



GRID INNOVATION ALLIANCE

Physical climate risk assessment: Rockfall

From hazard maps to asset-level decision support

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Why rockfall matters

TEGNA, TICINO | 23 NOV 2025

1–2 m³

Boulder volume

1'000–2'000 kJ

Kinetic energy

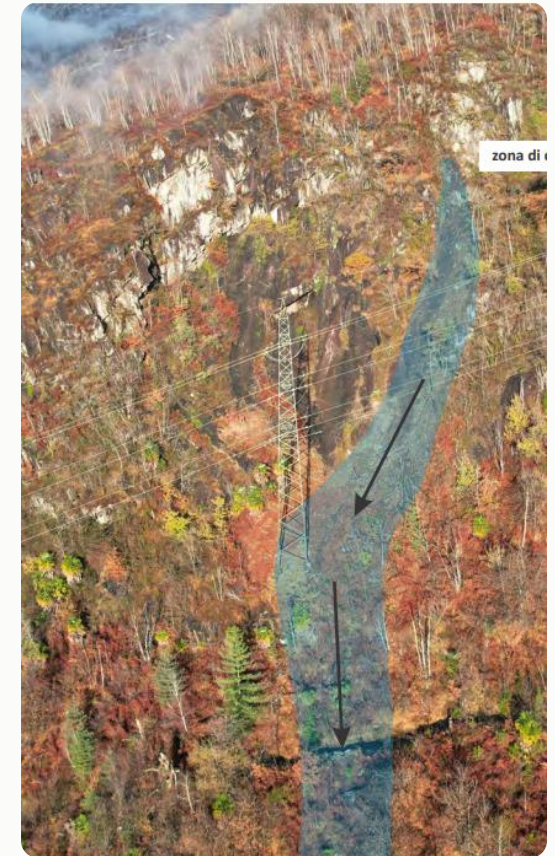
CHF ~1.5 Mio.

Pylon replacement and rockfall nets

**Rare, but severe: a single event
can require immediate action.**



Boulder impact at pylon 1900x006



Release area above settlement zone

Why an asset-level view of rockfall risk

01

Climate-driven hazards are intensifying

Glacier retreat, permafrost thaw at higher elevations and heavy rain are changing natural-hazard patterns across the Alps.

02

Low frequency, severe impact

Boulders can critically damage pylons, lines and substations, even where protective forests provide a natural barrier.

03

Static maps leave blind spots

Current hazard maps do not provide asset-level transparency or reflect how risks evolve under future climate uncertainty.

Resulting gaps

Need for forward-looking asset-level risk assessment +++ Existing hazard information does not answer the asset question +++
Future triggers and asset vulnerability need to be considered together



refinq 25 hazards covered. Rockfall was missing from the standard suite and required a dedicated model.

Scope of the PoC «Rockfall hazard»

RESEARCH QUESTION

Can rockfall hazard be translated into asset-level exposure and risk under current and future climate conditions?

136

pylons

4

lines, 220 and 380 kV

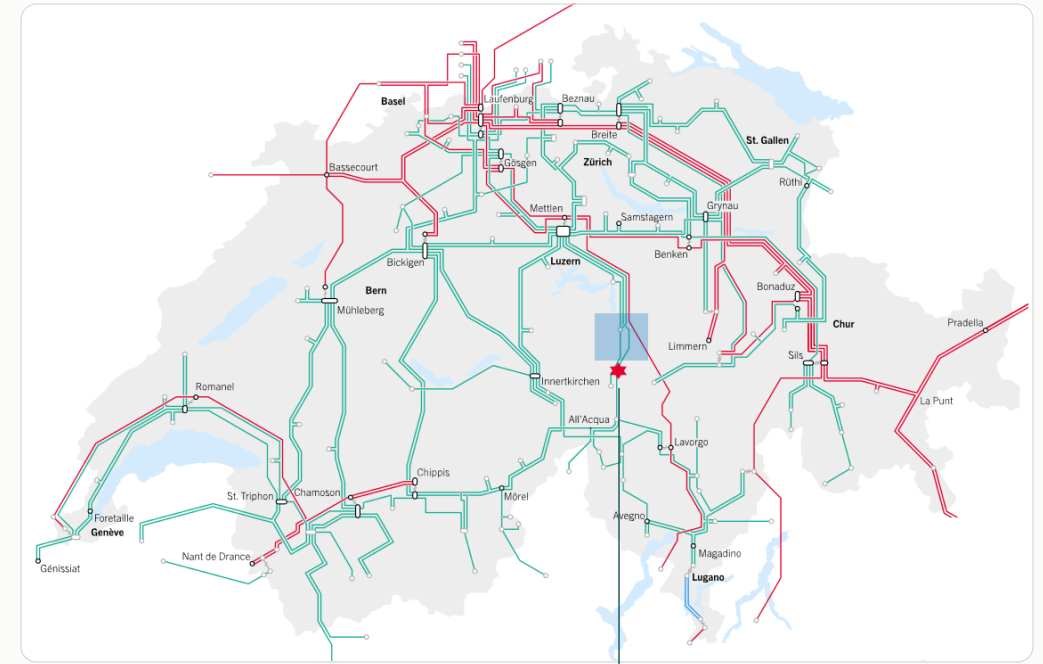
2

substations, 220 kV

~20 km Göschenen corridor, Reuss Valley (Canton Uri)

Planning context

Support renewal, routing and investment decisions for ageing power lines, before long-term planning choices are locked in.



Blue PoC assessment area

Assessment horizons:

2035

2050

2100

Four SSP pathways:

SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5

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Rockfall assessment in three questions

An asset scores high only when several answers are unfavourable.

1

Can a rock reach the asset?

REACHABILITY

Terrain and trajectory data show whether a falling block can reach a pylon or substation.

2

How often is it triggered?

CLIMATE TRIGGER

The model counts freeze-thaw and heavy-rain days per year, weighted by rock type.

3

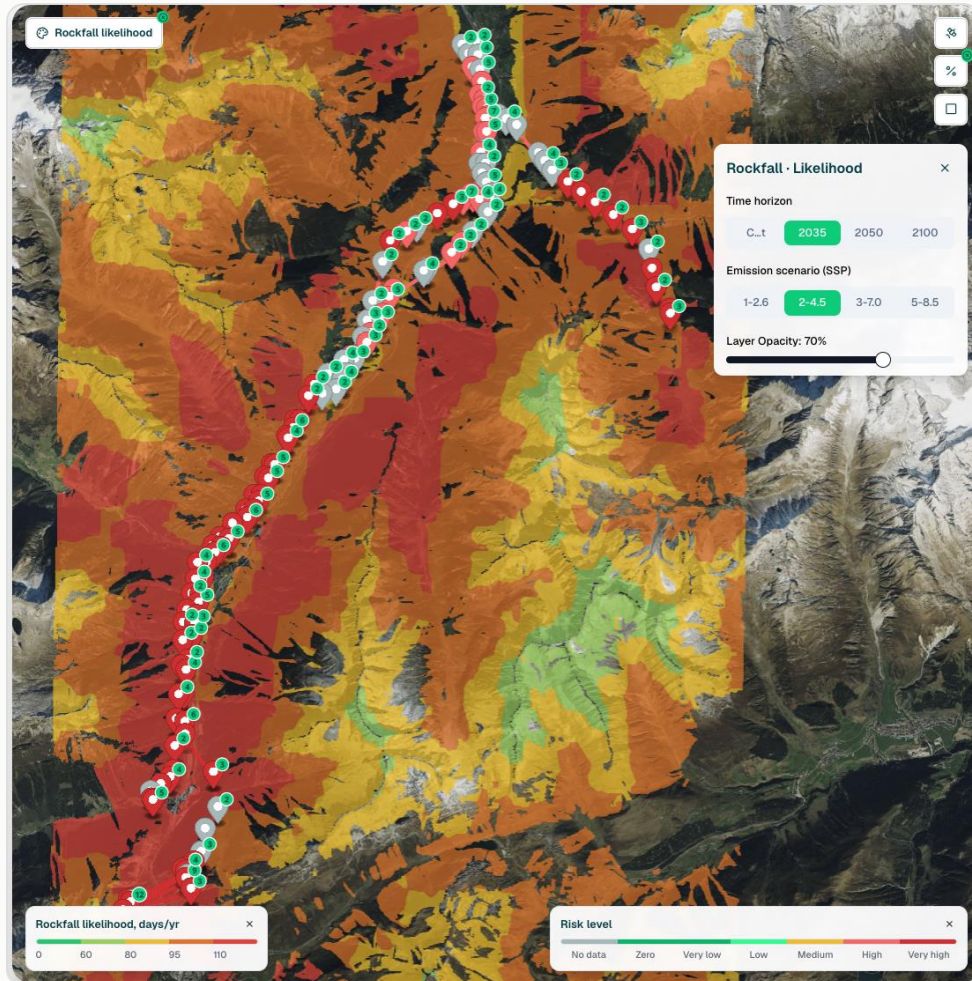
How severe is the impact?

IMPACT ENERGY

Impact energy in kJ, based on effective fall height and block mass, and reduced by upslope forest.

Rockfall hazard (likelihood + impact intensity) + Asset vulnerability → Asset-level rockfall risk

Every asset in the Reuss Valley, scored



refinq platform: rockfall likelihood layer, 2035 horizon, SSP2-4.5
Each pin represents one asset with its own risk profile.

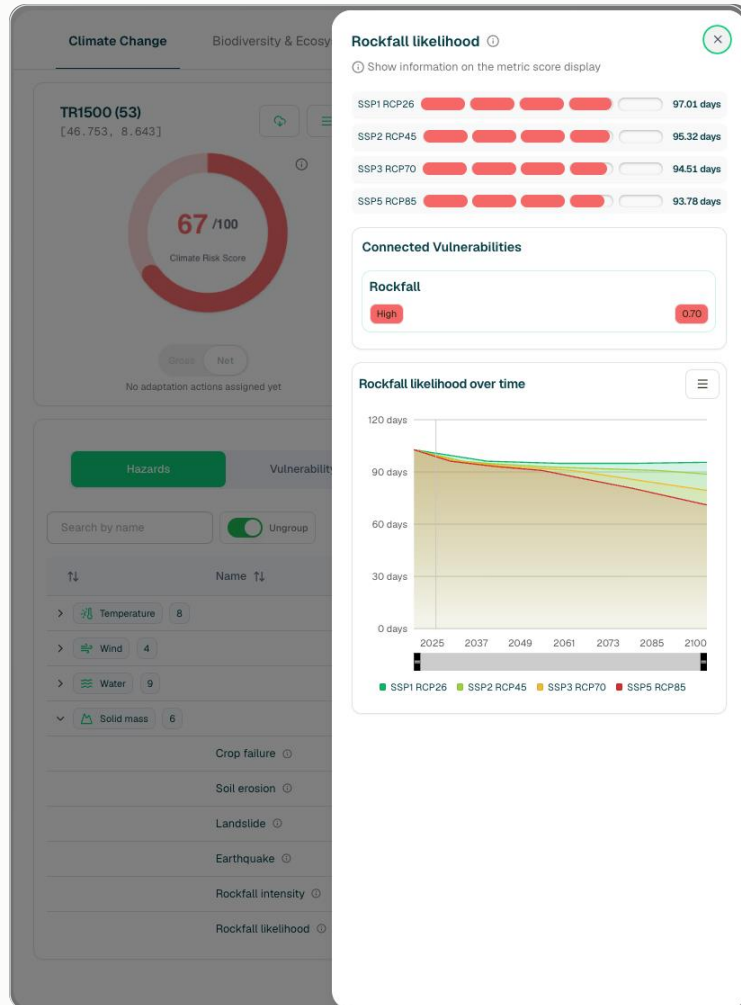
EXAMPLE: GÖSCHENEN 220 KV SUBSTATION

Impact energy	Very high, 3'022 kJ
Trigger frequency	High, ~28 days a year
Vulnerability	High, 0.70
Rockfall risk	High, 0.77

Rockfall is one of the dominate climate risk at this site.

Overall climate risk score: 53 out of 100

Triggering days decrease, but exposure persists



refin^q platform: line TR1500 (Pylon 53)

EXAMPLE: LINE TR1500 (PYLON 53)

TRIGGERING DAYS PER YEAR

Illustrative SSP5-8.5 pathway (2050)

97.0

Scenario SSP1-2.6



93.8

Scenario SSP5-8.5

At the asset elevation, freeze-thaw is the dominant trigger; permafrost thaw is not the relevant pathway. Fewer freezing days outweigh more heavy-rain days.

Trigger frequency remains high across all scenarios. Impact energy does not change with the climate pathway.

**Pylon 53 remains exposed through 2100,
despite the decline in triggering days**

Conclusions

Demonstrated

- Rockfall hazard is translated into **asset-level likelihood, intensity, vulnerability and risk.**
- The model explicitly links **climate triggers to rockfall likelihood.**
- **Approximately 29% of pylons within mapped trajectory zones** were found to be energetically **unreachable.**
- **Results support** screening and prioritization for **renewal, inspections and planning.**

Key lessons

- A warmer climate does not eliminate today's rockfall exposure.
- Freeze-thaw and heavy rain trigger rockfall here, not permafrost thaw.
- Keep likelihood, intensity and vulnerability visible to avoid masking the drivers of risk.

Next steps

- Validate against observed events and damage records.
- Refine climate uncertainty, geology and forest barrier.
- Embed rockfall into systematic climate and natural-risk management.