Climate stress testing modeling

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Agenda for today's discussion

Our ESG team with you today

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- **Climate risk overview**
- **Climate stress testing models – What we are seeing**
- **Modeling physical risk for residential mortgage loan portfolios**
- **Appendix**

Climate risk overview

The response to climate change across the industry is accelerating

Regulatory requirements are increasing

- **Emerging regulatory expectations** require ongoing investment, by both banks and their clients across disclosures, taxonomies, and risk management
- **Current and proposed rulemaking** includes requirements and guidance from the SEC, OCC, FRB, and non-US Regulators

Peers are taking action

- **220 asset managers responsible for $57 trillion** have committed to net zero by 2050 through the Net Zero Asset Managers Alliance
- **84 banks managing $64 trillion** joined together in the UN's Net Zero Banking Alliance to set emissions targets aimed at net zero by 2050

Climate as a risk and growth opportunity

- **Increased climate-related risks and product opportunities** may lead to climate 'winners and losers'
- **The opportunity cost** of not moving forward could result in lost business and reputational damage in addition to lost revenue
- Climate change presents a risk of **increased company expenditures** related,e.g., to physical damage from greater natural disaster occurrence

Investor and stakeholder expectations

- **Stakeholders are pushing the agenda** on climate-based solutions and strategies
- **89% of investors** say their firm has changed its voting policy to be more attentive to ESG risks
- **Investor and client pressure have made net-zero commitments and climate disclosures necessary**

Climate – US Regulatory horizon

Risk management and scenario analysis

Supervision has begun on climate matters, with most regulators formalizing new rules for climate-risk management and plans to roll out climate stress tests

- **FRB, OCC, NYDFS have established climate risk supervision groups** and named leaders
- **OCC has announced climate risk supervision** for large banks expected by end of year
- Acting Comptroller Hsu announced **climate risk range of practices review beginning this week**
- **FRB releases paper outlining impact of oil price shocks**
- FRB governor speeches indicate **upcoming climate scenario analysis requirements**

Disclosures and reporting

Regulations remain fragmented and mostly voluntary, which creates complexities for adaptation. However, momentum gaining to harmonize and to transition to mandatory disclosures

- **SEC mandatory climate and human capital disclosures** expected early in the new year
- **SEC Comment letters** evaluating financial vs. non financial reporting on climate
- **Globally - disclosure rules converge on leveraging concepts from TCFD framework** on how to disclose climate-related financial information will be mandatory for G7 nations, UK was the first to confirm official plans to mandate in 2020
- **Scope 3 - financed emissions baselining (TCFD endorsed PCAF)** likely to be a required activity for disclosure

Investor protection – Disclosures

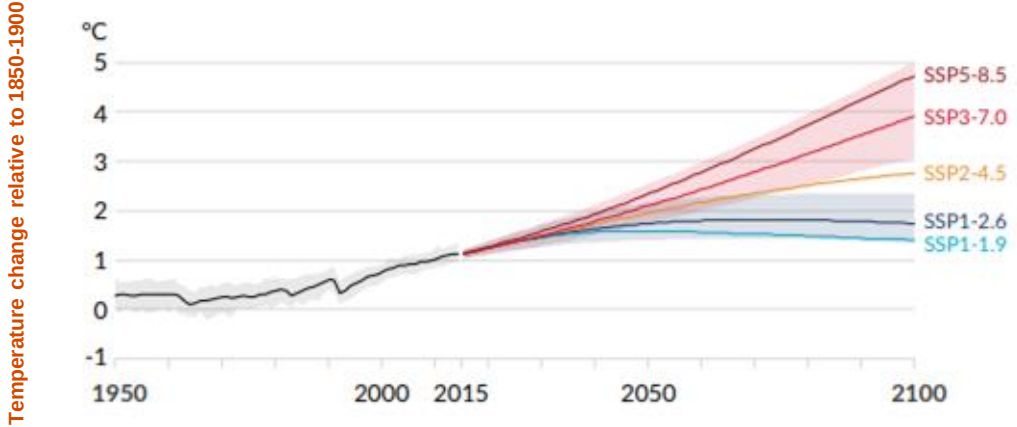
Many countries have taken steps to evaluate green or climate claims for sustainable finance marketed products

- Expect additional focus on labeling taxonomies similar to the **EU Taxonomy** is an EU-wide classification system for sustainable activities
- Also keep watch on **Sustainable Finance Disclosure Regulation (SFDR)** which aims to help institutional asset owners and retail clients understand, compare, and monitor the sustainability characteristics of investment funds by standardizing sustainability disclosures

Climate change poses new business risks to banks

Depending on future efforts to curb climate change, or lack thereof, banks will be faced with a new set of risks to consideras part of ongoing operations.

Global surface temperature change relative to 1850-1900 for select IPCC AR6[1] climate scenarios



[1] Intergovernmental Panel on Climate Change (IPCC) Assessment Report 6 (AR6) Climate Change 2021: The Physical Science Basis

Increased **physical** risk

Physical risk: Risks which arise from short & long term weather events (e.g., mortgage products perform poorly with increased level of defaults)
Physical risk is higher in climate scenarios with a temperature rise (relative to 1850-1900) greater than 2°C

Increased **transition** and **liability** risks

Transition risk: Risks which arise from the process of adjusting towards a low-carbon economy (e.g., impact of a carbon tax, volatile underwriting due to lack of data on green technologies, reputational risk if slow to go to net zero)

Liability risk: Risks of potential climate-related legal claims or regulatory proceedings to companies and directors

Transition and liability risks are higher in forward looking climate scenarios with a temperature rise (relative to 1850-1900) limited to 2°C

Climate risks and opportunities

Climate changes risks and opportunities are typically considered across the following categories:

Transition risks as a result of transition to a low carbon economy

Policy and legal

- Increased carbon policy/pricing of GHG emissions
- Enhanced emissions-reporting obligations
- Mandates on and regulation of existing products and services
- Exposure to litigation

Technology

- Substitution of existing products and services with lower emissions options
- Unsuccessful investment in new technologies
- Costs to transition to lower emissions technology

Market

- Changing customer behavior
- Uncertainty in market signals Increased cost of raw materials

Reputation

- Shifts in consumer preferences
- Stigmatization of sector
- Increased stakeholder concern or negative stakeholder feedback

Physical risks resulting from changes in the climate

Acute

- Increased severity of extreme weather events, e.g.
  - Floods
  - Wind storm
  - Storms and cyclones
  - Wildfire
  - Storm surge
  - Hail

Chronic

- Changes in precipitation patterns
- Changes in extreme variability in weather patterns
- Rising mean temperatures
- Rising sea levels

Opportunities

Resource efficiency

- More efficient resource use
- Move to more efficient buildings and modes of transport

Energy source

- Use of lower emission energy sources
- Use of supportive policy structures
- Use of new technologies
- Participation in carbon markets

Products and services

- Development/expansion of low emission goods and services
- Climate adaptation and insurance risk services

Markets

- Access to new markets
- Use of public sector incentives

Resilience

- Resource substitution/diversification
- Renewable energy programs, efficiency initiatives

Climate stress testing models – What we are seeing

Climate scenario selection and design

Climate scenarios are hypothetical constructs that delineate plausible states of the future, and provide a forward-looking view into how different types of climate-related risks and opportunities may materialise if certain trends continue or certain conditions are met.

There are two main types of climate scenarios:

- **Transition risk focused scenarios** outlining policy, technology, and market changes with the transition to a lower-carbon economy. The scenarios are linked to certain temperature rise outcomes based on emissions pathways.
- **Physical risk focused scenarios** describing the physical impacts of climate change, which include event driven impacts (acute) and longer-term shifts in climate patterns (chronic).

How to select scenarios?

Assessment criteria to assess the applicability of **scenarios and their relevance:**

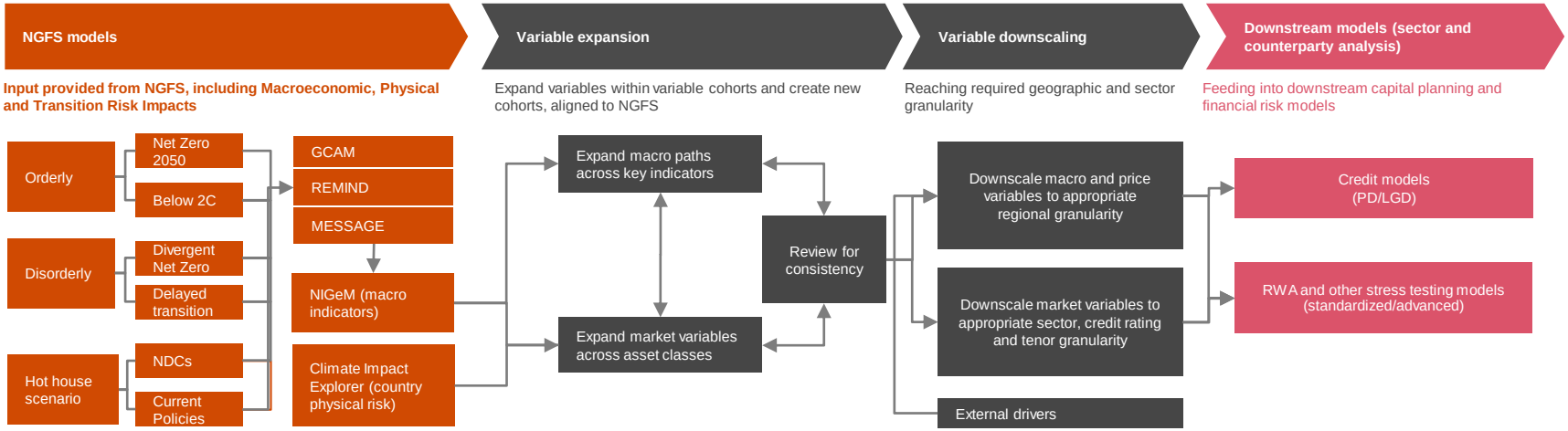
- Emissions/transition pathway and associated outcome of temperature rise
- Time horizons
- Frequency of update
- Reliability of sources
- Peer and industry selection
- Scenario variables
- Sector coverage and granularity
- Geographical coverage and granularity
- Alignment with regulatory expectations

Sources of scenarios for review?

Based on our observations of the widely used and recognised scenarios in the market, the **following publicly available climate scenarios are key for consideration:**

- **Transition risk focused scenarios**
  - Network of Central Banks and Supervisors for Greening the Financial System (NGFS)
  - International Energy Agency (IEA)
- **Physical risk focused scenarios**
  - Intergovernmental Panel on Climate Change (IPCC) scenarios, including the Representative Concentration Pathways (RCPs), used by scientists globally and the shared socioeconomic pathways

Process flow for scenario expansion with climate scenarios



Input	• **Potential global warming pathways:** air temperature, temperature rise, precipitation, etc. • **Environmental data,** including CO2 emission pathways,energy investment, and energy demand	• **NGFS Macroeconomic Impacts**	• **Expanded Macro and Market Indicators** • **External Drivers,** including Gross Value Added (GVA)	**Downscaled macro and market indicators**
Output	• **Macroeconomic Impacts,** including GDP, unemployment, inflation, and interest rates by country • **Transition Impacts,** including energy prices and carbon prices by country • **Physical Impacts,** including agricultural demand, emissions, and yields by country	• **Expanded macro indicators**, such as disposable income, and money supply • **Expanded market indicators**, such as credit spreads, equity market volatility, mortgage originations, foreign exchange rates, 30 year mortgage interest rate,	• **Downscaled macro indicators** at the appropriate regional level • **Downscaled key market indicators** at the appropriate sector, credit rating, and tenor granularity	• **Credit impacts** in the form of PD/LGD adjustments and adjusted expected credit loss • **RWA forecasts** at the portfolio, LOB and enterprise level

Climate scenario generation – NGFS scenarios provide a common starting point

The NGFS Scenarios have been developed to provide a common starting point for analysing climate risks to the economy and financial system. European Central Bank scenarios are based on NGFS while Bank of England scenarios are analogous

Orderly transition scenarios

Climate policies are introduced early and become gradually more stringent. **Both physical and transition risks are relatively subdued**

Net Zero 2050	Below 2°C
• **Transition Risk:** Medium **Physical Risk:** Low • **Net Zero 2050 limits global warming to 1.5°C** through stringent climate policies and innovation, reaching global net zero CO2 emissions around 2050; • **Transition Risk Overview:** Fast changes in technology necessary for the Net Zero 2050 policy impose a high transition risk • **Mitigating Factors:** Most ambitious of all scenarios, and will have the most mitigating effects on climate change	• **Transition Risk:** Low **Physical Risk:** Low • **Below 2°C scenario** gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2°C. • **Risk Overview:** Global warming will still increase between 1.5°C - 2°C, which will have more adversarial effects on key climate indicators, unlike the Net Zero Orderly Scenario • **Mitigating Factors:** No high-risk indicators in either physical or transition impact

Disorderly transition scenarios

Higher transition risk due to policies being delayed or divergent across countries and sectors.

Divergent net zero	Delayed transition
• **Transition Risk:** High **Physical Risk:** Low • **Reaches net zero around 2050** but with higher costs due to divergent policies introduced across sectors leading to a quicker phase out of oil use. • **Transition Risk Overview:** Fast and immediate changes in both policy and technology impose a high transition risk • **Mitigating Factors:** This policy still reaches net zero near 2050	• **Transition Risk:** High **Physical Risk:** Medium • **Assumes annual emissions do not decrease until 2030**. Strong policies are needed to limit warming to below 2°C. CO2 removal is limited. • **Transition Risk Overview:** High transition risk given delays in policy implementation • **Mitigating Factors**: A delay in response gives more time for institutions to prepare, given the strong policies to be implemented for decrease in emissions goals

Hot house world scenarios

Some climate policies are implemented in some jurisdictions, but globally efforts are insufficient to halt significant global warming.**Severe physical risk including irreversible impacts like sea-level rise.**

Nationally Determined Contributions (NDCs)	Current policies
• **Transition Risk:** Low **Physical Risk:** High • Includes all pledged policies even if not yet implemented, leading to ~2.5°C increase • **Physical Risk Overview:** Severe physical risk due to not mitigating any global warming, leading to devastating environmental, health, and economic outcomes	• **Transition Risk:** Low **Physical Risk:** High • Assumes that only currently implemented policies are preserved, leading to high physical risks and a ~3°C increase • **Physical Risk Overview:** Severe physical risk due to not mitigating any global warming, leading to devastating environmental, health, and economic outcomes

A bottoms-up, fundamentals-based approach used to assess transition risk impacts to key financial performance and risk metrics

Five steps to translate portfolio-level transition risk into financial impacts, expressed as EBIT(DA) - example with IEA scenario

- ISIN (if available)
- Company name, sector and country
- Asset type (equity, debt, etc.)
- Weighting of the asset/company in the portfolio (e.g. the % share of financing in the total portfolio)

Portfolio Input

For unlisted assets, we work with sector and sub-sector averages

Input | **Transition risks**

Outputs

Essential questions

1. Climate models

- The IPCC defines different CO_2 budgets for different scenarios
- A carbon budget can be linked to a number of global warming paths

2. Energy system models & scenario narratives

- The IEA scenarios distribute the remaining carbon budget to sectors with comprehensive information on regulatory, technological and market change impacts
- These serve as a basis for modelling financial impacts across sectors and regions based on anticipated transition risks

Scenario Data Example: International Energy Agency

3. Sector & company analysis

- Analysis of the fundamental market logic of the respective sector (product differentiation, dependency of value creation, operational efficiency)
- Identification of the essential characteristics of individual companies

Asset Level Data, PwC sector and climate expertise

4. Portfolio/company data & modeling

- Analysis of the scenario's impact mechanisms on the sectors and companies within the sector
- Modeling approach varies according to market logic of individual sectors

5. Financial impact

- The financial impact of the various scenarios is calculated and provides impact on profitability in the form of a change in EBITDA
- EBITA impacts can be used an input to model changes in Net Revenues for a relevant LOB (e.g. EBITDA impact as an input to model impact to net flows and fund performance for an investment management portfolio)

6. Risk impacts

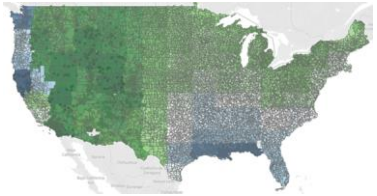
- Financial impact (e.g., change in EBITDA) can be used an input to a Merton Model to calculate climate-adjusted PD/LGD and expected loss

Legend: Data sources

Physical risk measurement is best performed at a granular level across perils relevant to the securities in an institution's portfolio

Requirement to model changes in physical risk intensity for all major perils

- Flood
- Hail
- Storm
- Drought
- Storm Surge
- Wildfire
- Tornado



Current risk

Future risk under different climate scenarios

Physical risk modeling approach

1. **Develop scenario narrative** by leveraging benchmark climate scenarios and identifying primary perils, based on expected frequency and intensity

2. **Use reinsurance and global climate model data** to calculate expected frequency and severity of relevant peril(s) under different climate change scenarios
3. **Convert model outputs** into relevant **Climate Metrics Forecasts** (e.g., forecast of risk by peril along with key drivers of risk/underlying parameters)
4. **Assess Financial Impact** by adjusting Financial Performance models to use climate metrics as an input
5. **Assess impact of mitigating factors:** Certain mitigating factors will have to be overlaid to results, in order to assess the true impact of physical risk on financial performance:

5a. **Insurance** will offset the impact of physical risk to collateral value

5b. **Fiscal and Monetary Support** will offset the impact to both corporate and retail clients

Data sources available to support physical risk modeling exercises:

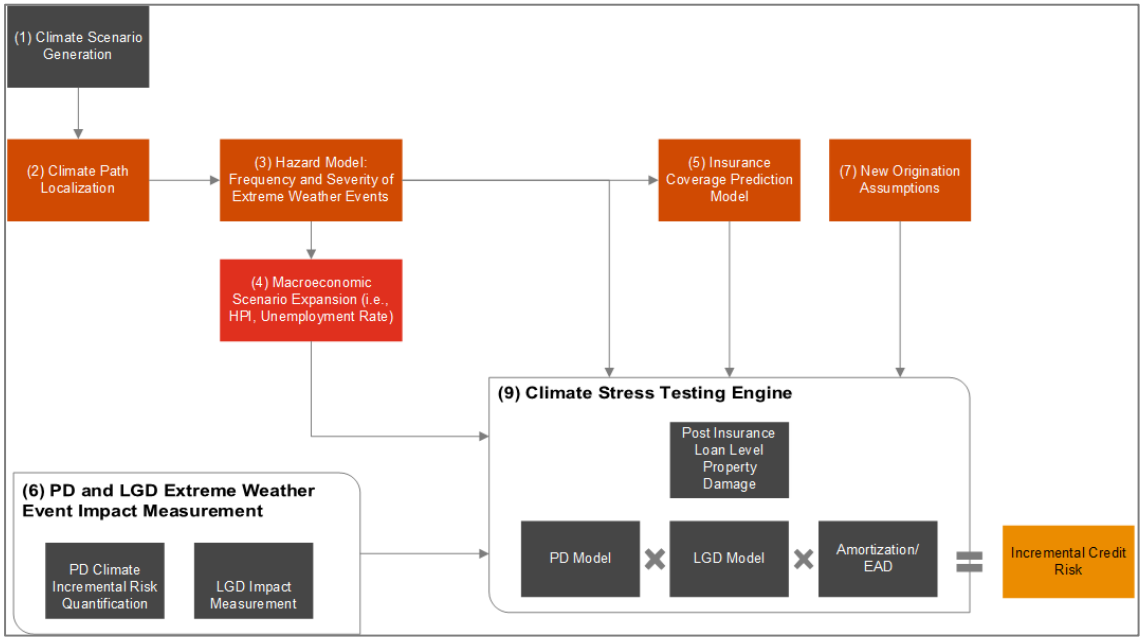
- **Historical weathe**r data including event data weather data at a granular local level and peril specific information
- **Catastrophe peril models** and data considering key climate perils and their modeled frequency and severity
- **Global climate models** modeling sea level rise, temperature change and precipitation impacts

Modeling physical risk:

Case study for residential mortgage loans

What models do you need for physical risk stress testing of loan assets?

- Climate Scenario Generation
- Climate Path Localization - From Global impact to regional impact (temperature, humidity, precipitation)
- Weather Hazard Event Prediction - Driven by localized climate forecasts - frequency and severity of various extreme weather events (i.e., hurricanes, wildfires, flood)
- Country level and Regional level macroeconomic impact (i.e., GDP, Unemployment Rate, HPI, etc)
- Insurance Coverage Model
- PD and LGD Impact Measurement
- New origination assumptions
- Climate stress testing engine



Challenges in climate stress modeling for credit risk

Measurement of incremental credit risk in the PD and the LGD component needs to overcome significant data challenges. The discussion below is mainly for secured lending (i.e., mortgage, CRE)

PD modeling challenges

Ideal scenario -- augment existing PD models with extreme weather indicators -- may not be feasible due to data challenges:

- Small number of loan defaults attributable to climate events
- Lack of data for certain types of hazard events (i.e., wildfire, heatwave, etc.)
- Loss mitigants offered by the banks and the government suppress short term delinquencies and defaults

LGD modeling challenges

Additional LGD modeling challenges:

- The extent of the property damage is the key driver of the LGD change, and is directly dependent on the severity of a hazard event
- According to a Fannie Mae survey, about 93% of inspected properties in a hurricane impacted area have no damage; and 4% have minimal damage -- property-specific impact modeling is needed

Additional Challenges:

Impact of multiple hazard events

Property insurance availability

Forecasting window for climate stress testing (30 ~ 50 years)

Portfolio balance and new origination assumptions

Probability of default impact measurement

Recent studies and our PwC analysis show the importance of **insurance coverage information** for PD impact measurement

Commonly seen approaches to introduce climate sensitivity to PD forecasts (short term and long term impact) –

Consistent with the early days of CCAR/DFAST modeling, there are currently four physical risk modeling approaches:

1) Shock the model drivers (i.e., FICO, LTV)
2) Shock the macroeconomic input factors (at appropriate granular geographic level)
3) Overlays or adjustments to existing model forecasts (i.e., shocks to predicted delinquency/default rates)
4) Re-estimate existing models after including extreme weather indicators

Our suggestions to measure the incremental PD risk –

- Use a longer observation horizon after the hazard event (i.e., 12 or 24 months) to estimate cumulative impact to reduce the impact of short term noise.
- Quantify the relative differences in the performance metrics (i.e., roll rates or default rates) between the control and the event-impacted groups. Control for loan and borrower characteristics, property insurance status, and property damage extent (if observable).

Fannie Mae study – Short term impact

- Compared to homes with no damage, **loans on moderately to severely damaged** homes were more likely to become 90 days delinquent shortly after Harvey;
- Loan performance (**12 or 24 months following the event**) depends on whether the property is located in areas where borrowers are required to have flood insurance
  - Where flood insurance is required, loan prepayment rate rises with property damage;
  - Where flood insurance is not required, **loan modification/180-dpd/default rate rise with property damage**.
- Policy implication - flood insurance protects homeowners and mortgage creditors against credit risk arising from flood events

"Flood Damage and Mortgage Credit Risk: A Case Study of Hurricane Harvey"

Freddie Mac study – Long term impact

- The study find that the prices of homes located in the floodplain were **already discounted by 2.3% or $7,300** in Harris County prior to Hurricane Harvey. After the hurricane, **the discount rose to 5.5% or $17,800— a $10,500 increase** in the discount
- The discount is a signal that the market perceives incremental flood risk prior to a hurricane and prices that risk accordingly
- These results indicate that a recent experience with flooding leads to **a perception of increased flood risk in the future**

"Unravelling Perceptions of Flood Risk: Examining Changes in Home Prices in Harris County, Texas in the Aftermath of Hurricane Harvey"

Loss given default and overall loss impact measurement

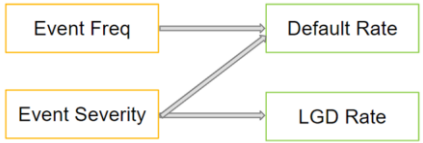
We are not there yet! How do we combine various impacts is another challenge

Inputs to a climate stress testing engine

- Localized extreme weather forecasts (i.e., frequency, severity, locations)
- Macroeconomic forecasts
- Loan level characteristics
- Insurance coverage (current and future projections)
- New Originations - business strategies reflecting considerations of climate change

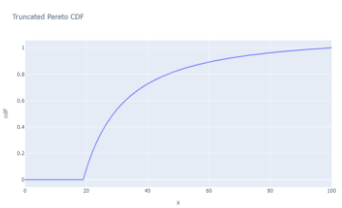
Linking hazard event forecasts to PD and LGD

- **Frequency** (e.g., annual probability): regardless of the "severity" of a event, how likely it is to occur over a particular period of time.
- **Severity**: each weather event's definition of severity could be different.

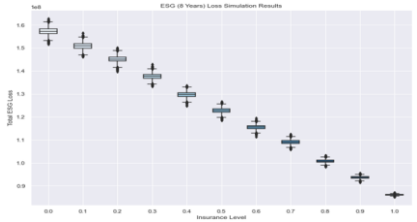


LGD/Property damage projection

- Predicted hazard event severity needs to be translated into loan level property damage
- An advanced approach is to use a catastrophic models
- A simplified approach/assumption is via a probabilistic damage curve (i.e., truncated Pareto shown below). The distribution represents **"%X of loans' property damage is larger than %Y of its property value"**



Property Damage Curve



Impact of Insurance Coverage on Credit Loss

Modeling post-insurance property damage

- Property/hazard insurance is like an option.
- In our view, simulation or a similar approach might be required to measure the value of a property/hazard insurance at loan level to quantify its offset to credit risk.

Thank you!

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