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How Insurers Can Lead Through Climate Risk Uncertainty

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Speakers

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Michael is Managing Partner at Kynesis and has over 20 years of experience working in the life insurance industry, having notably served as Group Chief Actuary of a multinational life insurer and Principal of an international consulting firm. Michael specializes in actuarial system transformation, modelling and balance sheet management. He has authored several publications and spoken at various EAA seminars and web sessions on modelling in general and climate modelling in particular. He has been teaching modelling as part of the EAA's CERA working party since 2011 and he is member of the Climate Scenarios working party of the German Actuarial Association since 2022.

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Abdal is Managing Partner at Kynesis and has over 15 years of experience working in the life insurance industry. Abdal specializes in Solvency II reporting, risk calibrations, proxy modelling and capital management and has delivered several projects in these areas for large UK- and EU-based life insurance companies. Abdal has led research into the impact of climate change on life insurance risks, applications of machine learning techniques to enhance historical climate data and improve future climate projections. Abdal has made several contributions towards the use of machine learning techniques for optimization of Solvency II Internal Model SCR calculations.

- **Introduction**
- Forecasting Emissions
- Market Risks
- Case Study A – Mortality
- Case Study B – Emerging Risks
- Conclusions

Quote from a speech by EIOPA Chairperson Petra Hielkema (04/2024)

> *Insurers have a monumental role to play in the fight against climate change by*
>
> - *Informing our societies*
> - *Incorporating risks*
> - *Investing funds*
> - *Incentivising consumers towards more resilient behaviours.*

Our focus today: Incorporating risks

- Examples of climate-induced market risks and a few ways of looking into these
- Examples of climate-induced insurance risks and a few ways of dealing with these

Categories of Climate-Induced Risks

Three categories: Physical risks, transition risks and litigation risks

Physical Risks

Risks that result from natural events or physical conditions

- **Acute:** Risks that are short-terms and occur suddenly, such as floods, hurricanes or wildfires
- **Chronic:** Longer-term risks that occur over time and develop gradually, such as sea level rise

Transition Risks

Risks from transition to low-carbon economy

- **Technology:** A product can be displaced
- **Market Price:** Rising raw material costs => rising price for a product
- **Regulatory:** Carbon tax increase => Extra costs of business model
- **Reputational:** Negative headlines / scandals

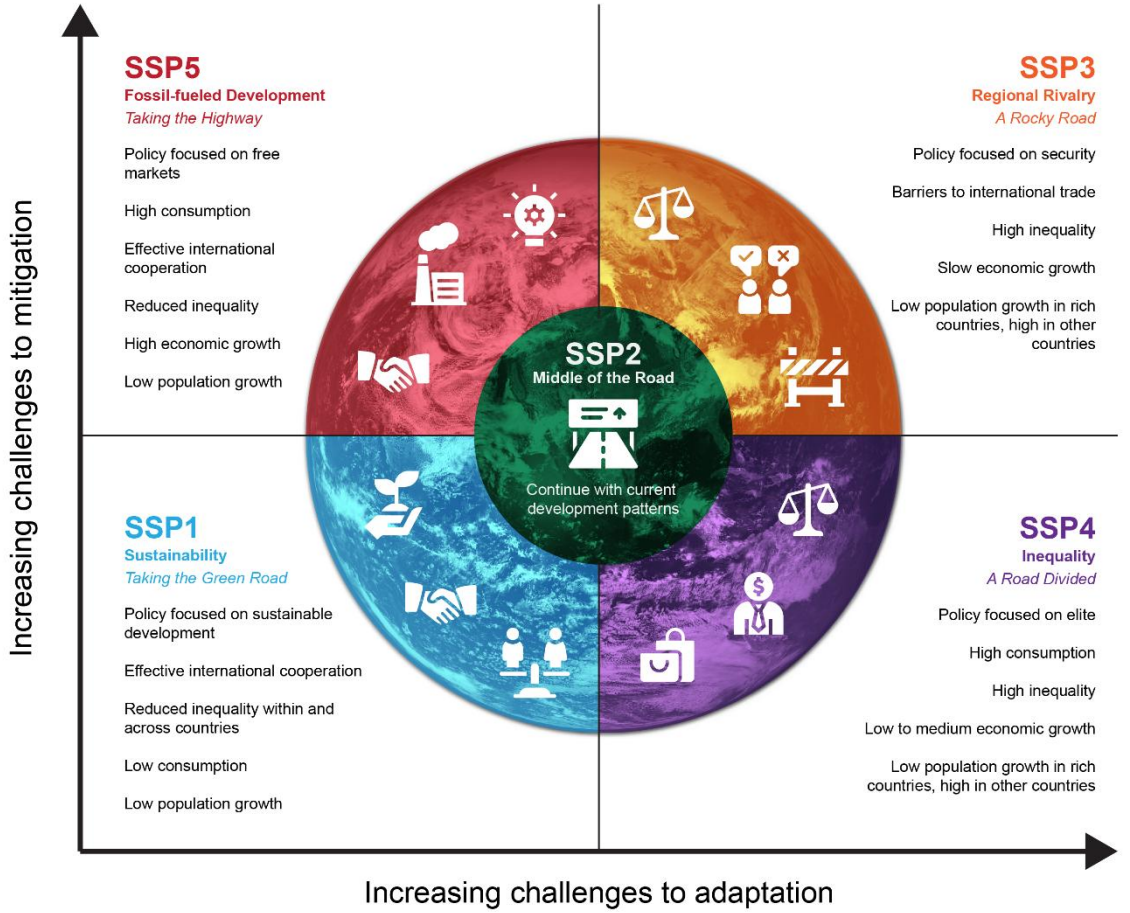
Litigation Risks

Legal risks of facing lawsuits, often arising from a failure to manage or disclose physical and transition risks

Outcomes Will (Greatly) Depend on Climate Scenario

- SSPs (aka **S**hared **S**ocioeconomic **P**athways) are very 'deterministic' about economic growth.
- Each narrative has one and only one economic growth trajectory and associated socioeconomic variables (per country/region) associated with it.
- Admittedly, if you condition on a particular GDP growth path, the probability of that path becomes 1.
- But this only makes sense if the conditioning paths have been chosen on the basis of being the most representative ones.
- There is no guarantee that the five SSPs narratives are the most likely, or indeed particularly representative.

Climate Stress Testing and Scenario Analysis, R. Rebonato



Understanding Shared Socio-economic Pathways (SSPs), March 2024, https://climatedata.ca/resource/understanding-shared-socio-economic-pathways-ssps/

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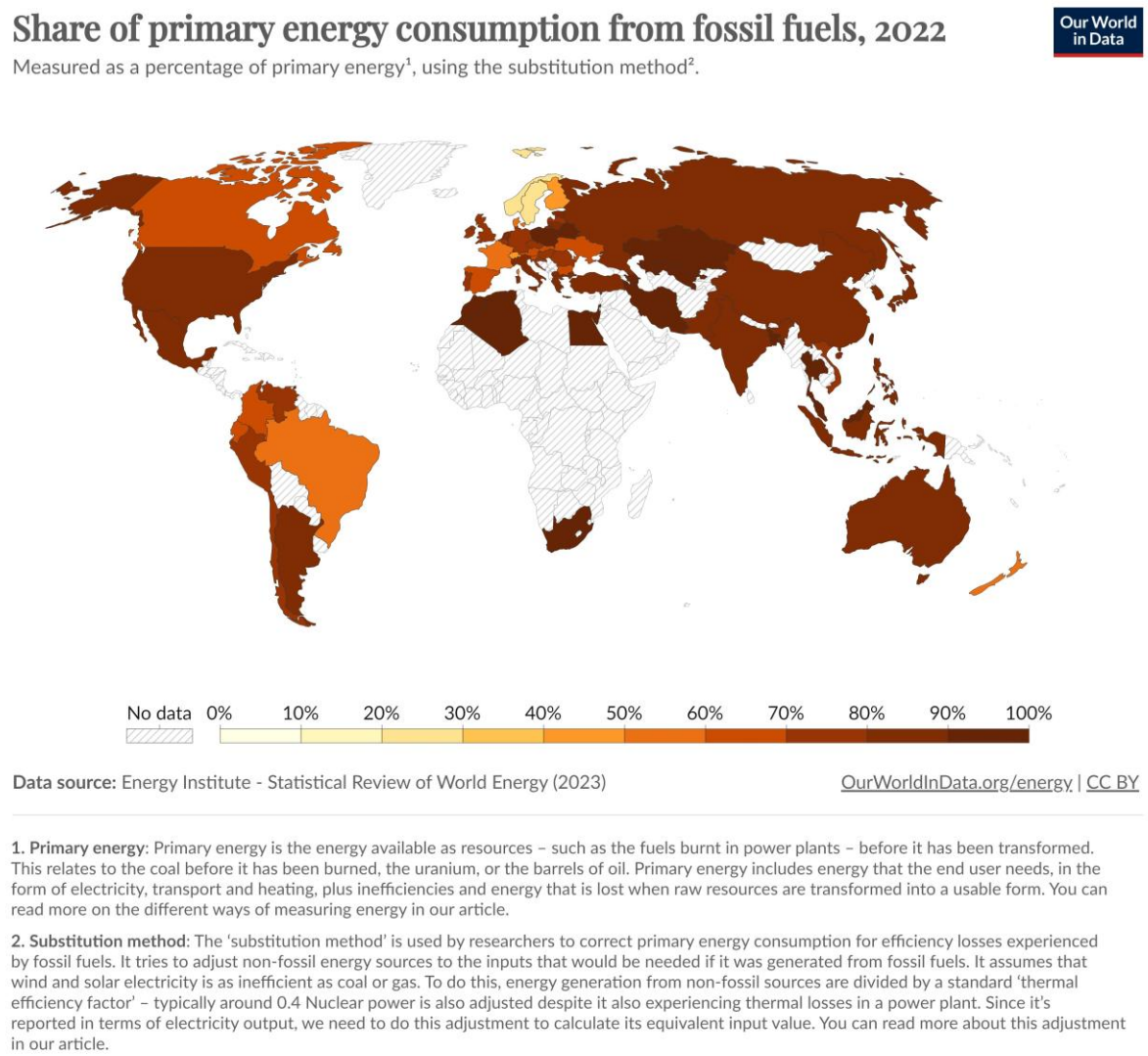
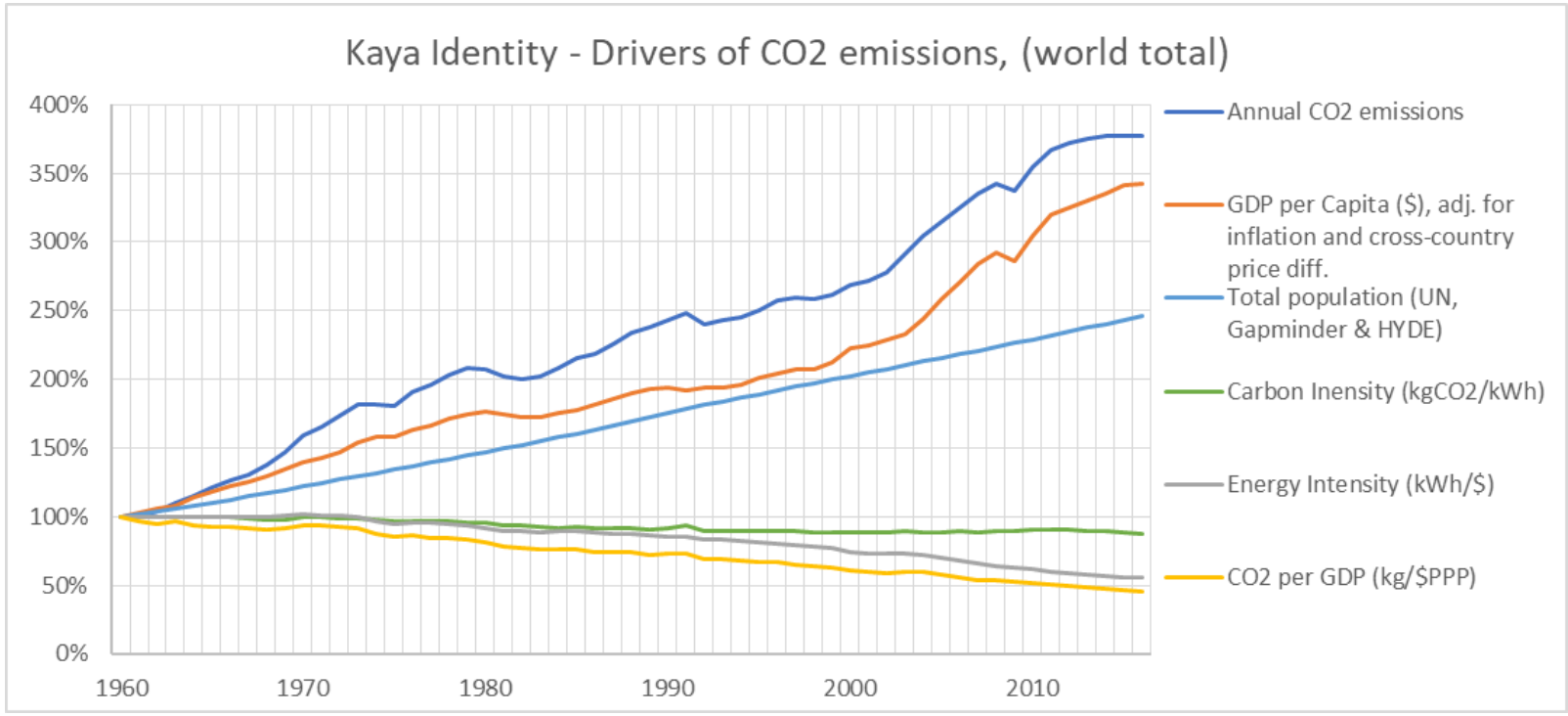
Fossil Fuels and Forecasting Emissions (1/4)

Most buried organic carbon is not suitable to use as fossil fuel! E.g. limestone rocks

- **Coal** – mostly elemental carbon, halfway between most oxidized and reduced form of carbon!
  - clear decline with still dominates emissions, ca. 40% of total global emission
  - Decline in US (11% 2019), EU (10% in 2019) and UK (42% in 2012 to 5 in 2019)
  - Increase in China and India
- **Oil** – more reduced than coal so produces more energy per carbon!
- **Natural Gas** – on rise roughly 2.6% per year globally
  - Replacing coal in some major markets but not in others e.g. Japan where it is substituting nuclear power.
  - Most reduced form of carbon, half the emission of coal.
- What our climate in 2100 will look like will largely depend on what happens to coal!



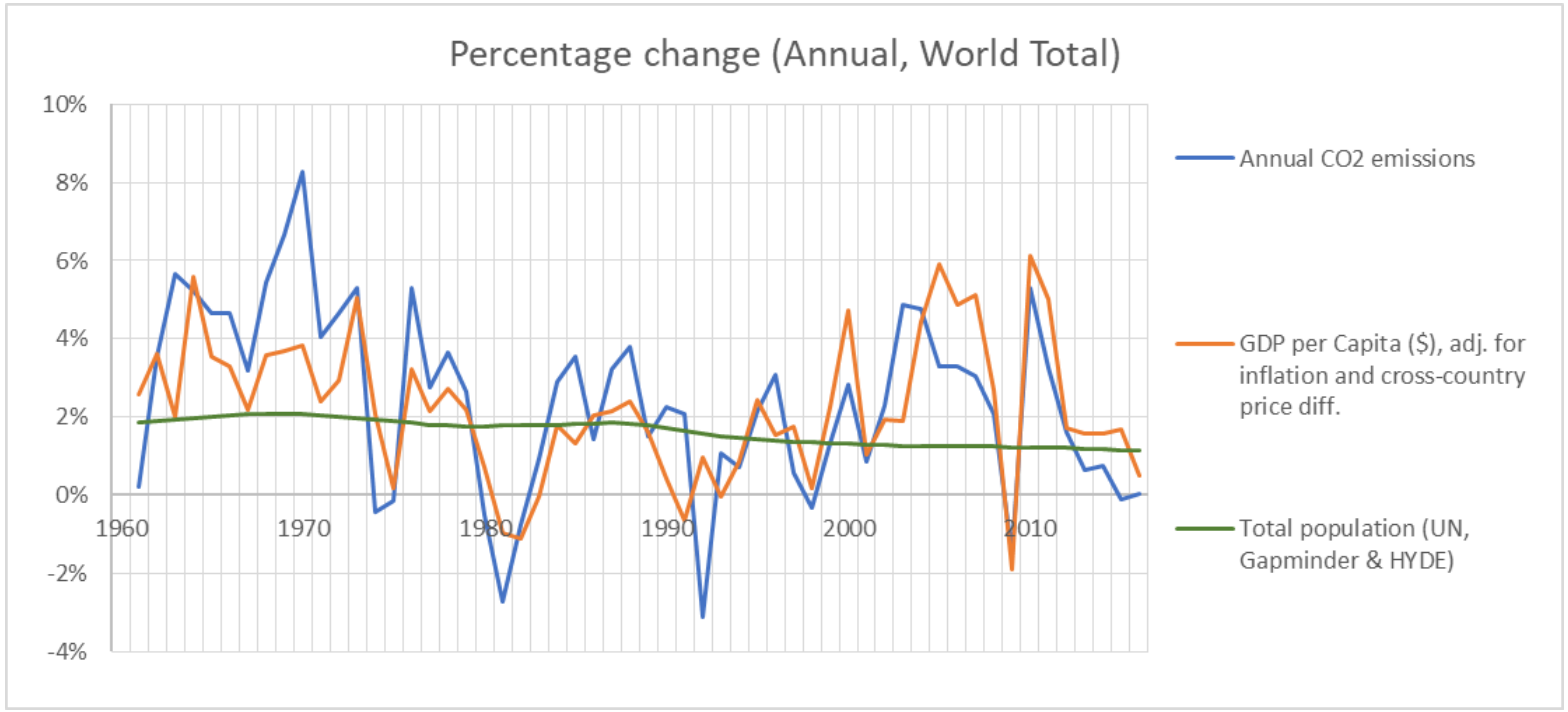
Fossil Fuels and Forecasting Emissions (2/4)



The Kaya Identity aims to break down total CO2 emissions into its key drivers:

$$Total\ CO2\ Emissions = Population * \frac{GDP}{Population} * \frac{Energy}{GDP} * \frac{CO2}{Energy}$$

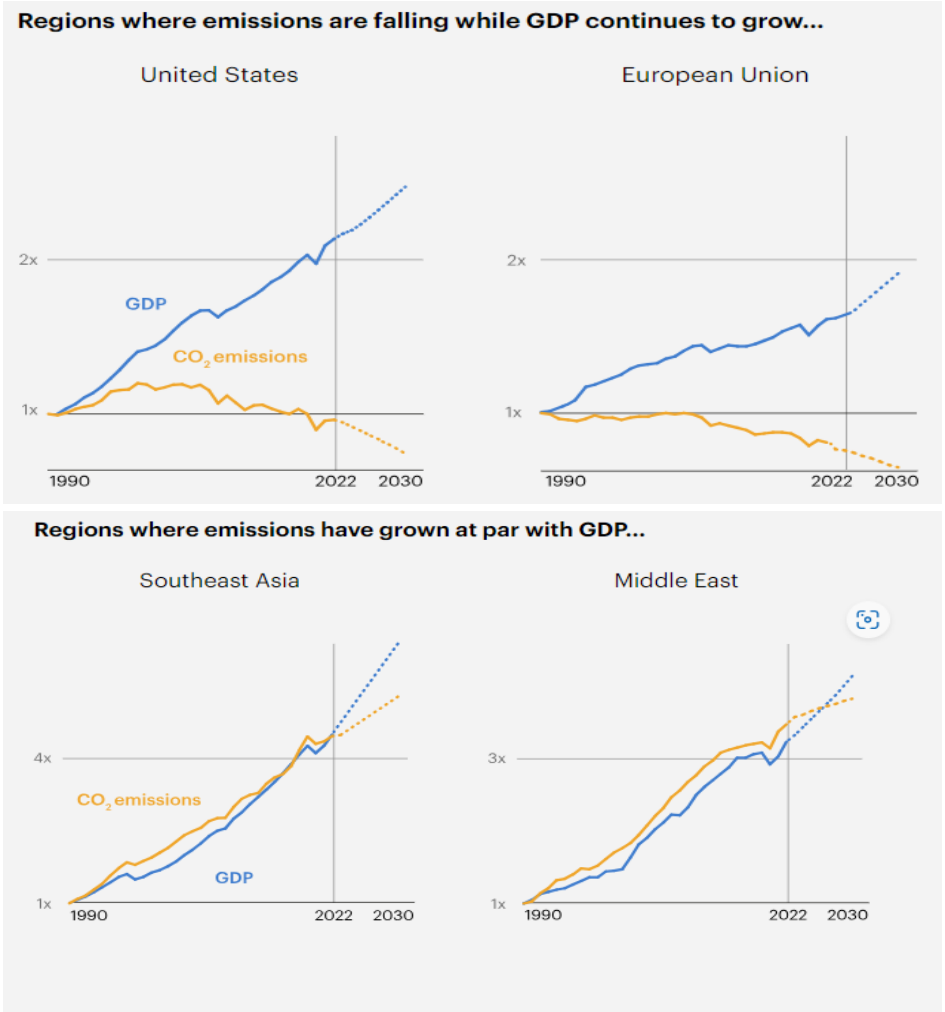
Fossil Fuels and Forecasting Emissions (3/4)



Changes in emissions are sensitive to changes in GDP and not so much to population change!

Fossil Fuels and Forecasting Emissions (4/4)

- Countries with higher GDP per capital emit more CO2, historically!
  - Strong correlations between GDP and emissions in past data.
  - Due to higher consumption of electricity, heating and transportation all powered by fossil fuels.
  - Historically, growth required higher strong reliance on fossil fuels
- Carbon intensity depends strongly on how fossil fuels include in our energy mix
  - Low if large share is nuclear or renewable (hydropower, wind, solar, biomass)
  - Dominated more by gas and less by coal.
- 'The relationship between growth in GDP and CO2 emissions has loosened in in the recent past but it needs to be cut completely.'



The relationship between growth in GDP and CO2 has loosened; it needs to be cut completely, Siddharth Singh, March 2024, https://www.iea.org/commentaries/the-relationship-between-growth-in-gdp-and-co2-has-loosened-it-needs-to-be-cut-completely

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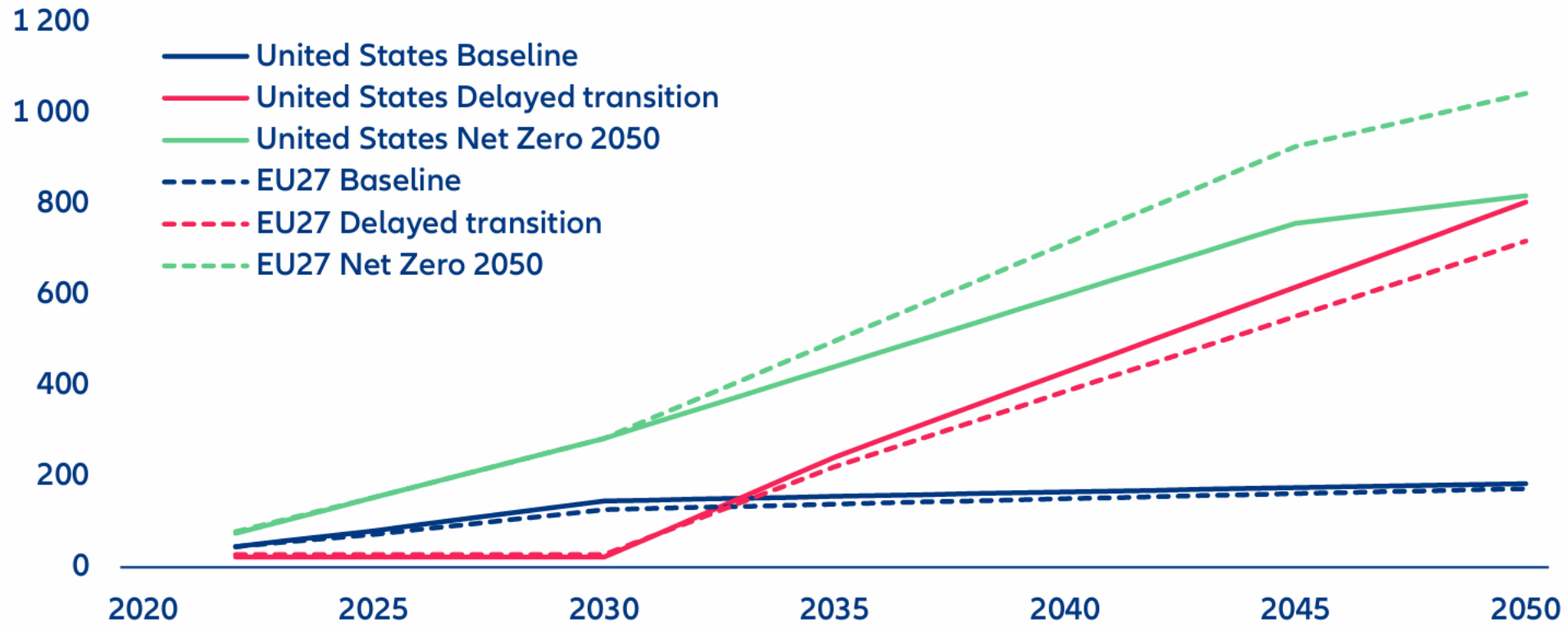
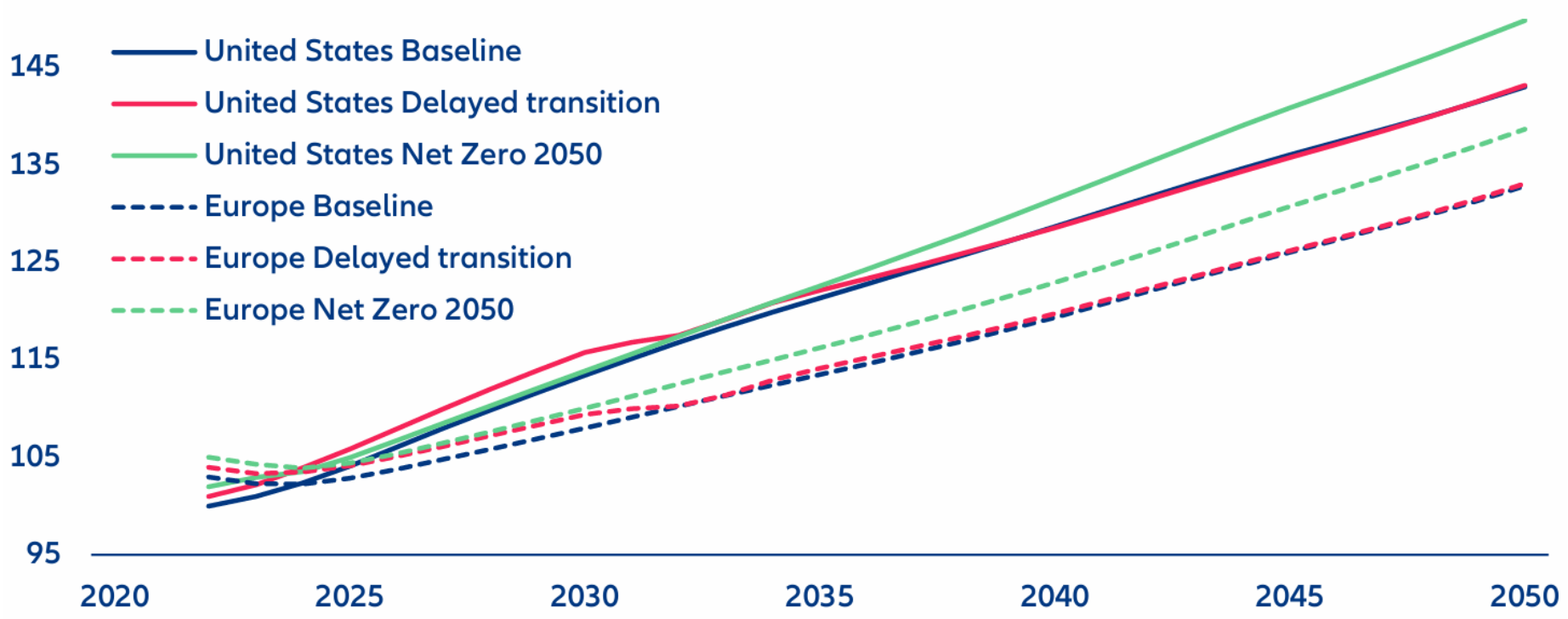
Key Variable: Carbon Price

Carbon price in USD per metric ton



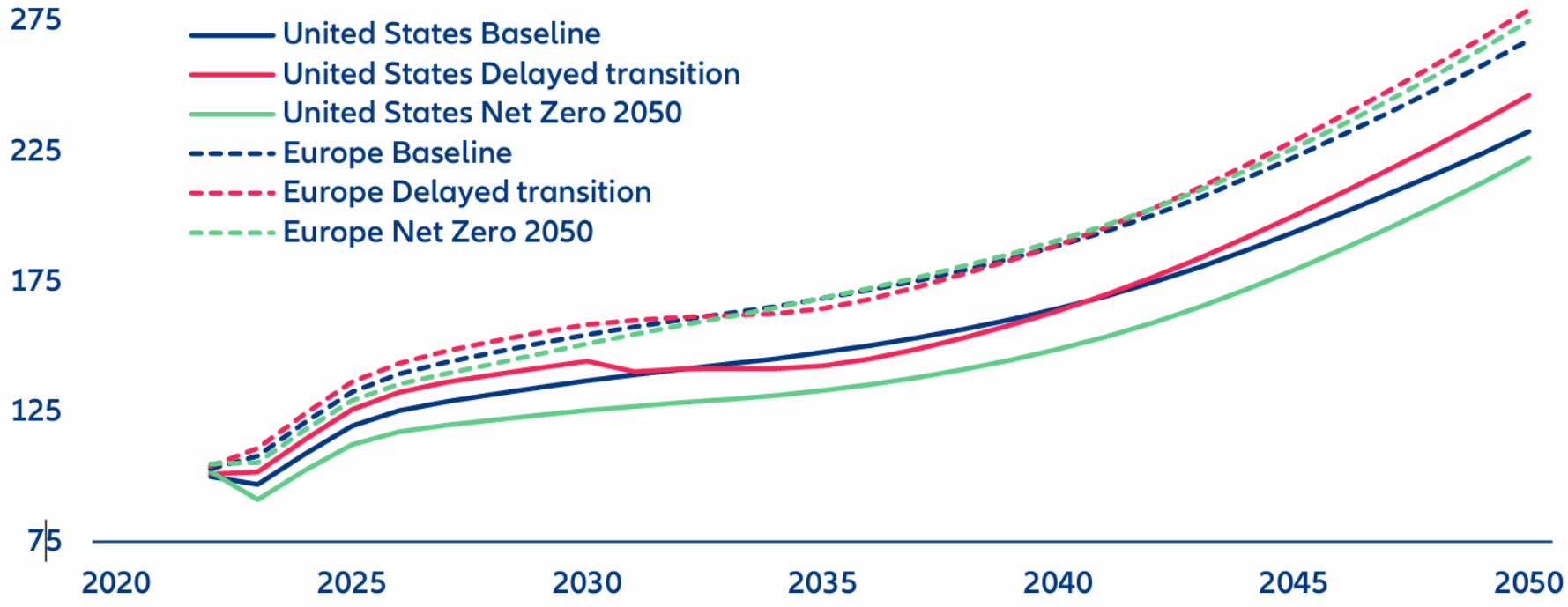
Source: NGFS, Allianz Research. Note: Based on NiGEM results for the REMIND model

Real GDP, rebased to 100 in 12/2021



Source: NGFS, Allianz Research

Equity prices, rebased to 100 in 12/2021



Source: NGFS, Allianz Research

Some Assets Will Become Stranded

Definition and some examples

What are stranded assets? Stranded assets are assets that have significantly devalued because the market around them has changed.

There are multiple ways for assets to become stranded:

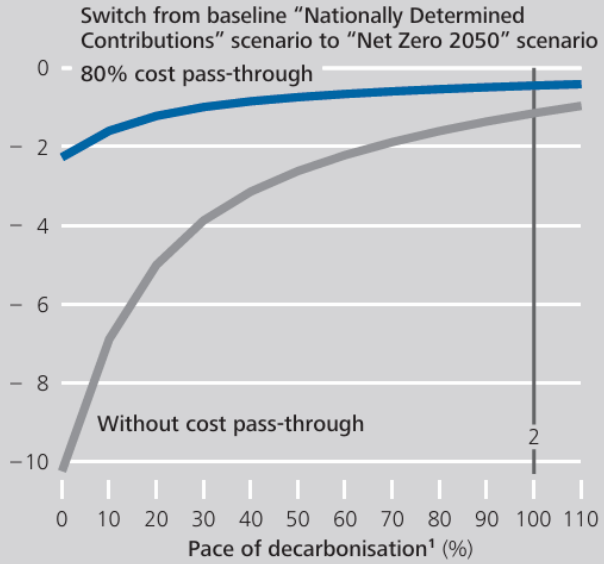
-- Due to shift of consumer preferences
- Due to global events such as natural disasters
- Due to a change in regulations.

A few examples:

- A diesel car may become a stranded asset due to transition to electric cars
- A building that is not energy-efficient may become a stranded asset due to (too) high costs of retrofitting
- An airport may become a stranded asset if planned passenger volumes fail to materialize

Even If Not Stranded, Assets May Lose Some of Their Value

Key consideration: (in)ability to pass through (emission-related) costs



Sources: Potsdam Institute for Climate Impact Research (REMIND-MAgPIE) and Bundesbank calculations. * Assumptions: Fictitious European stock corporation with an assumed return on equity of 8.5% and dividends (2021) in relation to direct greenhouse gas emissions (2019) of €1.70 per kg of emitted CO_2 equivalents. **1** Company decarbonisation relative to the emissions pathway in the "Net Zero 2050" scenario: 100% represents a proportional (Paris-aligned) decarbonisation, 0% represents the locus where companies' emissions remain unchanged at their 2019 level. **2** Cut-off at 100%: the present analysis looks at reductions in emissions in line with the "Net Zero 2050" scenario.

Deutsche Bundesbank

Stranding stock market capitalisation by sector

Scenario: "Net Zero 2050", baseline scenario: "Nationally Determined Contributions"

Sector	Losses in stock market capitalisation caused by stranding¹			
	Absolute, in € billion		As a percentage of respective (sector-specific) market capitalisation	
	Without cost pass-through²	80% cost pass-through²	Without cost pass-through²	80% cost pass-through²
Services	– 300	– 68	1.9	0.4
Manufacturing	– 127	– 19	0.8	0.1
Transport and infrastructure	– 211	– 67	26.7	8.4
Chemicals industry	– 392	– 54	23.3	3.2
Automotive industry	– 9	– 2	0.6	0.1
Construction and engineering	– 64	– 16	3.4	0.8
Airlines	– 111	– 98	98.4	86.9
Other aviation, aerospace and defence industry	– 137	– 66	13.2	6.3
Cement industry	– 245	– 157	97.7	62.7
Steel industry	– 236	– 145	71.4	44.3
Renewables	– 30	0	17.1	0.0
Oil and gas (extraction, power production)	– 1,256	– 246	61.6	12.1
Coal (mining, power production)	– 190	– 146	54.3	41.6
Other production of energy	– 901	– 491	62.7	34.1
Other mining and metal working	– 191	– 79	23.0	9.5
Total	– 4,401	– 1,653	9.9	3.7

Sources: ISS-EEG, Thomson Reuters, Potsdam Institute for Climate Impact Research (REMIND-MAgPIE) and Bundesbank calculations. **1** Stranding is defined here as a case in which, at a future point in time, the incremental emissions-related costs exceed the projected gross dividends. **2** Cost pass-through is understood as the incremental emissions-related costs being passed on to the companies' clients.

Deutsche Bundesbank

A generic degree warming metric definition

A company's degree warming metrics is the temperature that signifies which warming scenario the company's current actions are aligned with (for example, 3°C)*

A portfolio's metrics is then some weighted average of the asset-level metrics.

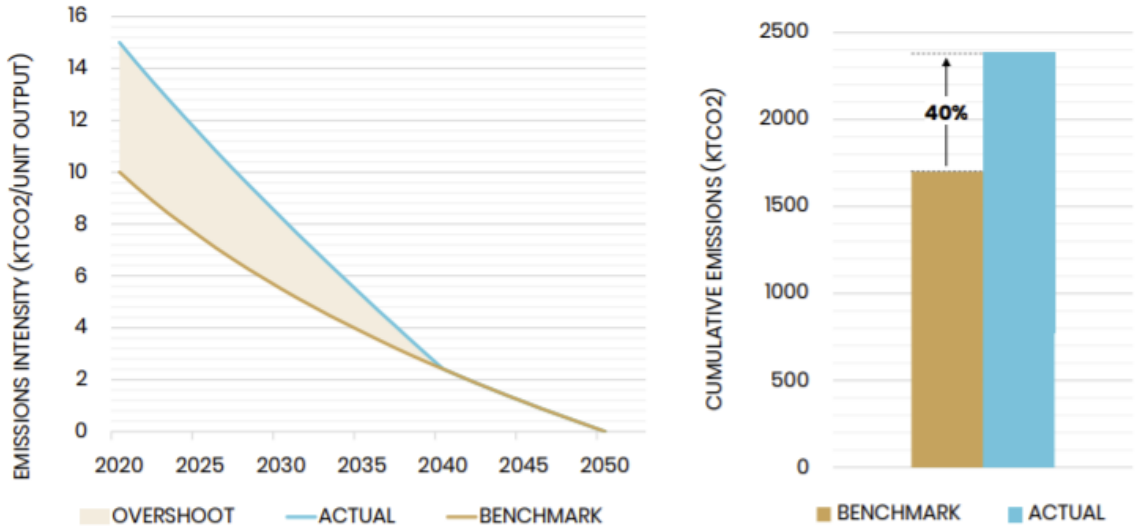
***Disclaimer** *:* Different service providers use different names for their degree warming metrics, such as ITR (Implied Temperature Rise) or XDC (X-Degree Compatibility)*

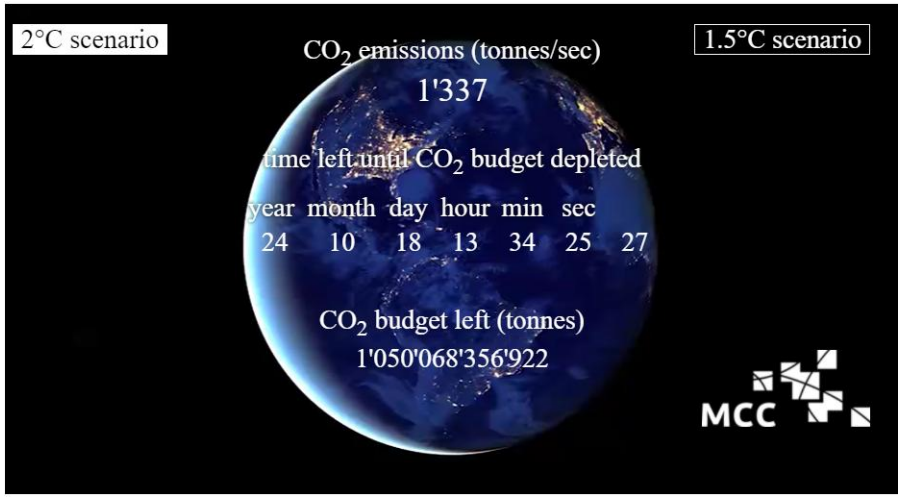
Key Objectives

- Express a portfolio's alignment level in easy-to-understand terms
- Support comparisons and progress monitoring (noting a myriad of uncertainties in data and modelling)

How to Calculate a Degree Warming Metric?

A simplified stylized calculation





If everyone overshot a carbon budget precisely like the company, how would the temperature increase?

- Say, the Company overshoots its *2°C* compatible emission target of 1700 ktCO2 by *40%*
- Say, the remaining global *2°C* compatible emission target is *1000 GtCO2*
- According to IPCC, a marginal GtCO2 emission leads to a warming of ***0.000545°C***
- Hence, the Company's degree warming metric is ***2°C + 40% * 1000 GtCO2 * 0.000545°C = 2.2°C***

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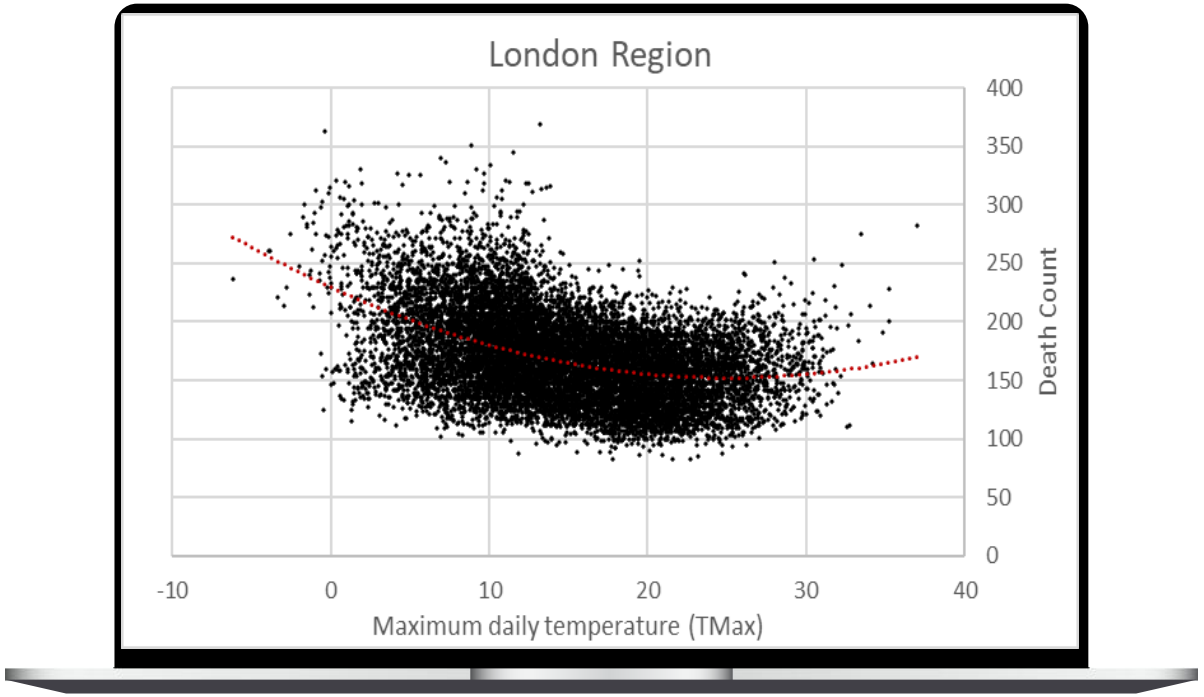
A Data Driven Approach to Mortality Risk

Data driven approach
LSTMs,
Historical Data (Weather Station & Deaths)

Climate Science
Learning the science of climate change



Climate Models
Using climate model projections to estimate future impacts

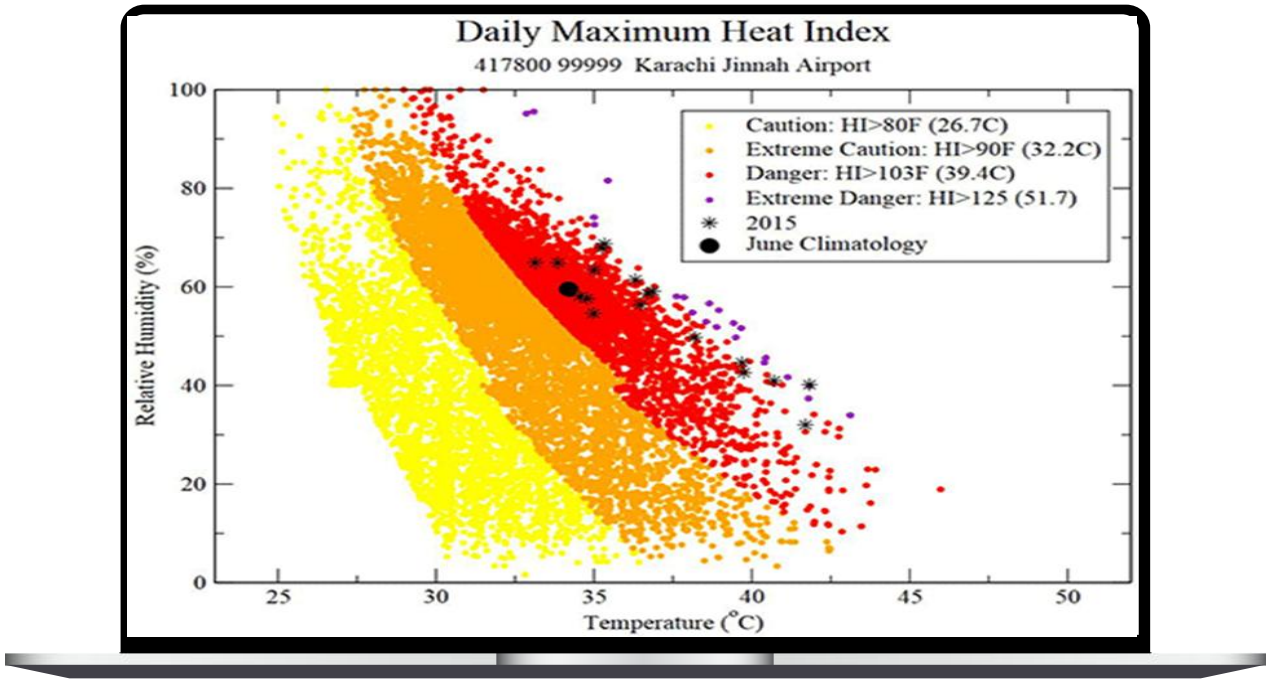
Actuarial Solution
Integrating climate science into actuarial models

Multiple variables impact mortality
Temperature, Humidity, Wind Speeds & Solar Intensity

Choice of Data

Heat Index
Combination of temperature and humidity

Wind Chill Index
Combination of temperature and wind speeds

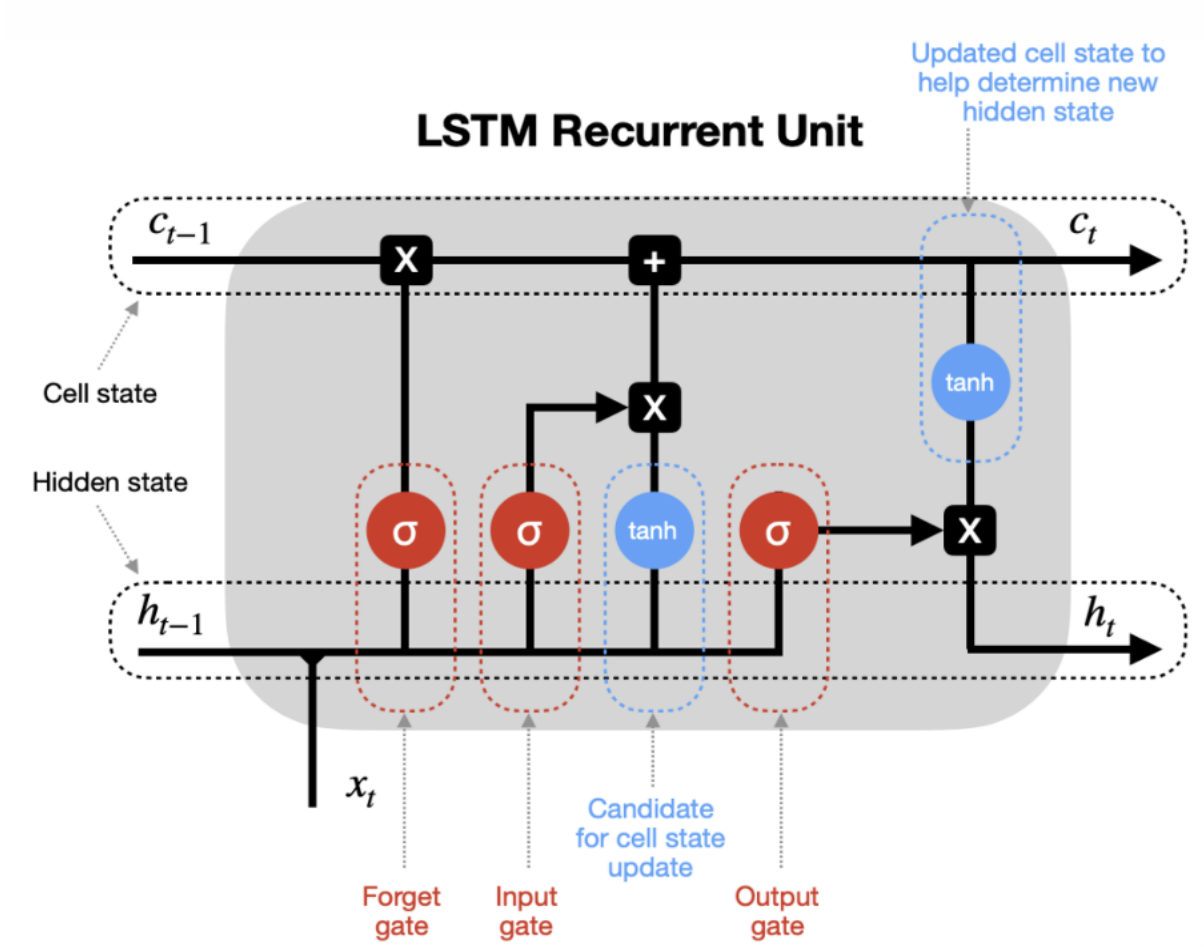


Wet Bulb Globe Temperature Index
Incorporates the impact of solar intensity

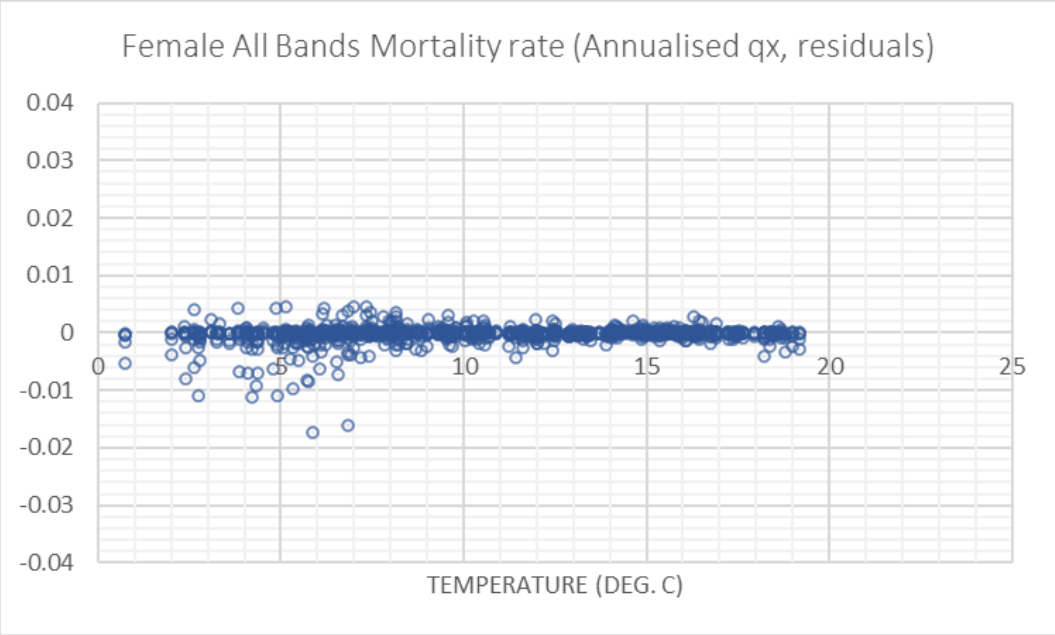
Use underlying variables
Capture the relationship in data

Timespan, frequency & aggregation approach
We have selected 1970-2020, daily measurements

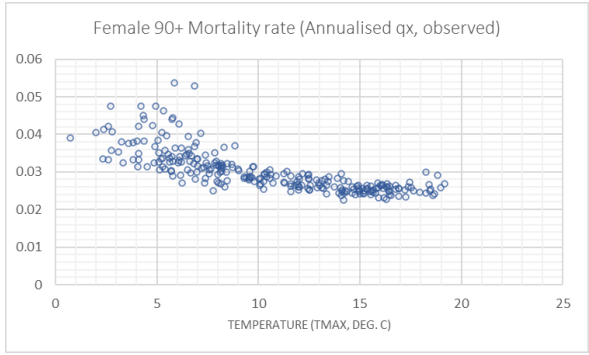
A brief overview of Long Short-Term Memory (LSTM) approach

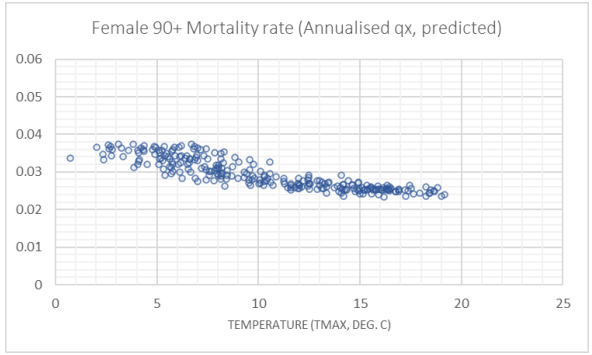


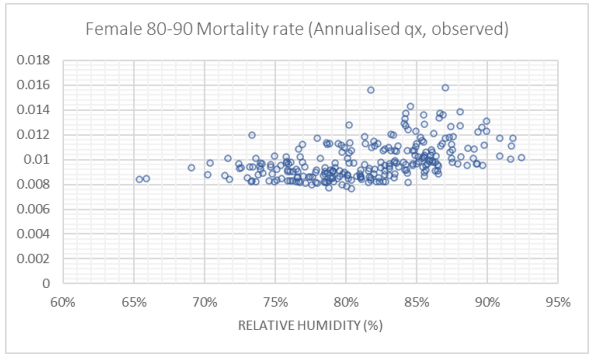
Calibrating an ML driven mortality model

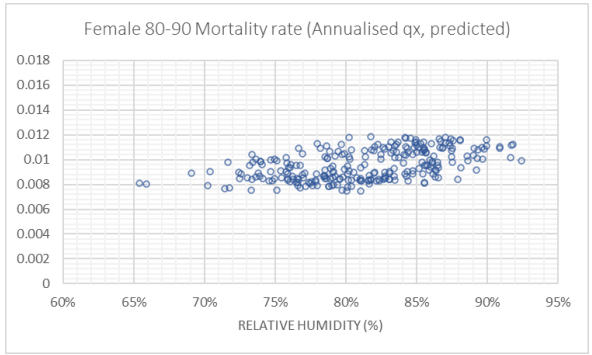


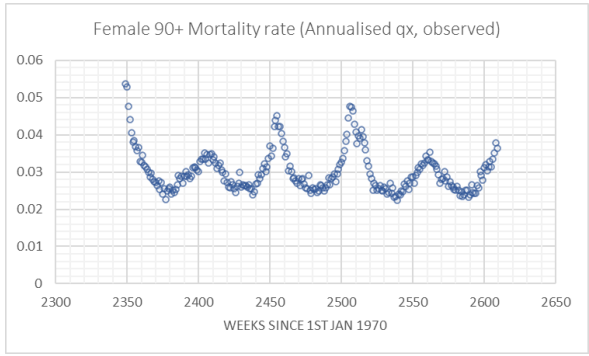
- 4-year, ca. 360 periods validation set, 2015 to 2019
- Clear relationship between climate variables and mortality is observed in the predicted mortality rates.
- Fitted mortality trend in line with observed.

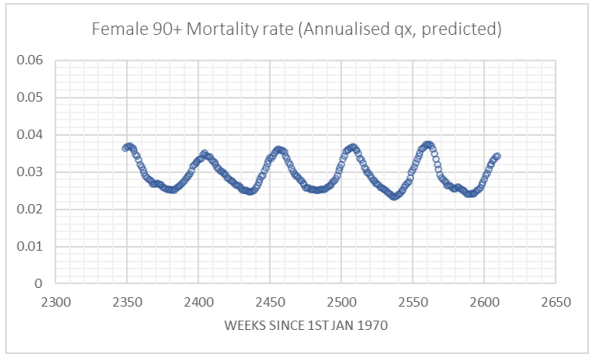




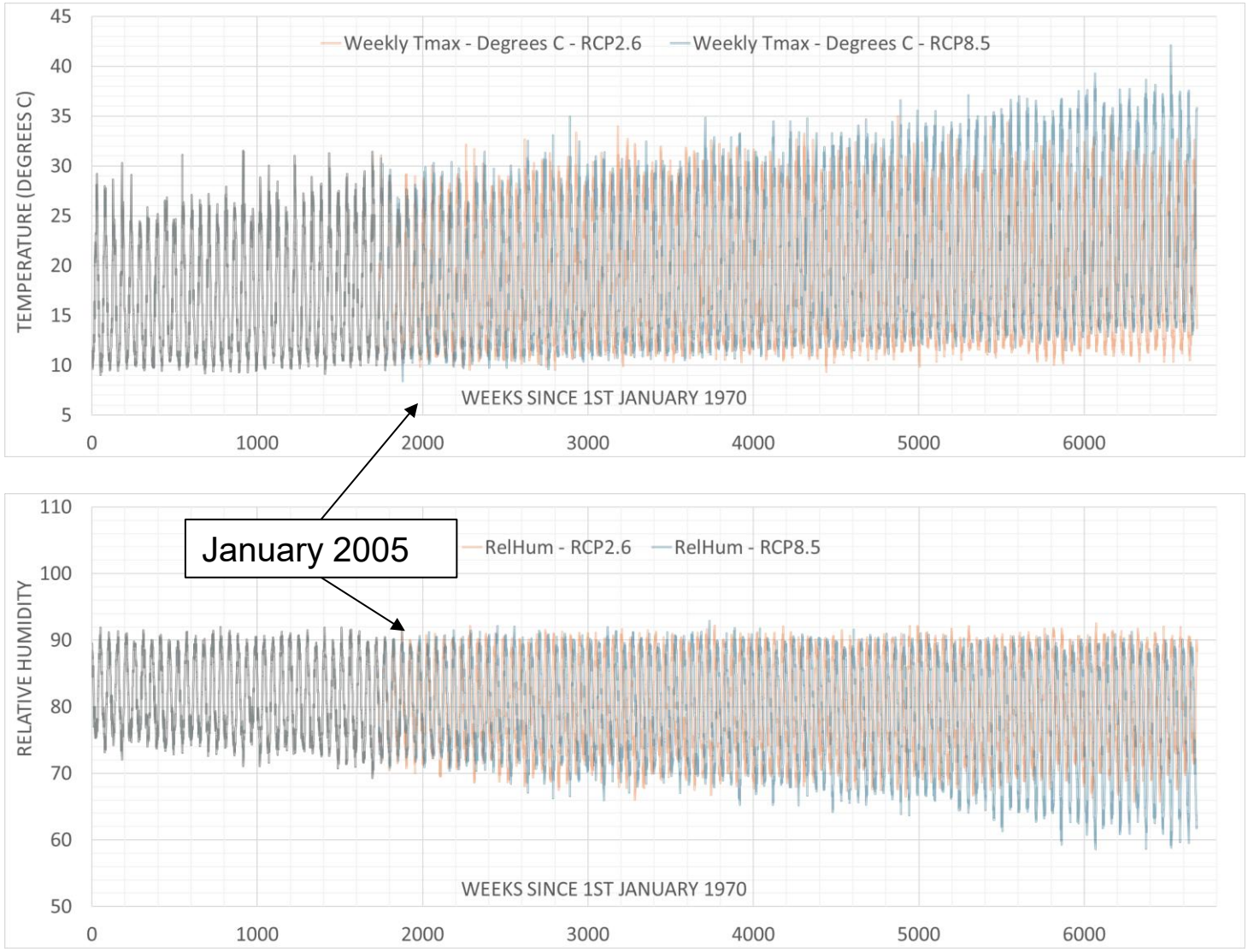








Comparison of Two Climate Scenarios

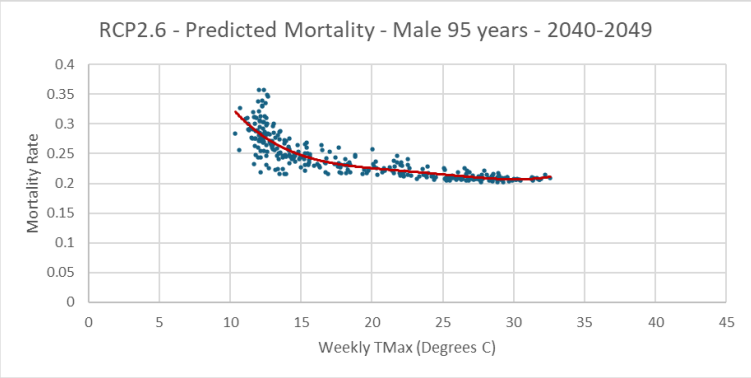


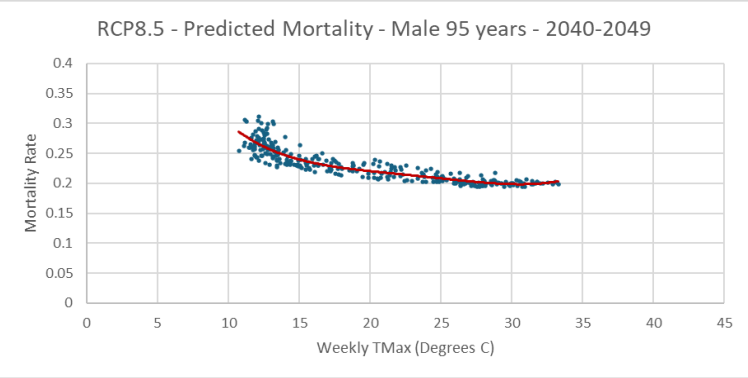
- RCP 8.5 features a steeper increase in weekly maximum temperature (and other temperature variables considered) during summer than during winter.
- RCP 2.6 features an increase in temperatures overall but significantly lower than RCP 8.5.
- RCP 8.5 features a reduction in relative humidity through the century, in particular, around the summer seasons.
- RCP 2.6 features a modest change in relative humidity.
- Average Wind Speeds (not shown) stay relatively stable between the two scenarios.

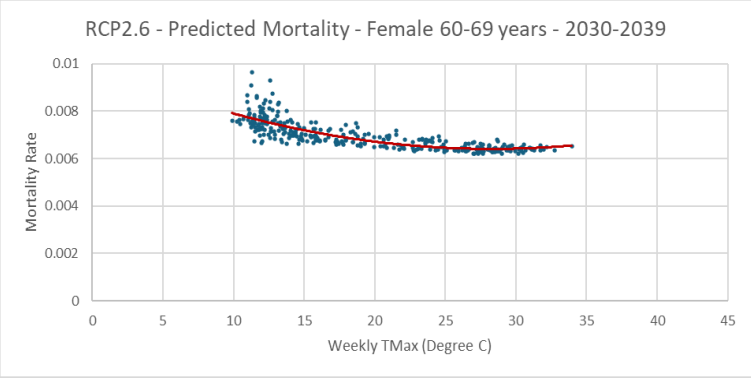
Issues with the use of this data

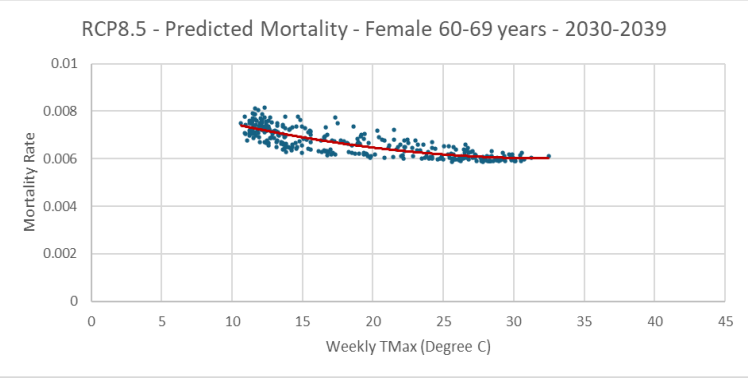
- Modelled climate data diverges from the 1st of January 2005 for the two scenarios.

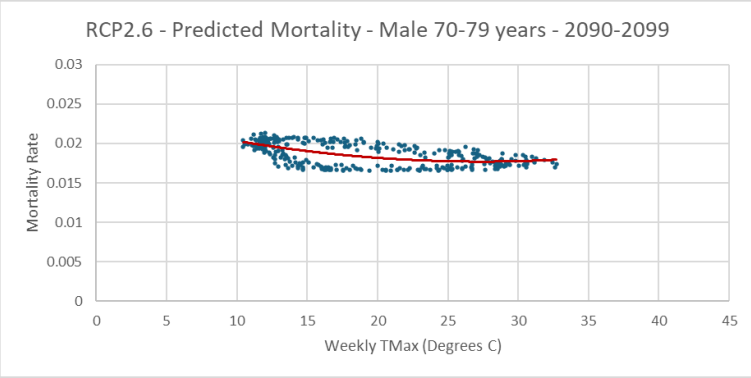
Initial Results of our LSTM Climate-Mortality Model (1/2)

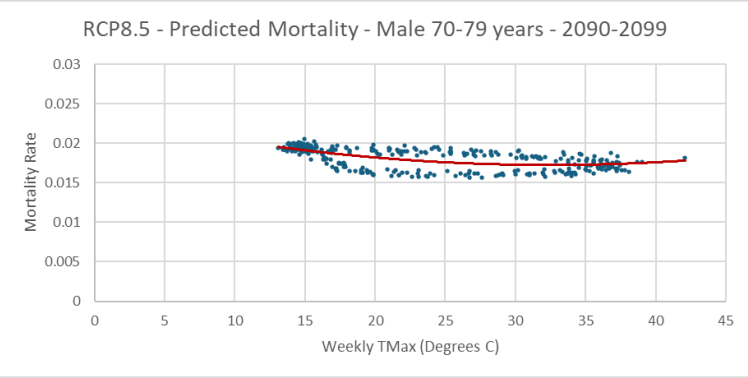








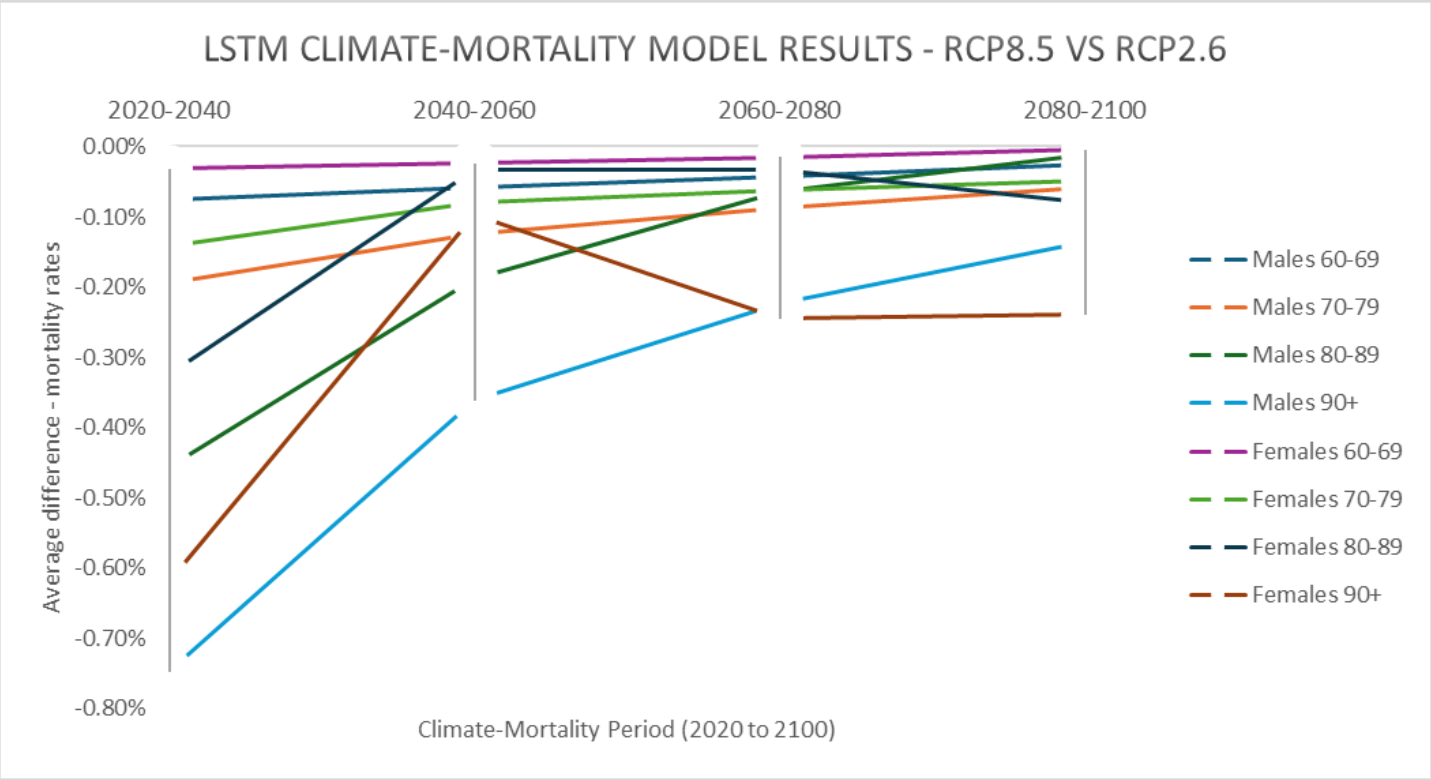




A few observations from our initial mortality projections

- A reduction in cold related deaths as temperature rises in the winters under RCP8.5. This pattern is observed for all age buckets as the century progresses.
- In the RCP8.5 scenario in particular and in the RCP2.6 scenario, we expect an off-setting impact from an increase in heat related deaths.
- While some heat related increases in mortality rates is observed, we believe this impact is missing from the historical data series for England and Wales

Initial Results of our LSTM Climate-Mortality Model (2/2)



Further insights from our initial mortality projections

- A reduction in cold related deaths as temperature rises in the winters under RCP8.5, compared to RCP2.6.
- This pattern is observed for all age buckets as the century progresses.
- In the RCP8.5 scenario in particular and in the RCP2.6 scenario, we expect a greater off-set from an increase in heat related deaths.

Improvements needed:

- More granular mortality data
- Include recent data (post-2014)

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A decade of weekly dengue cases

- Municipality-level data • Weekly records
- Ability to aggregate at sub-region, region & state

Key Finding:

2024 spike significantly above historical average

Contributing factors:

- El Niño weather events
- Four circulating virus serotypes
- Variable public health responses

A look at the available climate data

Available:

Humidity, Temperature (min/max/avg)

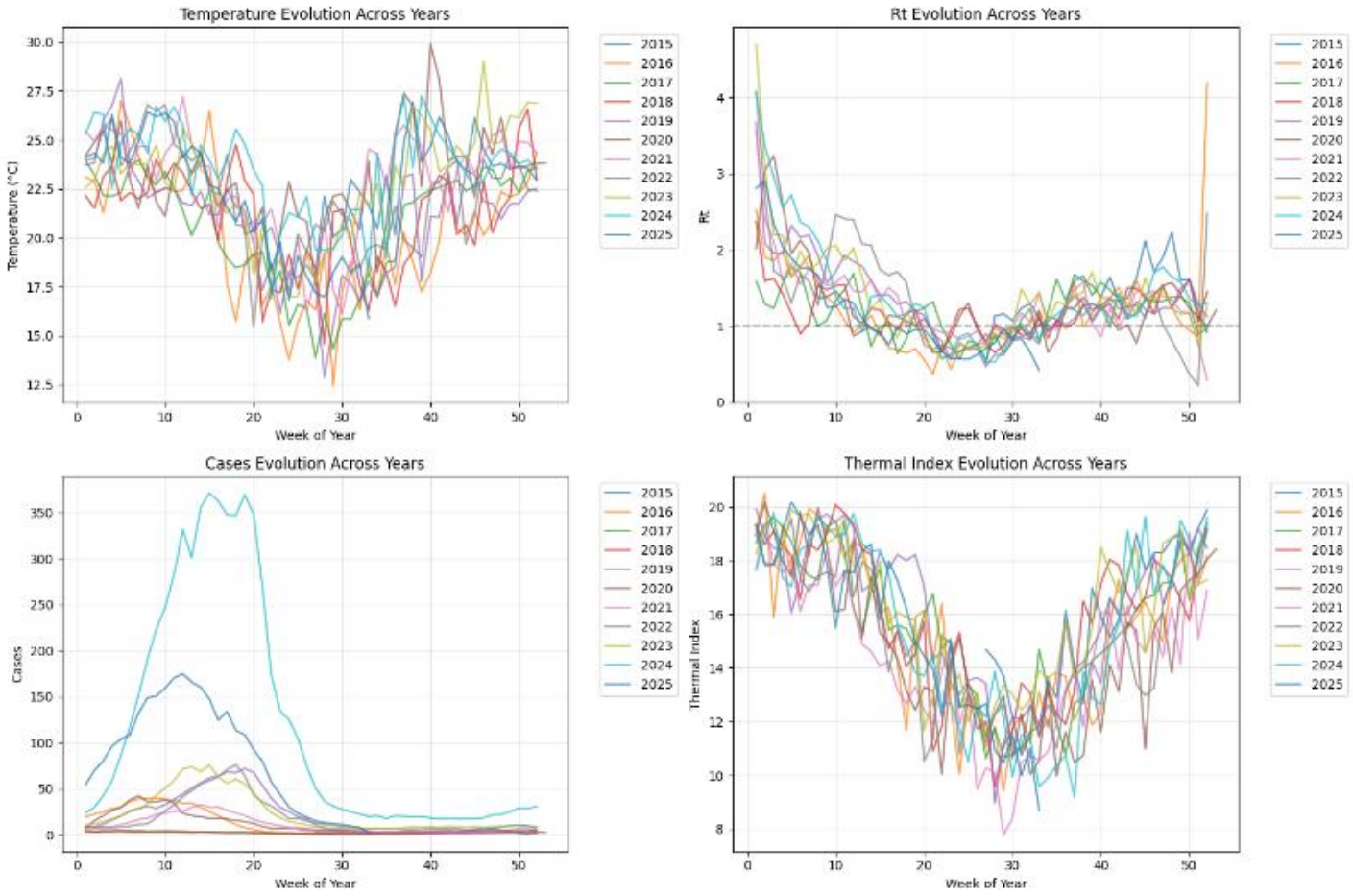
Missing:

~10% of data; No precipitation

Challenge:

Data is not granular (weekly, not daily) - unable to derive key climate indicators, such as:

- Number of days exceeding a precipitation threshold
- Ideal temperature-humidity combinations for mosquito breeding



How to build features for our Machine Learning predictions

Copernicus hourly climate data:

Temperature, Humidity, Evaporation, Precipitation, Vegetation

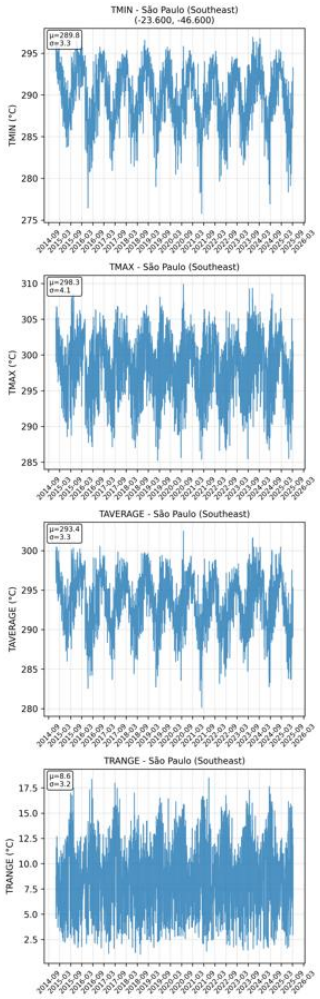
Hourly resolution enables:

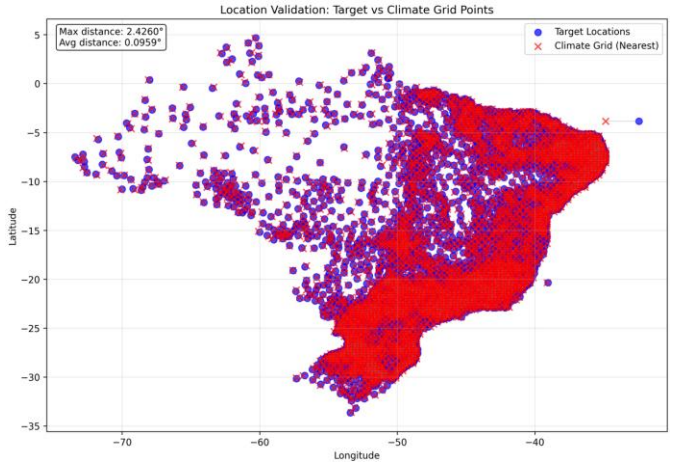
- Daily/weekly fluctuations
- Cumulative metrics
- Lagged indicators

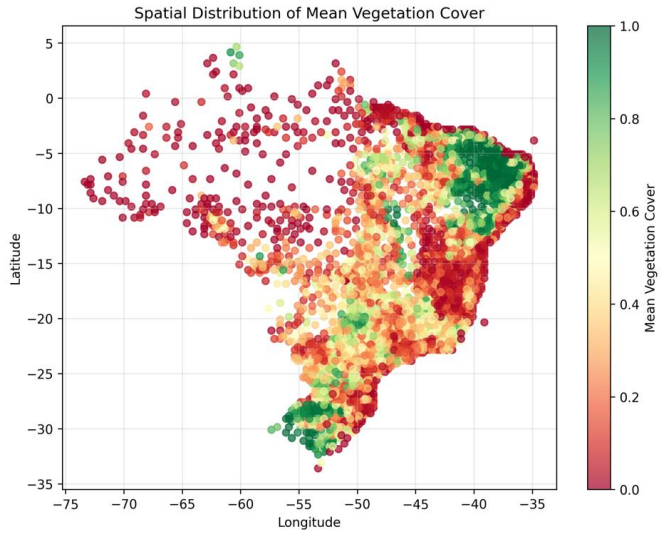
Result:

Captures nonlinear climate-dengue relationships:

- Daily/weekly temperature and humidity fluctuations
- Cumulative precipitation or number of rainy days above specific thresholds
- Lagged climate indicators to capture delayed effects on mosquito population growth



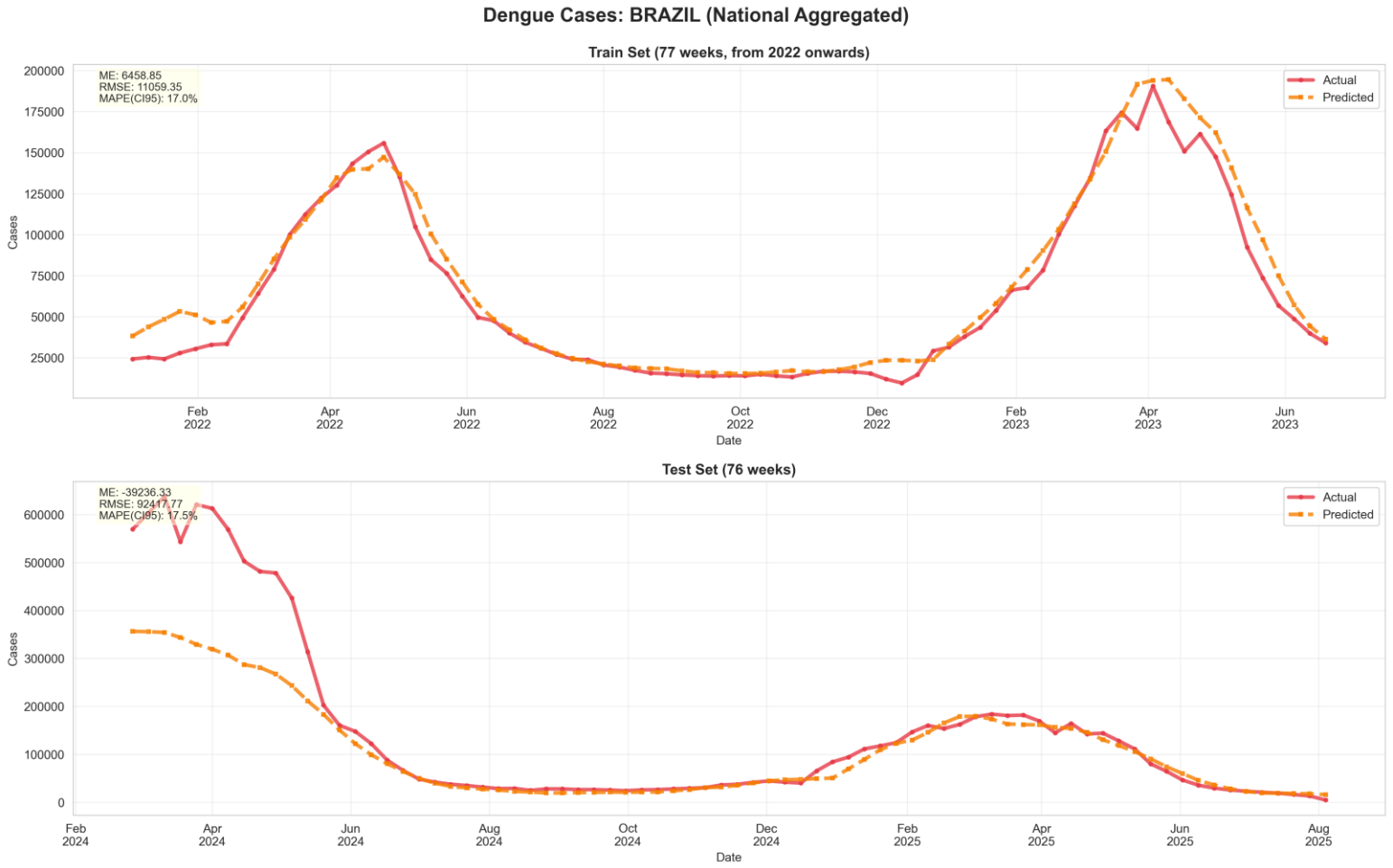




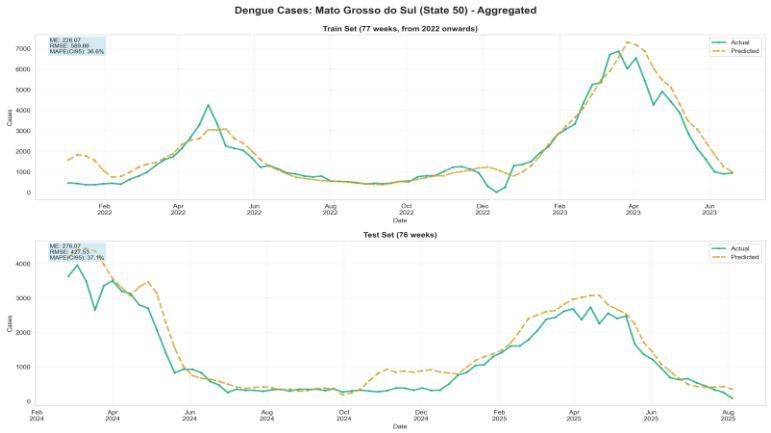
Overview of results and their limitations

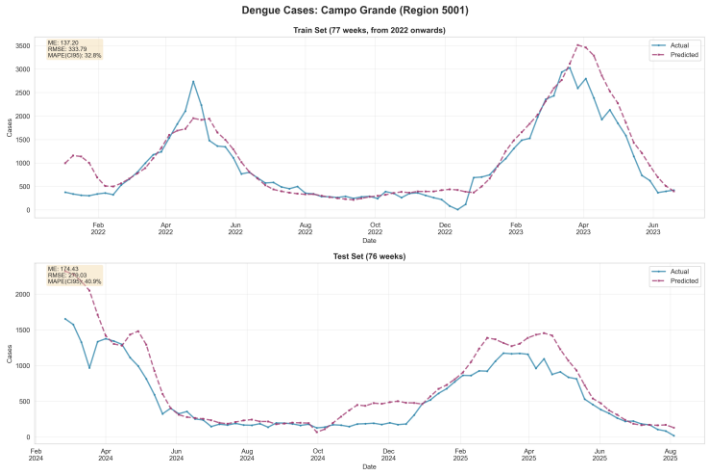
70/15/15 train/validation/test split • Strong generalization

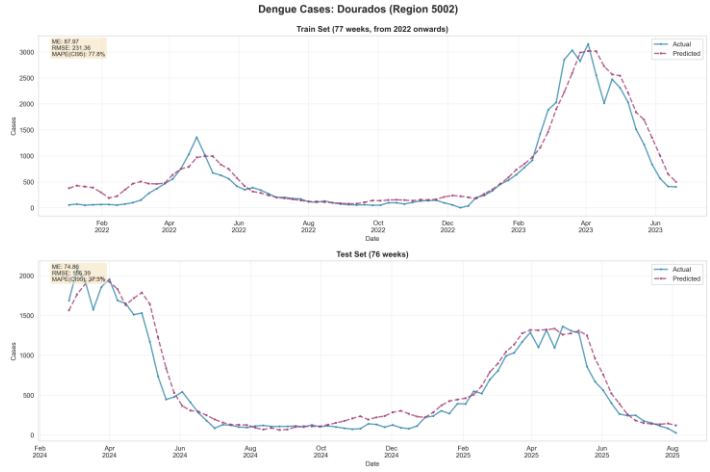
- Regional aggregation reduced municipality-level noise
- Model captured climate-dengue relationships (evident in 2025)
- 2024 spike not captured: *unprecedented, absent from training data*

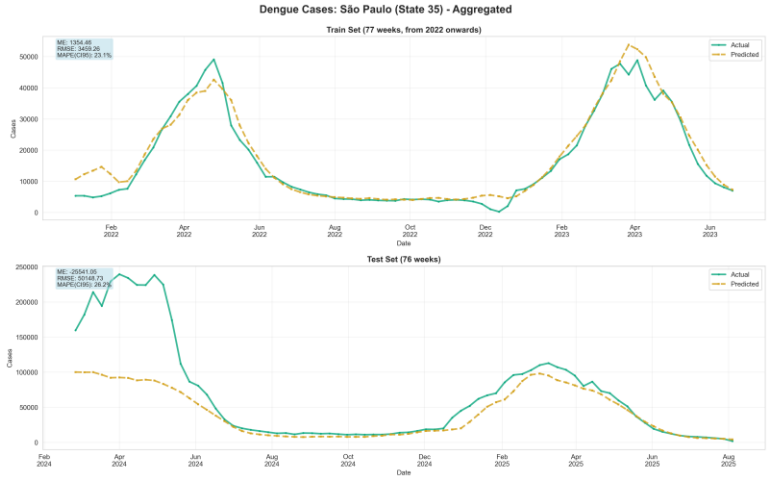


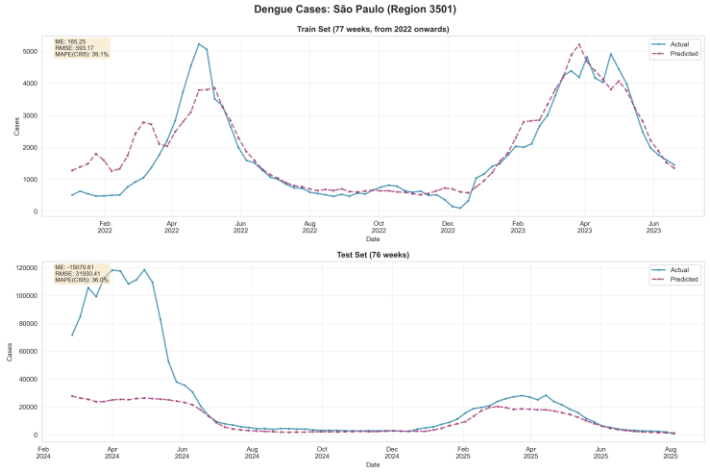
Detailed results

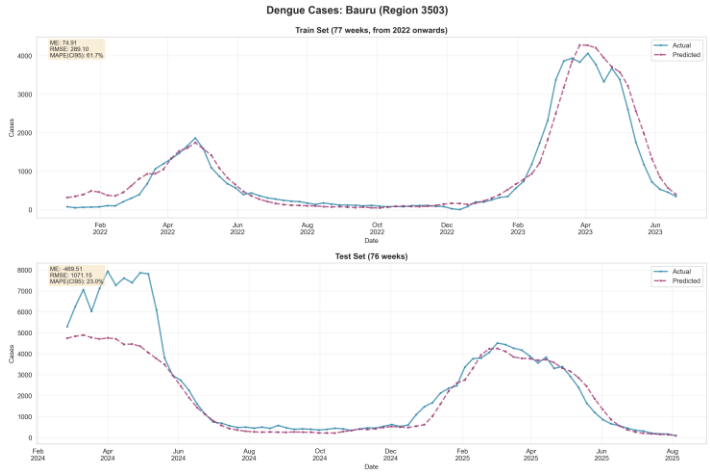










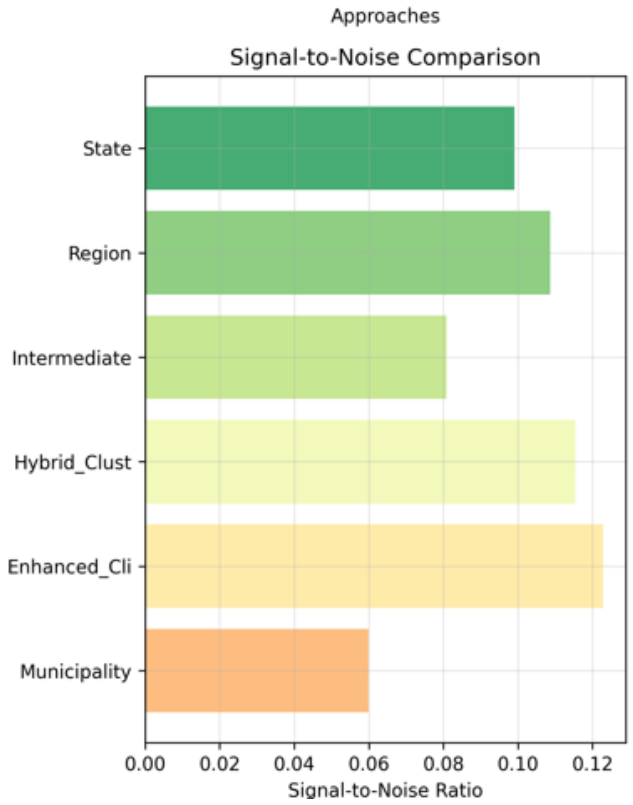


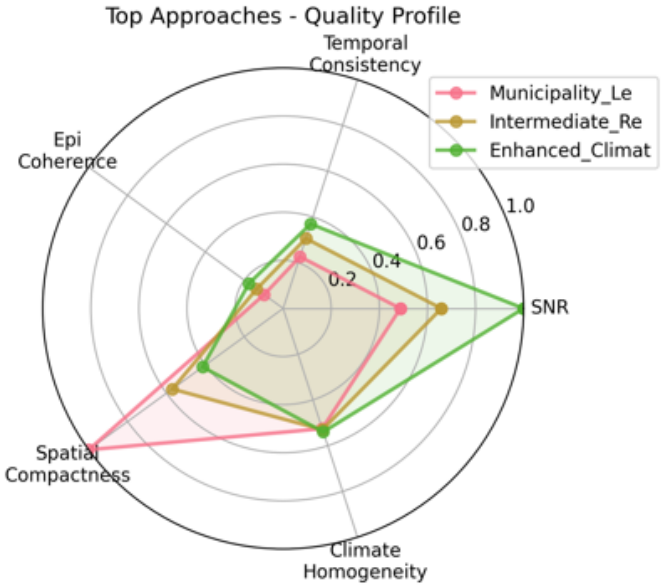
Results (3/3)

Outlook

Future improvements:

- Climate zone-based spatial aggregation
- Advanced models: ST-GNNs with LSTM layers
- Add public health response data
- Climate change scenario modeling (SSPs)





- Introduction
- Forecasting Emissions
- Market Risks
- Case Study A – Mortality
- Case Study B – Emerging Risks
- **Conclusions**

Our concluding remarks

Climate Scenarios:

- Outcomes will be (highly) conditional on climate scenarios
- While we certainly cannot predict which scenario will materialize, we need to think in terms scenarios and their likelihood

Transitional Market Risks:

- Various assets, not only coal mines, can become stranded
- Even without stranding, some assets will lose value
- Portfolio-level KPIs are very difficult to produce, yet worthwhile

Physical Climate Risks:

- Climate mortality risks are well-researched in actuarial practice
- Emerging vector-borne diseases (dengue, malaria, Zika) need greater attention as climate zones shift
- Actuaries must expand risk frameworks beyond traditional temperature impacts

Machine Learning in Climate Modeling:

- ML models effectively capture nonlinear climate-mortality dynamics
- Caution needed for long-term projections: models trained on historical data may not capture unprecedented future scenarios
- Regular recalibration with emerging data is essential

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