Z-Risk Engine®
Unlocking Credit Cycles

An Integrated Credit Risk Based Scenario Approach to Climate Stress Testing

June 7, 2023

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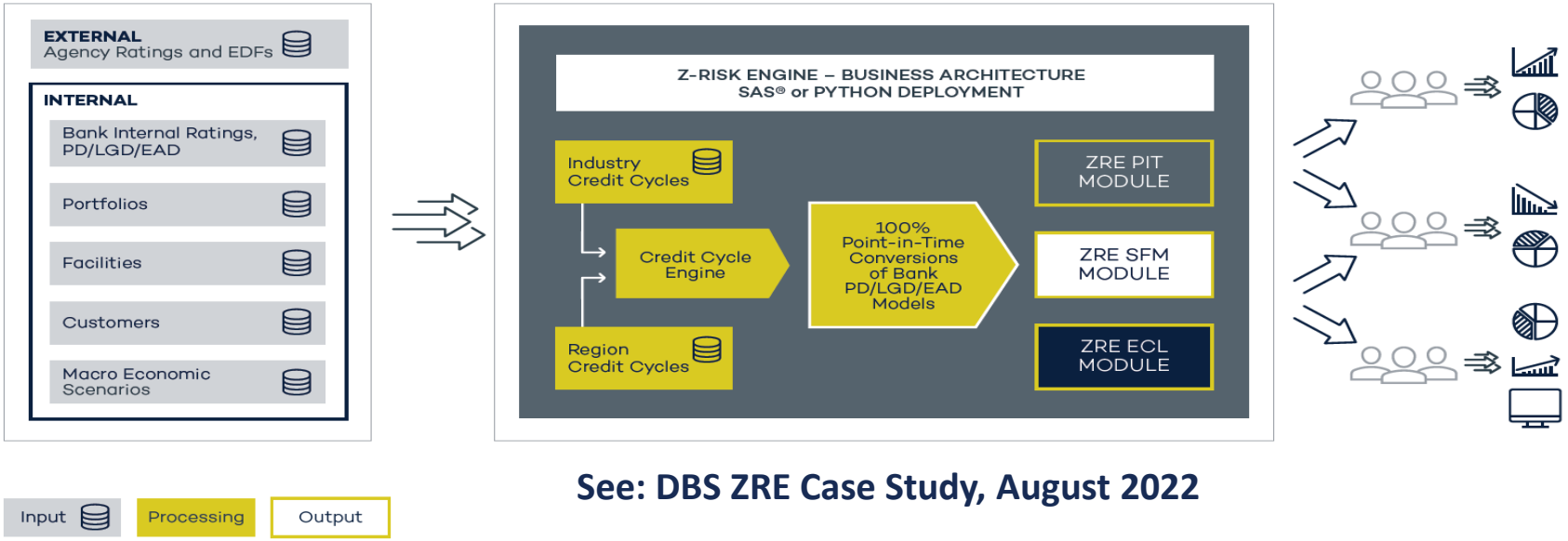
Agenda: Integrated Climate Stress Testing ('CST')

1. Climate Stress Testing Overview:
    - *FYI: Joining Oxford University CGFI as research fellow to collaborate on CST research*
    - **Foundation**: Z-Risk Engine Approach – **Credit Cycles Matter**
    - Climate 'Hockey Stock vs Credit Risk Volatility
    - **Key** Climate **Discussion Points** & Suggested **Responses**
2. An **Integrated** Climate Stress Test **Framework**
3. CST: Climate Risk **Models** and **Methodologies**
4. CST: E2E CST **Implementation**
5. CST: **DRAFT Planning** for YE 2024 EU CST **Deliverables**
6. **Appendix I**: Climate Stress Test Example Sources of High-Level Requirements
7. **Bibliography**: Our Climate Stress Test Research Publications

1. ZRE Solution: E2E Python Solution Supports IFRS9 Stress Testing - **Climate Stress Testing Added to Production ZRE**

- Single **E2E** Python **architecture – provide full implementation support**
- **Approved:** Basel/IFRS9/Stress Testing
- Runs Credit Risk **Scenario Simulations** & **Deterministic MEV Scenarios**
- **Climate Stress Test PoC** module completed (4 use cases)

- **DBS Bank: ZRE - Production E2E Corp/Comm IFRS9/Stress Testing Solution:**

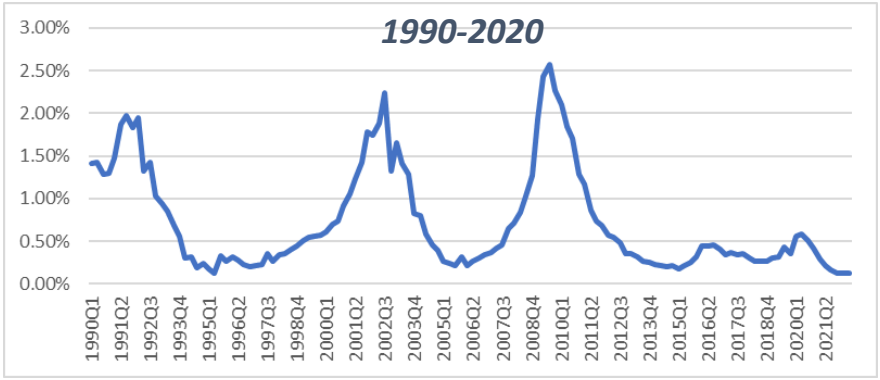


See: DBS ZRE Case Study, August 2022

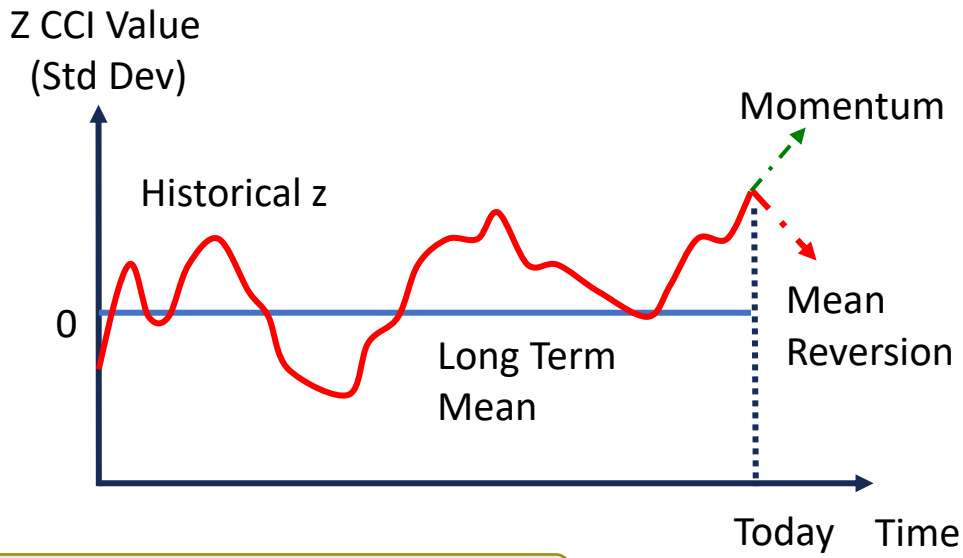
1. Credit Losses Vary Substantially Across the Credit Cycle – Z Credit Factor Models Form the Foundation of Projecting Long-Run Climate Scenarios

- ZRE industry sector & region Zs are modelled with mean reversion & momentum

Annualized US C&I Charge-Off Loss Rates (%)

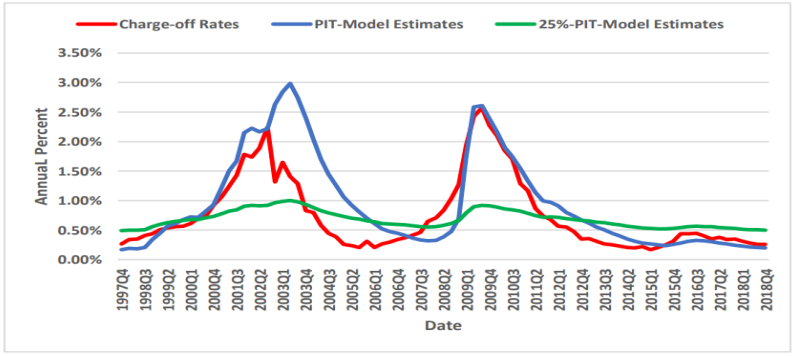


Source: Board of Governors of the Federal Reserve System



Annualized US C&I Charge-Off Loss Rates (%) Compared to ZRE PIT Model Estimates & Bank's IRB Models

Accurate ZRE Validation



Source: FRB , Z-Risk Engine Estimates

1. ZRE: Examples of Z Credit Cycle Indices – **Technology by Region** – 1990 – May 2023

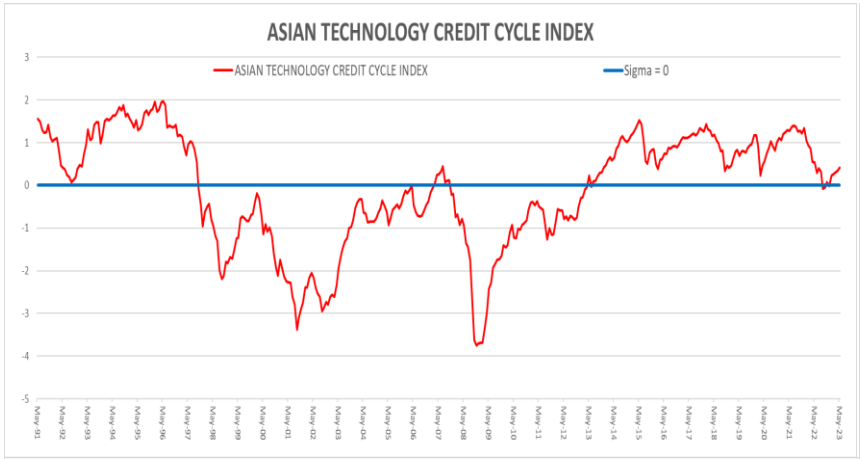
- ZRE industry sector & region Zs are ***customized*** to a bank's portfolio composition
- Industry sector and region Zs are ***combined*** to determine PIT credit model adjustments

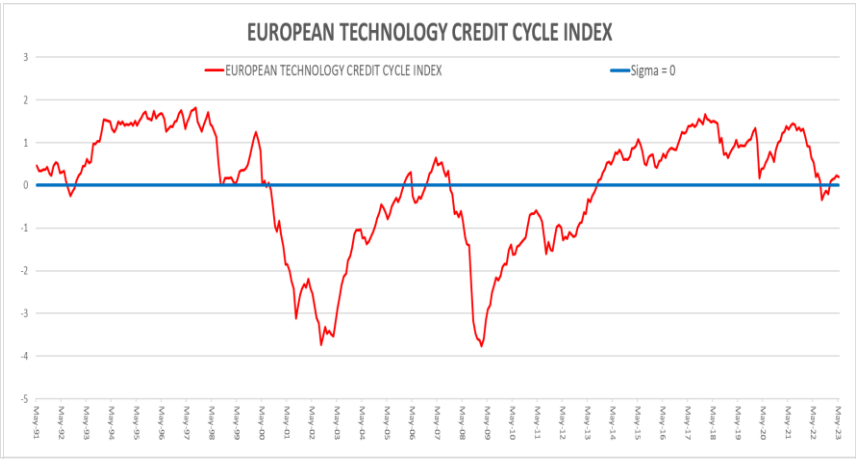
Z Std Dev

PIT < TTC PDs

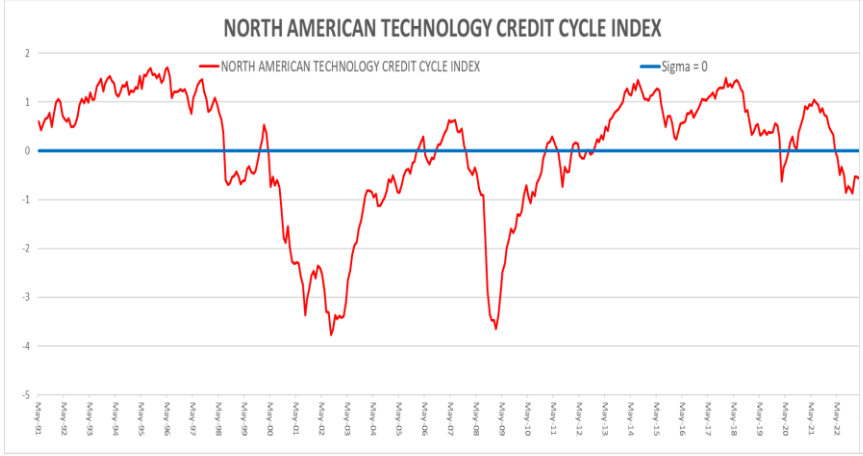
PIT = TTC PDs

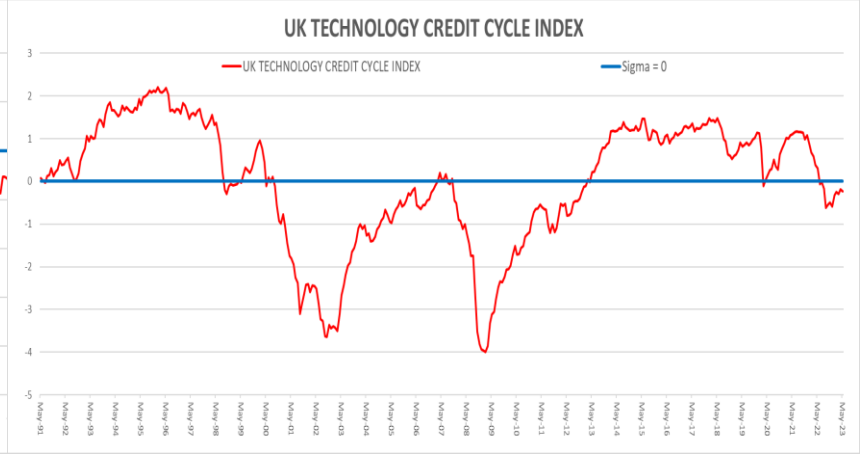
PIT > TTC PDs





Z Std Dev

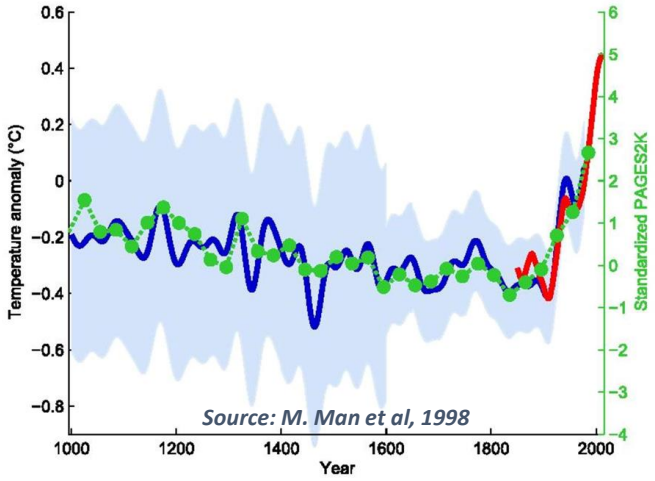




Source: Moody's CreditEdge and Z-Risk Engine

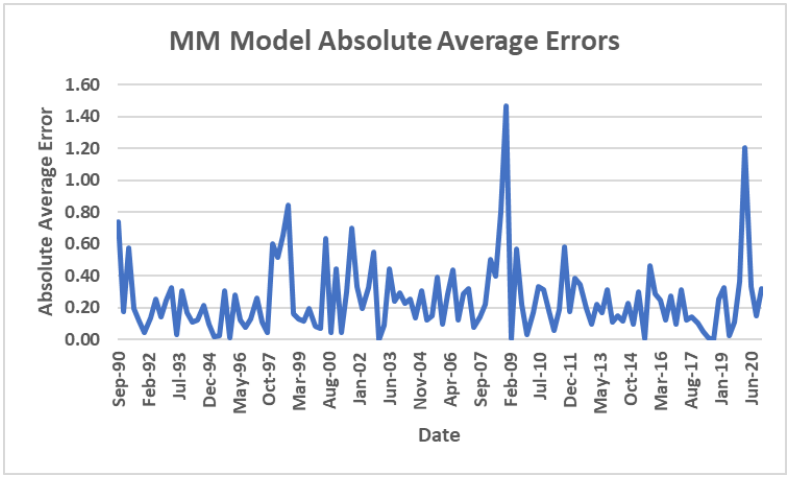
1. Climate 'Hockey Stick is Well Known – GMT Climate Impacts Are **Not Yet Observable** Impacting Credit Risk (Credit Risk Variability)

Observed Climate 'Hockey Stick': CO2/GMT



NEARLY ZERO CORRELATION

Observed Errors in Z Credit Cycle Indices



Source: Moody's CreditEdge and Z-Risk Engine calculations

'MM' – Mean Reversion-Momentum Model

1. Climate Stress Test ('CST') Key Discussion Points & Suggested Approach

KEY CLIMATE STRESS TEST 'DRIVERS'	SUGGESTED CLIMATE STRESS TEST APPROACH
• **'Relatively Smooth' LR Economic** Climate Adjustments **Possible**	• **Realistic or Unrealistic ?** Climate Impacts Manageable ? **Big Uncertainty !**
• **Regulatory** CST **- Infancy**	• ECB CST Results Suggest **- Minimal Credit Impacts**
• GMT Climate Trend **Impact on Credit Risk not Yet Observable**	• **Required**: **'What If'** Climate Scenario, Approach
• **Hard to Calibrate** Empirical CST Models	• **Need Existing, <u>Solid</u> Credit Risk** Factor Model **<u>Foundation</u>**
• **Increasing Volatility**, Socio-Economic Tipping Point **Shocks** and **Abrupt Carbon Policy Changes**	• Assess **'Shocks not Trends'** - Unexpected Climate Credit Risks/Uncertainty **Are Key**

CST Research in Infancy – No Real Consensus – NGFS Missing Key LR Risk Drivers → ***Banks – Can Lead Thought Leadership – 'Be in the Driver's Seat'***

2. Overall Climate Stress Test Framework for Credit Risk – Integrating Different Time Horizons, Methodologies & Risks

INTEGRATED CLIMATE RISK SOLUTIONS REQUIRE MULTIPLE MODELS/METHODOLOGIES

	SHORT RUN 1-5 YEARS	LONG RUN TO 2050 +
TRANSITION CLIMATE RISK	**SR: APPLY TRANSITION RISK CREDIT ADJUSTMENTS** ***IFRS9*** *CST CLIMATE TRANSITION ADJUSTMENTS (STATIC PORTFOLIO)* ***STRESS TESTING:*** *APPLY SR SHOCKS (DYNAMIC)*	**LR: PORTFOLIO CLIMATE SIMULATIONS PHYSICAL/TRANSITION RISKS** *CLIMATE SCENARIOS/NARRATIVES APPLIED USING 4 USE CASES:* • ***SECTOR/REGION VOLATILITY ADDONS*** • ***SECTOR/REGION SHOCKS*** • ***SECTOR/REGION 'TTC DRIFT' (ECB)*** • ***STRATEGIC PORTFOLIO ADJUSTMENTS ('BROWN-TO-GREEN', NET ZERO TARGETS)*** *ANY KIND OF INTERNAL/EXTERNAL SCENARIO (NGFS/CUSTOM)* *(DYNAMIC PORTFOLIO)*
PHYSICAL CLIMATE RISK	**CLIMATE-ADJUSTED CREDIT MODELS (PD/LGD) BCBS REQS** *APPLY PHYSICAL RISK/CARBON MITIGATON ADJUSTMENTS*	

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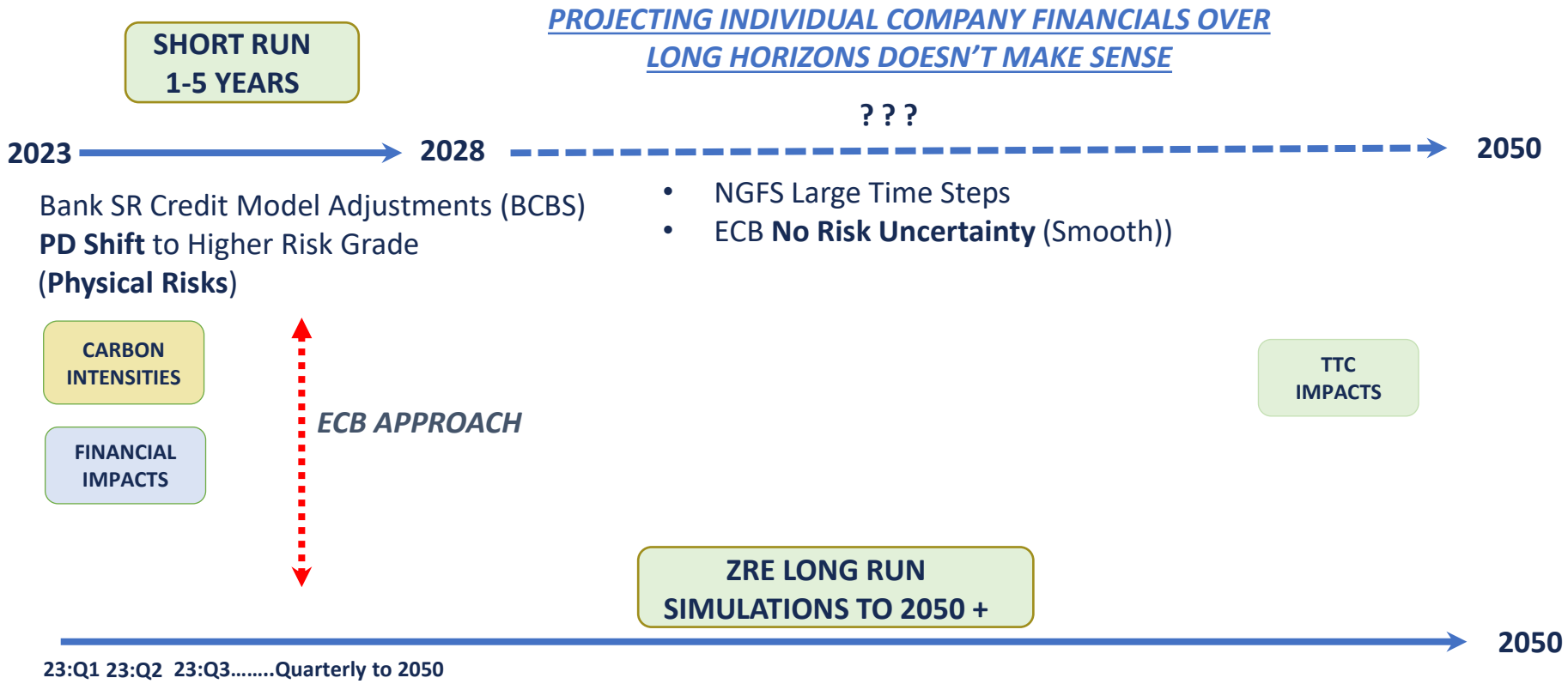
2. Climate Change: 'Tragedy ('Complexity') of the Horizon' – Requirement: Integrating SR vs LR Horizons



- **Unexpected Credit Risks/Shocks**
- **Quarterly Time Steps** – More Flexibility in Scenario Creation
- Apply **Fixed Risk Appetite** Consistently
- **Variance of Risks Rises** Over Time Horizon as it should

2. Consistent Integration of Multiple Climate Stress Test Models & Approaches

- **Consistent** application of **emissions data**
- SR financial impacts (ECB) integrated with LR ZRE simulations
- **Multiple** climate scenarios integrated as **aggregate scenario**
- **Flexibility: Run all kinds of scenarios**

ZRE RUNS NGFS MEV SCENARIOS

NGFS COUNTRY MEV/GDP SCENARIOS

(1) CONSISTENT CARBON CALIBRATION

SR CLIMATE-ADJUSTED CREDIT MODELS (PD/LGD)

CARBON INTENSITIES

ECB FINANCIAL IMPACTS

(2) ECB APPROACH – APPLIED IN LR SIMULATIONS

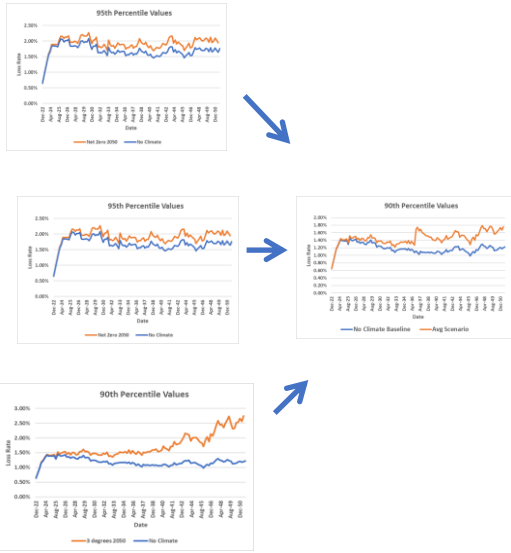
LR PORTFOLIO CLIMATE SCENARIOS

CLIMATE SCENARIO/NARRATIVES USE CASES

FLEXIBLE APPLICATION OF SCENARIOS (NGFS/CUSTOM)

BORROWER SECTOR REGION PORTFOLIO ECLS

(3) INTEGRATING MANY CLIMATE CREDIT LOSS SCENARIOS



Climate Portfolio Credit Loss Scenarios to 2050

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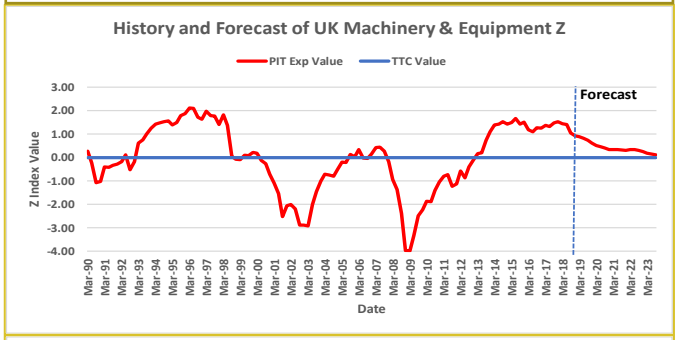
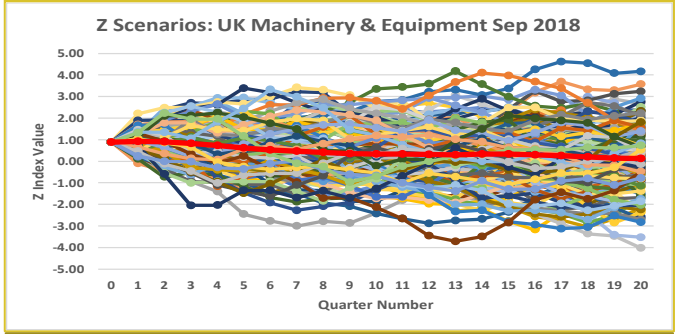
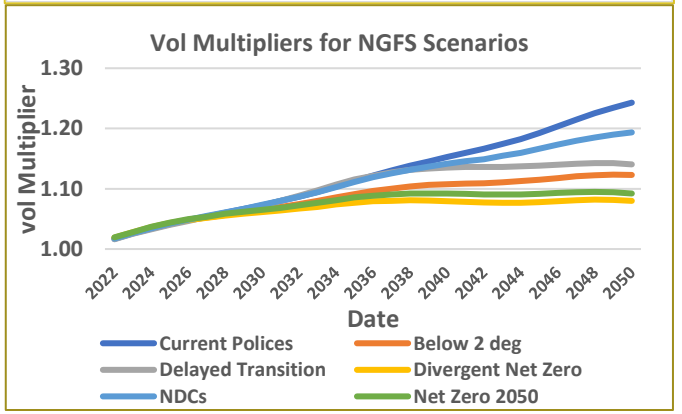
3. Overview: ZRE Models/Methodologies for Developing LR CST Scenarios

- Apply Z Credit Risk Factor Simulations:
  - Custom industry sector/region Z credit-cycle indices (CCI)
  - Example: Combined Z Ind/Reg CCI – UK Machinery/Equipment
  - Zs **Mean-Reversion Momentum** (MM) process
  - **Quarterly Time-Steps** – 2023-2050
- Add Climate-Change Effects to Scenarios:
  - Apply various climate **CST Use Cases**
  - Volatility Use Case example: **Vol Multiplier approach** increases Z vols with **NGFS GMT** temperature projections
  - 'Shocks' Event Use Case adds climate-related events
  - Volatility/Shocks represent physical-damage and transition events
- Flexibility to run deterministic NGFS MEV scenarios (although these are missing unexpected credit risk)

MM Model $\Delta Z^{\circlearrowleft}_{q+1,n} = m^{\circlearrowleft}_1 Z^{\circlearrowleft}_{q,n} + m^{\circlearrowleft}_2 \Delta Z^{\circlearrowleft}_{q,n} + \varepsilon^{\circlearrowleft}_{q+1,n}$





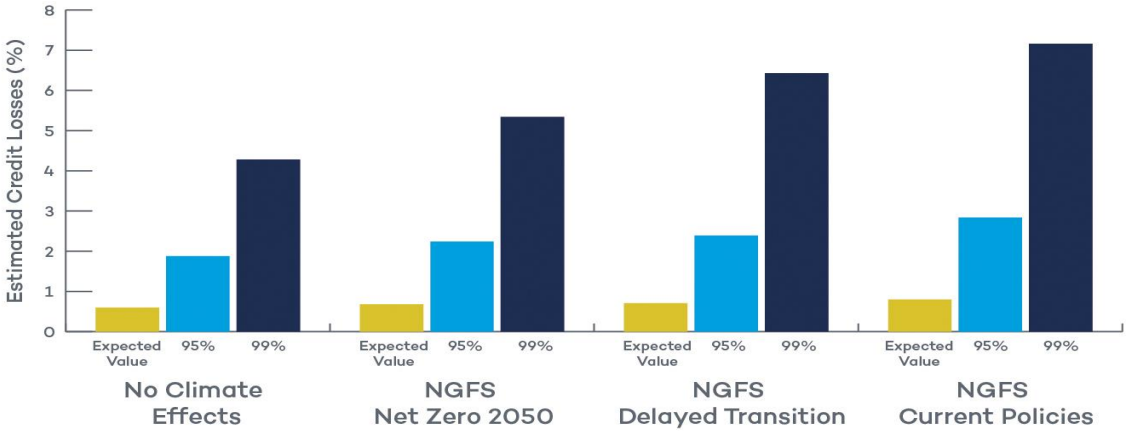


3. Future Climate Volatility Increases Tail Credit Losses: ZRE Vol Multipliers Applied in NGFS/GMT Simulations to 2050:

Results from Frontiers Paper

- Industry-Region Monte Carlo (IRMC) model:
  - Run climate-sensitive, industry & region, Z sims
  - Enters the industry-region Z sims into PD, LGD, and EAD models
  - Obtains loss sims
- Results for US C&I portfolio
- Future climate-driven volatility leads to higher credit losses when shocks occur – bigger 'tail risk'

Est 2050 Credit Losses for US C&I Portfolio



Source: Moody's CreditEdge, NGFS and Z-Risk Engine

Est 2050 Credit Losses for US C&I Portfolio

	Credit Losses 2050						
	Relative to Limit				Relative to Baseline		
Statistic	No Climate Effects Baseline	NGFS Net Zero 2050	NGFS Delayed Transition	NGFS Current Policies	NGFS Net Zero 2050	NGFS Delayed Transition	NGFS Current Policies
99th Percentile	4.55%	5.67%	6.32%	7.53%	1.25	1.39	1.65
95th Percentile	2.30%	2.75%	3.01%	3.56%	1.20	1.31	1.55
Expected Value	0.66%	0.75%	0.80%	0.90%	1.13	1.21	1.36

Source: Moody's CreditEdge, NGFS, and Z-Risk Engine

3. Models/Methodologies: Key Issues With Developing & Applying Climate Scenarios

- Implementing the Usual Stress Test **Fixed Portfolio Approach**:
  - SR stress testing ('static') assumes: 'constant balance sheet/unchanged business model'
  - But this isn't straight-forward in LR stress test simulations

- **Static technology assumptions** exclude a central feature of climate change economics

- Some CST Models Rely on **Unconventional Assumptions** of Less-than-Full Cost Passthrough

- Some CST Approaches **Apply Mostly 'TTC' PD Formulas** as opposed to PIT measures

- Contrary to Empirical Evidence, Models Assume that Credit Losses Occur Due to **Changes in Trends** (GDP) not **Shocks** (Unexpected Credit Risk)

4. E2E CST Implementation: Overview

- E2E ZRE Python CST Architecture:
  - Customized industry/regions
  - Run MEV (Deterministic or Simulations) or Credit-Factor Simulations
  - Flexible Scenarios: NGFS, Custom, Bank Management
- Integrated SR/LR, Borrower/Industry/Region E2E Model Architecture
- CST Scenario 'Sandbox': Multiple, Flexible Use Cases
- Climate Module Logical Architecture
- Z-Regional Segmentation Flexibility – Region Zs Potentially Reflect LR Physical Risk Differences
- Scenario Examples

4. 'What if' Scenario 'Sandbox': Supports Substantial Scenario Flexibility – Multiple Use Cases/Multiple Scenario 'Levers'

USER/BENCHMARKED DETERMINED 'WHAT IF' SCENARIO PARAMETERS

INDUSTRY X REGION X TIME

- **Apply use cases to individual industry sectors & regions**
- **'What if' scenario parameters – applied at any point over scenario time horizon**

USE CASES

- Vol Multiplier (GMT)
- SETP Event Shocks
- ECB/TTC Drift
- Strategic Portfolio Repositioning

USE CASE PARAMETERS

INDUSTRIES Zs

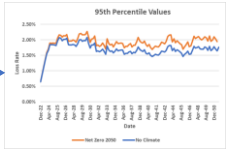
AEROSPACE & DEFENSE
AGRICULTURE
BANKING
BASIC INDUSTRIES
BUSINESS & CONSUMER SERVICES
CHEMICALS & PLASTIC PRODUCTS
CONSTRUCTION
CONSUMER PRODUCTS
FINANCE, INSURANCE & REAL ESTATE
MOTELS & LEISURE
MACHINERY & EQUIPMENT
MEDIA
MEDICAL
METALS
MINING
MOTOR VEHICLES & PARTS
OIL & GAS
RETAIL & WHOLESALE TRADE
TECHNOLOGY
TRANSPORTATION
UTILITIES

REGION Zs

NORH AMERICA
LATAM
EUROPE
UK
GERMANY
FRANCE
NORDICS
CHINA
SE ASIA
AUSTRALIA
MIDDLE EAST
UTILITIES

ZRE CLIMATE ECL SIMULATIONS

SCENARIO %'TILE ASSUMPTION



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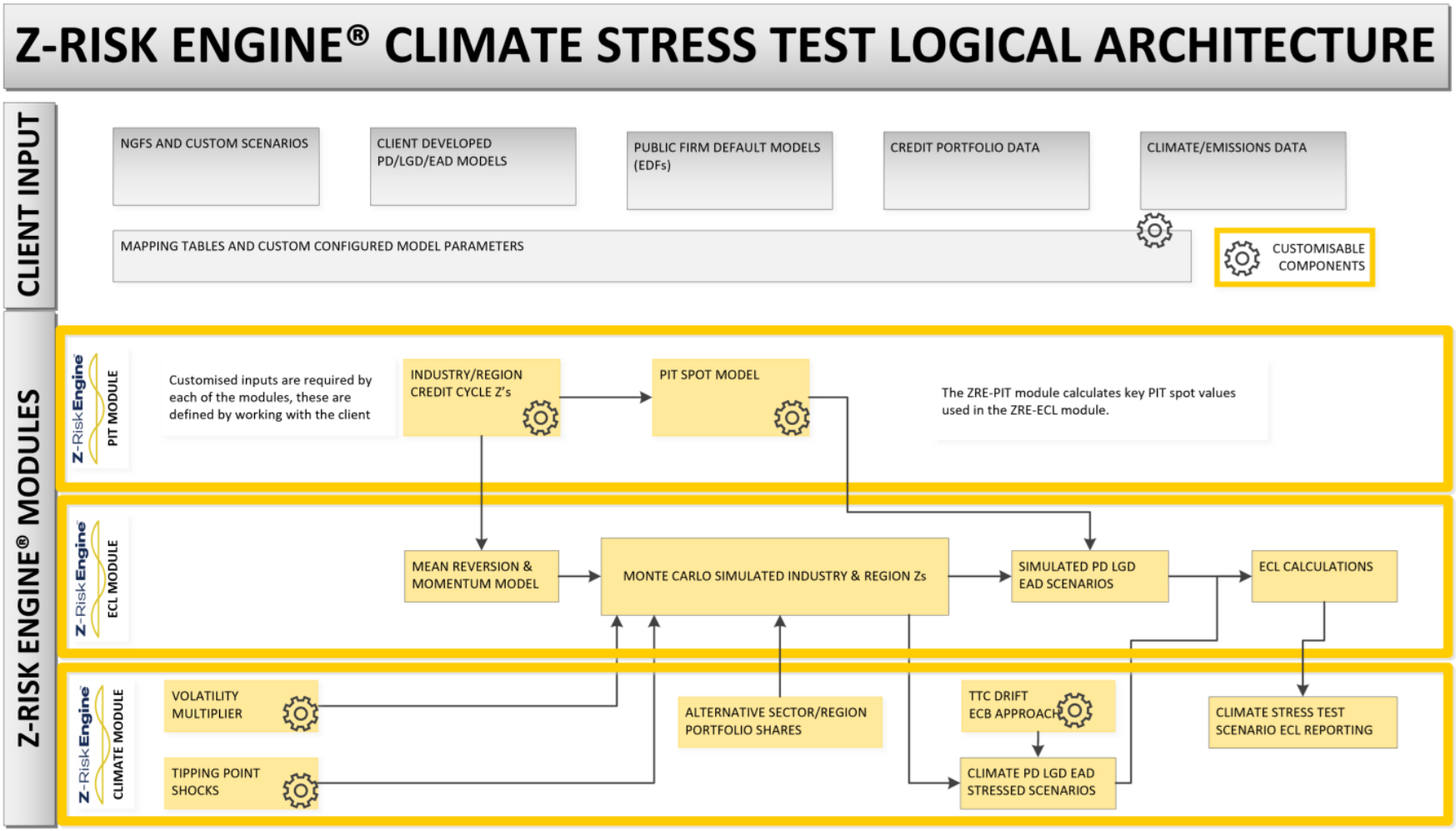
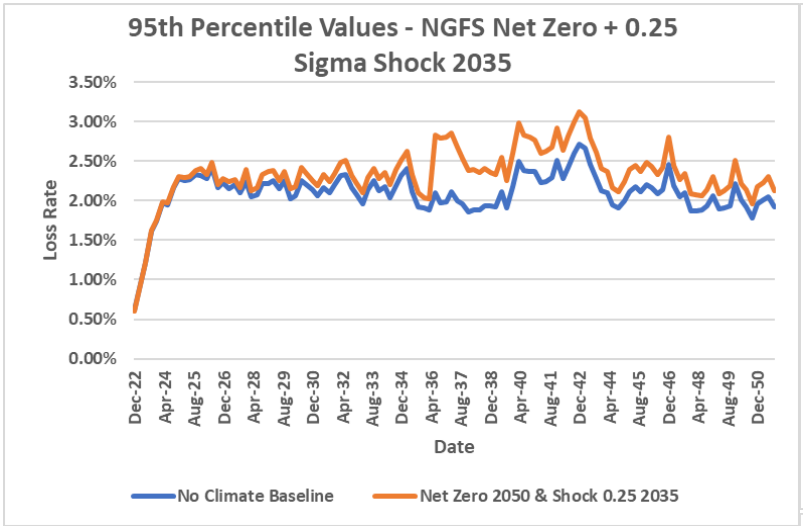
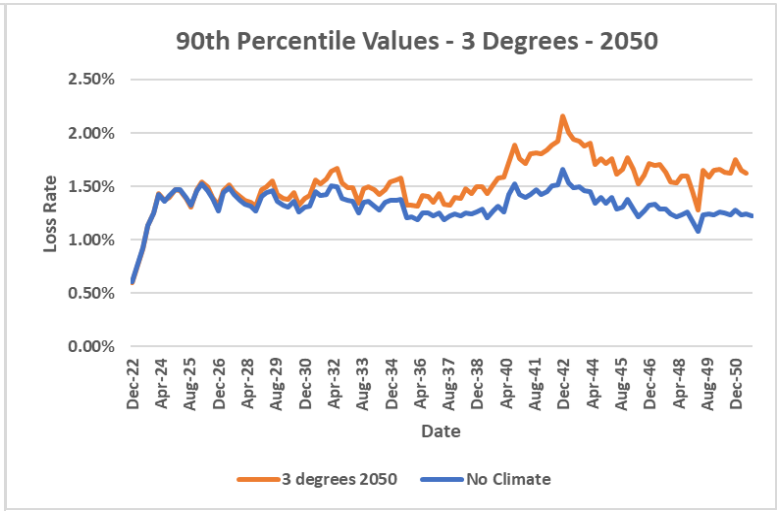
4. Z-Risk Engine Climate Stress Test Module Logical Architecture

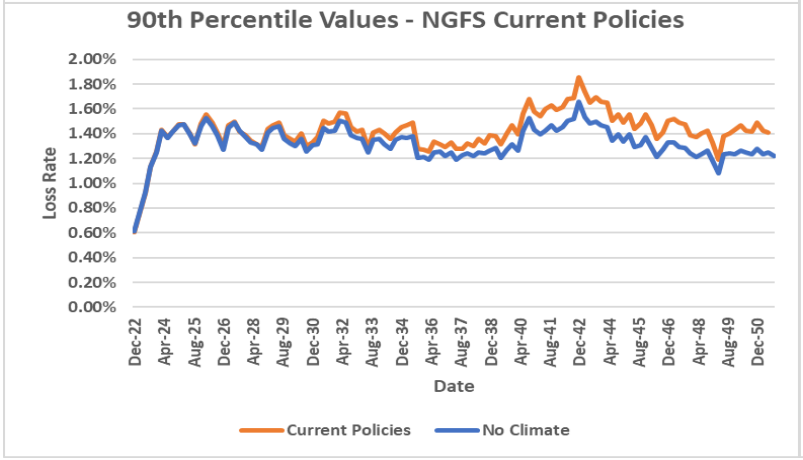


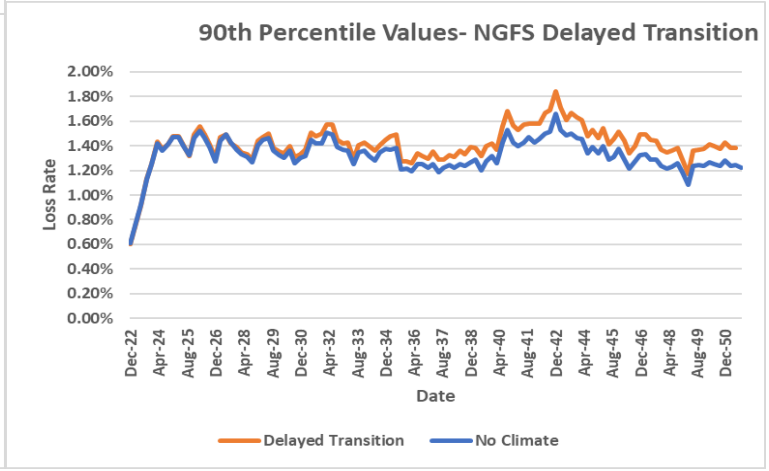
4. Examples of NGFS Scenario Credit Portfolio Losses – Volatility & Climate Shocks Use Cases – Preliminary PoC Results

- ZRE industry sector & region Zs are ***customized*** to a bank's portfolio composition
- Industry sector and region Zs are ***combined*** to determine PIT credit model adjustments





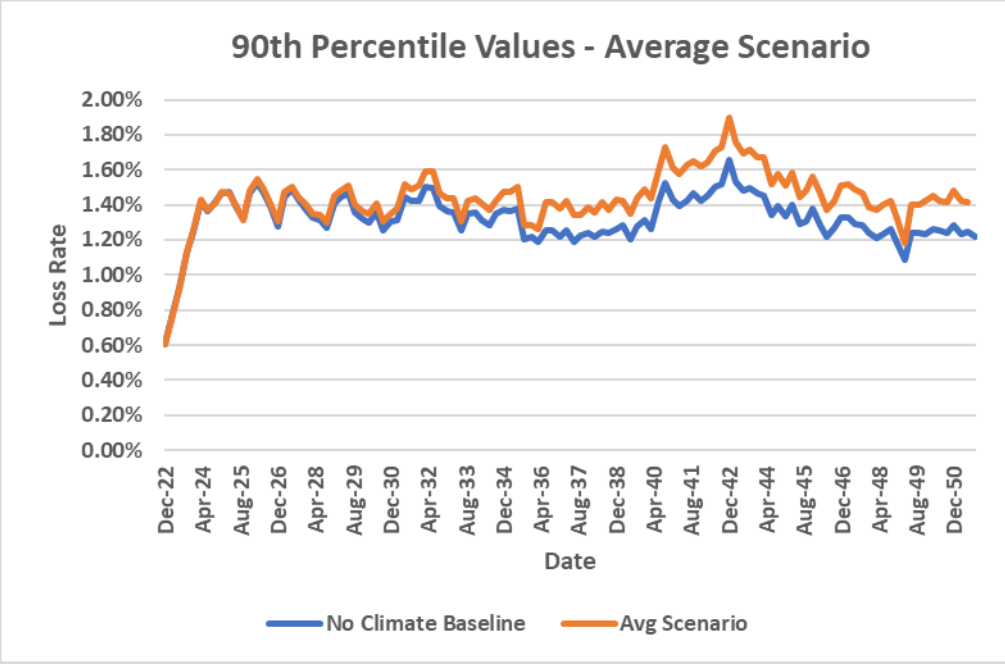




4. Combining Multiple Climate Scenarios – Weighted-Average 90th Percentile Climate Scenarios From 4 Scenarios – Preliminary PoC Results

- *No Climate Impact Scenario (30%*)*
- *NGFS Current Policies (14%)*
- *NGFS Delayed Transition (14%)*
- *3 Degrees C Net GMT Rise by 2050 (14%)*
- *NGFS Net Zero + 1.0 sigma shock in 2035 (14%)*

- **User determined loss %'tile**
- **Unlike most IFRS9 model scenario aggregation the scenario weights can have some empirical foundation**



** Weights are illustrative ('no climate' = 30% weight, the 4 climate scenarios are equally weighted, 17. 5%)*

Source: Z-Risk Engine Climate Simulations using 2k facility US/UK credit portfolio from 2023 c ZRE Climate Research Note Appendix

5. Implementation Roadmap: Integrated CST Scenario Solution for EU/ECB/EBA

- EU/ECB Roadmap Due – Solution: Three-Month PoC Pilot + 1 Year Implementation
- Review & Apply High-Level CST Requirements (See Appendix I for examples)
- Design & Implement Integrated LR Credit-Factor Scenario Approach:
  - LR scenario solution **integrated** with Bank climate credit-model adjustment approach
  - **Climate Customized** industry/region segmentation
  - Run MEV (Deterministic or Simulations) or Credit-Factor Simulations
  - **Flexible Scenarios**: NGFS, Custom, Bank Management etc
  - **Multiple Scenario Use Case 'Sandbox'** – Vol, Shocks, ECB/TTC Drift, Strategic Portfolio Repositioning
- Key Task: **Enhance 'Brown/Green' Climate Segmentation** – Industry Sectors
- CST Model Validation – **ZRE Approach Officially Approved** by in Multiple Banks – **'Jump Start' for CST LR Model Validation**
- E2E ZRE Python Code Architecture Integrated With Bank Data Systems & Bank Climate Credit Models

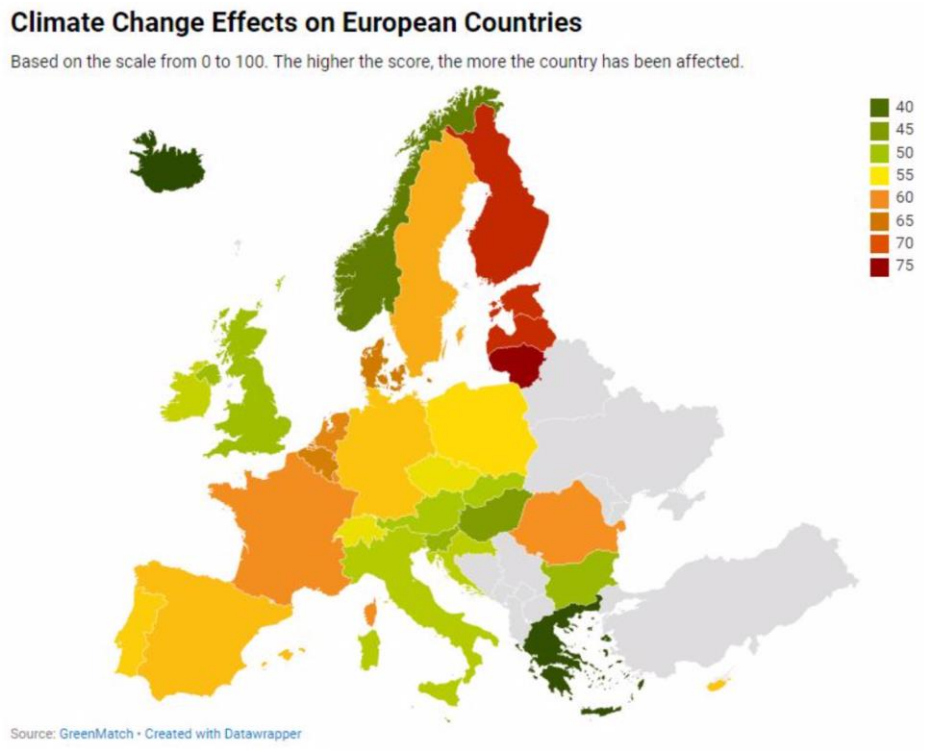
5. ZRE EU CST Implementation – Region Z Proxies for LR Physical Risk?

Extreme Weather Indices Show Current Volatility Has a Regional Dimension

Region Factor May Impact Systematic Population Migration/Social Shocks etc

POTENTIAL EURO REGIONAL Zs SEGMENTATION

EUROPE
SOUTHERN EUROPE
UK
GERMANY
FRANCE
SPAIN
ITALY
NETHERLANDS
NORDICS
SWEDEN
DENMARK
TURKEY
OTHERS (Benelux, Poland) ?



5. Industry Sector Data Segmentation Concerns: Expand EDF Sector Segments for Better Brown/Green Climate Differentiation

GOAL: Enhancing Credit-Factor Sector Segmentation – Develop 'Bottom-up' CreditEdge EDF Exercise

ZRE Industry Sectors vs NACE Level 1 Used as a Foundation of Some Climate Segmentations

CURRENT ZRE NDUSTRY SECTORS

AEROSPACE & DEFENSE
AGRICULTURE
BANKING
BASIC INDUSTRIES
BUSINESS & CONSUMER SERVICES
CHEMICALS & PLASTIC PRODUCTS
CONSTRUCTION
CONSUMER PRODUCTS
FINANCE, INSURANCE & REAL ESTATE
MOTELS & LEISURE
MACHINERY & EQUIPMENT
MEDIA
MEDICAL
METALS
MINING
MOTOR VEHICLES & PARTS
OIL & GAS
RETAIL & WHOLESALE TRADE
TECHNOLOGY
TRANSPORTATION
UTILITIES

- 'CPRS' – 'Climate Policy Relevant Sectors' – Process for Mapping (Battiston)
- Current CST Research – Industry Sectors – No Standards Yet
- Focus is on mapping GHG/Emissions to Sectors
- IAMs Variables – 1000s
- NACE – 1000s of 4-digit codes
- ***Need enhanced, climate sectors for CST risk modelling***
- **CreditEdge 37k EDFs – detailed 'risk' source**

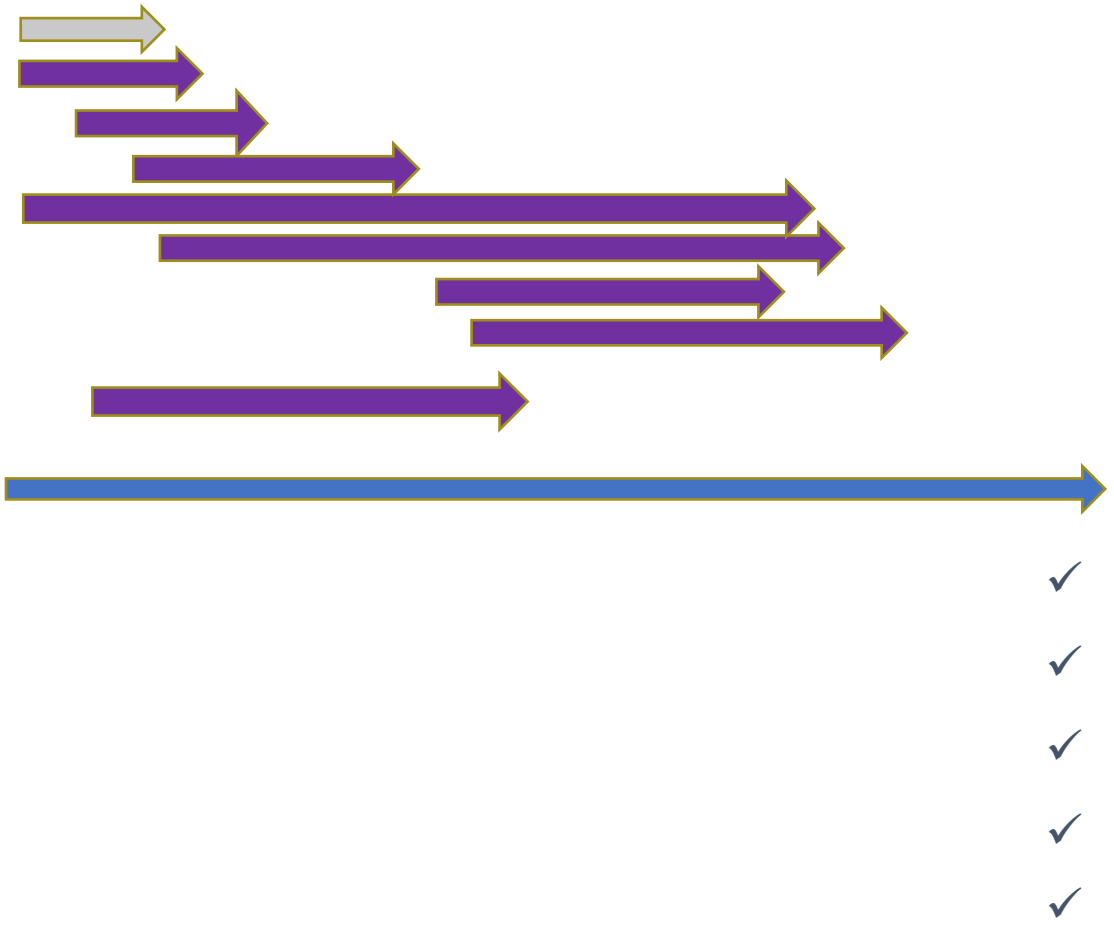
NACE LEVEL 1 INDUSTRY SECTOR CODES*

AGRICULTURE, FORESTRY & FISHING
MINING & QUARRYING
MANUFACTURING
ELECTRICITY, GAS STEAM & AIR CONDITIONING
WATER SUPPLY, SEWAGE & WASTE WATER MANAGEMENT
CONSTRUCTION
WHOLESALE & RETAIL TRADE
TRANSPORTATION & STORAGE
ACCOMODATION & FOOD SERVICE ACTIVITIES
INFORMATION & COMMUNICATION
FINANCIAL & INSURANCE ACTIVITIES
REAL ESTATE ACTIVITIES
PROFESSIONAL, SCIENTIFIC & TECHNICAL ACTIVITIES
ADMINISTRATIVE & SUPPORT SERVICES
PUBLIC ADMINISTRATION & DEFENSE
EDUCATION
HUMAN HEALTH AND SERVICES
ARTS, ENTERTAINMENT & RECREATION
OTHER SERVICES
ACTIVITIES OF HOUISEHOLDS AS EMPLOYERS
ACTIVITIES OF EXTRETERRESTRIAL ORGANISATIONS

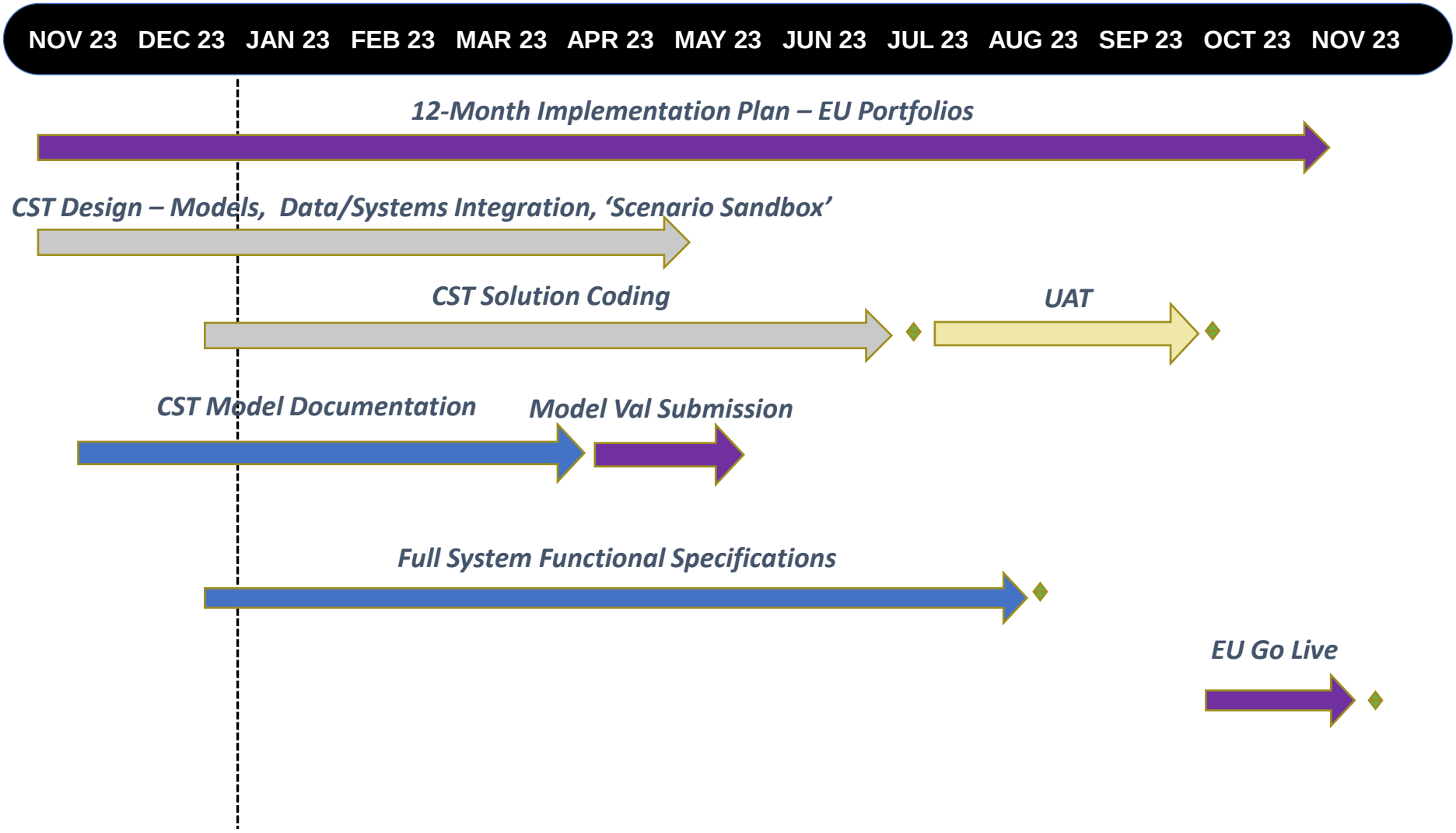
** Source: Battiston et. al, (2022), 'The NACE – CPRS – IAM mapping: A tool to support climate risk analysis of financial portfolios using NGFS scenarios', October.*

5. CST PoC Pilot DRAFT Project Plan: Integrated CST Scenario Capability

CST PILOT: PLAN & TASKS
Pilot Plan & Project Set-up
Review Key ECB CST Regulatory Requirements
Conduct Workshops on ZRE Models & Architecture
Conduct Workshops on 4 ZRE CST Use Cases
Develop Joint CST PoC 'Sandbox' Working Prototype
Review Required Bank Data/Systems Integration
Assess Bank EU test portfolios – impact analysis
Expand Brown/Green Industry Sector Segmentation – Develop Regional Segmentation Linked to Physical Risk Indices
Develop Preliminary Bank Scenario Process & Pilot Deliverables – Integrated with bank borrower climate-adjusted models
CST PILOT: EU DELIVERABLEs
Full EU Implementation Plan, Model Val, Test & Go-Live
High-Level Business Case & Resource Requirements
Proposed Integrated CST Architecture
Bank Data/Source Systems Integration Plan
CST Models/Methodology Overview
CST Implementation Data Attributes List
Stakeholder Plan & Syndication Approach
CST PoC 'Sandbox' Prototype With EU Test Portfolio



5. DRAFT EU CST Implementation Plan – EU Climate Scenario Capability



** Draft Plan based on previous ZRE production implementation timeframes.*

6. Key Summary Points:

- Current CST Approaches: **Can't Project Long-Run Company Financials Well**
- Complex Future LR Climate Risk – **'Shocks Not Trends'**
- Climate Credit Risk Not Observed Empirically: **Need Solid Credit Factor Foundation**
- Climate Stress Testing – Infancy – **Banks can influence their destiny**
- **ZRE CST Implementation:**
  - **Integrated flexibility**: SR, LR, Multi-Scenario, Multiple Use Cases, Bank Developed Borrower Models
  - **Existing Production Architecture:** Minimizes Implementation Risks – Clear Migration Path to Global Portfolio Coverage
  - **Joint development** – Bank controls source code & models

6. Regulatory Background Documents Examples of High-Level Requirements

- Borrower Climate-Adjusted Credit Models:
  - BCBS (2022), 'Frequently asked questions on climate related financial risks', BIS, December

- Climate Stress Testing - General:
  - ECB (2021): 'Climate risk stress test: SSM stress test 2022', October.
  - ECB (2022): '2022 climate risk stress test', July.
  - ECB (2022), 'ECB report on good practices for climate stress testing', December.
  - ECB (2021), 'ECB economy-wide climate stress test – Methodology and results' No 281, September
  - BIS, FSI, (2021), 'Stress-testing banks for climate change – a comparison of practices', July.
  - BoE (2023), 'Bank of England report on Climate-related risks and the regulatory capital frameworks, March.
  - BoE, (2021), 'Results of the 2021 Climate Biennial Exploratory Scenario (CBES)', May.
  - NGFS (2022), 'Final report on bridging data gaps', July.
  - EBA, (2021), 'Mapping climate risk: Main findings from the EU-wide pilot exercise', May.
  - Battiston et. al, (2022), 'The NACE – CPRS – IAM mapping: A tool to support climate risk analysis of financial portfolios using NGFS scenarios', October.

7. Bibliography: Recent Climate Risk, Stress Test Papers, DBS ZRE Case Study

Aguais, S. and Forest, L. (2023 d), 'Developing Climate Change Scenario Impacts on Credit Models – Applying the ECB Climate Stress Test Approach Through ' TTC PD Drift', Z-Risk Engine, Climate Stress Testing Research Note Num Three, June.

Aguais, S, and L. Forest, (2023, c), 'Climate-Change Scenarios Require Volatility Effects to Imply Substantial Credit Losses–Shocks Drive Credit Risk Not Changes in Economic Trends', Decision Making for the Net Zero Transformation: A Compendium of Best Practice, www.frontiersin.org, April.

Aguais, S. and Forest, L. (2023 b), 'Assessing Climate Related 'Socio-Economic Tipping Point' Risk Impacts by Applying Credit-Factor Shocks, Z-Risk Engine, Climate Stress Testing Research Note Num Two, April.

Aguais, S. and Forest, L. (2023 a), 'The Climate Change 'Hockey Stick' is Observable – But Climate Change Impacts on Economic Risks are Note Yet Observable', Z-Risk Engine, Climate Stress Testing Research Note Num One, March.

Aguais, S, and L. Forest, (2022, a), 'Climate Change Credit Risk Triptych, Paper One: Smooth NGFS Climate Scenarios Imply Minimal Impacts on Corporate Credit Losses', ZRE Working Paper Published at RiskMinds International, November 7.

Aguais, S, and L. Forest, (2022, b), 'Climate Change Credit Risk Triptych, Paper Two: Climate Change Volatility Effects Imply Higher Credit Losses', ZRE Working Paper Published at RiskMinds International, November 7.

Aguais, S, and L. Forest, (2022, c), 'Climate Change Credit Risk Triptych, Paper Three: Climate Change Macro Volatility Effects Imply Higher Credit Losses', ZRE Working Paper Published at RiskMinds International, November 7.

Aguais, Scott, (2022), 'Musings on Long Run Climate Stress Test Modelling for Banks', presentation, Marcus Evans, Climate Stress Testing, June 16, 2022, London, ZRE website.

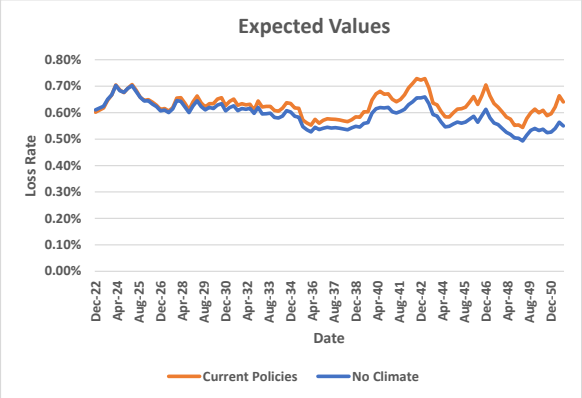
Z-Risk Engine Case Study, (2022) 'Supporting Integrated IFRS 9 and Stress Testing at DBS Bank', August, https://www.z-riskengine.com/media/myukq4mu/zre_dbs_case_study_aug22.pdf

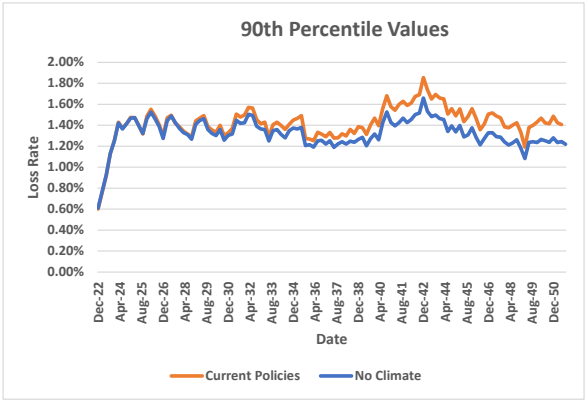
1. Why the sudden uptick in loss rates at the beginning few years? Non-climate related factors?

The early sharp rise in the 90th percentile loss rate occurs as a result of accumulating shocks, driving projected, tail losses up relative to the last, historical, point estimate based on known, Z values. In that last, historical quarter, the loss distribution is degenerate, reduced to a point, and the 90th percentile loss is no different from the mean. As random shocks add risk during future quarters, the loss distribution spreads out (variance increases) and the 90th percentile value rises both absolutely and relative to the mean. The skewness in the loss distribution contributes to making this effect large. The tail loss initially rises sharply. But, due to ever declining proportional effects of additional shocks (remember the square root rule), the rate of increase in the tail loss diminishes as the scenarios move out in time. Finally, the tail loss stabilizes as mean reversion attenuates growth in the variance. Any further, slow growth at that point would arise from intensifying effects of climate change.

Secondarily, the early profile of tail losses will reflect any mean reversion and momentum implied by initial credit conditions. But in the examples shown those effects are small.

As one can see below, expected values, which aren't affected by the expanding variance nearly as much as 90th percentile values, don't have a big uptick in the early periods.

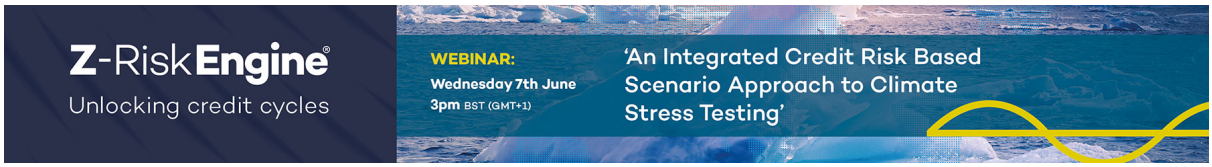




2. What kind of simulations do you run for each shock scenario? and does the systematic risk factor change when you apply the climate shocks?

All of our simulations involve credit-factor shocks selected at random from a probability distribution derived from past experience. The shocks for industries and regions come either from a normal distribution with variances and covariances determined from the historical record or, more often and in the results presented in the Webinar, from an historical, empirical distribution. In scenarios with future, climate-change effects, we apply to the shocks selected from the historical distribution multipliers with above-unitary values obtained from the assumed, GMT/volatility relationship.

The multipliers vary over time as GMT changes in a climate scenario. However, for each climate scenario, the GMT paths are deterministic, the same for each of the sims. A more general and realistic approach would treat the GMT changes as stochastic, affected by such things as unexpected policy changes, technological breakthroughs, and natural phenomena. We're unaware of any models today that model climate change stochastically.



We also presented an example in which we assumed that, in addition to the randomly selected shocks, a major, climate-change, credit event occurs in a particular quarter. All of the sims in this example include this specified, discrete shock. This is a heuristic case, which illustrates how a shock affects credit losses not only in the quarter in which it occurs but also in subsequent quarters. But shocks are unexpected events. So, it's better to generate them by the random-selection approach.

The systematic factors become more volatile as climate-related events become more important. Otherwise, the factors don't change. We view climate-related shocks as a source of risk on top of unchanging, non-climate shocks.

The systematic risk factors in ZRE consolidate effects of all kinds of credit events, including climate-related ones. One could select climate and non-climate shocks separately, but, after that, to get credit impacts one would have to consolidate the two kinds of shocks. Thus, deconsolidation would have no big, overall effect on the credit-loss estimates. However, one might deconsolidate in distributing effects differently to climate-sensitive and insensitive sectors. ZRE does this currently by assigning larger volatility increases to more, climate-sensitive industries. Deconsolidation of shocks might provide for more refined allocations of effects.

3. Can you specify what is the reference for the ECB framework that is mentioned across the slides?

Occasional Paper Series**,** ECB economy-wide climate stress test. Methodology and results
Spyros Alogoskoufis, Nepomuk Dunz, Tina Emambakhsh, Tristan Hennig, Michiel Kaijser, Charalampos Kouratzoglou, Manuel A. Muñoz, Laura Parisi, Carmelo Salleo, No 281 September 2021

4. How can we link this model with the macrovariables projections (GDP...) in NGFS or EBA scenarios?

As an option, ZRE includes a module that generates Z and credit loss scenarios on the basis of either user provided or simulated, macroeconomic variable (MEV) paths. You'll find results from MEV-based scenarios in some of our publications.

In running such scenarios, ZRE uses a bridge model that translates MEV paths into industry and region, Z paths, which then produce credit loss projections. We estimate the bridge model on the basis of past data on MEVs and Zs. However, if, as shown in one of our recent publications, the MEVs defining the scenario include only National Account aggregates such as GDP, the projections will show unduly modest effects on credit losses. Again, one need large, adverse shocks to credit-related, PIT indicators to obtain large, credit losses. Thus, one must take care to select MEVs with strong PIT relationships to credit risk. Such MEVs might include stock-price and credit-spread indices.

As with ZRE's standard sims produced by AR(2) models for industry and region Zs, the approach that starts with credit-relevant, MEV sims translated into industry and region, Z sims produces probability distributions for credit losses. Thus, one gets a richer set of results than possible with user-defined, MEV scenarios.

5. Also it will be great to have the list of your publications which create the background of the framework presented.

Please see the presentation.

6. What Is the justification for assuming this mean reversion, as opposed to considering a drift perhaps for extreme physical risk scenarios?

ZRE does allow the user to input a drift in TTC PDs attributable to rising physical risk or other, accreting changes. However, one can argue that businesses would adapt to such, gradually rising risks, by relocating or fortifying facilities or insuring against damage. Costs would likely rise, but, with full passthrough of industry-wide costs, the broad impact on credit losses would be small. Based on past experience, large, portfolio-wide credit losses arise from big, sudden, unexpected events, not slowly accreting ones.

Mean reversion of the factors is a longstanding empirical property. Mostly we see it in recoveries from recessions. We might attribute it to business and governmental, countercyclical actions.

7. Have you looked at any potential correlations between EDF time series and crop production, food prices to investigate 'a hook'

Haven't look for a relationship between PDs and crop production/food prices. Will do so. However, crop production and food prices are notoriously, idiosyncratically volatile. So, while one might well find agribusiness PDs moving together with crop production and food prices, it would be surprising to find a broader relationship.

8. What is the data model that should be in place in order to run in 3 months a pilot as described in slide 22?

ZRE's Required Data:

- Include about 10 attributes
- Describe the default risk of each facility/transaction
- Provide TTC or DT LGDs and EADs for each facility or alternatively a list of model inputs permitting calculation of those LGDs and EADs
- Reveal the primary industry and region for each facility's obligor
- Offer enough classification information to allow summation across all important sub-portfolios

INSTRUMENT ID	FACILITY ID	OBLIGOR ID	PRIMARY COUNT	PRIMARY INDUST	TTC PD	DT LGD	DT CCF	DT FCF	LIMIT	EIR	UTILIZATION	MATURITY
CONINST0000000001INST-INST3INST-INST2020	CONFAC0000000001FAC-FAC3FAC-FAC2020	1 PHL	N59		0.00258	0.516399	0.31	0.12	6024000	0.1312	0.507485817	31/08/2025
CONINST0000000001INST-INST3INST-INST2019	CONFAC0000000001FAC-FAC3FAC-FAC2019	1 PHL	N59		0.00258	0.374528	0.31	0.25	680400	0.317319	0.275175731	31/08/2023
CONINST0000000002INST-INST6INST-INST2018	CONFAC0000000002FAC-FAC6FAC-FAC2018	2 AUS	N38		0.000206	0.618822	0.31	1	140800	0.292148	0.223330213	30/11/2024
REVINST0000000002INST-INST6INST-INST2016	REVFAC0000000002FAC-FAC6FAC-FAC2016	2 AUS	N38		0.000206	0.725224	0.39	1	457600	0.68317	0.46360672	30/06/2025
TERINST0000000002INST-INST6INST-INST2013	TERFAC0000000002FAC-FAC6FAC-FAC2013	2 AUS	N38		0.000206	0.966669	1	1	1142400	0.258744	1	31/05/2031
TERINST0000000003INST-INST3INST-INST2021	TERFAC0000000003FAC-FAC3FAC-FAC2021	3 AUS	N18		0.000206	0.403764	0.31	0.66	7867800	0.266081	1	30/06/2026
REVINST0000000005INST-INST3INST-INST2018	REVFAC0000000005FAC-FAC3FAC-FAC2018	5 JPN	N11		0.00258	0.553021	0.39	1	6333600	0.012332	0.026086536	31/12/2023
TERINST0000000005INST-INST3INST-INST2015	TERFAC0000000005FAC-FAC3FAC-FAC2015	5 JPN	N11		0.00258	0.806001	0.31	1	1585600	0.5213	1	30/11/2026

ZRE INPUT REQUIREMENTS	DESCRIPTION	CONDITIONS
Unique identifier	This could be an instrument ID, Facility ID or obligor ID	Must be unige in the data provided
TTC PD	**PD Calculation** - Through-The-Cycle (TTC) probability of default (PD) as required by Basel capital calculations	must be a value betwee 0 and 1
DT LGD	**LGD Calculation** - Downturn (DT) Loss-Given-Default rate (LGD) as required by Basel capital calculations	must be a value betwee 0 and 1
DT CCF	**EAD Calculation** - DT Credit-Conversion-Factor (CCF) as required in determining DT Exposure-At-Default (EAD) used in Basel capital calculations	must be a value betwee 0 and 1
DT FCF	**EAD Calculation** - DT Fulding-Conversion-Factor (CCF) = expected proportion of contingent exposure that becomes funded in a DT (aka DT prdouct CCF)	must be a value betwee 0 and 1
LIMIT	**EAD Calculation** - maximum drawn or outstanding amount undjer a facility (aka commitment or authorized commitment)	Absolute value
UTILIZATION	EAD Calculation - current utilization, identifying drawn amount. DRAWN amount can be provided and utilization can be derived by drawn/limit	must be a value betwee 0 and 1
MATURITY	Remaining term of the facility	Date
EIR	Effective Interest Rate of the facility	must be a value betwee 0 and 1
PRIMARY INDUSTRY	Industry code that a ZRE industry can be mapped	
PRIMARY COUNTRY CODE	ISO 2 or 3 letter code that a ZRE region can be mapped	

ZRE OUTPUT	DESCRIPTION
PIT SPOT VALUES	PD, LGD and EAD PIT spot values
PIT FORECASTED VALUES	PD, LGD & EAD forecasted values
ECL ONE YEAR	Expected Credit Losses during the next 12 months (or upto maiurity if less); expressed as a present value using EIR for discounting
ECL LIFETIME	Expected Credit Losses over remaining maturity; expressed as a present value using EIR for discounting

ZRE STANDARD INDUSTRIES
AEROSPACE AND DEFENSE
AGRICULTURE
BANKING
BASIC INDUSTRIES
BUSINESS AND CONSUMER SERVICES
CHEMICALS AND PLASTIC PRODUCTS
CONSTRUCTION
CONSUMER PRODUCTS
FINANCE, INSURANCE AND REAL ESTATE
GLOBAL
HOTELS AND LEISURE
MACHINERY AND EQUIPMENT
MEDIA
MEDICAL
METALS
MINING
MOTOR VEHICLES AND PARTS
NEC
OIL AND GAS
RETAIL AND WHOLESALE TRADE
TECHNOLOGY
TRANSPORTATION
UTILITIES

ZRE STANDARD REGIONS (CORPORATE & FI)
AFRICA
ASIA
EUROPE
LATIN AMERICA
MIDDLE EAST
NORTH AMERICA
PACIFIC
UK

9. Time series modelling can focus too much in short term prediction (quarters), Would not be more interesting to use macrovariables to predict long term behaviour?

See the previous answer regarding the use of MEVs as the basis for credit-loss projections. We've experimented with both the time-series and selective-MEV-based projections over extended horizons. We get similar results.

Note that the ZRE Zs are MEVs in the sense that they are aggregate indicators. Involving summary data related to business cash flows, asset values, liabilities, and volatility, they are aggregate measures of credit risk and not of something else that might have only a tenuous relationship to credit. Most MEVs other than the ones closely related to the Zs have only tenuous relationships to credit. Further, the Zs involve credit relationships that have been enduring for more than 30 years. Thus, they seem proper for both short- and long-run forecasting. Will the changes in business behaviour and technology over many years upend the longstanding finding that credit risk arises from the volatility in cash flows and asset values relative to liabilities? Probably not, we believe.