🌍 Introduction

RiskX is designed to quantify the chronic risks associated with climate change and extreme events at the level of individual assets. The platform enables detailed, asset-level risk assessment by combining high-resolution hazard modelling, building-level exposure data, and vulnerability functions. With limited resources, the prototype is only applied to Bergen.

For each building, RiskX provides:

- **Risk scores** under various climate change scenarios (e.g., RCP pathways, though not implemented in the prototype) and building-level adaptation options.
- **Loss ratios** and **expected damage estimates**.
- **Portfolio-level risk aggregation** to manage systemic risk.

🧭 Methodology Overview

Risk in RiskX is conceptualized as the combination of three key components:

$$Risk = Hazard \times Exposure \times Vulnerability$$

- **Hazard**: The probability and intensity of damaging events, e.g., windstorms under current and future climate conditions.
- **Exposure**: The physical assets at risk, described by their location, type, value, and structural characteristics.
- **Vulnerability**: The expected damage given a hazard level, determined by the building characteristics such as materials, and resilience measures.

By integrating these three elements at **high spatial resolution**, RiskX aims to:

✅ Asset-level risk mapping
✅ Scenario-based planning (including climate change and adaptation levels)
✅ Portfolio risk evaluation under evolving climate conditions

Hazard: Wind Data and Downscaling Methodology

This section explains how RiskX estimates high-resolution wind hazard layers suitable for **asset-level risk analysis**. The goal is to provide detailed wind speed maps that account for local terrain effects, using both existing climate model data and statistical methods.

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1. Source Data: NORA3 Wind Speeds

- The **NORA3** dataset provides wind gust data over Northern Europe at ~3 km spatial resolution.
- While NORA3 is excellent for regional analyses, its resolution is too coarse for estimating risk at individual building or asset level.

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2. The Need for Downscaling

- Wind speeds are highly influenced by **local terrain** features such as hills, valleys, and land cover.
- To model these local effects, RiskX downscales the coarse wind fields to a ~90 m resolution grid (this can be further downscaled to 30m resolution).
- This enables detailed estimation of wind hazard for **individual buildings or infrastructure assets**.

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3. Statistical Downscaling Approach

RiskX uses **statistical learning methods** to model the relationship between wind speed and terrain features. The general idea:

- Coarse-resolution wind data is paired with terrain variables to learn how wind speeds vary with local features.

- This relationship is then applied to a high-resolution Digital Elevation Model (DEM) to predict wind speeds at fine scale (30m-90m resolutions).

3.1 Training Data

- The coarse NORA3 wind gust values are used as the **target variable** for learning.
- Terrain variables are the **predictor variables**, including:
    - Elevation (from Copernicus DEM)
    - Slope and aspect
    - Terrain roughness metrics
    - Land cover / vegetation type

3.2 Machine Learning Model

- A **Random Forest regression** model is used to learn the relationship between wind speed and terrain features (wind speed ~ f(terrain features)).
- This model is chosen for its ability to capture nonlinear relationships and interactions.

3.3 Application to High-Resolution Grid

- Once trained, the model is applied to the full ~90 m DEM grid.
- This produces fine-scale wind hazard maps that capture local variability, critical for asset-level risk assessments.

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4. Data Sources Used

- **NORA3 wind speed data**: Regional climate reanalysis at ~3 km resolution.
- **Digital Elevation Model (DEM)**: Copernicus DEM at ~90 m resolution.

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5. Planned Enhancements and Calibration

RiskX is designed to be **modular and upgradable**. Planned improvements include:

- Incorporating **observational wind station data** for calibration and validation of downscaled fields.
- Including additional terrain-derived predictors such as:
    - Aspect and slope at multiple scales
    - Local roughness length estimates
- Using ensemble approaches to estimate **uncertainty ranges** in downscaled wind speeds.
- Hazard layers for future periods (e.g., 2050, 2080) using bias-corrected EURO-CORDEX projections.

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6. Limitations

- The accuracy of downscaled wind fields depends on the quality of input data (DEM, land cover, NORA3).
- Initial implementations used simpler models (e.g., elevation only) while advanced models with more predictors will be phased in.
- Local microclimate effects (urban roughness, small-scale channeling) may not be fully captured without further calibration.

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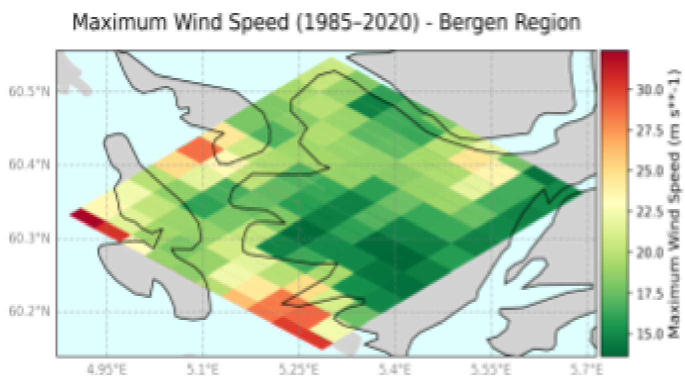
7. How It’s Used in RiskX

- Downscaled wind speed maps at ~90 m resolution serve as the **hazard layer** in RiskX’s risk calculations.
- Each asset is overlaid on these layers to extract **wind speeds at various return periods** (e.g., 2-, 5-, 10-, 50-, 100-, 200-year events).
- These hazard estimates feed into the **damage functions and vulnerability curves** to compute expected loss metrics.

✅ **Summary**
RiskX transforms coarse regional wind data into **high-resolution, asset-level hazard maps** using statistical downscaling techniques. This process enables insurers, banks and asset owners to quantify wind risk at the level of individual buildings, while also supporting future climate scenario analysis.



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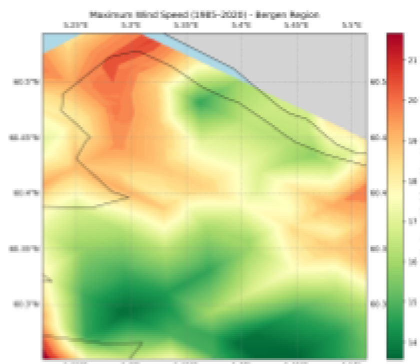

downscaled

🏠 Exposure: Building-Level Data

Accurate **exposure data** is essential for asset-level climate risk assessment. In the RiskX framework, exposure represents the characteristics of individual buildings that determine their susceptibility to wind damage.

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1. Current Data Sources

- **OpenStreetMap (OSM)** provides widespread coverage of building footprints (shapes and locations).
- While valuable for mapping, OSM data is typically limited to **geometry only**, without detailed structural attributes.

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2. Importance of Detailed Building Attributes

To assess individual building risk meaningfully, additional characteristics are required, including:

- **Number of storeys** (affecting wind load)
- **Roof type** and geometry (critical for damage modeling)
- **Building material** (e.g., wood, concrete, steel)
- **Construction year or age** (proxy for building codes and resilience standards)

These variables directly influence vulnerability curves and damage functions used in RiskX.

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3. Challenges

- Such detailed attributes are **rarely available** in open data globally.
- Local building databases (when they exist) are often incomplete, proprietary, or not harmonized across regions.

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4. Planned Enhancements with AI and Remote Sensing

The plan is to evolve by **augmenting basic building footprints with richer attributes** derived from satellite imagery:

- **Computer vision models** applied to high-resolution satellite or street-level imagery can classify:
  - Roof shapes and materials
  - Number of storeys
  - Construction types
- **Multi-source data fusion** can combine OSM shapes, and remote sensing features.
- **Machine learning approaches** will be trained on regions with labeled data and generalized to new geographies.

These methods promise to systematically generate the critical building attributes necessary for asset-level risk modeling, even in data-poor regions.

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5. Role in RiskX Calculations

- Each building's attributes influence its **vulnerability curve**—the mathematical function relating wind speed to expected damage.
- Accurate exposure data enables **tailored risk estimates** rather than relying on generic assumptions.
- As RiskX improves exposure data enrichment, the precision of loss forecasts for individual assets will increase substantially.

✅ Summary

While current open data (like OSM) offers only basic building shapes, RiskX will extend these footprints with advanced AI-driven mapping of critical structural details. This enables a truly asset-level risk assessment capable of supporting insurers, banks, and public planners in understanding climate-related wind risk in unprecedented detail.

🧱 Vulnerability: Estimating Wind Damage to Buildings

The **vulnerability module** in RiskX translates wind hazard into expected damage at the **individual building level**. This is achieved using **vulnerability curves**—functions that relate wind speed to the fraction of asset value likely to be damaged.

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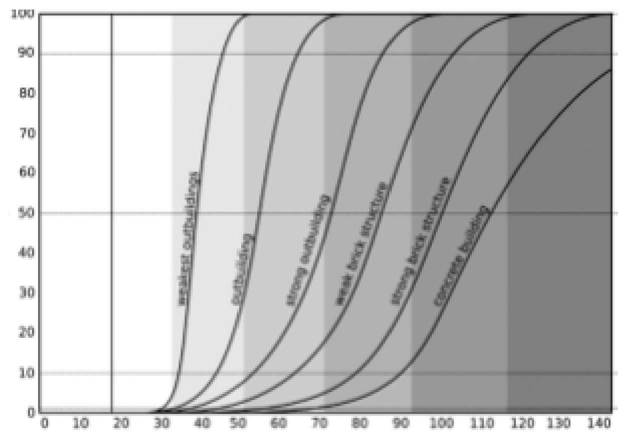
1. Current Approach

- RiskX currently adopts **generalized vulnerability curves** derived from **Koks & Haer (2020)**, who developed a **high-resolution wind damage model for Europe**.



Vulnerability curves from koks et al (2020)

- Their approach demonstrated that **open-source exposure data (e.g., OpenStreetMap footprints) combined with hazard layers and generalized vulnerability curves** can produce credible, building-level wind damage estimates across large areas.

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2. Why Vulnerability Curves Matter

- Vulnerability curves capture **how much damage** a building is likely to sustain at a given wind speed.
- They account for:
    - Building type and construction quality
    - Age and code compliance
    - Structural features (e.g., roof type)
- In the risk model, these curves convert hazard metrics (e.g., gust speed for 50-year return period) into **expected damage ratios (EDR)**—which then feed into **loss estimates**.

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3. Current Implementation Details

- For the initial prototype, **standardized damage functions** are applied across similar building classes.

- These curves represent **average expected damage** for given wind speed thresholds.

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4. Planned Enhancements

RiskX is designed to support **progressive refinement** of vulnerability estimation:

- **Incorporation of proprietary insurance claims data** to locally calibrate vulnerability curves.
- Vulnerability curves has to be tailored to:
    - Local building codes
    - Construction practices
    - Material types
- Differentiation by **asset class** (residential, commercial, industrial) to reflect varying structural resilience.
- Post-disaster damage surveys and remote sensing analysis to validate and update curves.

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5. Role in Risk Calculations

- For each asset, the selected vulnerability curve maps **wind hazard metrics** (e.g., gust speeds at specified return periods) to **expected damage ratios**.
- The final risk calculation multiplies:
    - Hazard (wind speed probability)
    - Vulnerability (damage ratio)
    - Exposure (asset value)
- This produces:
    - **Expected Annual Loss (EAL)**

- **Scenario-based loss estimates** (e.g., 10-, 50-, 100-year events)

✅ Summary

RiskX's vulnerability module applies proven, peer-reviewed damage functions to estimate wind damage at building scale. While initial implementations use generalized curves (Koks & Haer, 2020), the platform is designed to integrate **regionally calibrated, proprietary, or engineering-based models** over time, increasing accuracy and value for insurers, planners, and asset owners.

📈 Risk Score Computation

RiskX assigns **risk scores** to individual buildings to reflect their relative wind hazard exposure under current and future climate conditions, including adaptation scenarios.

The computation follows these steps:

1 **Wind Speed Normalization**

- For each grid point, the maximum wind gust v_max is compared to a defined adaptation threshold v_threshold:

$$\left(\frac{v_{\text{max}} - v_{\text{threshold}}}{v_{\text{threshold}}}\right)^3$$

- This formula emphasizes extreme exceedances above the threshold while ignoring non-damaging winds.

2 **Adaptation Levels**

- Different adaptation scenarios adjust the threshold:
  - **Low adaptation:** v_98 (98th percentile wind speed)
  - **Medium adaptation:** v_99

- ○ **High adaptation:** v_99.5
- By raising the threshold, better-adapted buildings show lower risk scores.

3 **Pooling Across Scenarios**

- Scores are calculated for each adaptation level.
- These values are pooled to represent the building's performance across varying adaptation strategies.

4 **Normalization**

- All pooled scores are scaled between 0 and 100:
  - The **highest-risk building** receives a score of 100.
  - The **lowest-risk building** receives a score of 0.
- This ensures **relative comparability** across all assets in the study area.

✅ **Interpretation:**

> A higher RiskX score indicates a building is significantly more exposed to damaging wind events relative to its local adaptation threshold. This enables users to prioritize adaptation investments, insurance pricing adjustments, or urban planning interventions.

🌐 RiskX Interactive Application

An interactive web application has been developed to **demonstrate and explore RiskX's asset-level wind risk assessment**.

✅ Users can access the app here:
[RiskX Demo Application]

Purpose

The app allows to:

- Explore **building-level risk scores**.
- Examine **loss ratios and expected damages** for individual buildings.
- Analyze **portfolio-level risk metrics**.

Access and Sharing

- The hosted application is **publicly accessible** to facilitate review, collaboration, and feedback.
- It is intended for demonstration purposes and can be used to showcase RiskX's preliminary version.

✅ **Note:** The current version is only a prototype.