



Bigger, Fewer, and Farther North

How climate change is redrawing the solar hail risk map

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The stakes

\$600M+

Hail losses, Texas

Estimated 2021–2024

25 mm

IEC 61215 standard

Historical design threshold

>100 mm

Hail, Fighting Jays TX

350 MW project, March 2024

Solar buildout concentrated where hail risk growing.

IEC 61215 25 mm baseline designed for European climates, not US Great Plains; gap grows as very large hail increases.

US hail losses driven by **increasing exposure**, not storm frequency. Solar buildout itself a risk multiplier. (Battaglioli et al. 2026)

Primary atmospheric drivers of hail change

Moisture & CAPE

Water vapor rises $\sim 7\%/^{\circ}\text{C}$ (Clausius–Clapeyron). Greater CAPE* drives stronger updrafts, producing larger hailstones aloft.

Projected to increase across the US, Europe, and Australia.

Result: larger hailstones; stronger storms

Melting Level Height (MLH)

MLH rose 32 meters per decade globally (1979–2010). Smaller hailstones melt completely before reaching the ground.

Size distribution shifts toward larger surviving stones.

Result: larger stones likelier to reach surface

*Source: Raupach et al. 2021, Nature Reviews Earth & Environment | *CAPE: Convective Available Potential Energy*

Forward projections: hailstones ≥ 30 mm increase 32–52% by end of century (SSP2-4.5 to SSP5-8.5); US increase robust across all models and scenarios; onset shifts ~ 9 days earlier.
Zhang et al. 2026, Gensini et al. 2024; Brimelow et al. 2017; Trapp et al. 2019

The threat is already changing

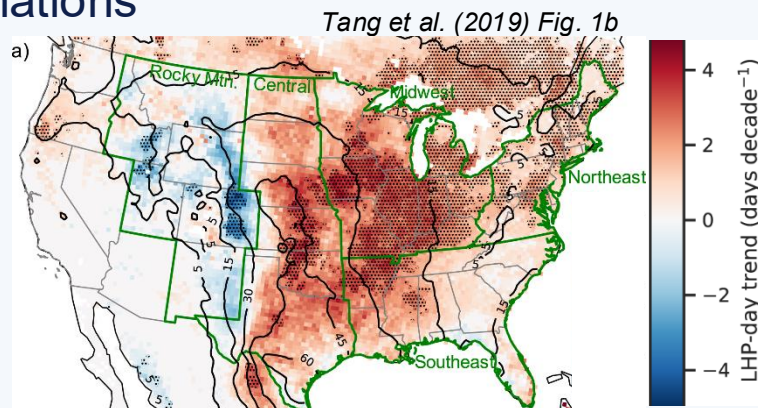
ENVIRONMENTS EXPANDING | Tang, Gensini & Homeyer 2019

1979–2017 | NARR reanalysis | Radar Large Hail Parameter

+2 to +4 more per decade

favorable large hail days

- Large hail environments expanding northward and eastward
- Driven by steeper lapse rates and instability-shear combinations



STORMS ALREADY SHIFTING | Liu et al. 2024

2000–2022 | NOAA Storm Events Database | Eastern US

+0.75°N

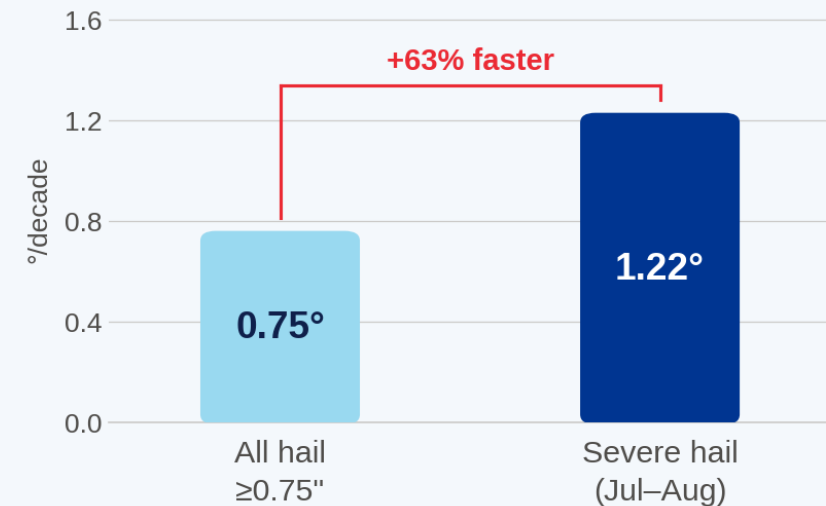
per decade (all hail $\geq 0.75''$)

35.1 → 39.9°N

centroid shift 2000–22

Northward shift accelerates with hail size

Northward shift rate (°/decade) | All trends significant (>95%)



Regional risk profile

HIGHEST RISK Great Plains & Central US

- Globally highest very large hail frequency ([Battaglioli 2026](#))
- Favorable environments +2 to +4 days/decade since 1979 ([Tang 2019](#))
- Colorado: up to 3 additional hail days/year ([Bolinger 2024](#))

INCREASING RISK Midwest & Northern Plains

- Favorable environments expanding northward and eastward ([Tang 2019](#))
- Major solar buildout in core Midwest; risk and exposure are growing in tandem

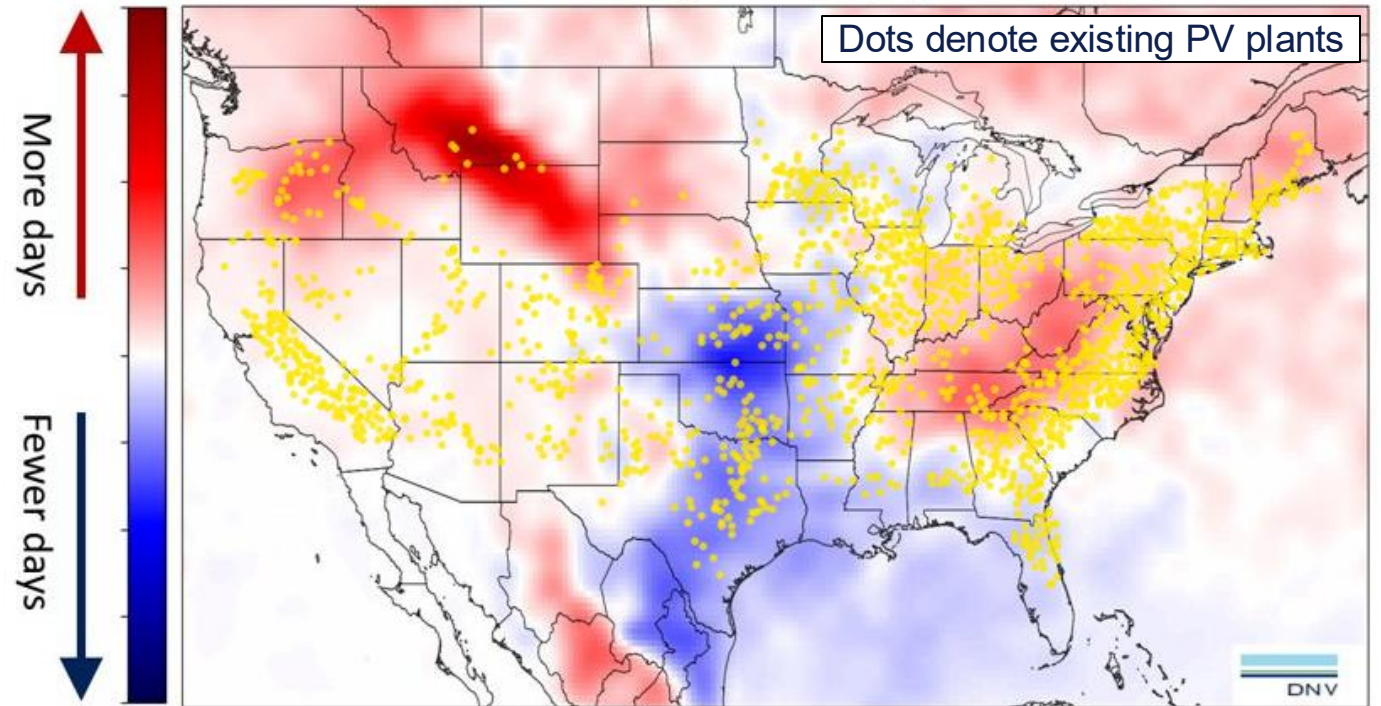
EMERGING RISK Northeast US

- Hail activity has shifted nearly 5° poleward; Wisconsin, Mid-Atlantic, New England now regularly affected ([Liu 2024](#))
- Strengthening Bermuda High funneling more moisture northward, expanding favorable environment for large hail

CHANGING CHARACTER Southeast US & Gulf Coast

- Overall hail frequency declining as rising melting levels cause more stones to melt before reaching the surface
- Damaging large-stone events persist despite fewer total hail days; risk center shifting north ([Liu 2024](#))

Difference in Annual Average Hail Days (> 2 inch): 2050 vs. 2025



DNV / Jupiter Intelligence Hail Model — ML trained on SPC reports + ERA5, applied to 3 CMIP6 GCMs.

The risk is not diminishing. It is redistributing.

The Great Plains and Texas remain the primary hail hazard zone, but the fastest-growing exposures are now in the core Midwest and Mid-Atlantic, where a major solar buildout is underway.

Four Implications for Solar PV

01

Design standards frequently exceeded

IEC 61215 tests to 25 mm. Very large hail (≥ 50 mm) increases 15–146% by end of century. Events that were historical outliers become recurring.

02

Historical data understates future risk

Non-stationarity documented in all five studies. P90/P99 return periods from historical hail records will systematically underestimate future exceedance frequency.

03

Geographic expansion into low-risk zones

Northward shift (Liu 2024) puts Midwest and Northeast assets at risk they were not designed for. Historical siting decisions did not account for this trend.

04

Exposure growth amplifies total losses

US losses driven mainly by increasing exposure, not storm frequency (Battaglioli 2026). Rapid solar buildout in eastern US means growing total annual losses even with flat risk per storm.

The emerging risk is not theoretical

Two events in 2025-2026 that illustrate what “northward shift” means in practice

INDIANA | March 2026

2 - 4"

hail diameter

A supercell outbreak in March 2026 produced hail ranging from 2 to 4 inches across northern Indiana and the Illinois border. A solar farm in the storm track sustained direct damage.

Indiana has minimal solar hail loss history. Underwriting in this region has little empirical foundation.

Sources: NWS Indianapolis Event Summaries; CBS Chicago / NWS Storm Reports, March 10-12, 2026

NORTH CAROLINA | Ongoing

19%

of industry hail losses

kWh Analytics found that 19% of solar hail losses in their industry database occurred in North Carolina, a state not historically considered high-risk.

A utility-scale PV plant was severely damaged. NC ranks 5th nationally for installed solar capacity.

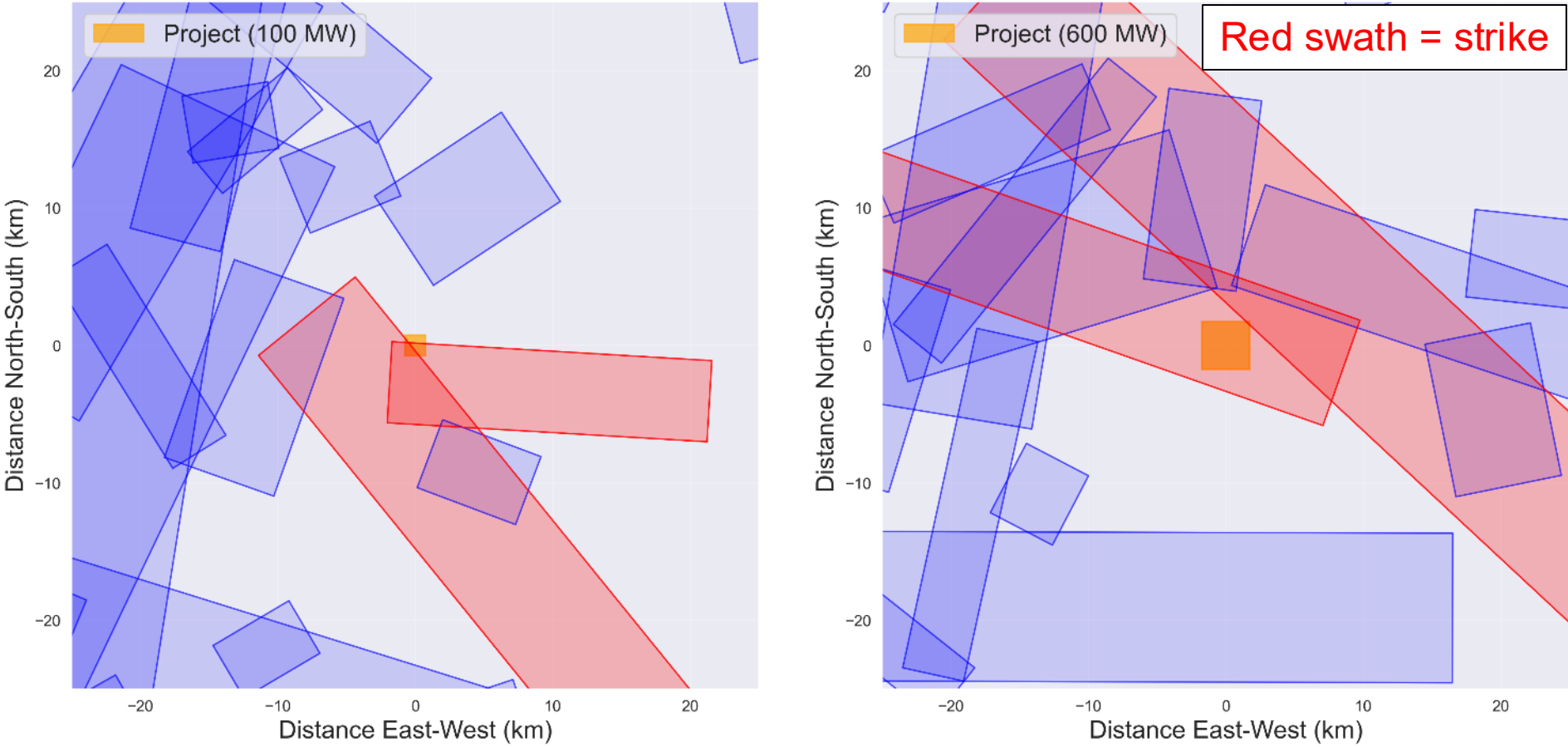
Source: kWh Analytics 2025 Solar Risk Assessment; VDE Americas, March 2026

Texas gave the industry a crash course. The tools built from that experience are necessary, but not sufficient for regions without a loss history.

That is why physics-based modeling matters -->

DNV stochastic weather emulator: Hail damage swaths

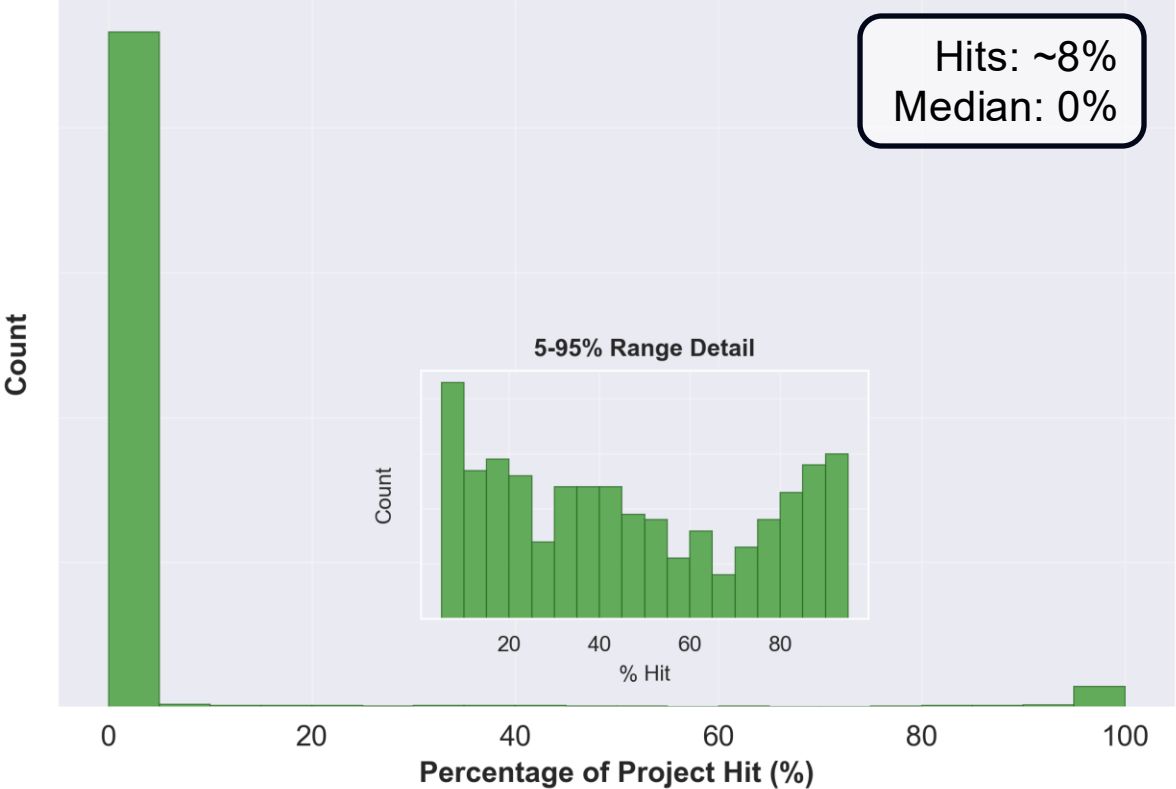
Sample of 10,000 synthetic hail swaths based on observed statistics



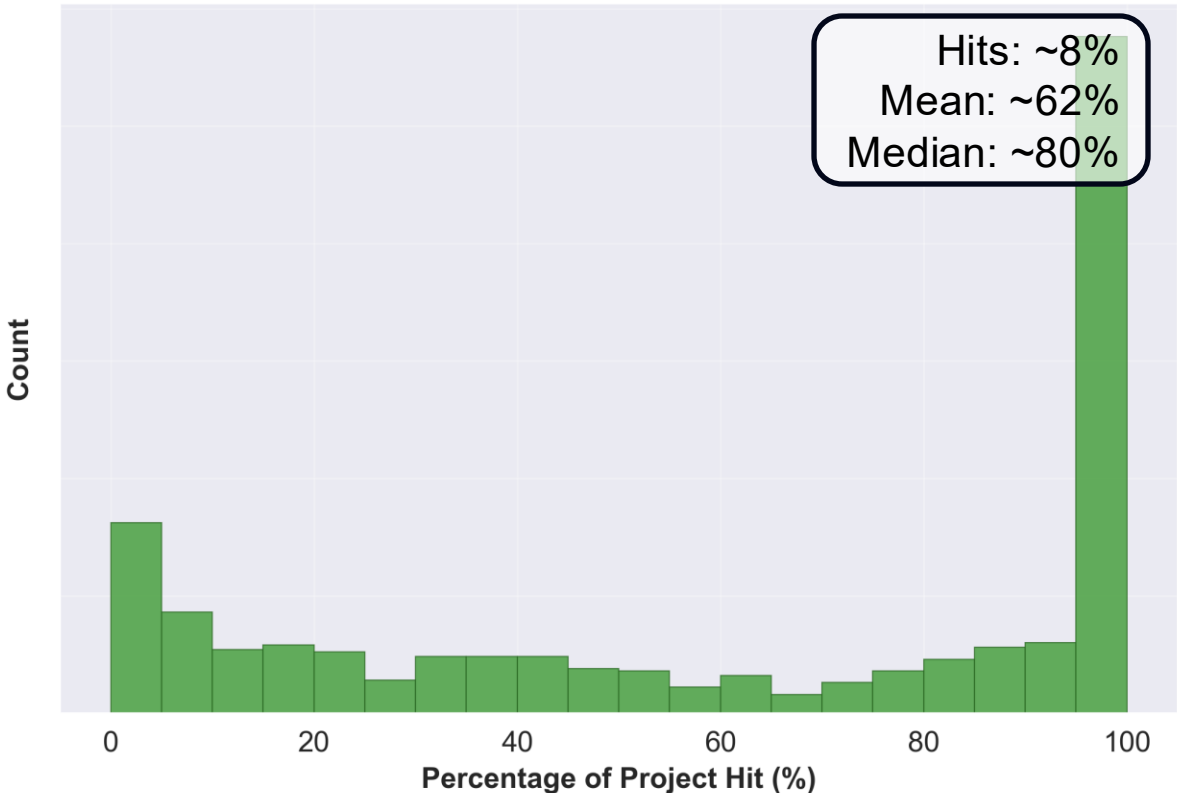
Incorporates equivalent solar project footprint for precise loss estimation

Case study: 600 MW solar project

Project Area Impacted by Hail
(All Events)



Project Area Impacted by Hail
(Hits Only)



Key findings

- Low-probability of being hit, high-consequence potential
- Results consistent with observed loss data
- Reinforces need for robust mitigation—industry has made significant strides
- Insurers may reward demonstrated risk reduction

A cost-benefit framework

The modeling output is a means to an end. The end is a defensible financial decision.

01

Know Your PML

Probable Maximum Loss defines your financing exposure. A P99 event that destroys 80% of a 600 MW project is a fundamentally different lender conversation than one that wipes 20%.

Without a credible PML, that conversation starts from a guess.

02

Price Your Coverage

Traditional underwriting tools were not built for solar PV, but the market is evolving as loss experience accumulates. Some insurers now reward demonstrated resilient design with better terms and capacity¹.

A defensible risk model gives you standing in that negotiation.

03

Evaluate Technology Investment

Hail-resistant modules and stow-to-safe protocols have upfront costs. The cost-benefit only closes if you can quantify what risk you are reducing.

Expected annual loss and PML are the inputs that make that calculation possible.

The question is not whether to manage hail risk. It is which combination of capital, coverage, and protection makes financial sense for your specific project.

¹ kWh Analytics case study: resilient design project achieved 72% insurance cost reduction (pv magazine, Nov 2024)

Before Financial Close: Five Questions

Practical takeaways for developers, asset managers, and lenders

1 Does your risk model reflect current and projected hail climatology?

Historical-record-based models systematically understate exposure in a non-stationary climate. Ask whether climate change is incorporated.

2 What is your project-specific PML, and how was it derived?

A credible PML requires a stochastic model that captures the full distribution of outcomes, not a rule of thumb or an industry average.

3 Is your coverage limit aligned with your actual PML, or with a sublimit?

The Fighting Jays farm had a \$50M hail sublimit against damage that likely exceeded that. Know what your policy actually covers for large events.

4 If you are in an emerging risk region, how is your underwriter pricing that uncertainty?

Regions with thin loss history may see pricing that does not yet reflect the true risk. A physics-based risk assessment gives you a basis for that conversation.

5 Have you quantified the return on mitigation investment?

Stow-to-safe protocols and resilient modules have documented loss-reduction effects. The cost-benefit closes differently depending on your site's PML.

Thank you

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Supplemental material

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