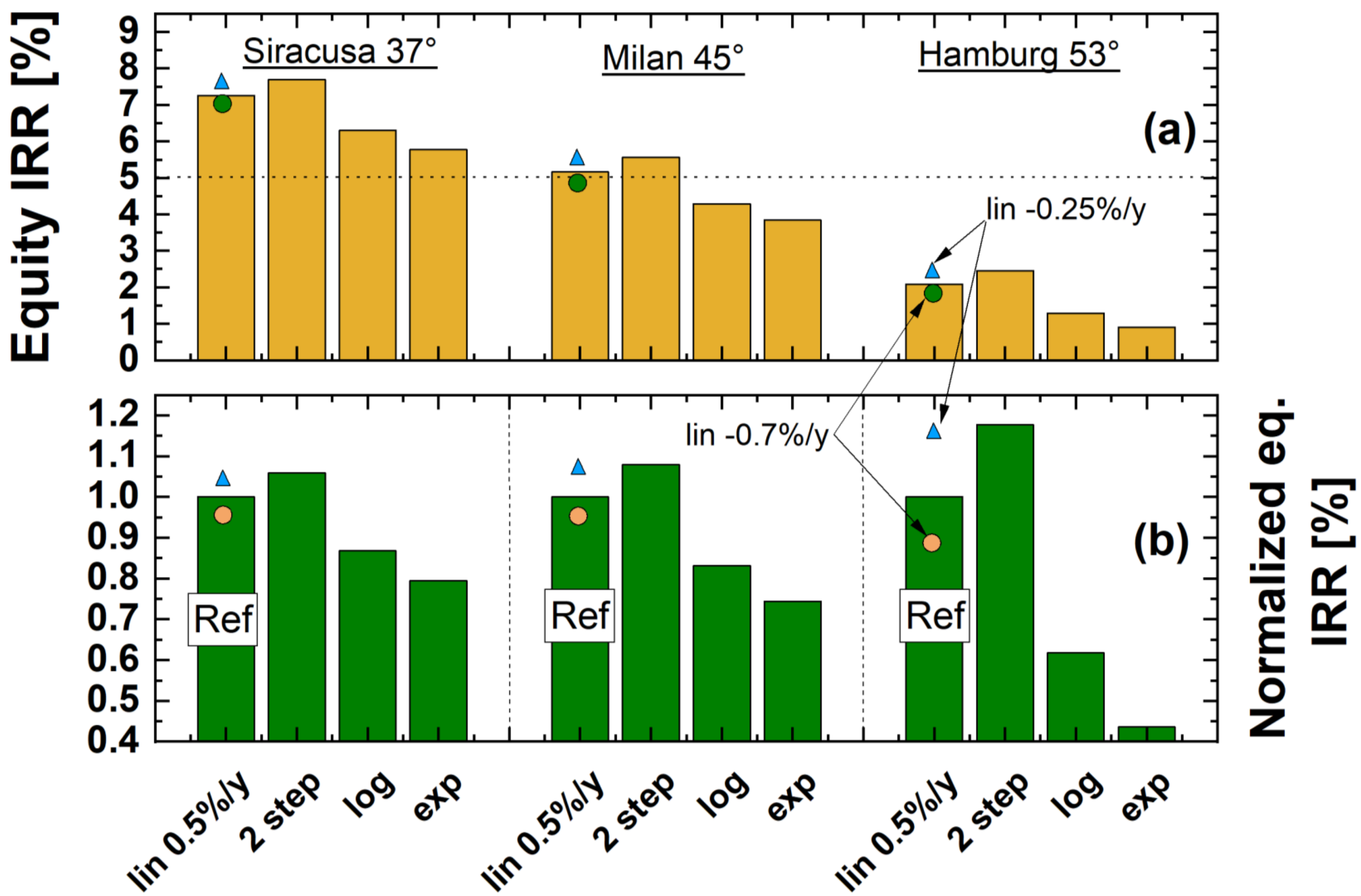
Virtuani et al., PiP 2019
Annigoni et al. PiP 2019
Jordan et al. PiP 2016

Literature data on long-term degradation curves is extremely limited.

In this work we use:

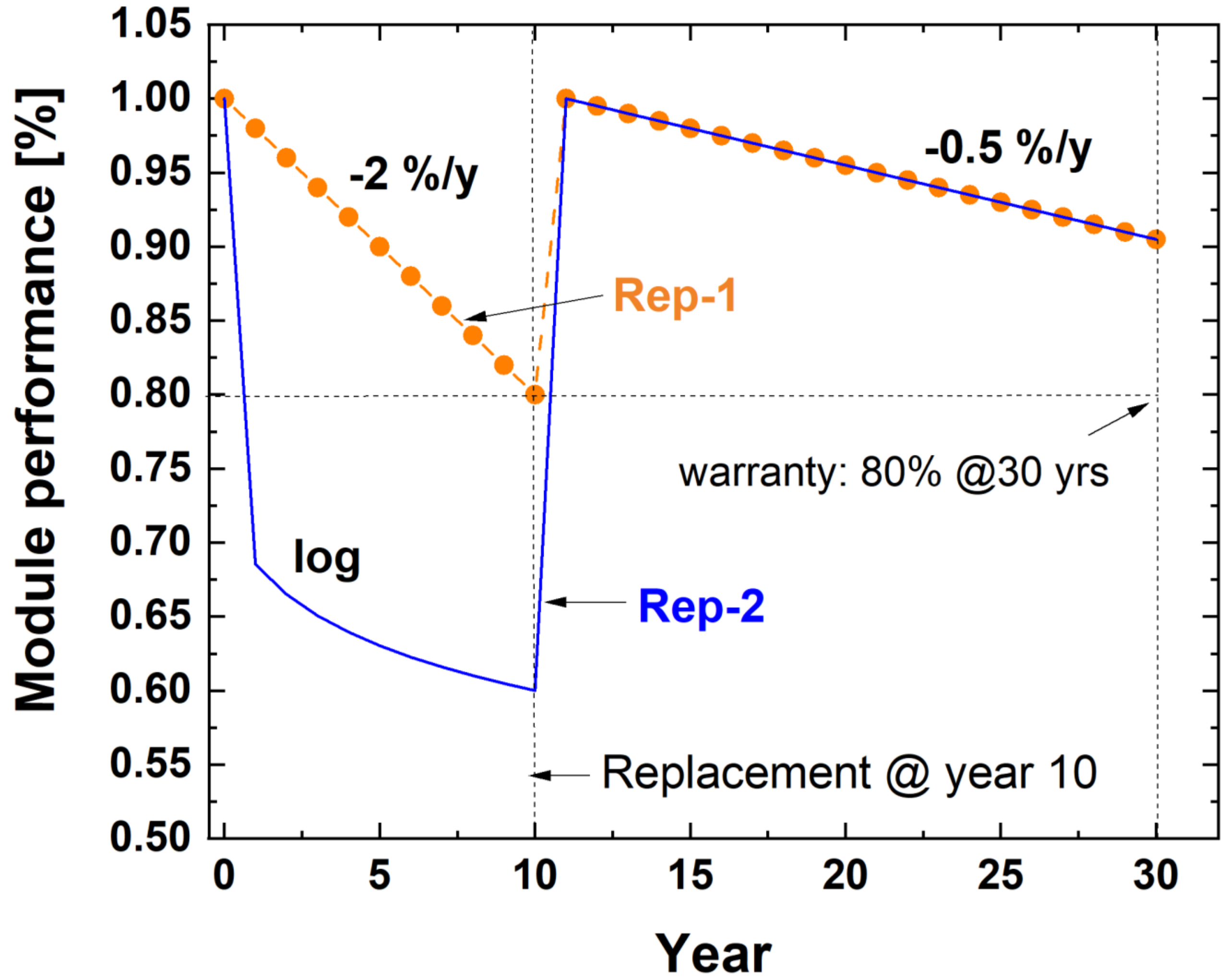
1. **REFERENCE**: linear degradation curve PLR -0.5%/y (other PLR -0.25%/y & -0.7%/y)
2. **2-step** curve: no degradation in first 20 years of operation, followed by PLR -1.8%/y
3. **Neg exponential** and **logarithmic degradation**

Unleveraged-IRR (or project IRR)



- Unleveraged-IRR (Interest Return Rate) for 3 sites in Europe;
- Non-linear degradation rates (or higher PLR) have a higher impact for sites in which the availability of solar resources is lower.

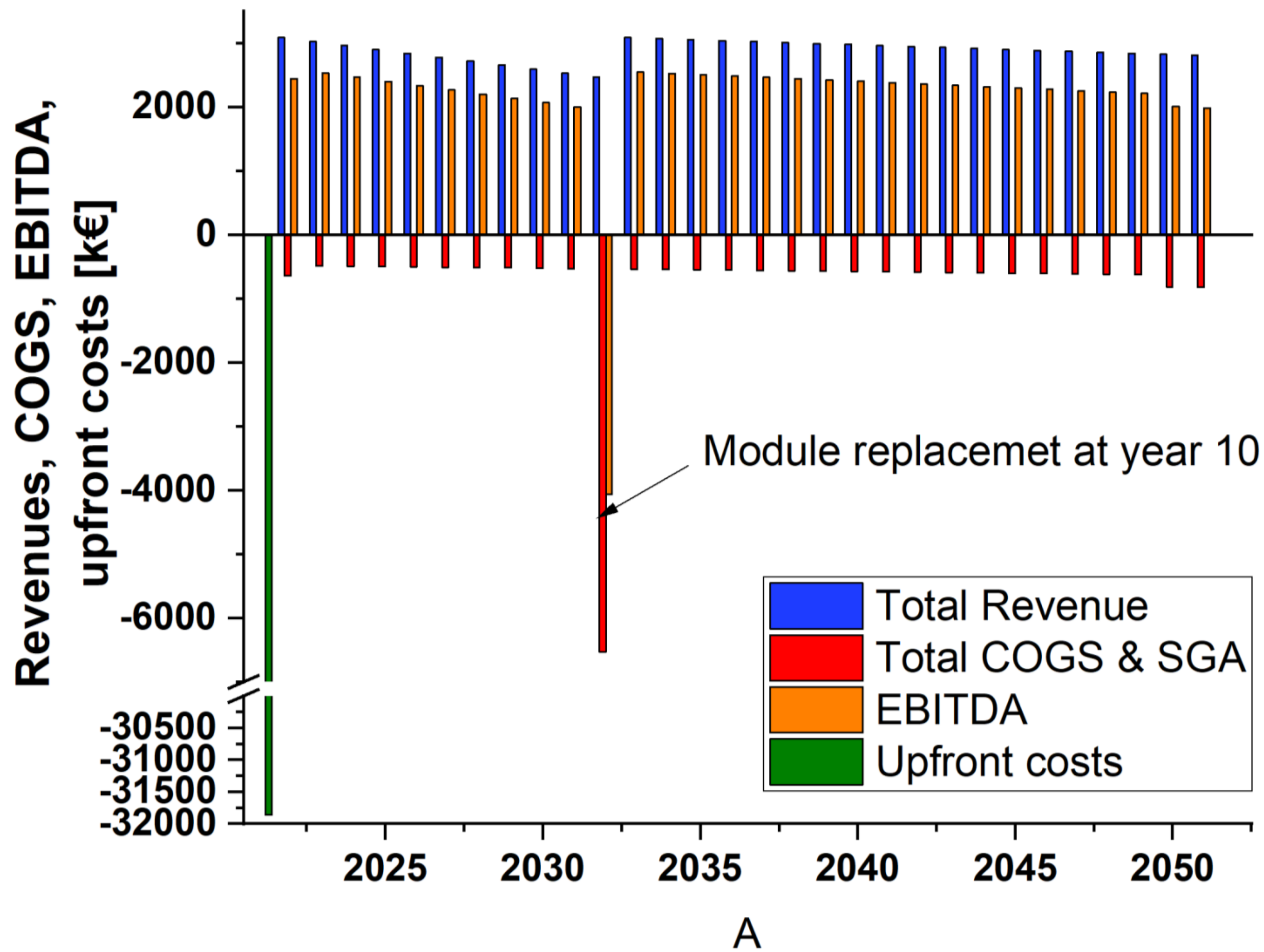
Modelling revamping



We model two scenarios leading to a **full module replacement after 10 years of operation**:

1. **REP-1**: Linear degradation (PLR -2%/y >> -20% after the 10 years), followed by a full module replacement;
2. **REP-2**: Logarithmic degrdation (-40% after 10 yrs) .

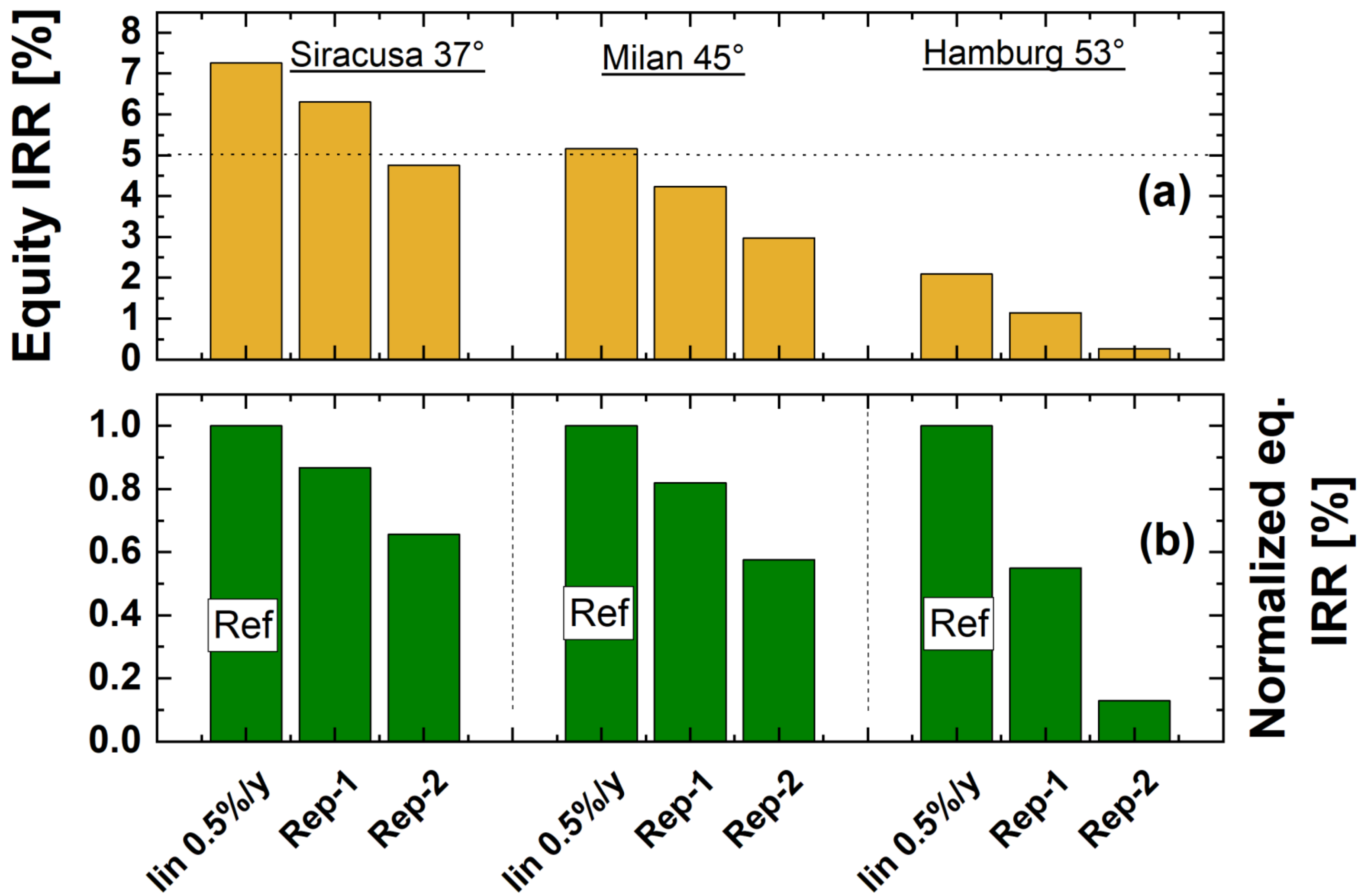
Cash-flows of revamping scenario 1: REP-1



Full module replacement at year 10.

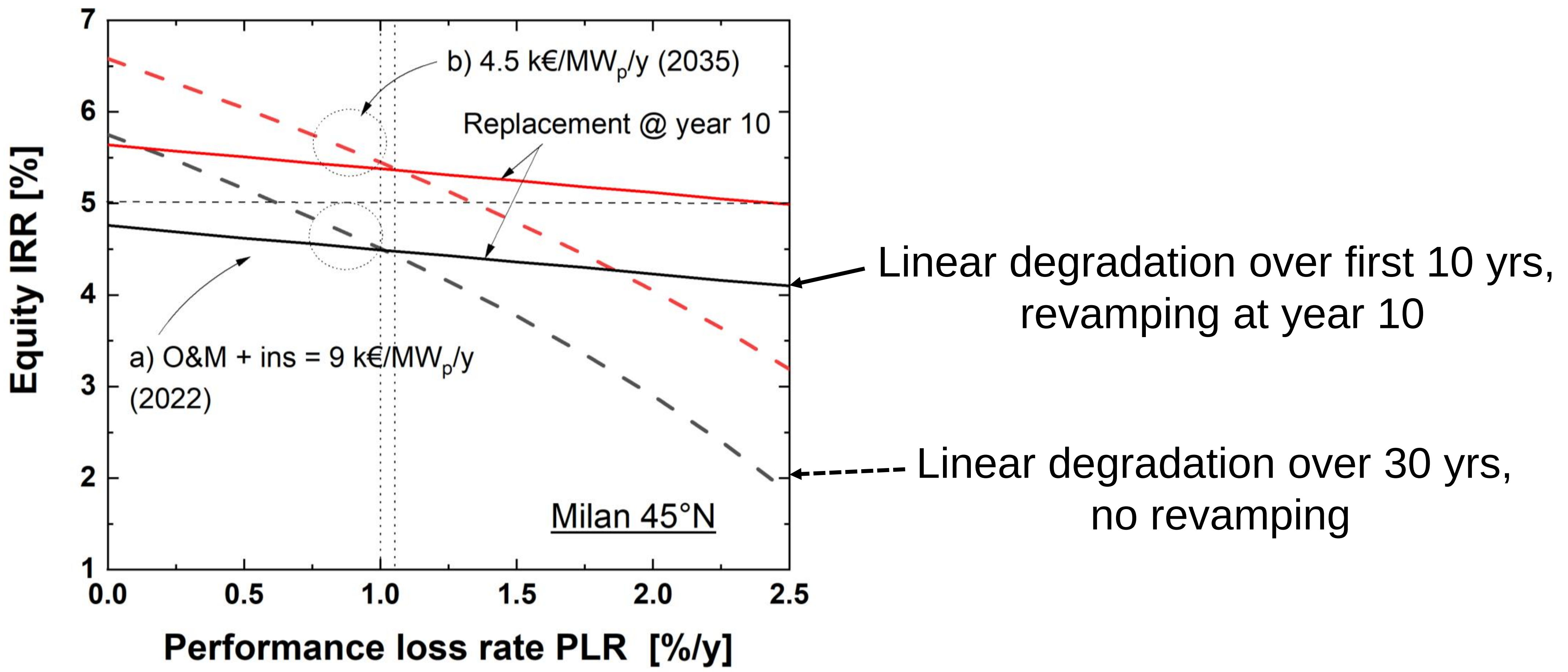
Costs of modules in 10 years from now modelled assuming market growth with CAGR of 30% and historical learning rate for module costs of 22.8%.

Modelling revamping



- Unleveraged-IRR (Interest Return Rate) for 3 sites in Europe for revamping scenarios REP-1 & REP-2.
- An unplanned revamping intervention may considerably impact the profitability of solar projects.
- The impact is higher for sites with a lower yearly cumulative irradiance.

When is revamping justified?



For revamping scenario **REP-1** (Milan, 45°N), we assume:

- a linear degradation curve and different PLRs;
- different O&M (+insurance) costs

We show that a full substitutions of the modules at year 10 is fully justified if the PLR is higher than 1%/y.

Discussion (1)

BP STRESS TESTS

To assess the energy yield potential of a site generally two metrics are used: **P50** and **P90**.

1. Analogously, we suggest to **stress-test BPs** to assess the impact that non-linear degradation curves may have on the profitability of BPs;

   particularly when the projects are deployed in **non-temperate climates** or when **novel technologies** (without adequate track-record) are adopted.

2. Besides the conventional linear degradation rate with a -0.5%/y PLR (**reference**), we suggest thus to use:

   a. a 2-step curve (optimistic assumption)

   b. the neg log curve (pessimistic assumption).

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Discussion (2)

DEBT, LEVERAGED-Equity-IRR and cost of capital

In a later phase, projects are realized resorting to financial leverage. The **leveraged-Equity-IRR** (affected by the cost of capital) is then used a metric in this later stage.

By running some preliminary simulations, we observe that having prudent estimates of the PLR is increasingly important with higher bank interest rates and when larger portions of debt are used (i.e. when the cost of capital is higher).

This is a very relevant aspect worth being explored further and will be the subject of a follow-up work.

Conclusions

1. **Non-linear degradation curves** or high PLR may strongly impact the profitability of solar projetcs;
2. The impact is higher for sites with lower solar resources;
3. We suggest that BPs are regularly **stress-tested** using at least 3 degradation curves:
   a. **linear** with constant PLR -0.5%/y PLR (reference)
   b. a **2-step** curve (optimistic assumption)
   c. the **neg log** curve (pessimistic assumption)

4. **Unplanned revamping interventions** (e.g. full module replacement) impact the profitability of solar projects. Their economical viability can be - and should be - modeled to judge whether these interventions are fully **justified or not**.

Paper soon to appear in:

Solar RRL

WCPEC-8

Thank you for your attention !

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