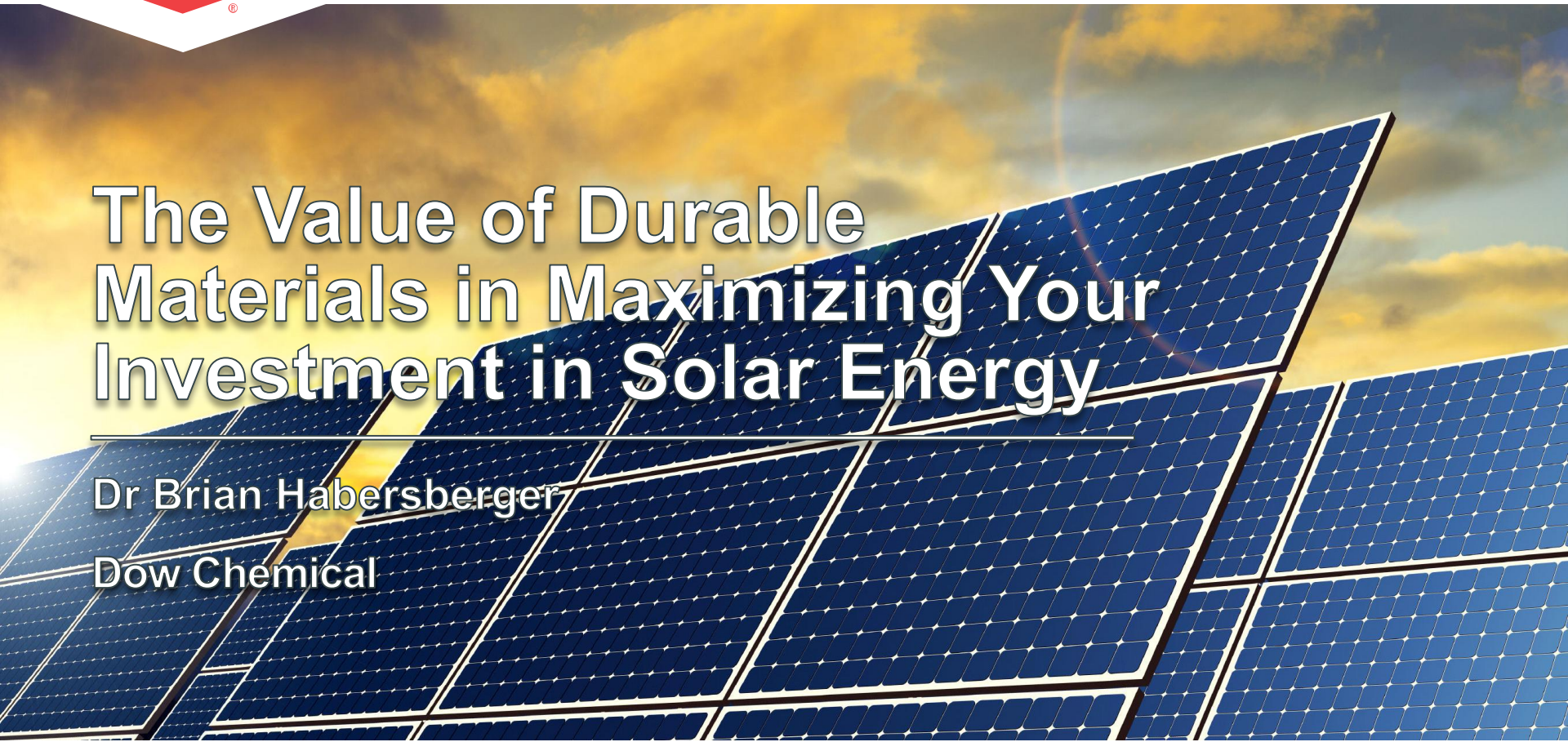

# The Value of Durable Materials in Maximizing Your Investment in Solar Energy

Dr Brian Habersberger

Dow Chemical

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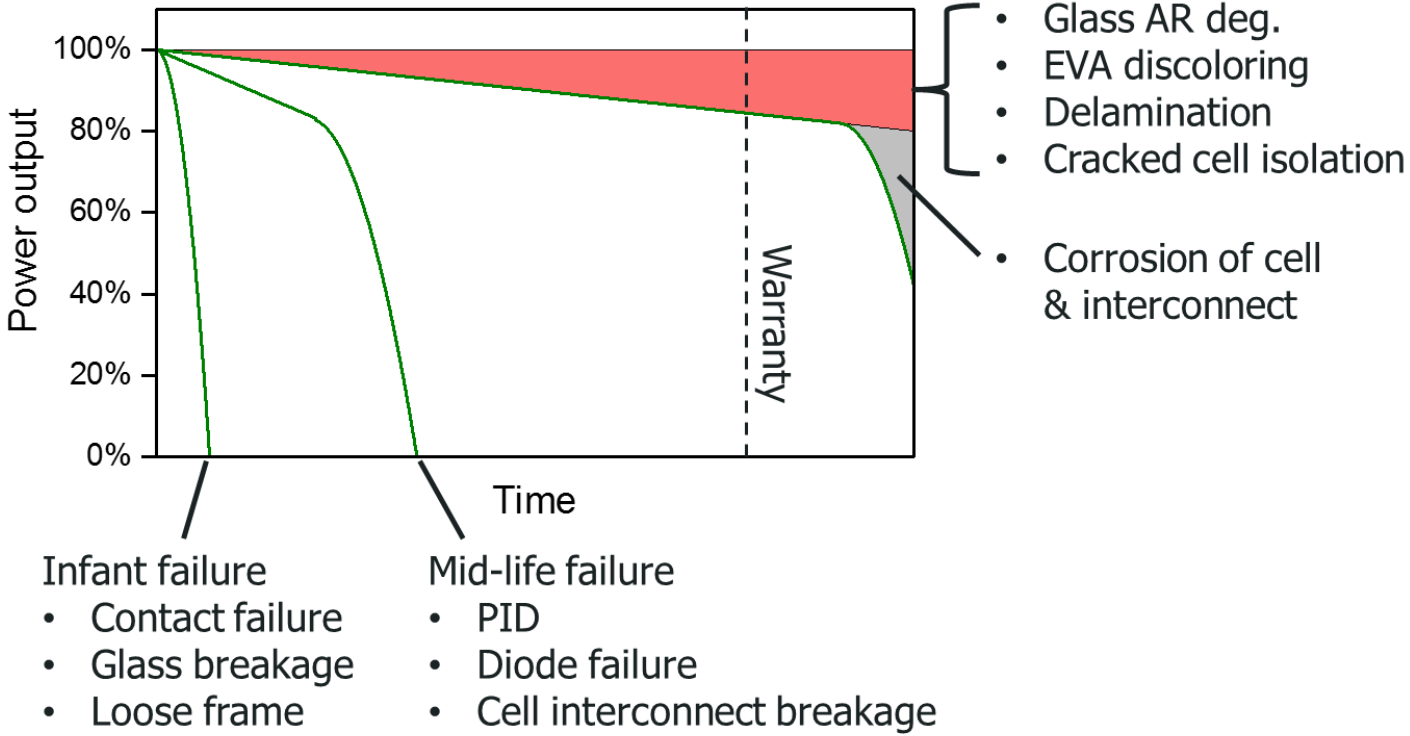
# Module lifetime and failures




*IEA: "Review of Failures of Photovoltaic Modules", Task 13 external final report, IEA-PVPS, March 2014*

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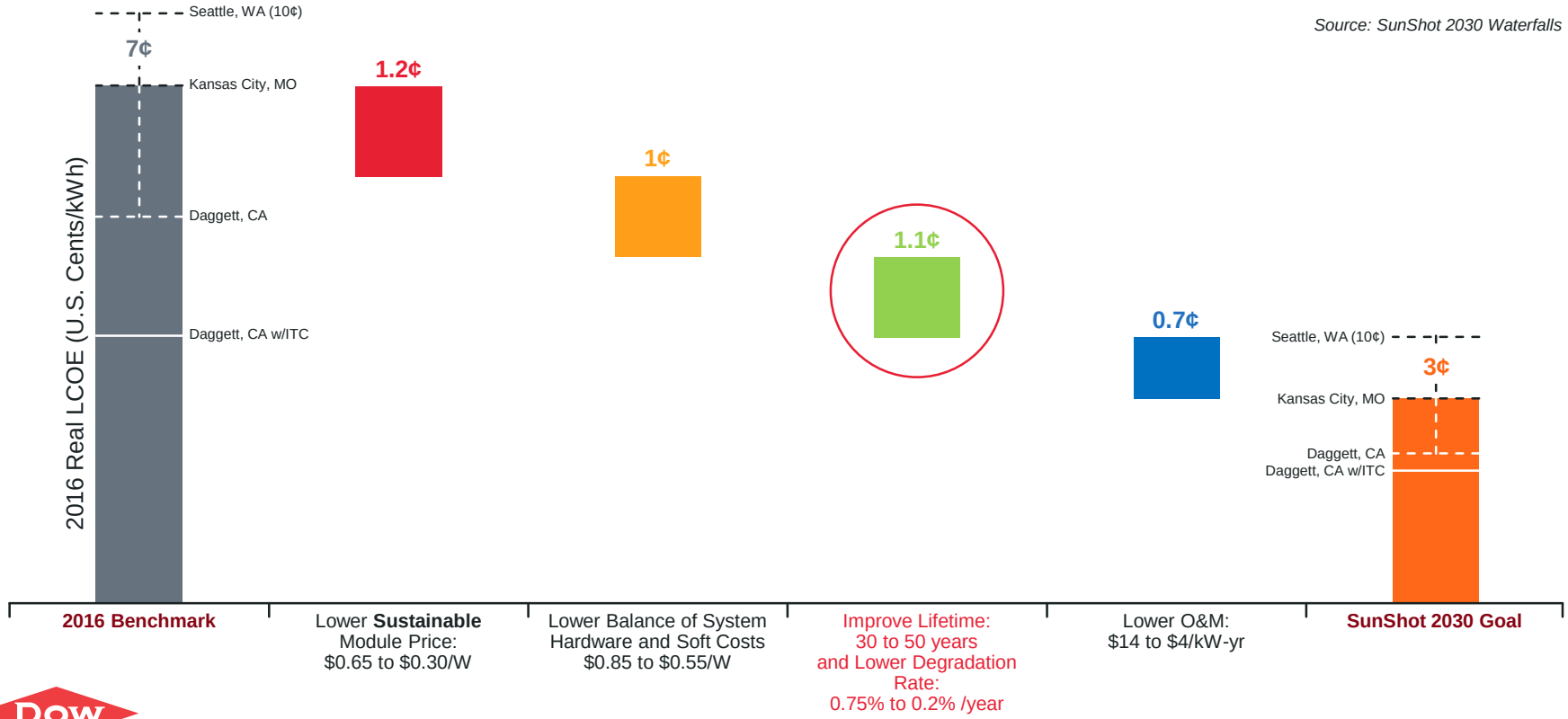
# DOE Sunshot Initiative: Pathways to grid price parity

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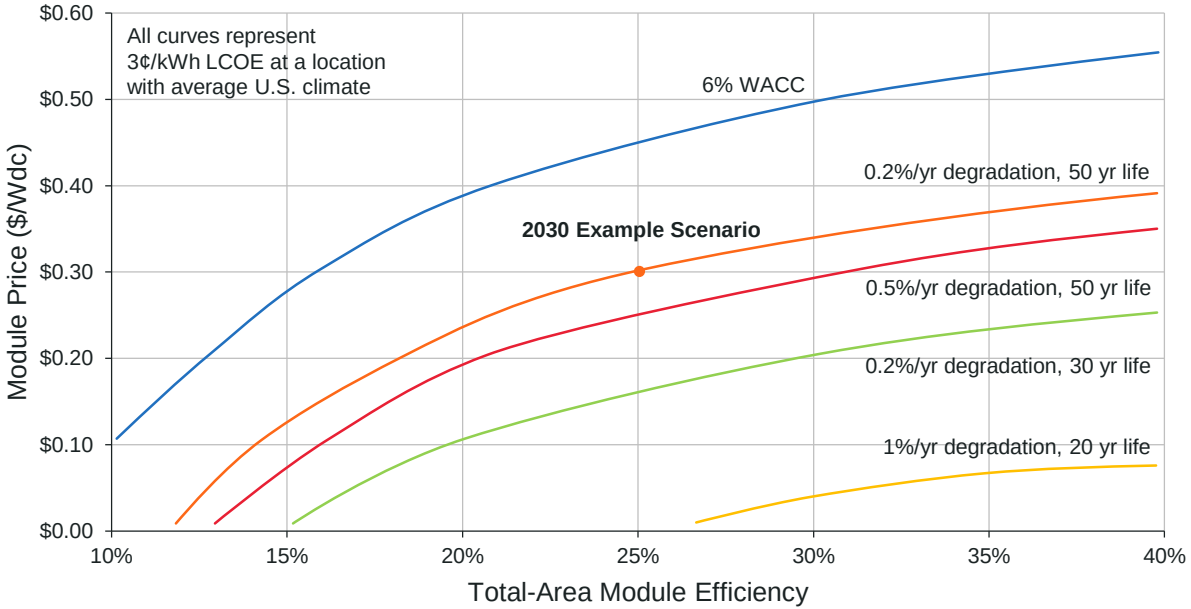
# Durability is a Necessity




With a system lifetime of 20 years and a degradation rate of 1%/year, even a free module would need to have an efficiency of at least 27% in order to reach the SunShot goal.

In other words: module durability is not a nice-to-have, it is necessary.

*Source: SunShot 2030 Fact Sheet*

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# How to financially evaluate durability

$$\text{LCOE} = \frac{\text{Total costs over lifetime}}{\text{Total energy over lifetime}}$$

**How much additional energy must durable materials yield in order to justify their cost?**

$$\text{LCOE} = \frac{PC - CBI - PVPBI + \sum_{n=1}^{N} \frac{LP_n}{(1+d)^n} - \sum_{n=1}^{N} \frac{LP_n}{(1+d)^n} * ETR + \sum_{n=1}^{N} \frac{OM_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{EO_n}{(1+d)^n}}$$

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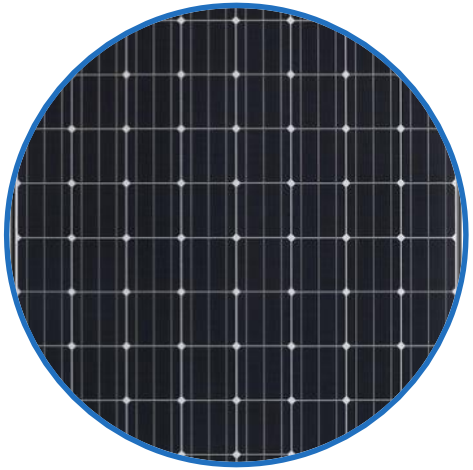
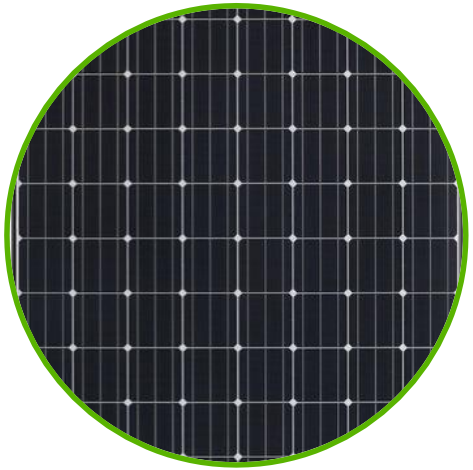
# Let’s go shopping for PV modules…



300 W PV Module
**$100**



300 W PV Module
with “durable materials”
**$105**

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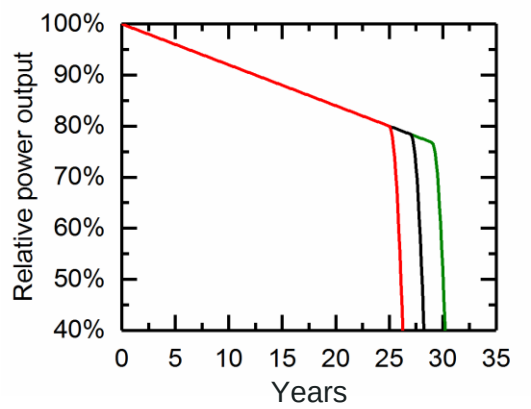
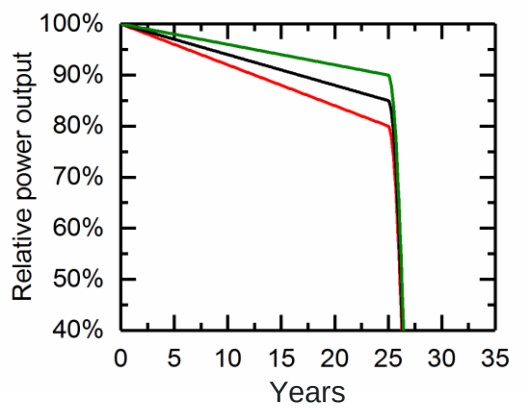
# How to model PV performance scenarios

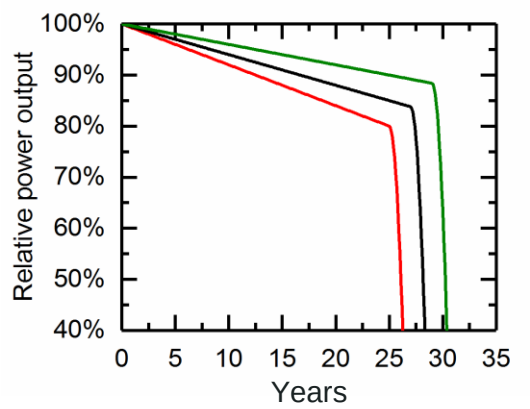
## What reduction in LCOE can be accomplished by…




**Increased lifetime?**




**Reduced degradation?**




**Both?**

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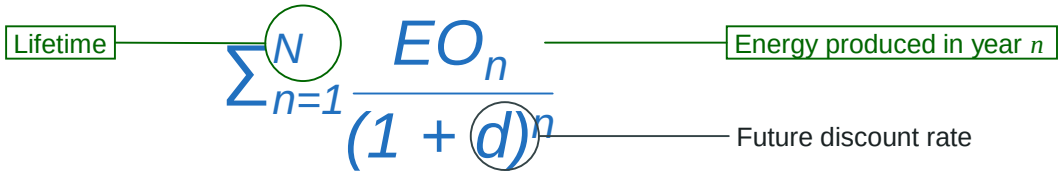
# Durability value calculation

## Total costs over lifetime




**Model assumptions (borrowed from DOE SunShot):**

- Default module: 25 year lifetime, 0.75% annual degradation rate
- Discount rate: 9.5%
- Sun-hours per year: 1860 (sunny climate)

**Additional assumption:**

- Cost of performance improvement: 0.016 $/W

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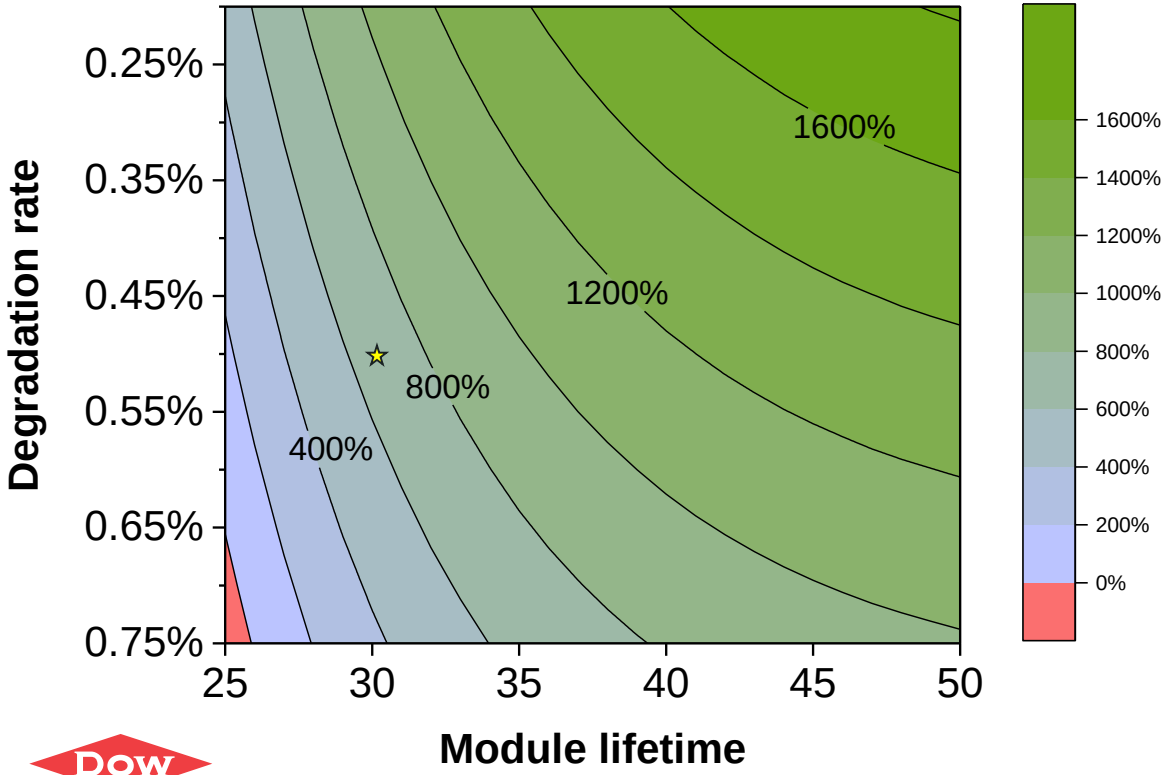
# Significant ROI potential in this scenario




Value of additional energy yield from Durable PV module vs the added cost of such a module.

This chart is calculated at fixed marginal durability cost (0.016 $/W); for the point marked with the star, we will investigate as a function of cost.

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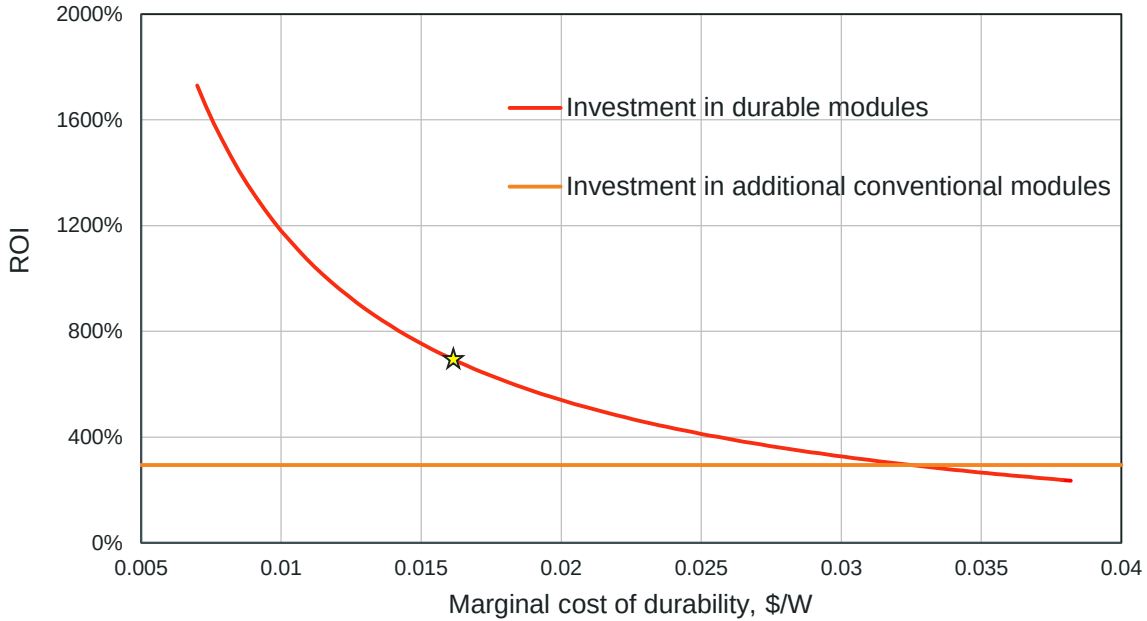
# Significant ROI potential in this scenario




| | Degradation rate | Lifetime |
|---|---|---|
| Conventional | 0.75%/yr | 25 yr |
| Durable | 0.5%/yr | 30 yr |

- Investment $ could be used to buy additional conventional modules
- ROI of durable modules vs. spending the same amount on additional conventional

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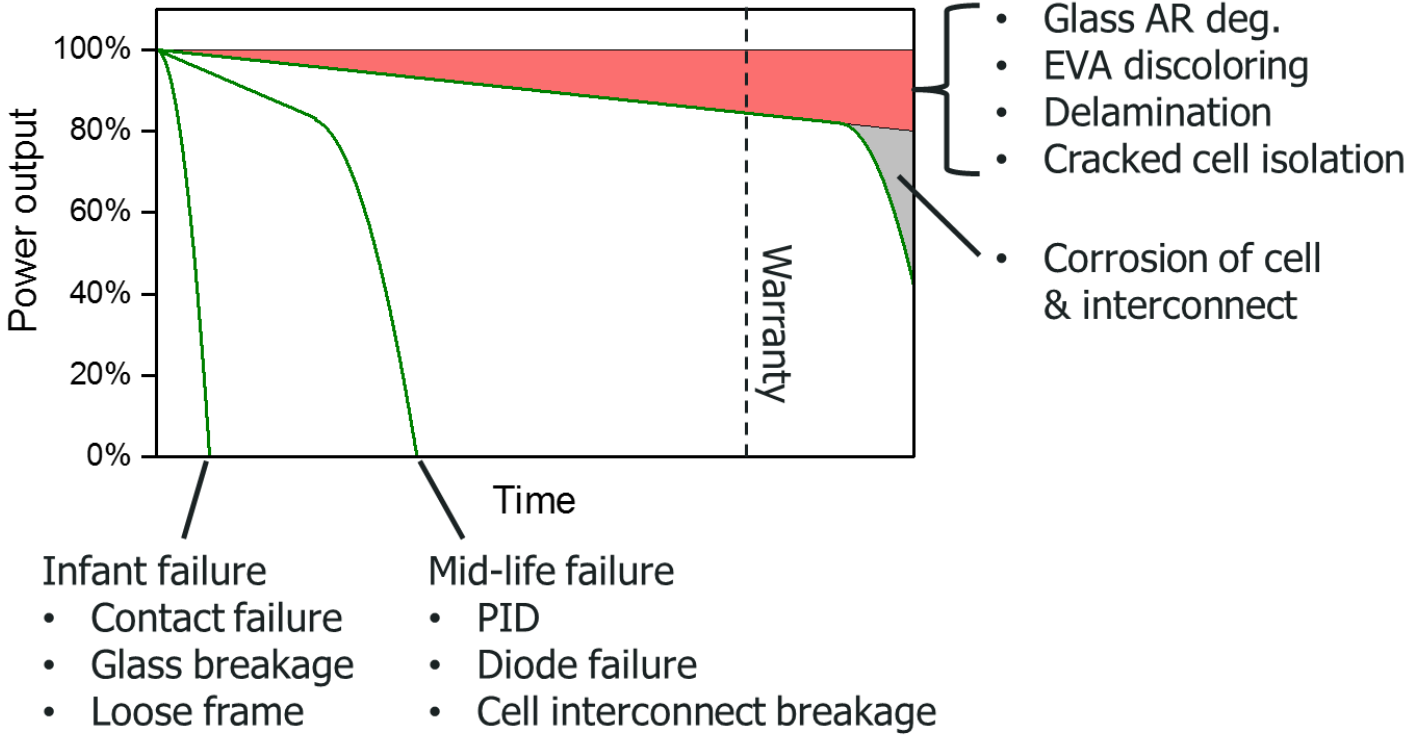
# Module lifetime and failures




*IEA: "Review of Failures of Photovoltaic Modules", Task 13 external final report, IEA-PVPS, March 2014*

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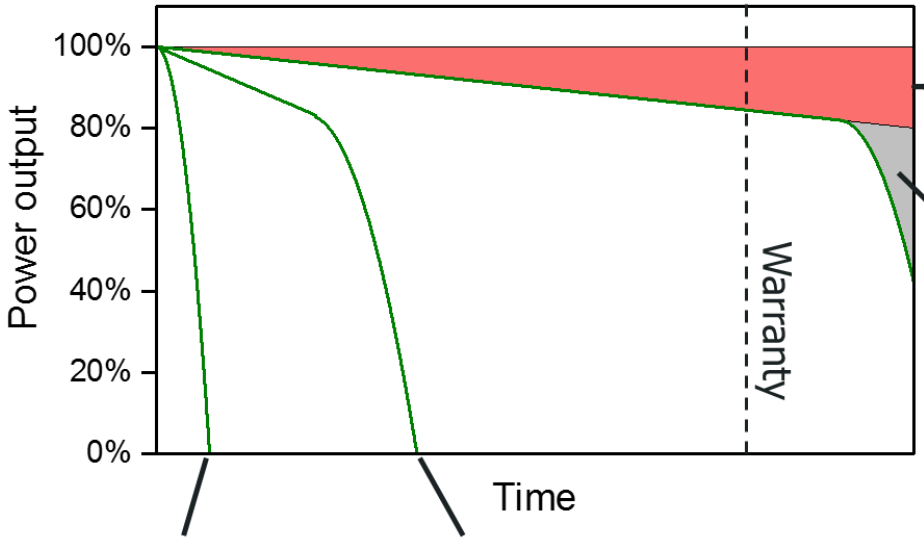
# Module lifetime and failures




- Glass AR deg.
- EVA discoloring
- Delamination
- Cracked cell isolation

- Corrosion of cell & interconnect

**Infant failure**
- Contact failure
- Glass breakage
- Loose frame

**Mid-life failure**
- PID
- Diode failure
- Cell interconnect breakage

Many mechanisms of power loss are affected by the choice of encapsulant material

*IEA: "Review of Failures of Photovoltaic Modules", Task 13 external final report, IEA-PVPS, March 2014*

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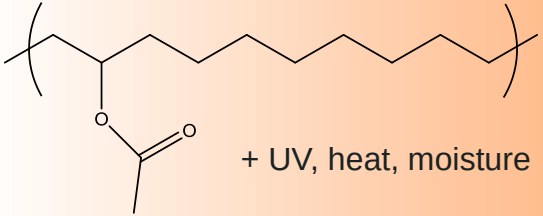
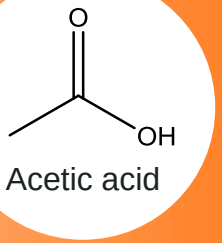
# EVA degradation yields corrosive byproducts

**Ethylene vinyl acetate copolymer**

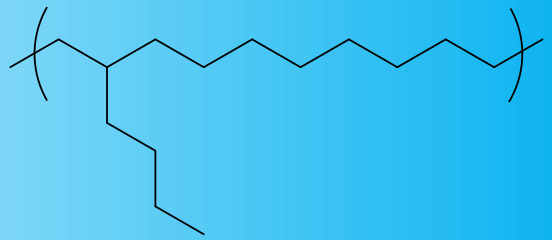


+ UV, heat, moisture




Acetic acid


**Polyolefin**



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# Encapsulant durability: Key properties

| Key Properties | Problems with EVA | Benefits of POE |
|---|---|---|
| Electric resistivity | Low resistivity leads to PID and other electrochemical corrosion | POE has up to 1000x higher resistivity, completely prevents PID |
| Water vapor transmission rate | Moisture ingress can lead to corrosion | POE has 10x lower MVTR |
| Acetic acid formation | Acid leads to corrosion | POE does not form corrosive byproducts |

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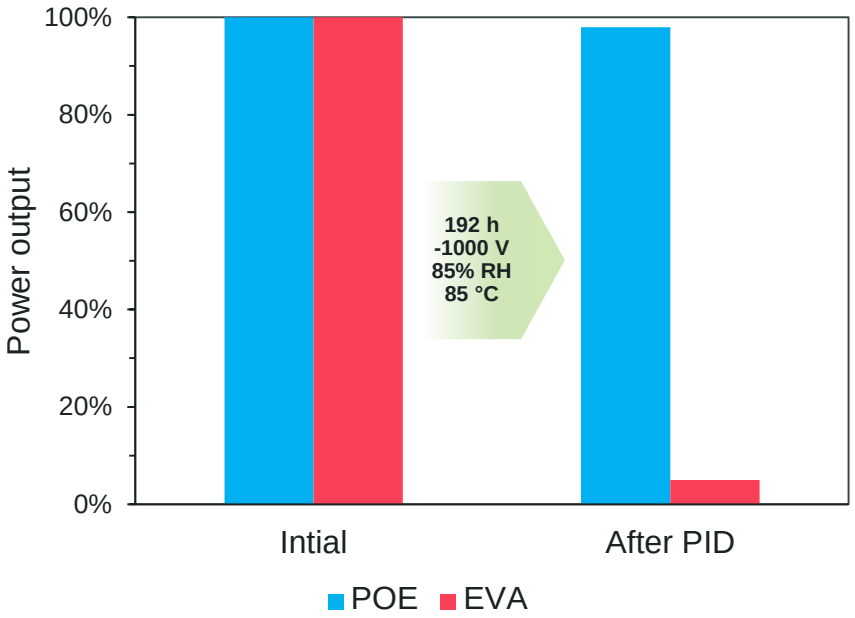
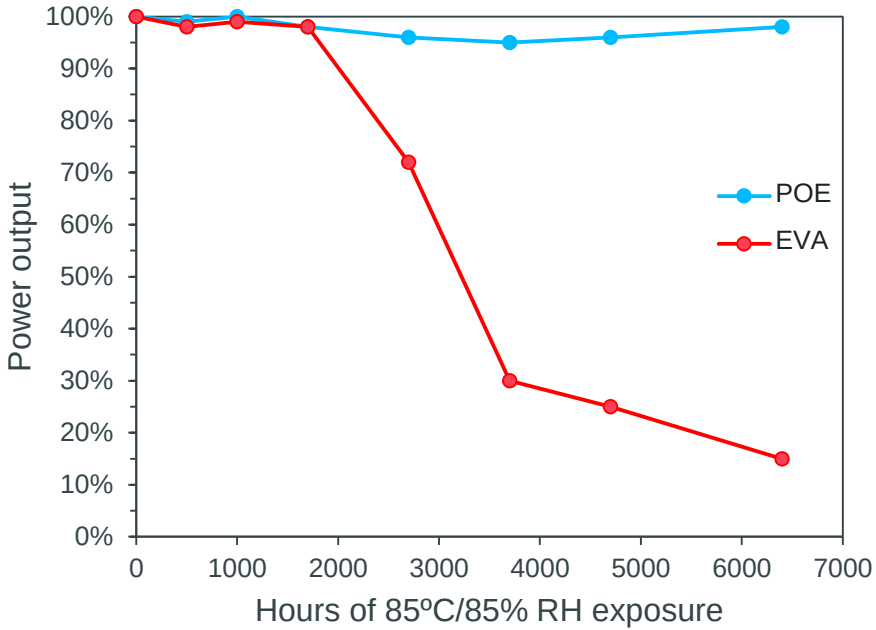
# POEs consistently outperform EVA in accelerated stress testing

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# Polyolefin durability is key in many applications

Simple hydrocarbon chemistry and flexible formulation allow for decades of performance in variety of applications

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# References in which POE outperforms EVA


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# How do warranties reflect value of durable materials?

**Module manufacturers express confidence in durability through their warranties.**

**Typical warranty for modules made with conventional materials:** **0.70%/yr**

**Average warrantied degradation rate among module manufacturers who disclose POE encapsulant:** **0.33%/yr**

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# Durability: A key part of maximizing your solar investment

- Module durability is a necessity
  - LCOE goals cannot be reached without it
- Investments in durability offer a significant ROI
  - Model your own durability-based LCOE scenario
- Polyolefin materials consistently outperform EVA in durability-related testing

ENGAGE™ PV
polyolefin elastomers

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# ENGAGE™ PV Polyolefin Elastomers

- World's largest polyolefin elastomers producer, with broadest portfolio in the industry
- Only producer with world-scale trains on three continents, new Asia plants start-up in 2016
- Unparalleled manufacturing, application development and market reach around the global
- Solution provider for Photovoltaic module encapsulation
- Since entering the global PV industry in 2012, Dow has grown to become the supplier of choice for POEs in PV encapsulant film.



ENGAGE™ PV polyolefin elastomers

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