

Behind and Beyond the Global Seismic Risk Model

**Vitor Silva, Al Mouayed Nafeh, Catarina Costa, Martina
Caruso, Alejandro Calderon**
Global Earthquake Model Foundation



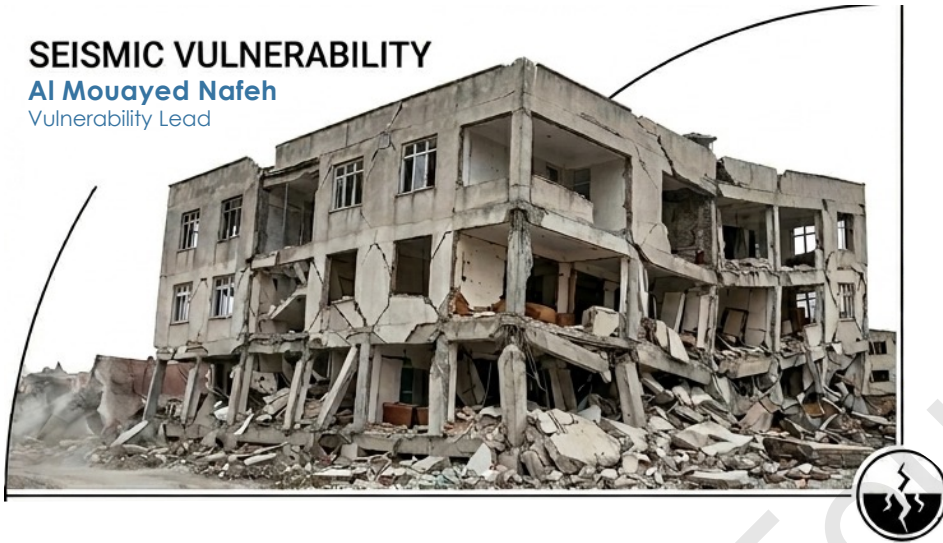
June 23 - 25, 2026
University of Zagreb, Croatia
GEM CONFERENCE
FROM FAULTS TO FUTURE SCENARIOS

Behind and Beyond the Global Seismic Risk Model

SEISMIC VULNERABILITY

Al Mouayed Nafeh

Vulnerability Lead



NEXT-GENERATION GLOBAL SEISMIC VULNERABILITY MODEL

Introducing a new seismic vulnerability model for improved earthquake risk analytics

Al Mouayed Bellah “Moe” Nafeh, on behalf of the risk team

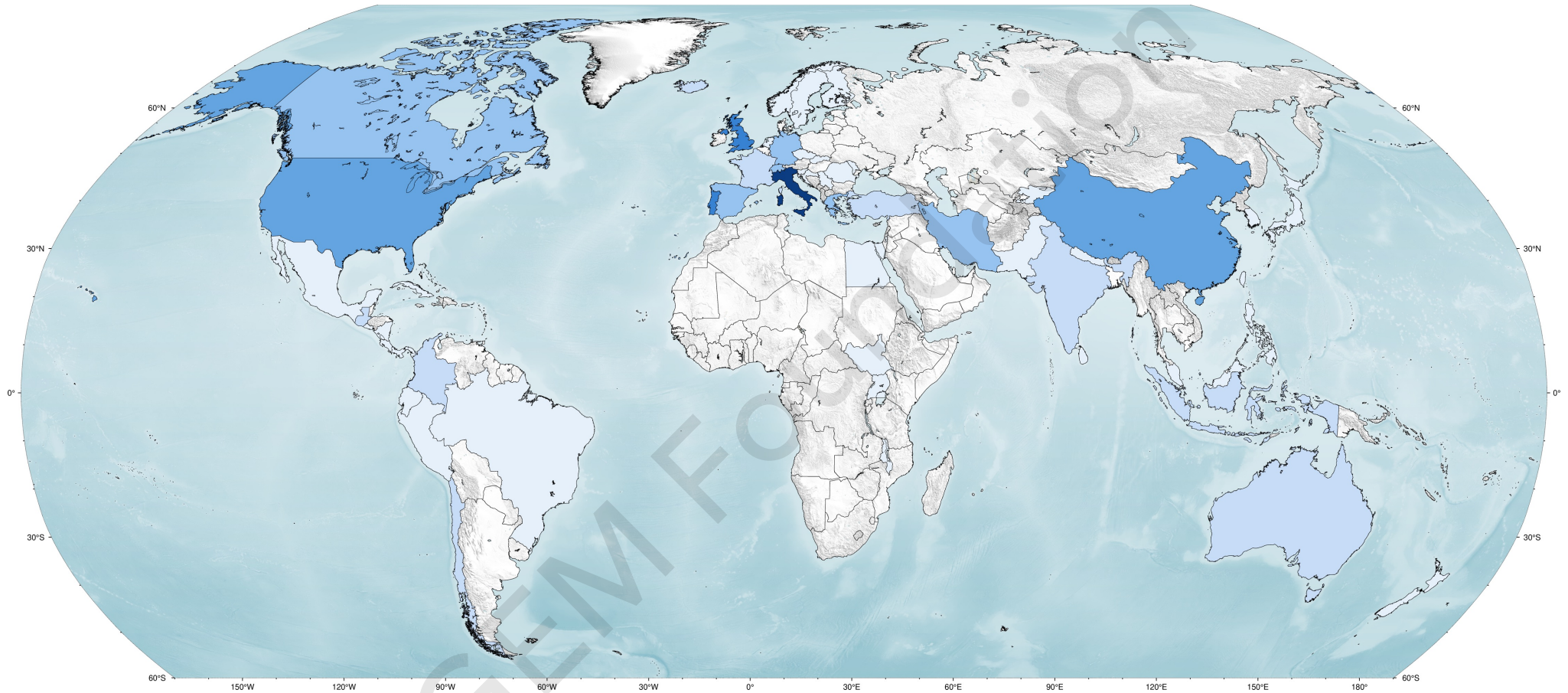
Global Earthquake Model (GEM) Foundation

June 23 - 25, 2026

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FROM FAULTS TO FUTURE SCENARIOS

An Ode to the v2023 Global Seismic Vulnerability Model



Global distribution of works citing version 2023 of the Global Seismic Vulnerability Models (Martins & Silva, 2021) as retrieved from OpenAlex

Introducing the v2026 Global Seismic Vulnerability Model



Extended Building Class Coverage

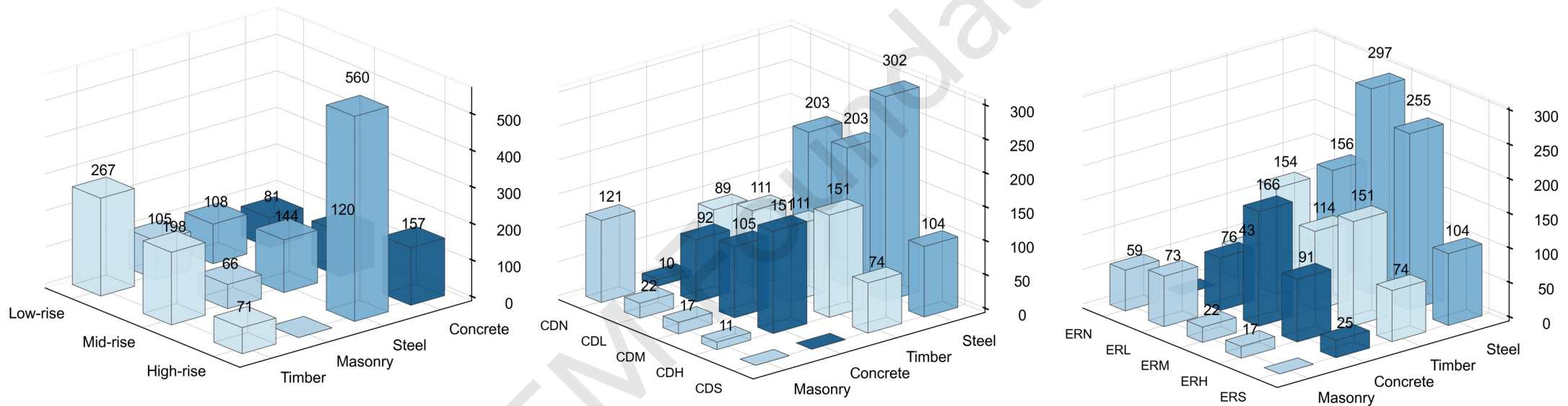


Illustration of the lateral load-resisting systems supported in the Global Vulnerability Model for engineered and non-engineered structures

Introducing the v2026 Global Seismic Vulnerability Model



Extended Building Class Coverage

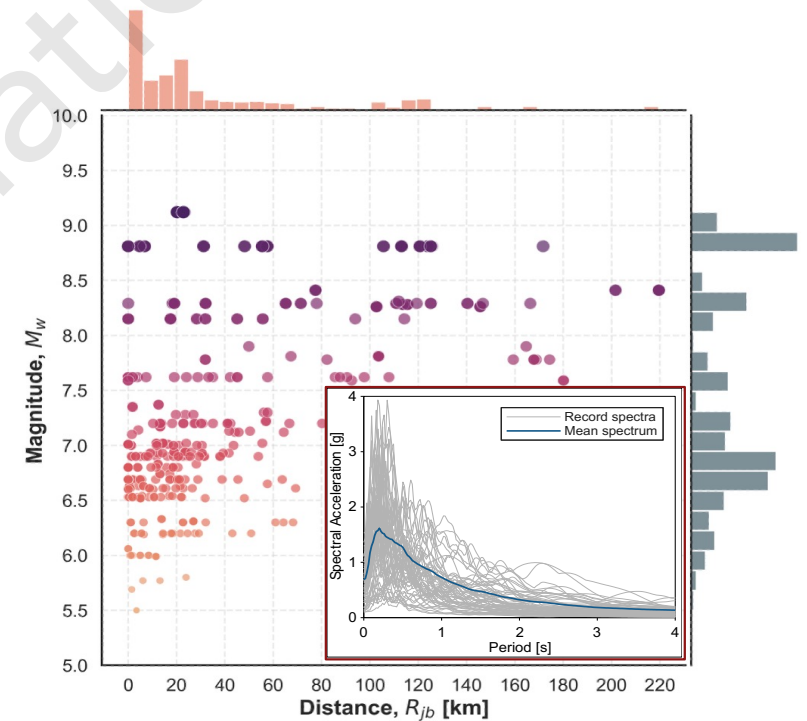
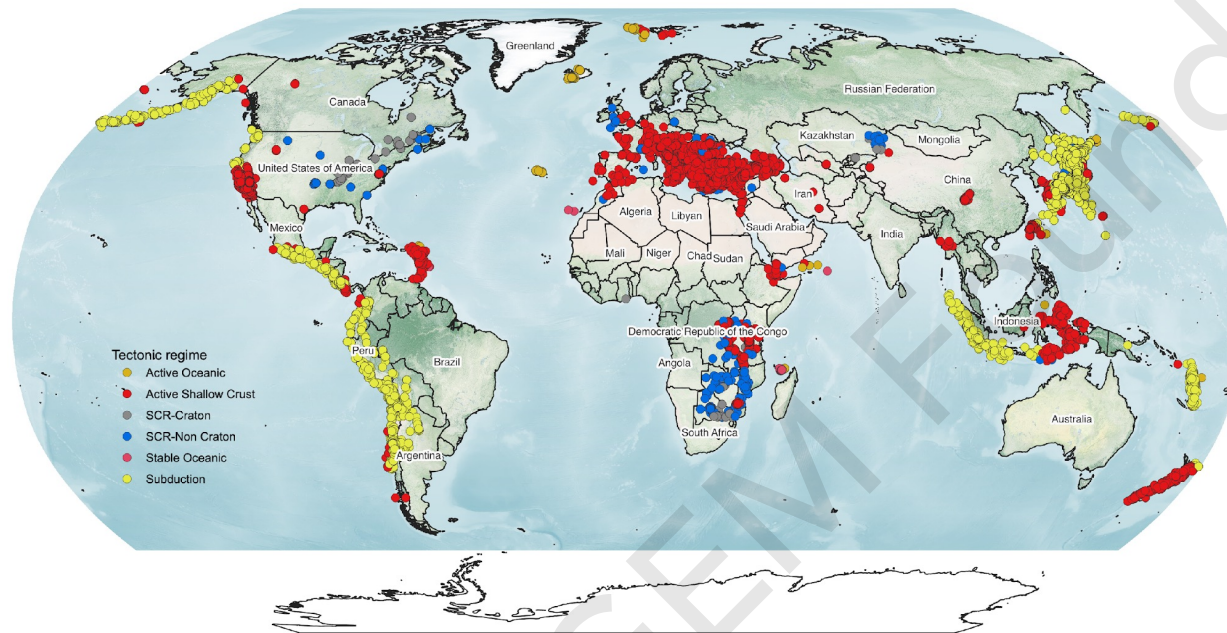


Distribution of vulnerability classes by primary construction material, number of storeys, seismic design code level and earthquake-resistant design levels

Introducing the v2026 Global Seismic Vulnerability Model



Sufficient Ground Motion Suite

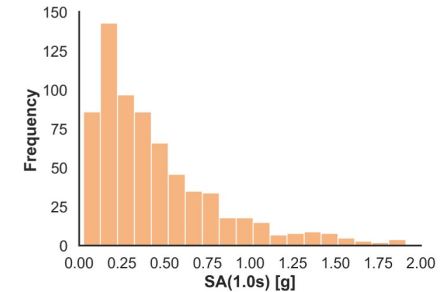
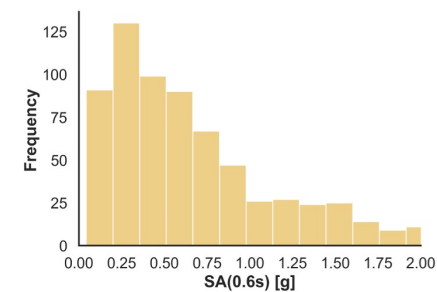
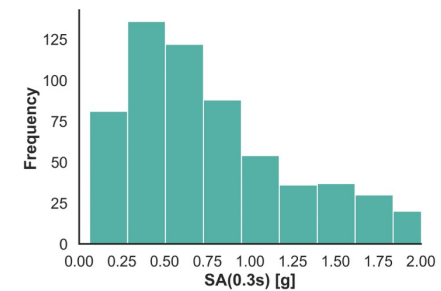
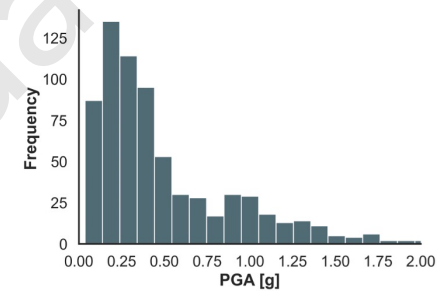
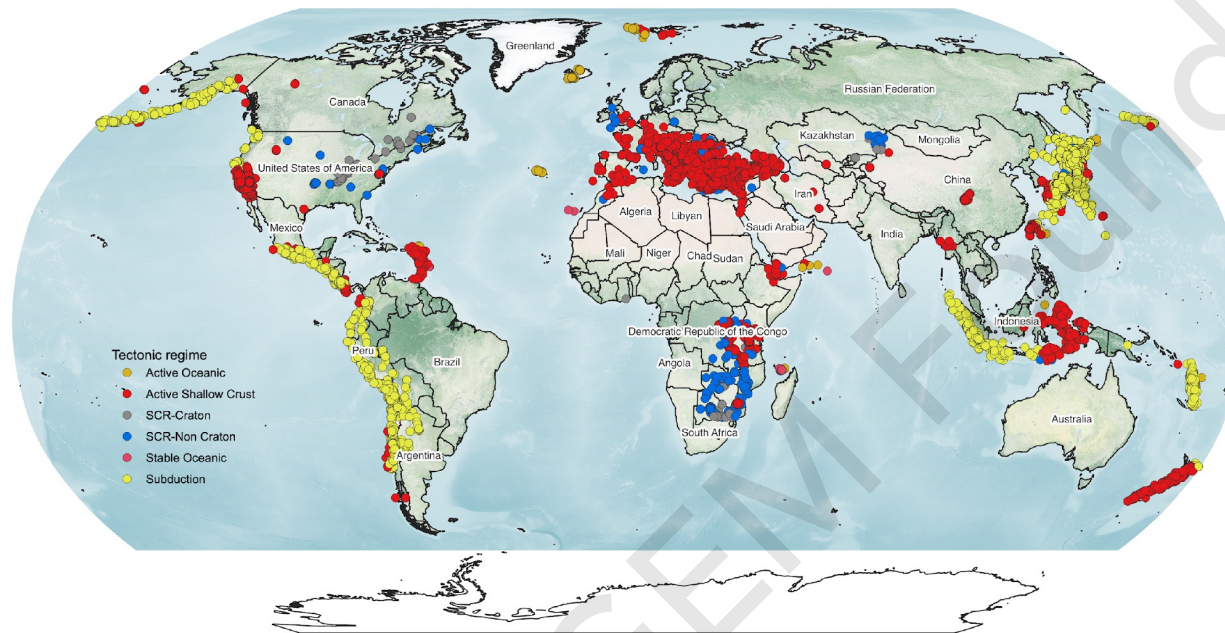


Distribution of selected ground motion record set used for nonlinear dynamic analysis representing global tectonic regime types and databases

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Sufficient Ground Motion Suite



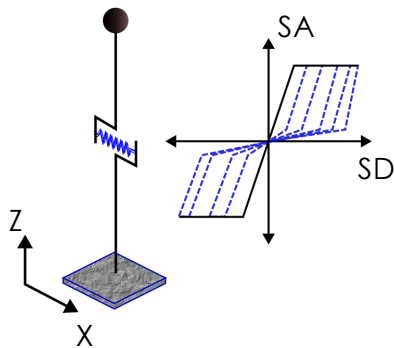
Distribution of selected ground motion record set used for nonlinear dynamic analysis representing global tectonic regime types and databases

Introducing the v2026 Global Seismic Vulnerability Model



Efficient Numerical Modelling

Single-Degree-of-Freedom Oscillators – v2023



Pros

- **Simplicity:** Easy to model and analyze
- **Speed:** Requires minimal computational resources
- **Intuitive Understanding:** Provides clear insight into the building's fundamental behaviour

Cons

- **Over-simplification:** Ignores complex mechanisms and higher modes of vibration
- **Limited accuracy:** Not suitable for applications requiring distribution of demands

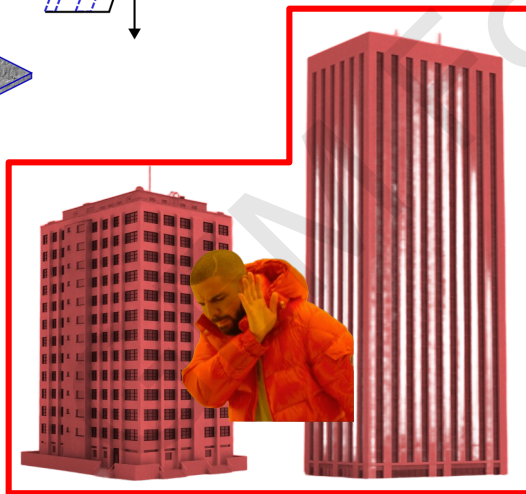
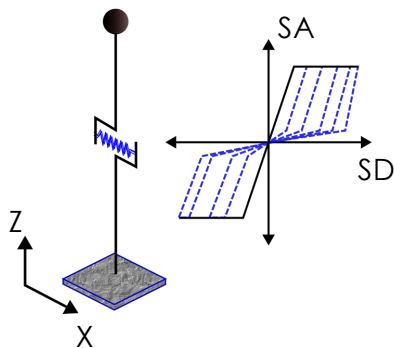


Introducing the v2026 Global Seismic Vulnerability Model



Efficient Numerical Modelling

Single-Degree-of-Freedom Oscillators – v2023



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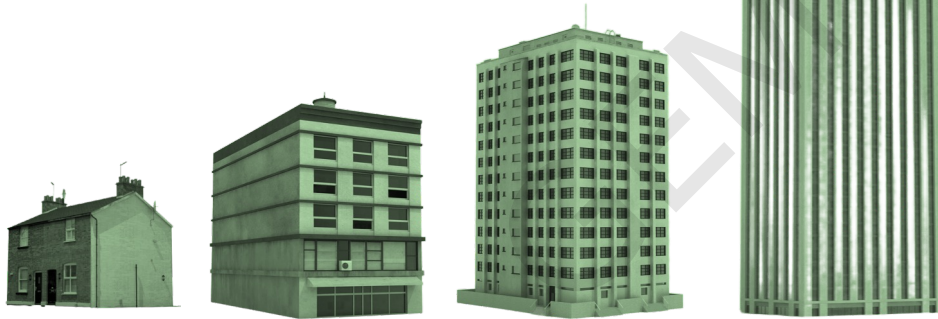
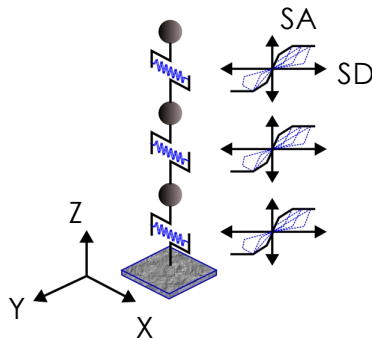
- **Over-simplification:** Ignores complex mechanisms and higher modes of vibration
- **Limited accuracy:** Not suitable for applications requiring distribution of demands
- **Applicability:** Best for structures that behave predominantly in a single mode of vibration

Introducing the v2026 Global Seismic Vulnerability Model

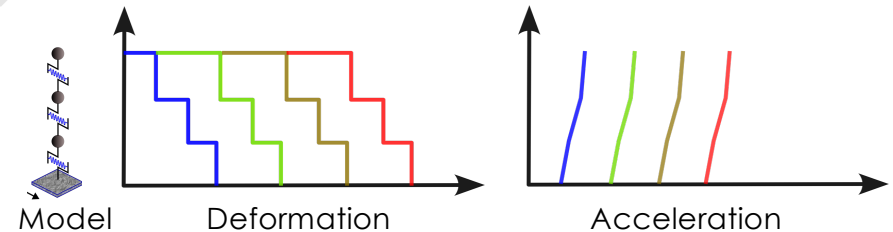


Efficient Numerical Modelling

Multi-Degree-of-Freedom Stick-and-Mass Models – v2026



- Low computational cost
- Better representation of higher-mode effects
- Direct estimation of storey- and floor-level demands

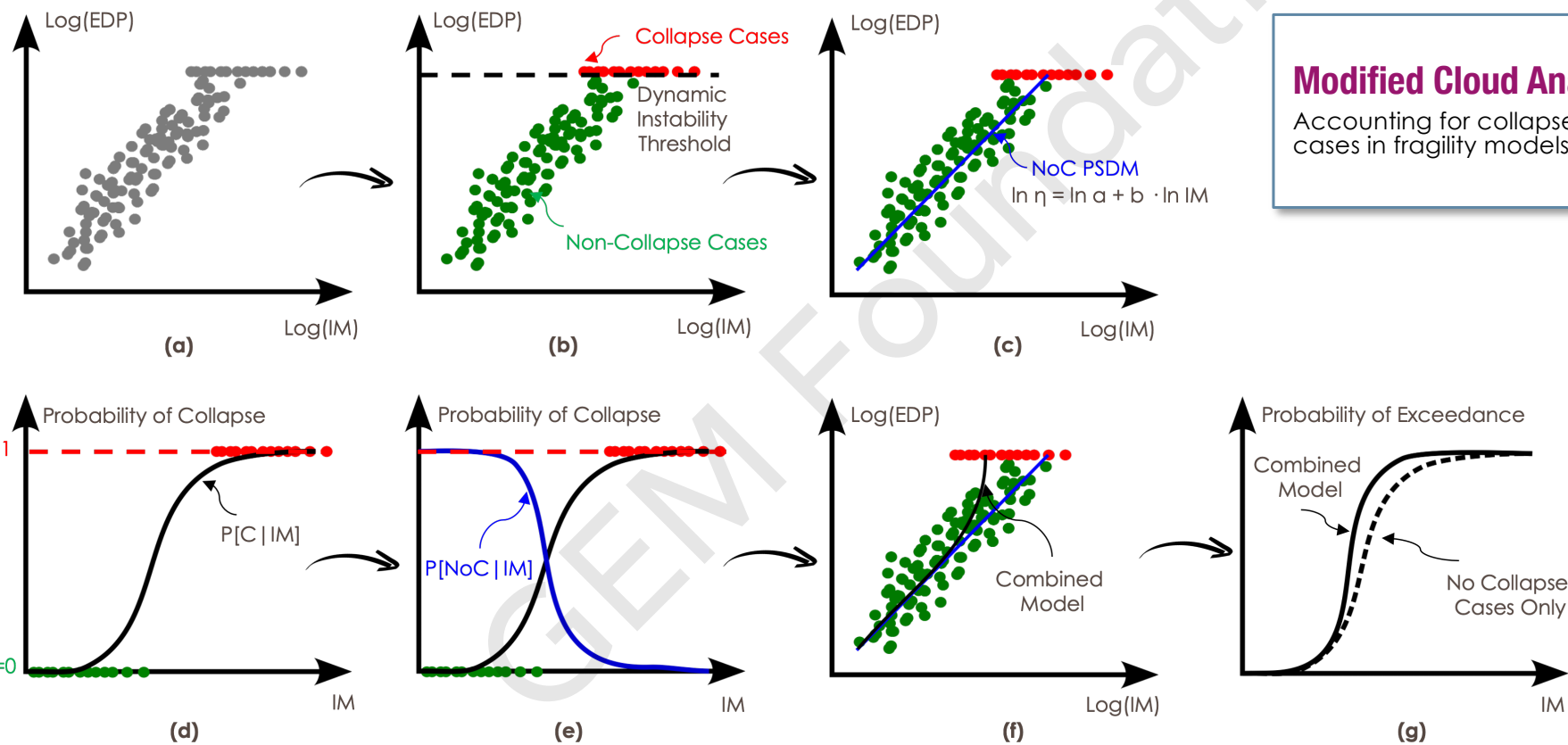


- Explicit modeling of vertical irregularities (soft-storey mechanisms, catastrophic collapse modes)
- Better linkage to modern fragility frameworks

Introducing the v2026 Global Seismic Vulnerability Model



Efficient Probabilistic Seismic Demand Modelling



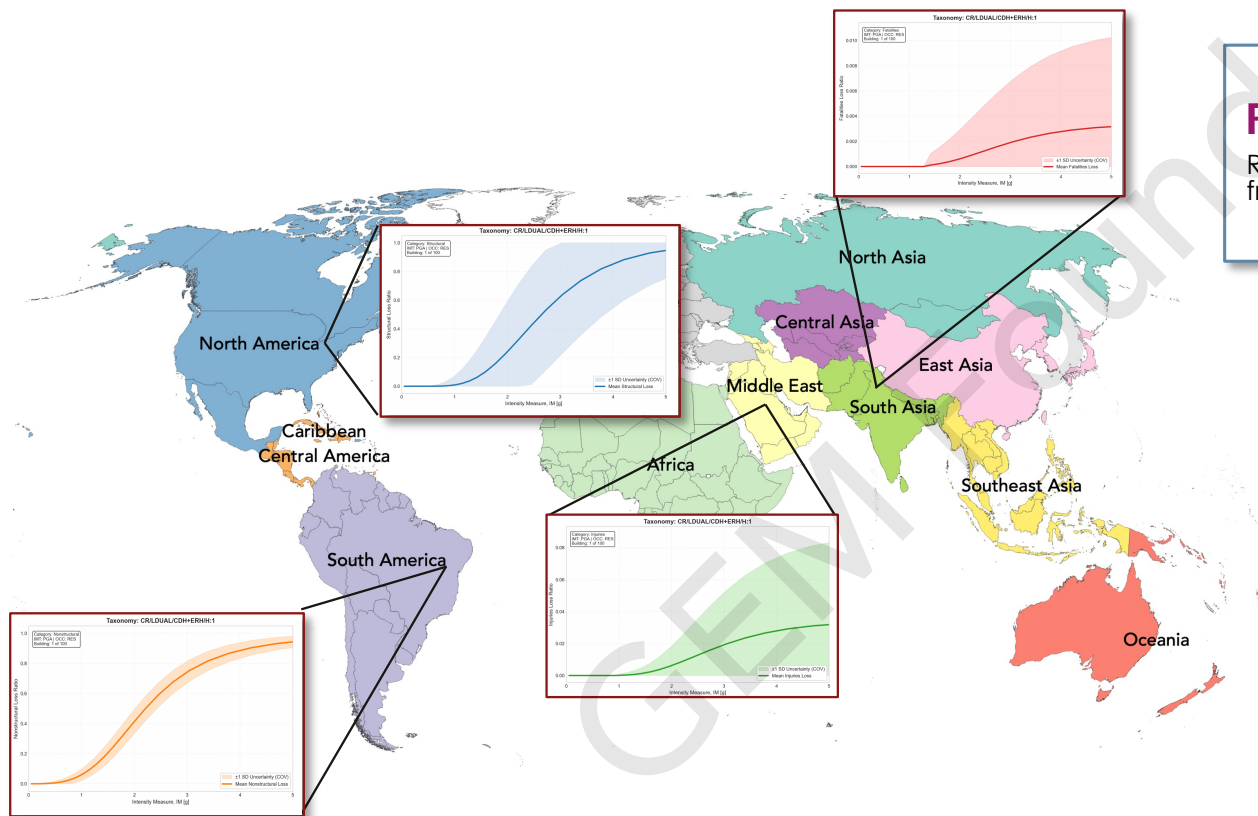
Modified Cloud Analysis Approach

Accounting for collapse/dynamic instability cases in fragility models

Introducing the v2026 Global Seismic Vulnerability Model



Finer Resolution Assessment



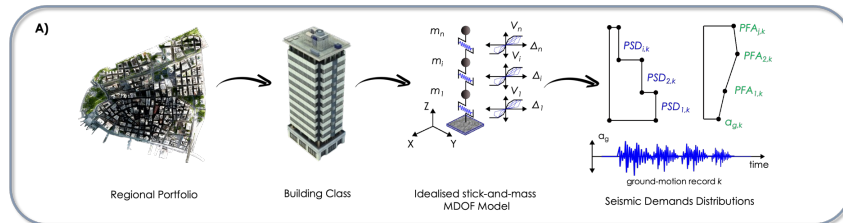
Region-Specific Models

Regional differences in nonstructural component quantities, fragilities and consequence models accounted for

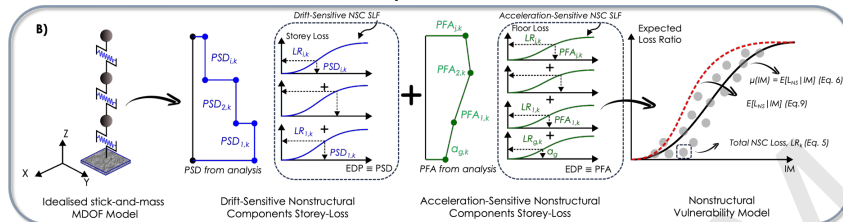
Introducing the v2026 Global Seismic Vulnerability Model

Finer Resolution Assessment

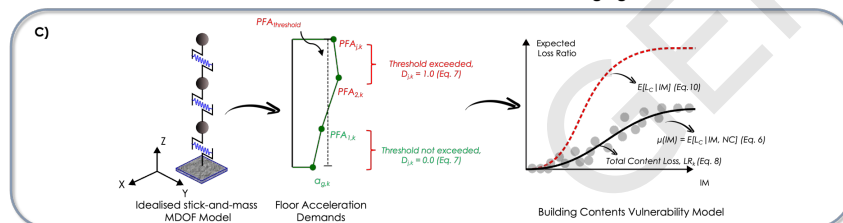
Building Class Idealisation via Numerical Modelling of Representative Stick-and-Mass Models and Seismic Demand Characterisation via NLTHA



Nonstructural Components Vulnerability via Storey-Loss Functions



Building Contents Vulnerability Evaluation via Exceedance-Based Losses and Contents Salvaging



Region-Specific Models

Regional differences in nonstructural component quantities, fragilities and consequence models accounted for

Storey- / Floor-Based Modelling

Direct integration of seismic demands with storey- and floor-level consequences derived extensively on component-level data

Introducing the v2026 Global Seismic Vulnerability Model

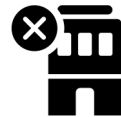


Product Coverage



Economic-Based

- ▶ **Structural**
- ▶ **Nonstructural**
- ▶ **Contents**
- ▶ **Building:** Structural + Nonstructural
- ▶ **Total:** Structural + Nonstructural + Contents



Damage-Based

- ▶ **Structural fragility models**
- ▶ **Area damaged**
- ▶ **Number of buildings completely damaged**



Population-Based

- ▶ **Affected Population**
- ▶ **Displaced Population**
- ▶ **Injured Population**
- ▶ **Casualties**

Introducing the v2026 Global Seismic Vulnerability Model



Product Coverage



Embodied Carbon

Ground Shaking



Building Damage



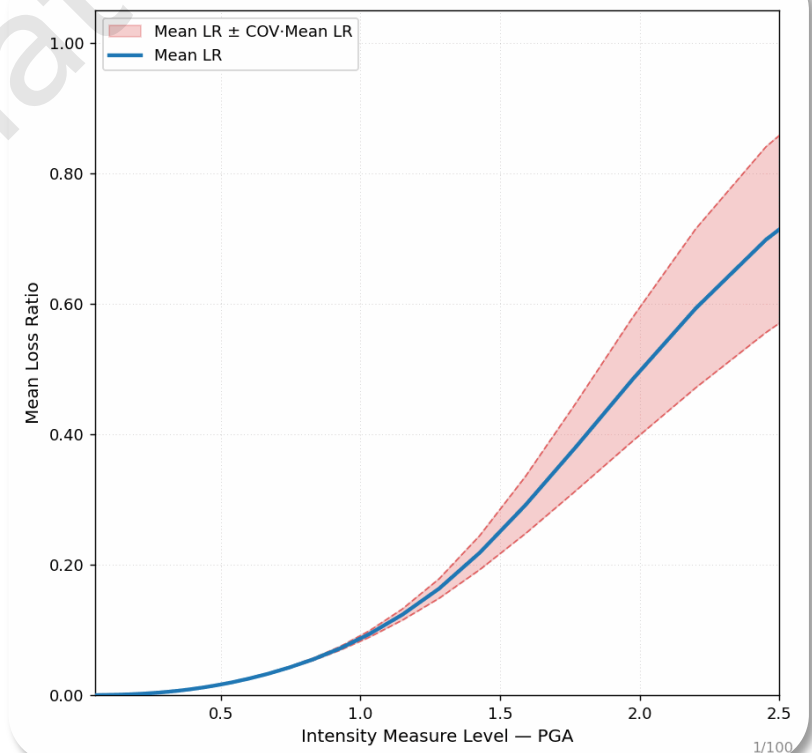
Material Supply



Carbon Emissions



Embodied Carbon Vulnerability · W+WLI/LWAL/CDH+ERM/H:3/RES



Testing and Validation



Four-Tier Testing Framework

**Test
Product**



Internal Model Consistency

Testing and Validation



Four-Tier Testing Framework



Internal Model Consistency



Risk Metrics Sanity Checks

Testing and Validation



Four-Tier Testing Framework



Testing and Validation



Four-Tier Testing Framework



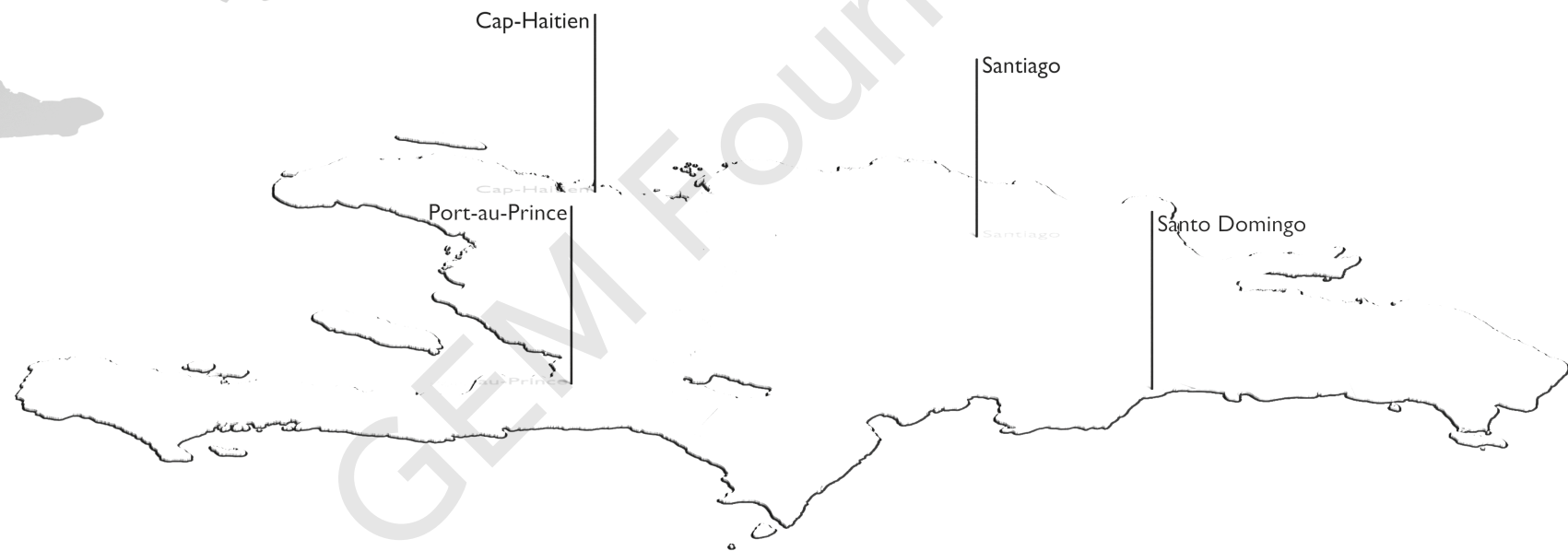
Testing and Validation



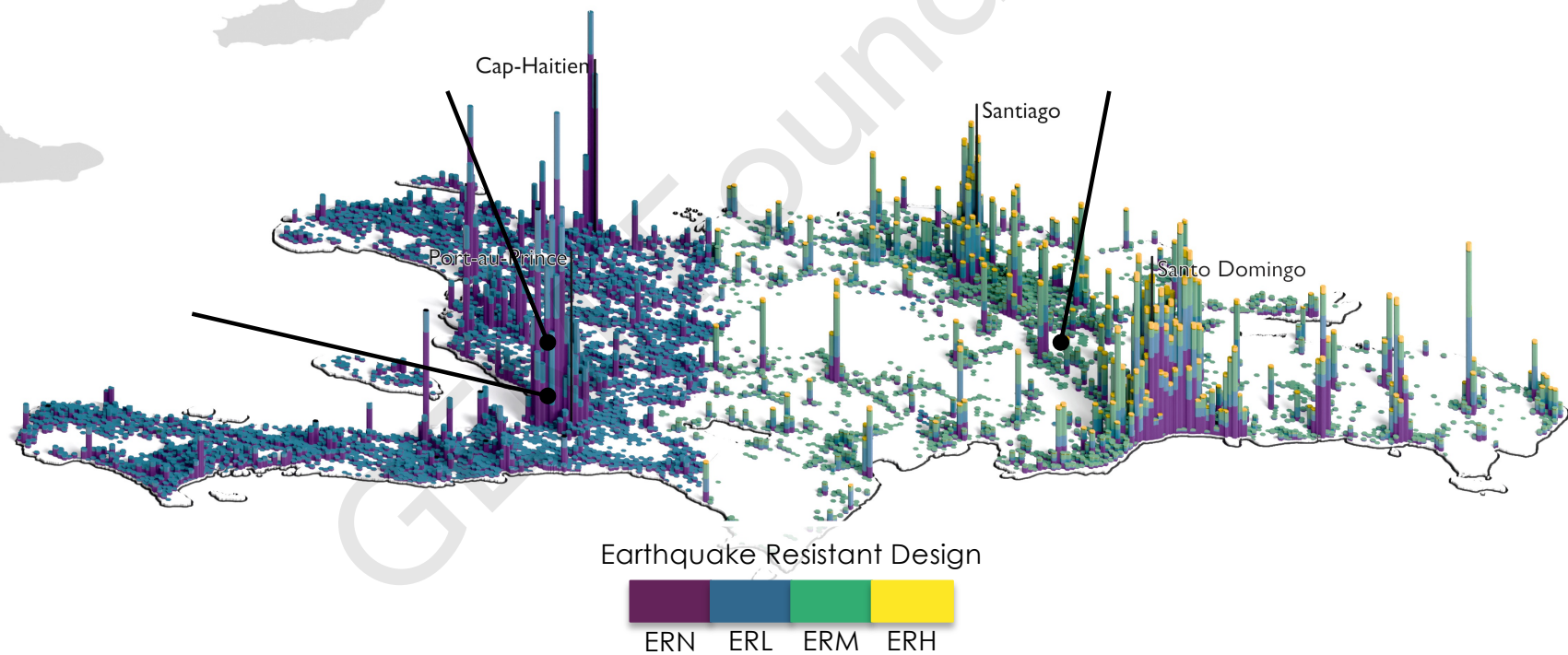
Four-Tier Testing Framework



The case of Hispaniola - Vulnerability Distribution



The case of Hispaniola - Vulnerability Distribution



The case of Hispaniola - Vulnerability Distribution

Primary Construction Material

- Masonry: 1,553,277 (54.3%)
- Informal: 651,975 (22.8%)
- Timber: 479,460 (16.8%)
- Concrete: 167,782 (5.9%)
- Steel: 7,968 (0.3%)

Height Categories

- Low-Rise: 2,857,909 (99.9%)
- Mid-Rise: 2,553 (0.1%)
- High-Rise: -

Seismic Design Code Levels

- CDN: 2,465,852 (86.3%)
- CDL: 387,196 (13.5%)
- CDM: 5,414 (0.2%)

Primary Construction Material

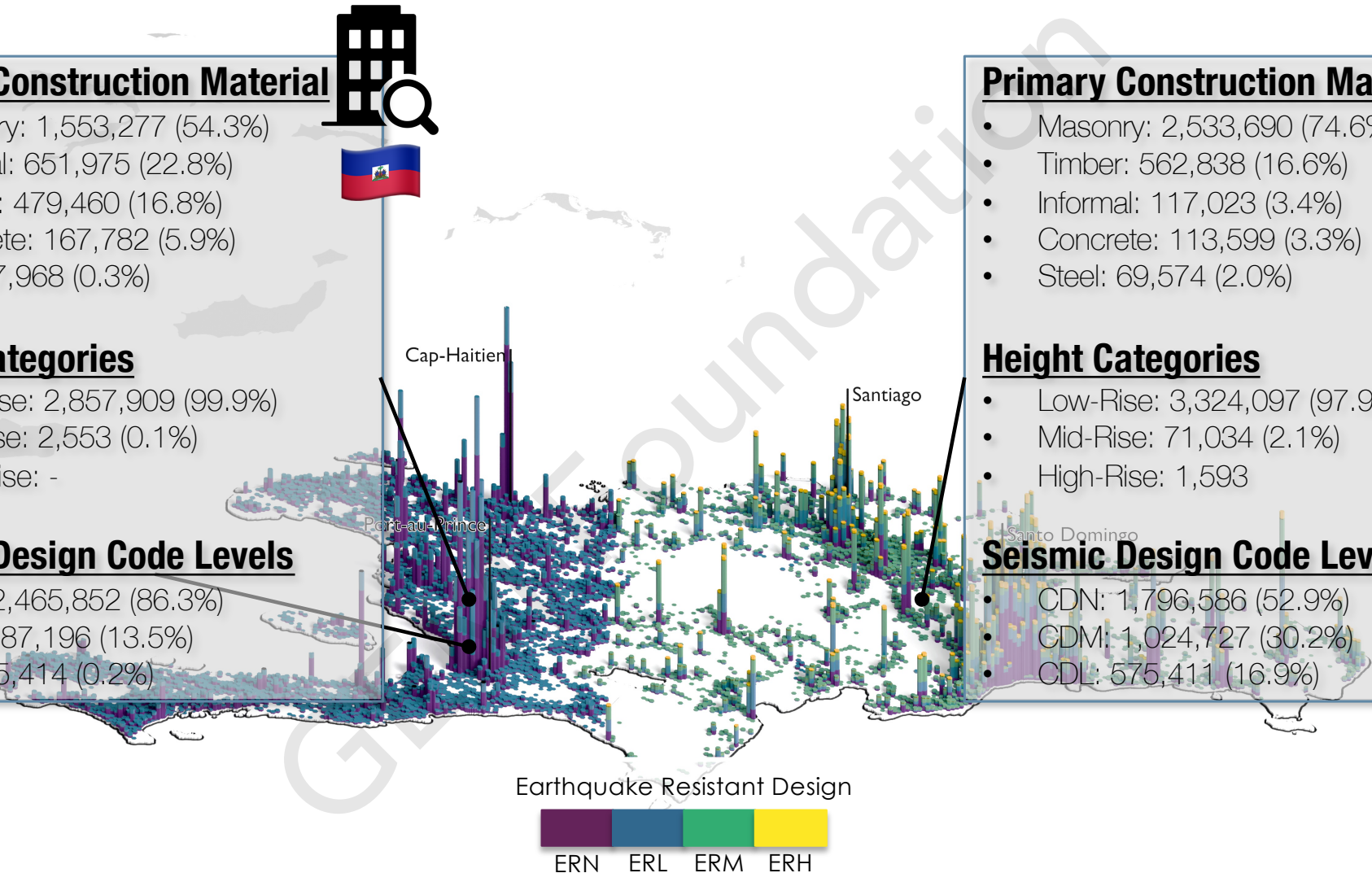
- Masonry: 2,533,690 (74.6%)
- Timber: 562,838 (16.6%)
- Informal: 117,023 (3.4%)
- Concrete: 113,599 (3.3%)
- Steel: 69,574 (2.0%)

Height Categories

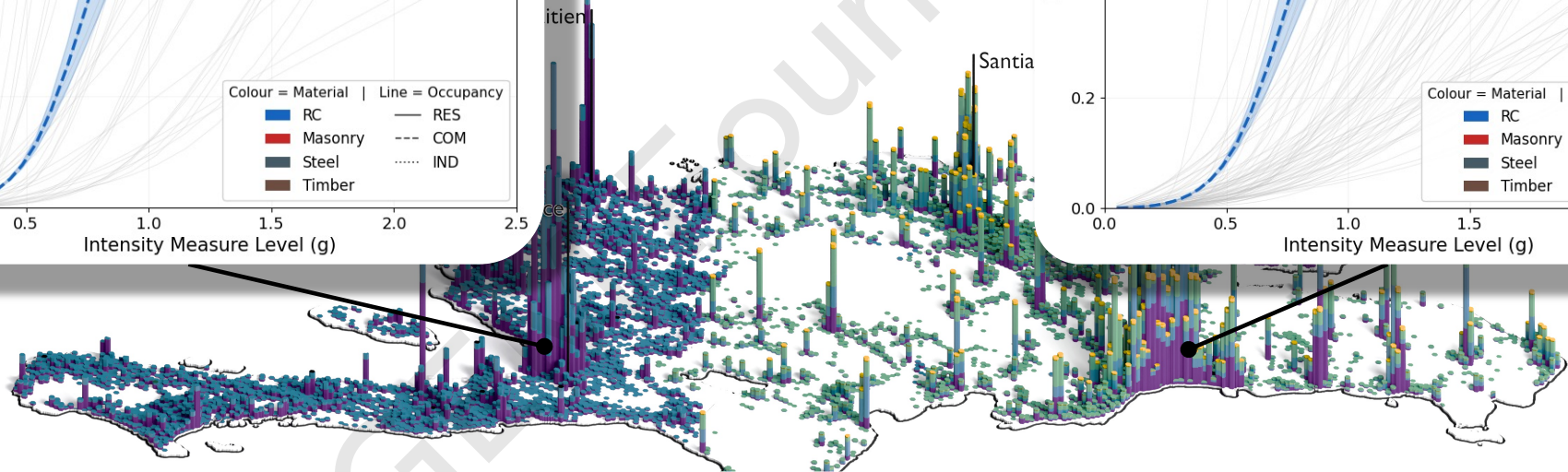
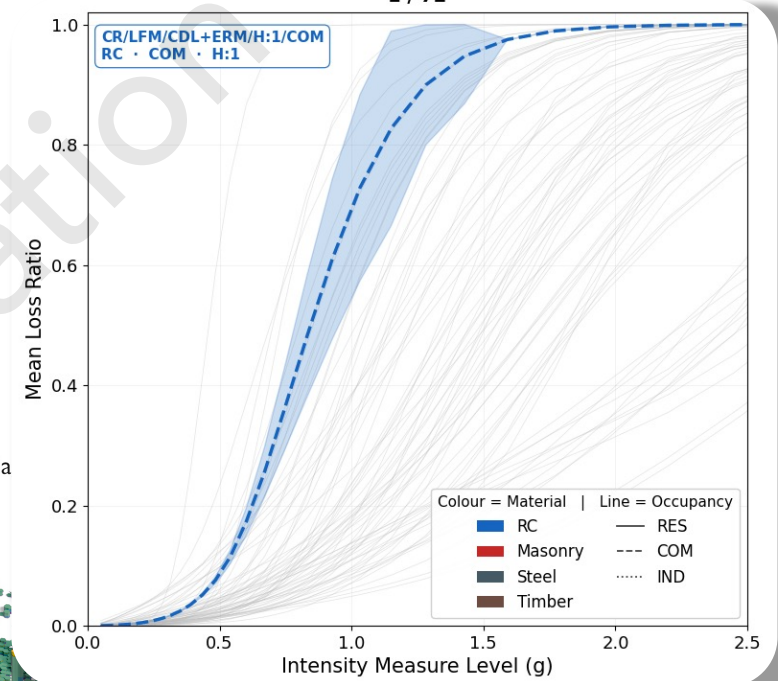
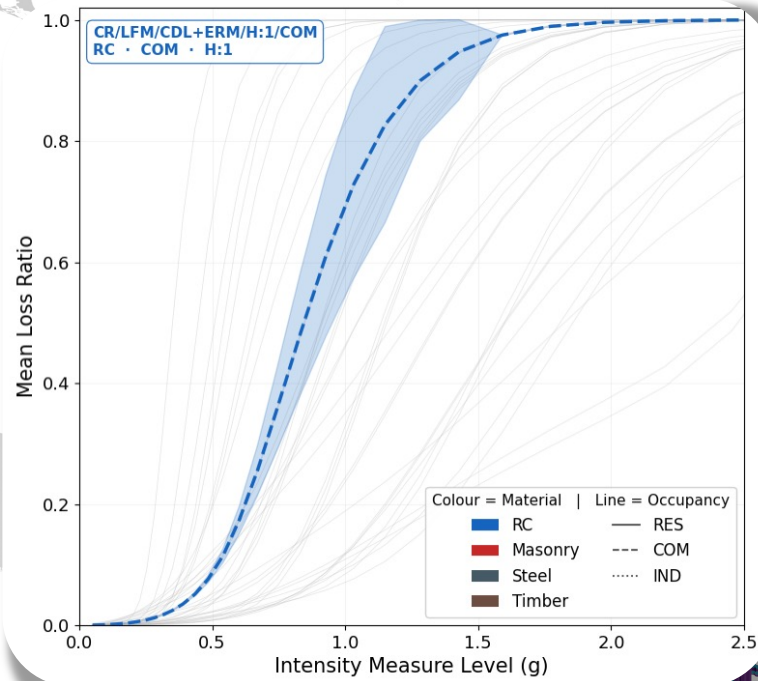
- Low-Rise: 3,324,097 (97.9%)
- Mid-Rise: 71,034 (2.1%)
- High-Rise: 1,593

Seismic Design Code Levels

- CDN: 1,796,586 (52.9%)
- CDM: 1,024,727 (30.2%)
- CDL: 575,411 (16.9%)



The case of Hispaniola - Vulnerability Distribution



Earthquake Resistant Design



Model Repositories



Link to Open-Access
Country-Specific Models



Includes loss models for
structural, nonstructural,
contents and fatalities



Request Access/License for
Supplementary Models



Includes all models,
including human-centric
losses

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- Overview
- Capacity Models
- Ground-Motion Records
- Structural Analysis
- Fragility Models
- Consequence Models
- Vulnerability Models
 - Vulnerability Model Comparison
- Risk Metrics
- License

GEM Vulnerability Models Documentation

Welcome to the documentation for the GEM Global Vulnerability Models. This documentation provides comprehensive information about the building vulnerability models developed by the GEM Foundation for seismic risk assessment.

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 - [Intensity Measures](#)
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Documentation



[Link to Model Documentation](#)

Behind and Beyond the Global Seismic Risk Model

SEISMIC VULNERABILITY

Al Mouayed Nafeh

Vulnerability Lead



Global Liquefaction Map and Roads Exposure

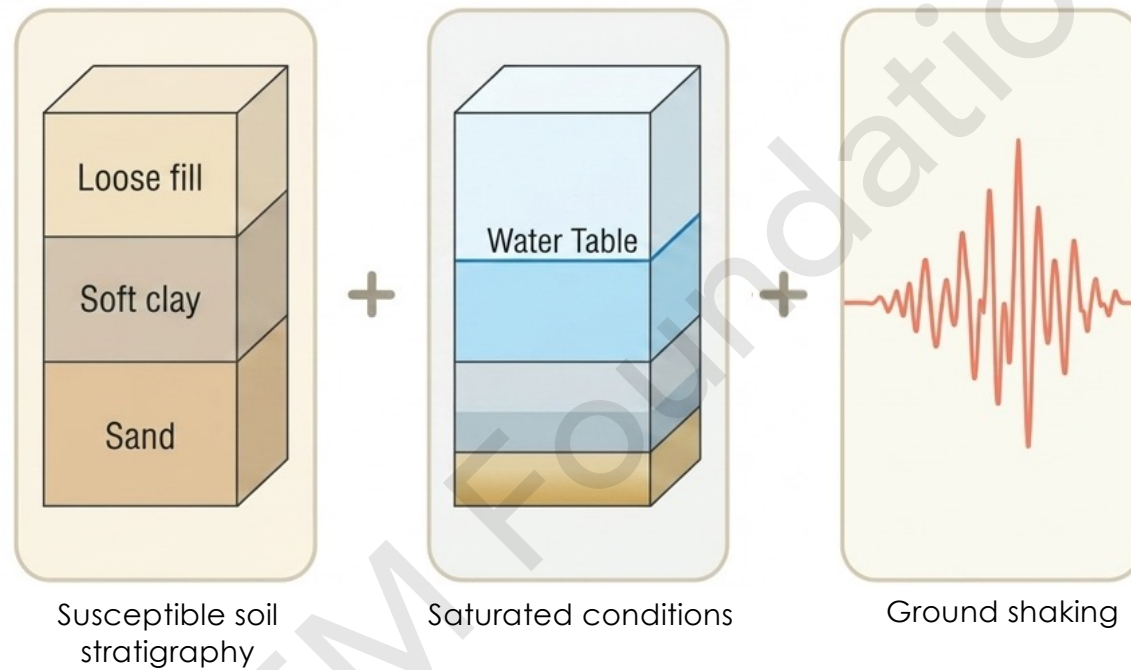
Understanding liquefaction patterns and implications for road connectivity

Catarina Costa and Lana Todorovic on behalf of the Risk Team

Global Earthquake Model (GEM) Foundation

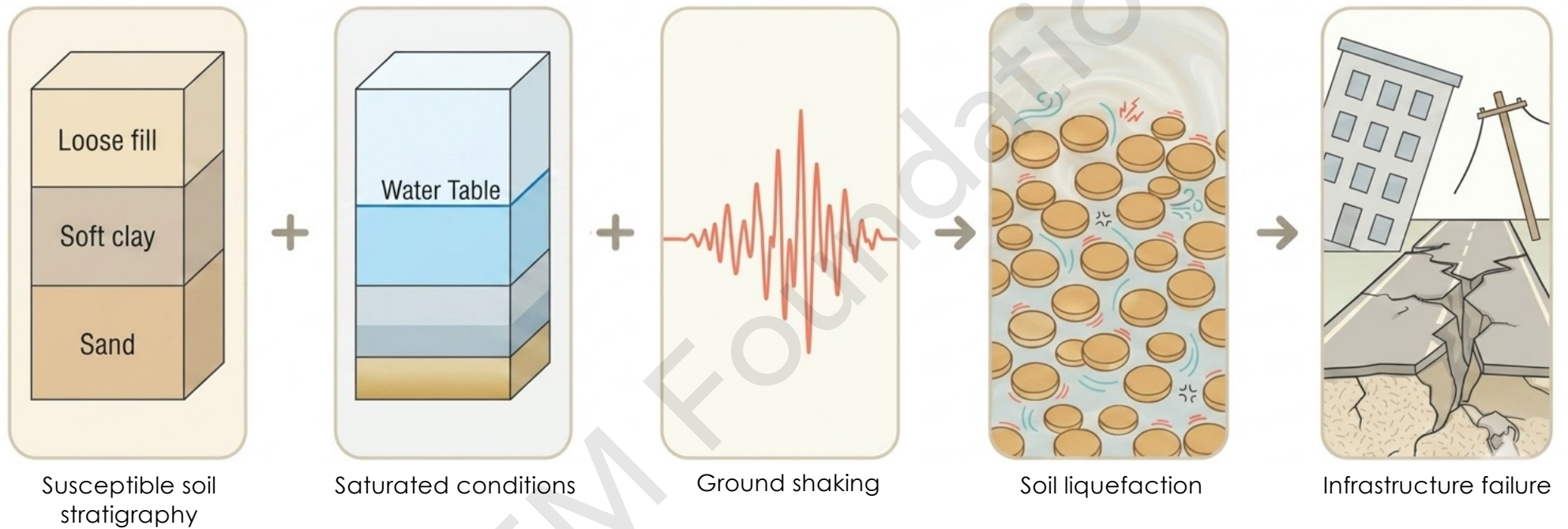


What is soil liquefaction?



Loss of soil strength and shear stiffness in saturated, cohesionless soils during shaking.

What is soil liquefaction?

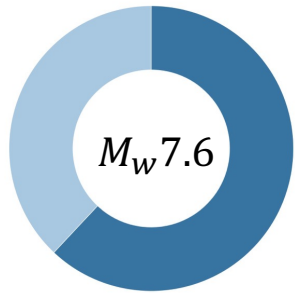


Loss of soil strength and shear stiffness in saturated, cohesionless soils during shaking.

Liquefaction-related losses in past earthquakes

Liquefaction impacts critical infrastructure in ways that are underrepresented in conventional loss estimates.

1964 Niigata, Japan



Loss due to liquefaction was estimated at **US\$800M.**

2011 Christchurch, NZL



Liquefaction-induced damage to residential buildings and infrastructure amounted to **NZ\$10B**, affecting nearly 20,000 properties.



Source: Wikipedia

Liquefaction-related losses in past earthquakes

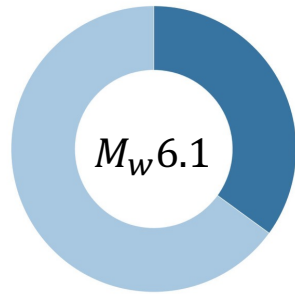
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Liquefaction-induced
damage to residential
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affecting nearly 20,000
properties.



Source: RNZ

Liquefaction-related losses in past earthquakes

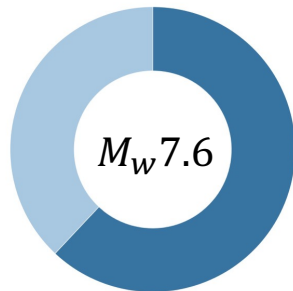
Liquefaction impacts critical infrastructure in ways that are underrepresented in conventional loss estimates.

1964 Good Friday, Alaska



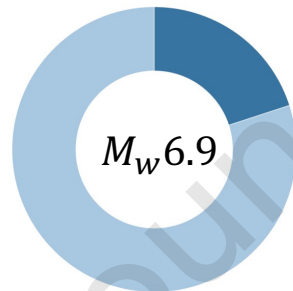
Road damage (highways and road bridges) and transmission towers damage due to liquefaction resulted in **US\$344M** losses.

1964 Niigata, Japan



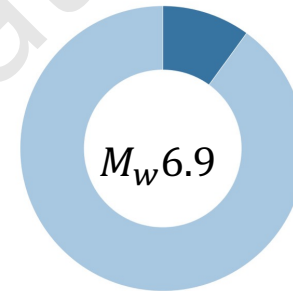
Loss due to liquefaction was estimated at **US\$800M**.

1989 Loma Prieta, USA



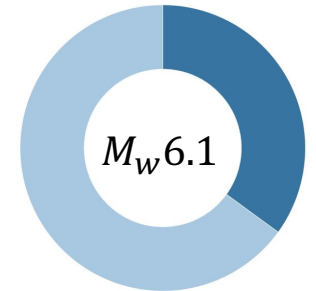
Liquefaction-induced damage to port facilities, lifelines and buildings amounted to **US\$282M**.

1995 Kobe, Japan



Liquefaction-induced widespread damage to the Port of Kobe caused direct losses of **US\$11B**.

2011 Christchurch, NZL



Liquefaction-induced damage to residential buildings and infrastructure amounted to **NZ\$10B**, affecting nearly 20,000 properties.

From ground shaking to liquefaction

Geotechnical Models

Geospatial Liquefaction Modelling

Numerical Models

GEM Foundation

From ground shaking to liquefaction

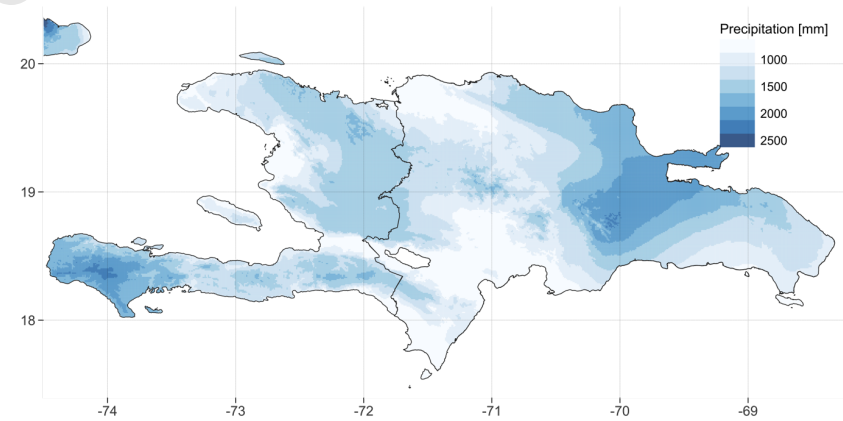
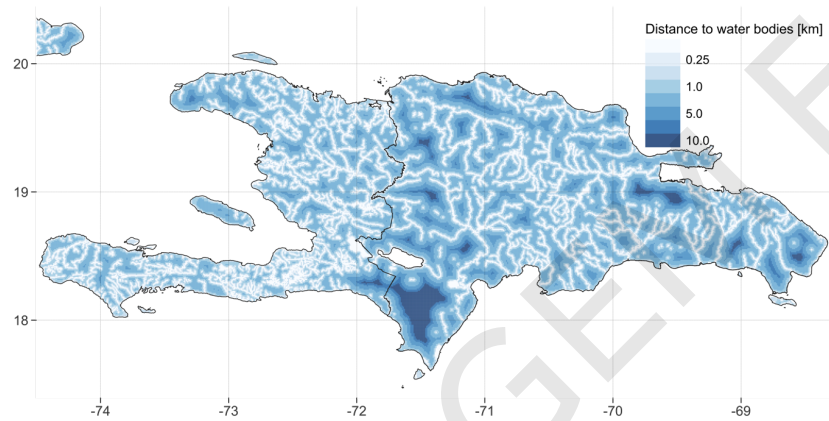
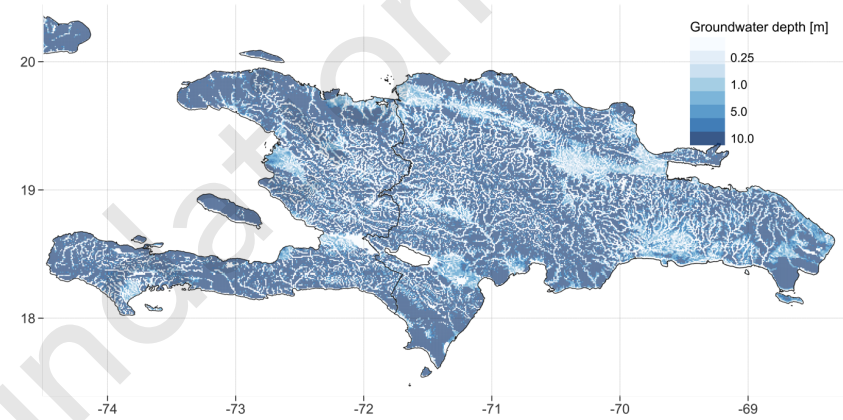
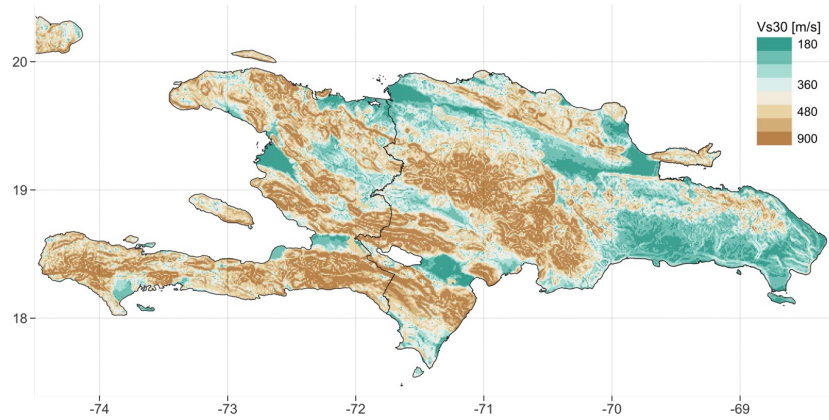
Geotechnical Models

Geospatial Liquefaction Modelling

Numerical Models

- Cost-effective alternative for regional scale assessment
- Uses globally available variables as proxies for inferring liquefaction triggering potential:
 - **Density**: Vs30, slope, distance to water bodies
 - **Saturation**: groundwater depth, precipitation, compound topographic index, distance to water bodies
- Available in both **logistic regression** and **machine learning** formulations

Geospatial drivers used to estimate liquefaction



From ground shaking to liquefaction spatial extent

Input variables

Ground shaking:
PGA, PGV

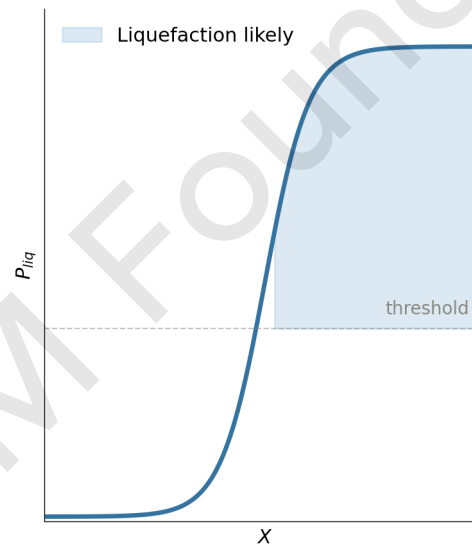
Density:
Vs30, slope, distance
to water bodies

Saturation:
groundwater depth,
precipitation,
distance to water
bodies

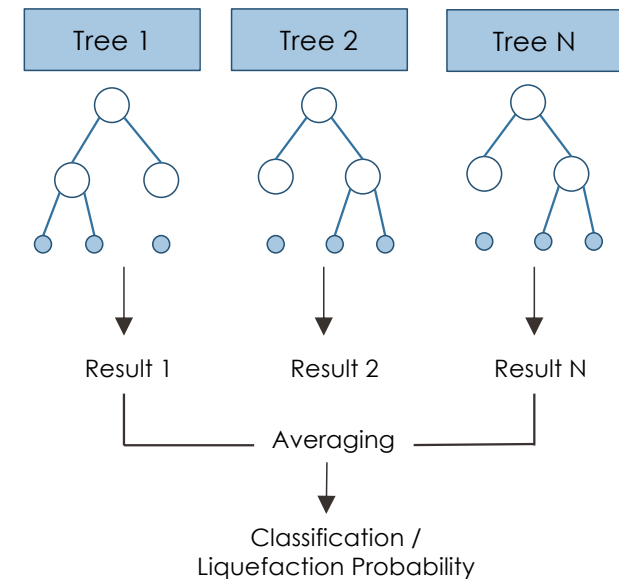


Liquefaction Models

Allstadt et al., 2022



Todorović and Silva, 2022



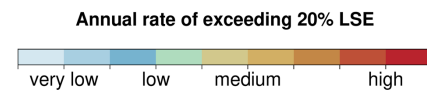
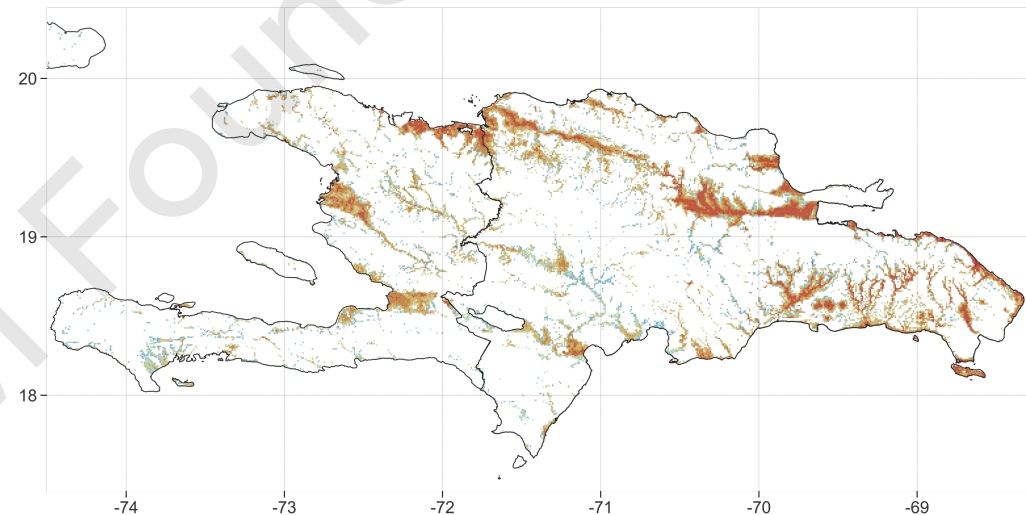
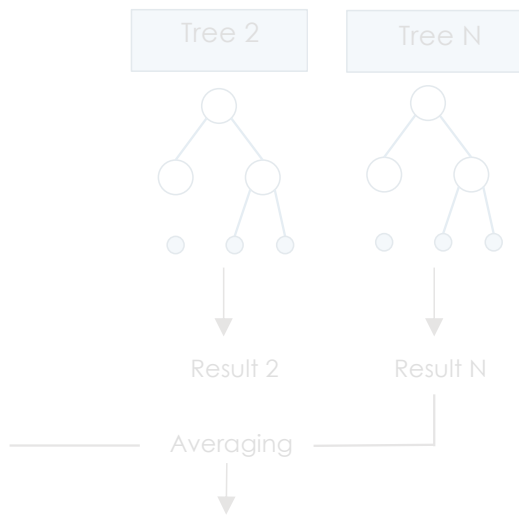
From ground shaking to liquefaction spatial extent

Liquefaction Models

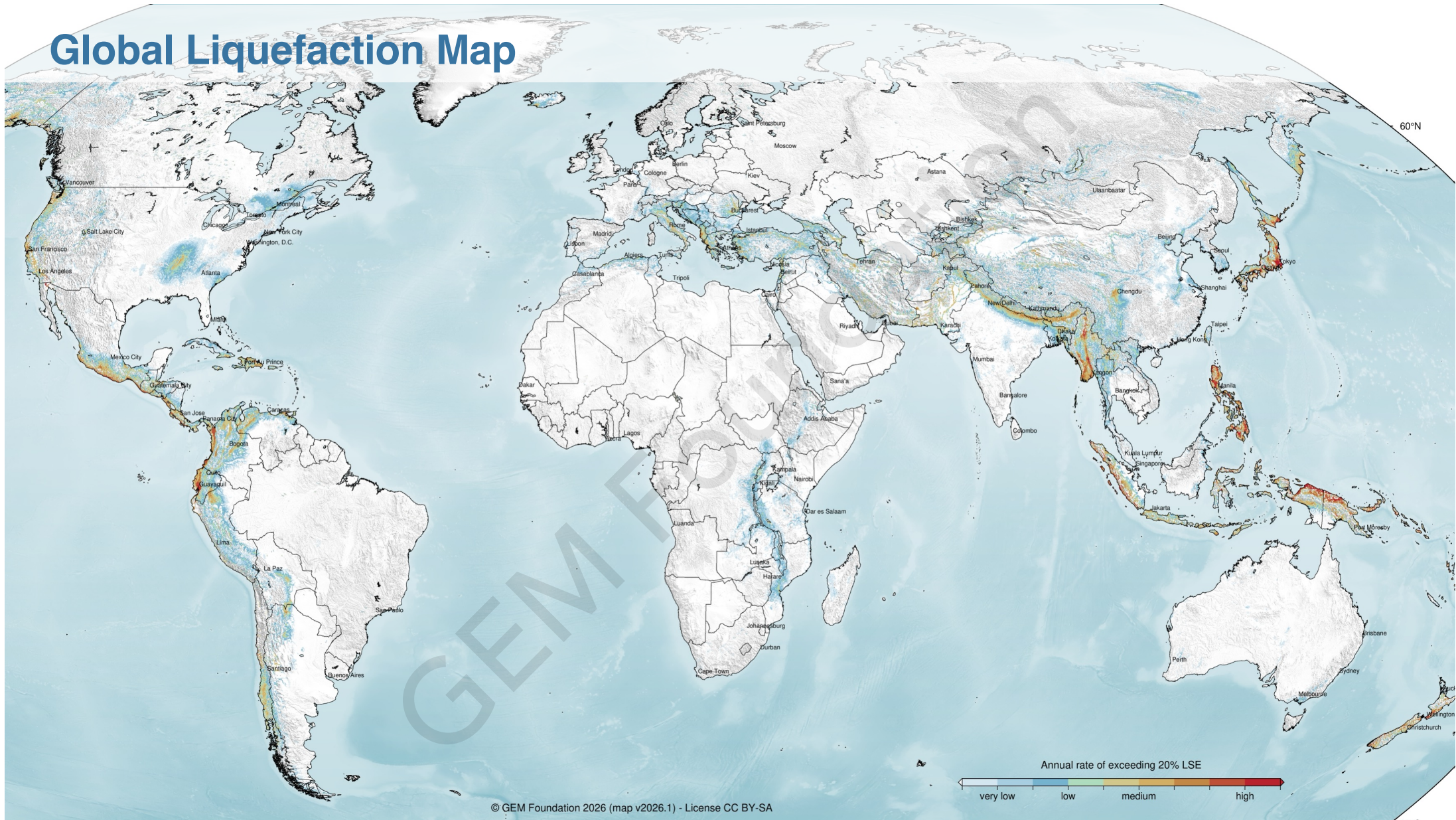


Outputs

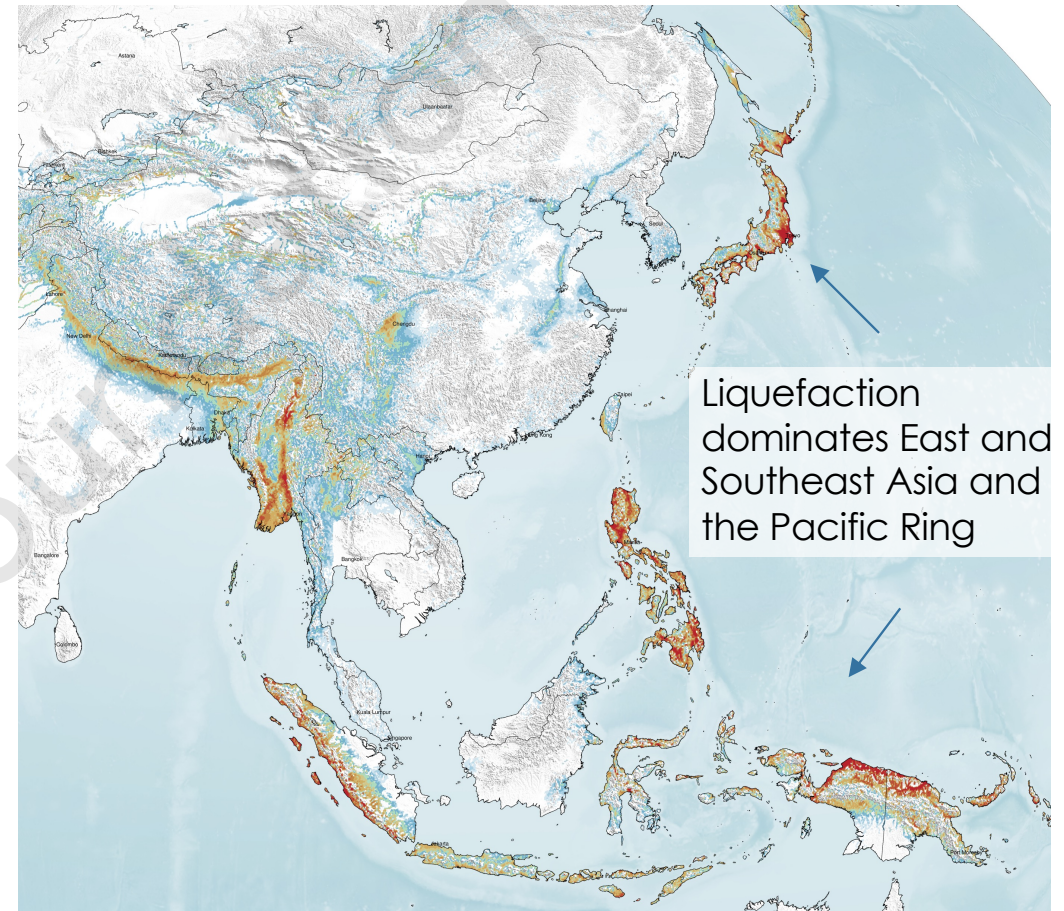
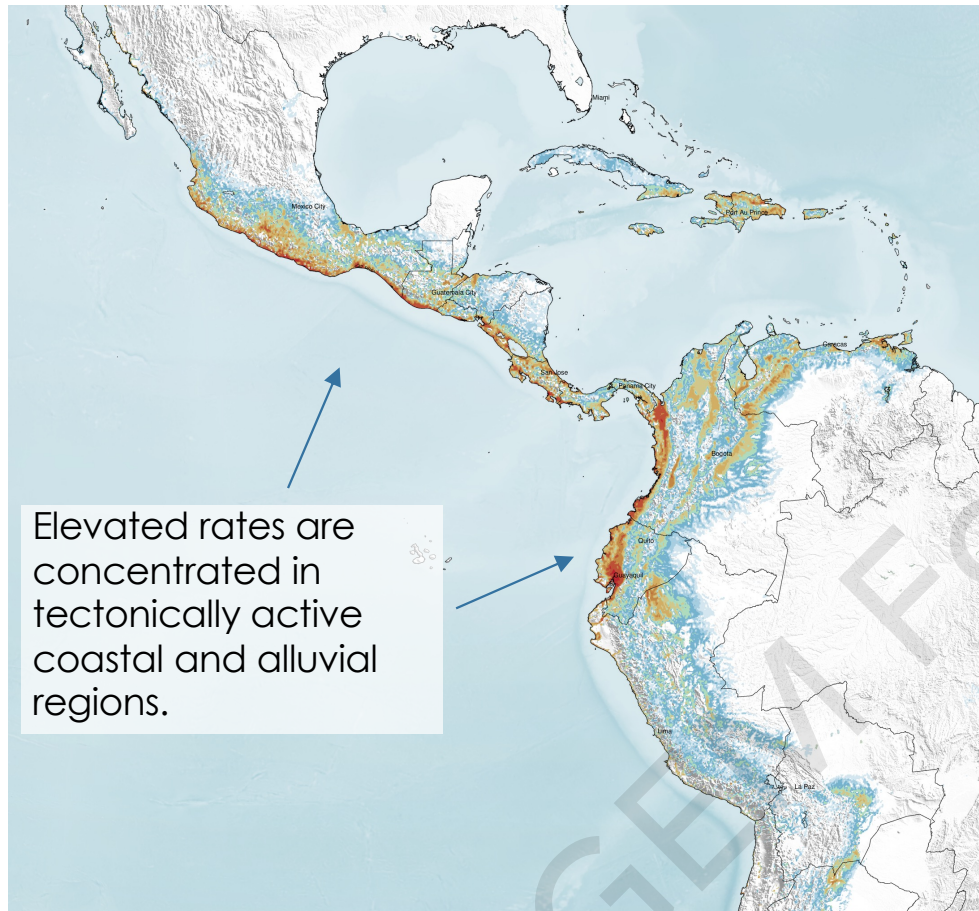
Average annual rates of exceeding liquefaction spatial extent, at any scale using the event-based approach



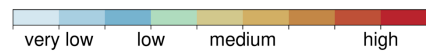
Global Liquefaction Map



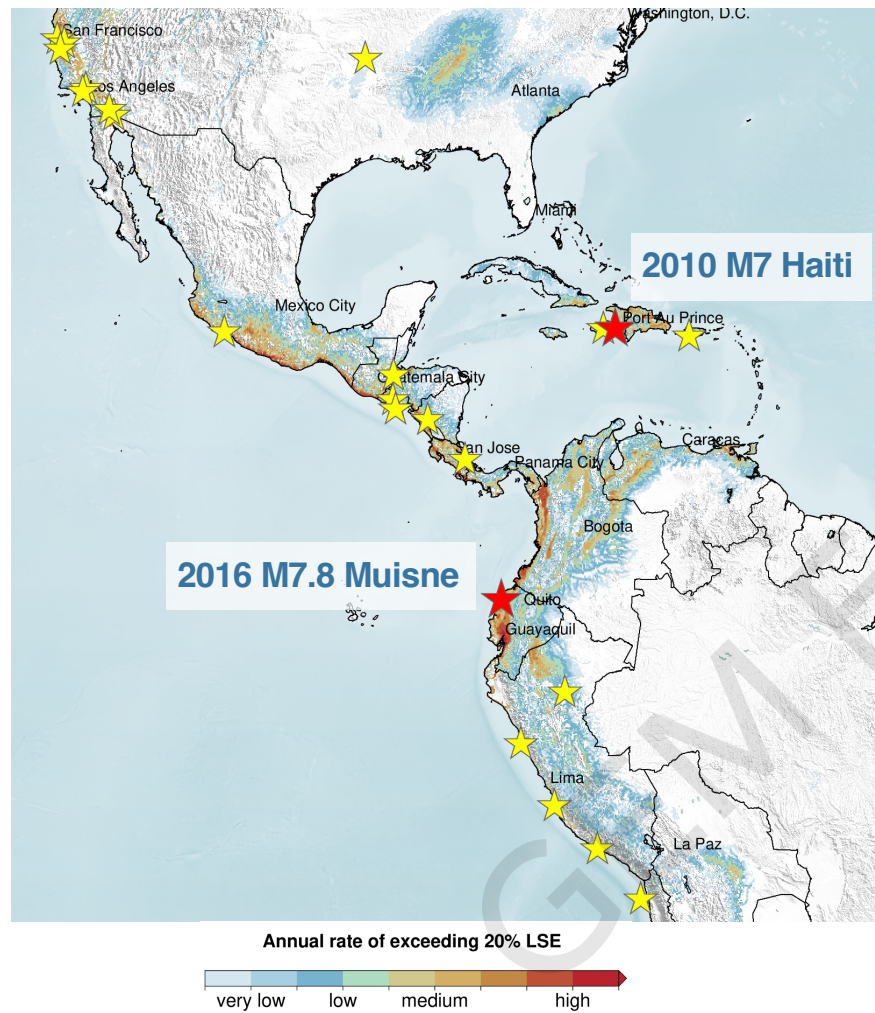
Regional patterns of liquefaction



Annual rate of exceeding 20% LSE



Regional patterns of liquefaction



Source: USGS/EERI Advance Reconnaissance Team Report



Source: EERI Earthquake Reconnaissance Team Report

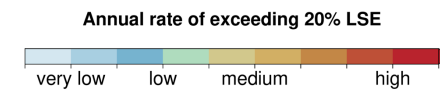
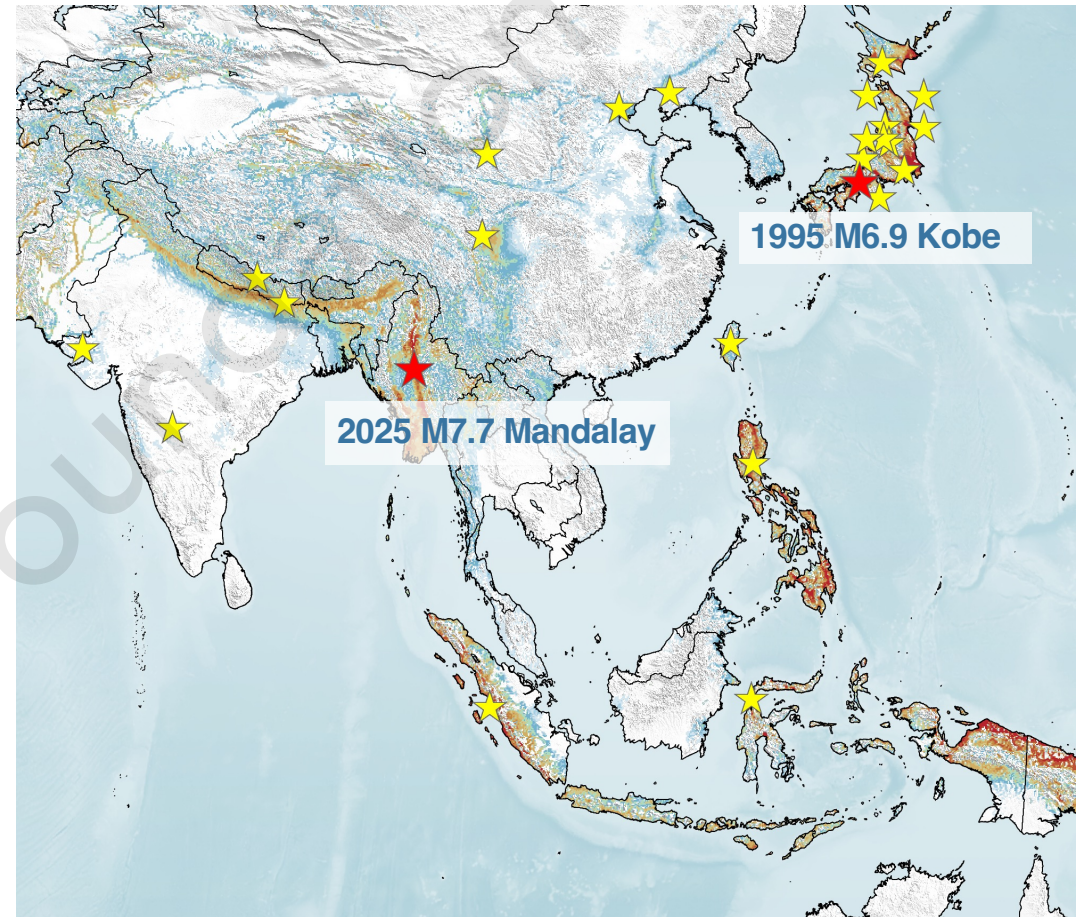
Regional patterns of liquefaction



Source: Fot. Dr. Roger Hutchison/NGDC



Source: <https://doi.org/10.1007/s11803-025-2343-3>

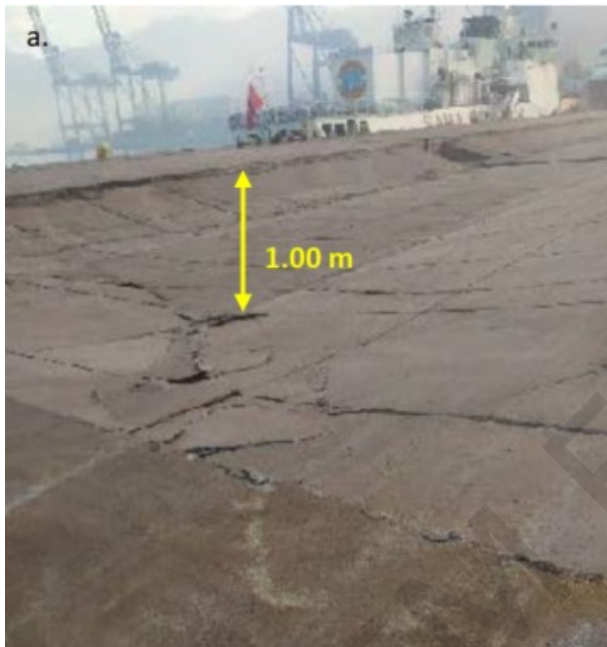


Liquefaction impacts on infrastructure



Collapse of the Showa bridge in Niigata, Japan

Liquefaction impacts on infrastructure



Port and pipe damage in Turkey

Source: Dulger and Kilic, 2024

Liquefaction impacts on infrastructure



Road damage in Sulawesi

Source: <https://phys.org/news/2018-10-liquefaction-terra-firma-mush.html>

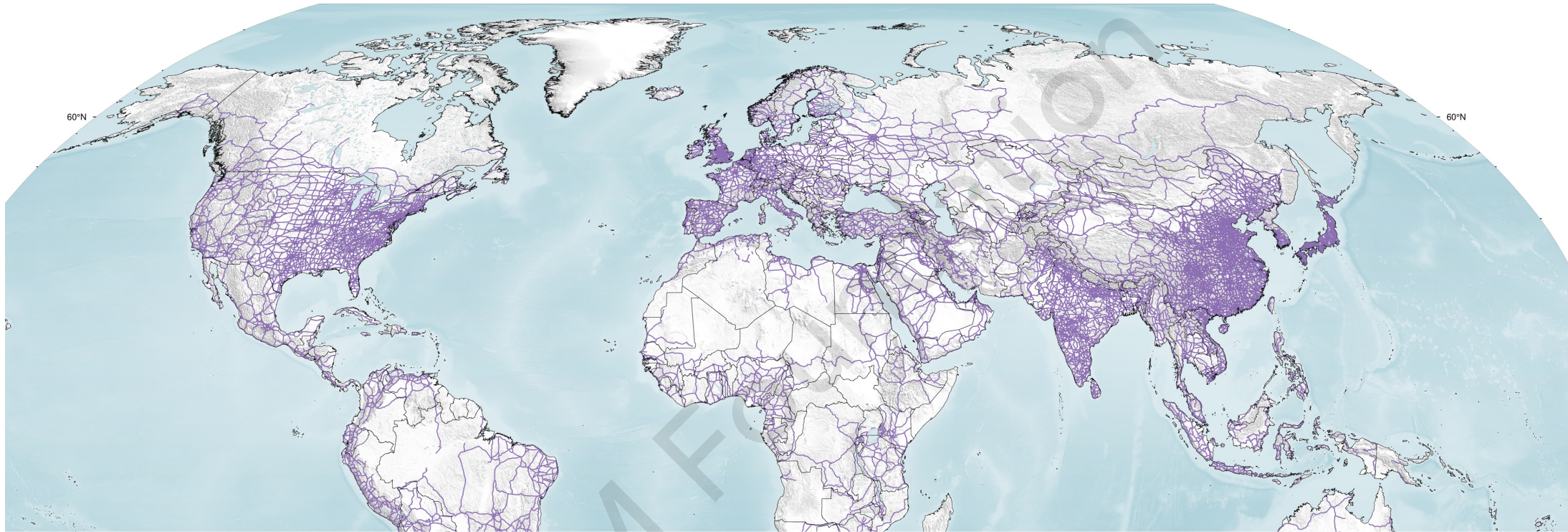
Liquefaction impacts on infrastructure



Port damage in Kobe

Source: <https://depts.washington.edu/liquify/html/quakes/kobe/kobe.html>

Global road network



**17.5 million
Km of Roads**
(derived from
OpenStreetMap)

18%
Highways

14%
Primary

22%
Secondary

46%
Tertiary

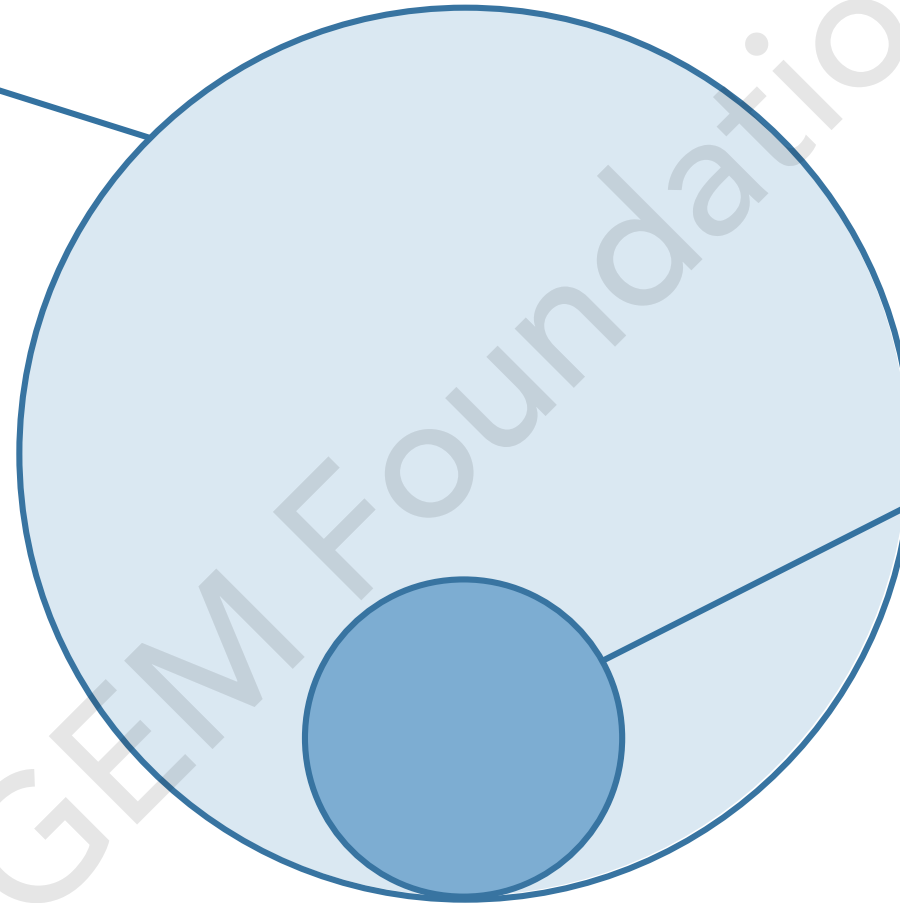
~ **40%** of global road
length concentrated in
China, US and India

How are roads exposed to shaking vs liquefaction?

2,090,000 km

Roads exposed to high **shaking** levels (PGA>0.3g for the 475-year return period)

Which represents **12%** of the entire road dataset



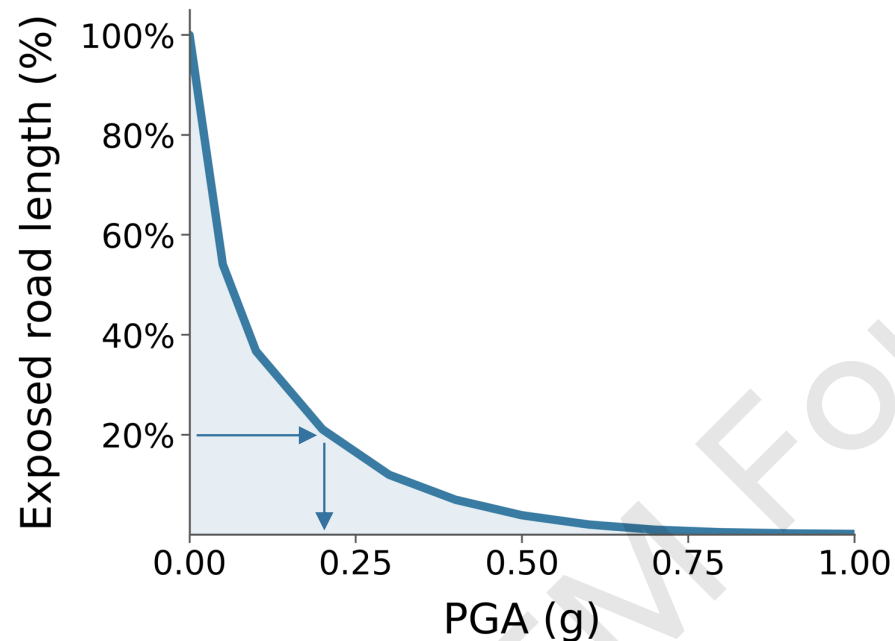
264,000 km

Roads exposed to severe **liquefaction** at least once in 475 years

Equivalent to all the roads up to the tertiary level in **Germany**

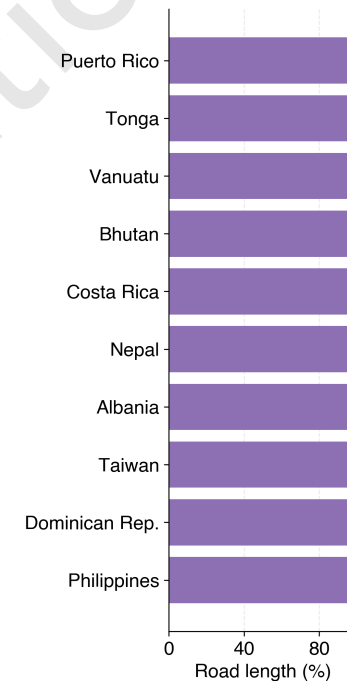
Equivalent to **60%** of all the **highways in Europe**

Global road exposure to ground shaking



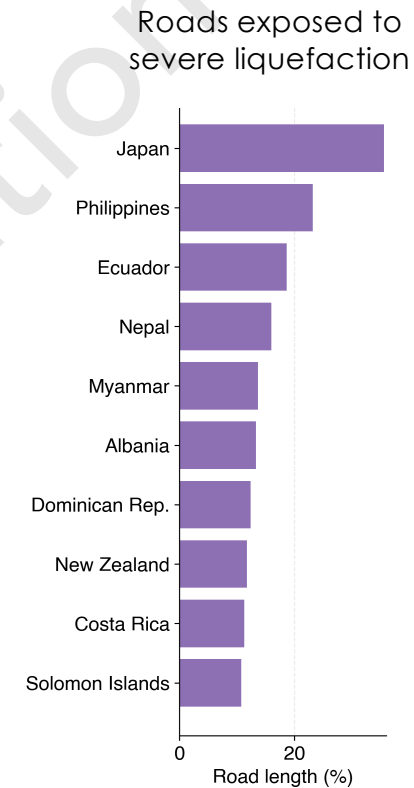
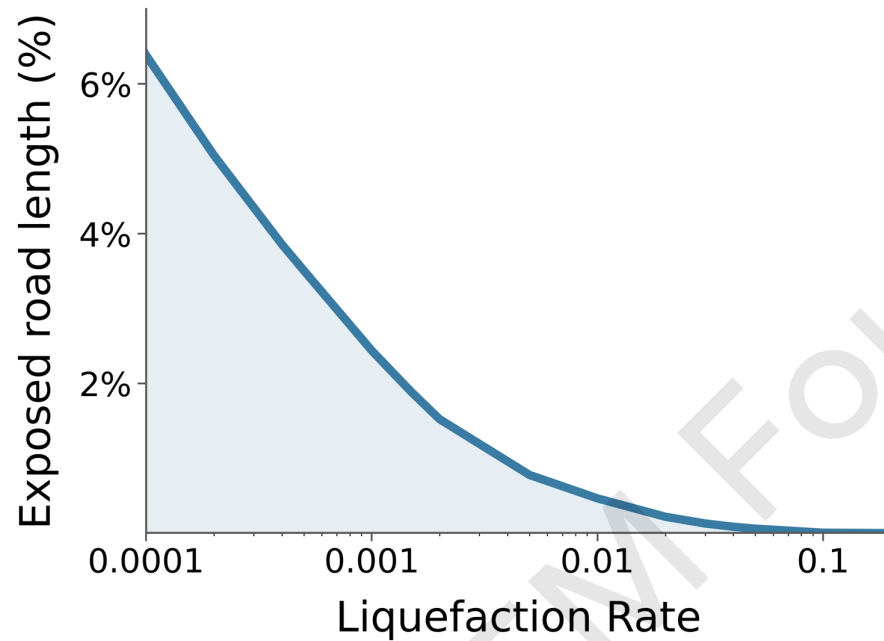
Around **20%** of global roads are exposed **PGA > 0.20g** for the 475 years return period

Roads exposed to PGA > 0.3g



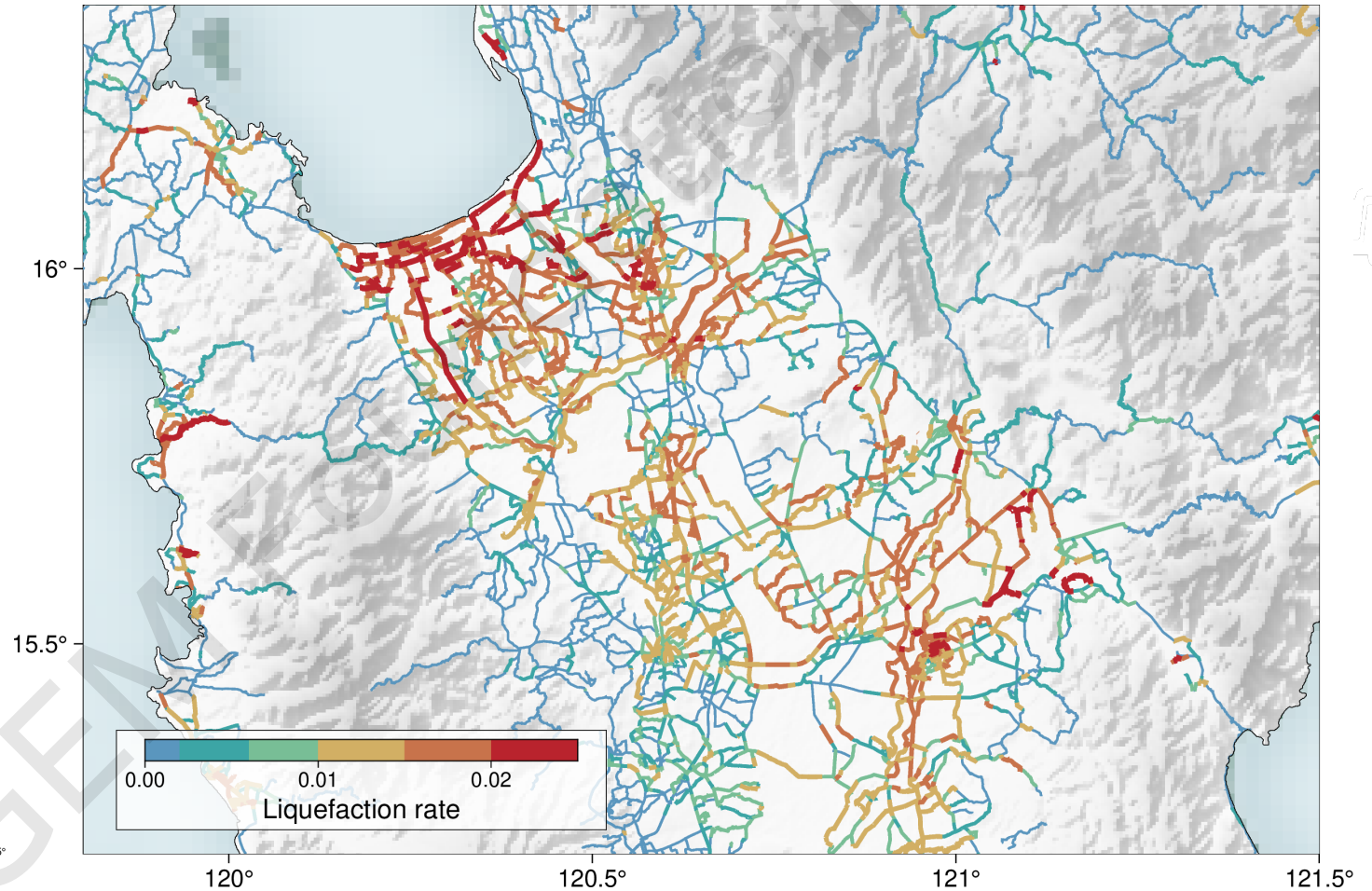
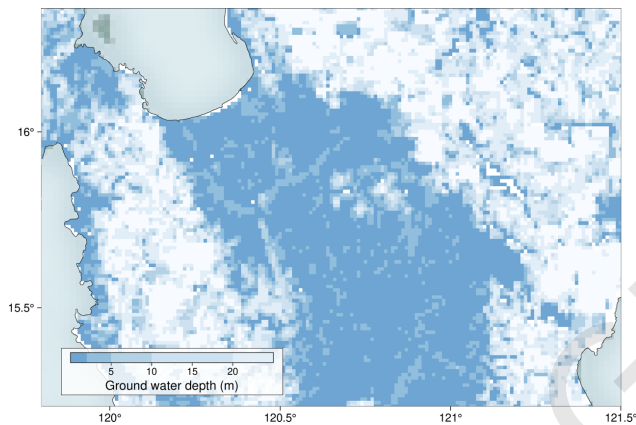
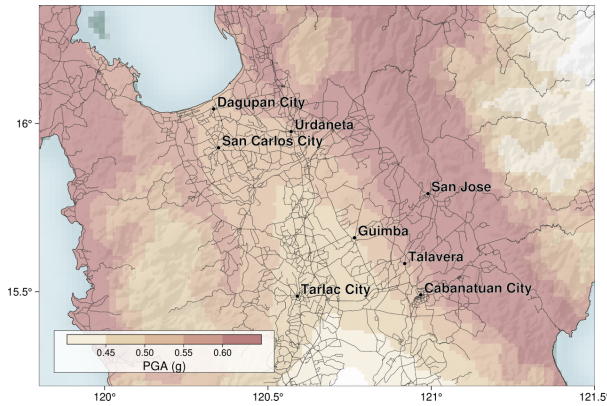
14 countries have at least **90%** of their roads exposed to high shaking (**PGA > 0.3g** for the 475 years return period)

Global road exposure to severe liquefaction



Japan has **36%** of the road network exposed to **severe liquefaction** at least **once in 475 years**

Regional example: roads and liquefaction exposure in the Philippines



Liquefaction and urban infrastructure disruption in previous events

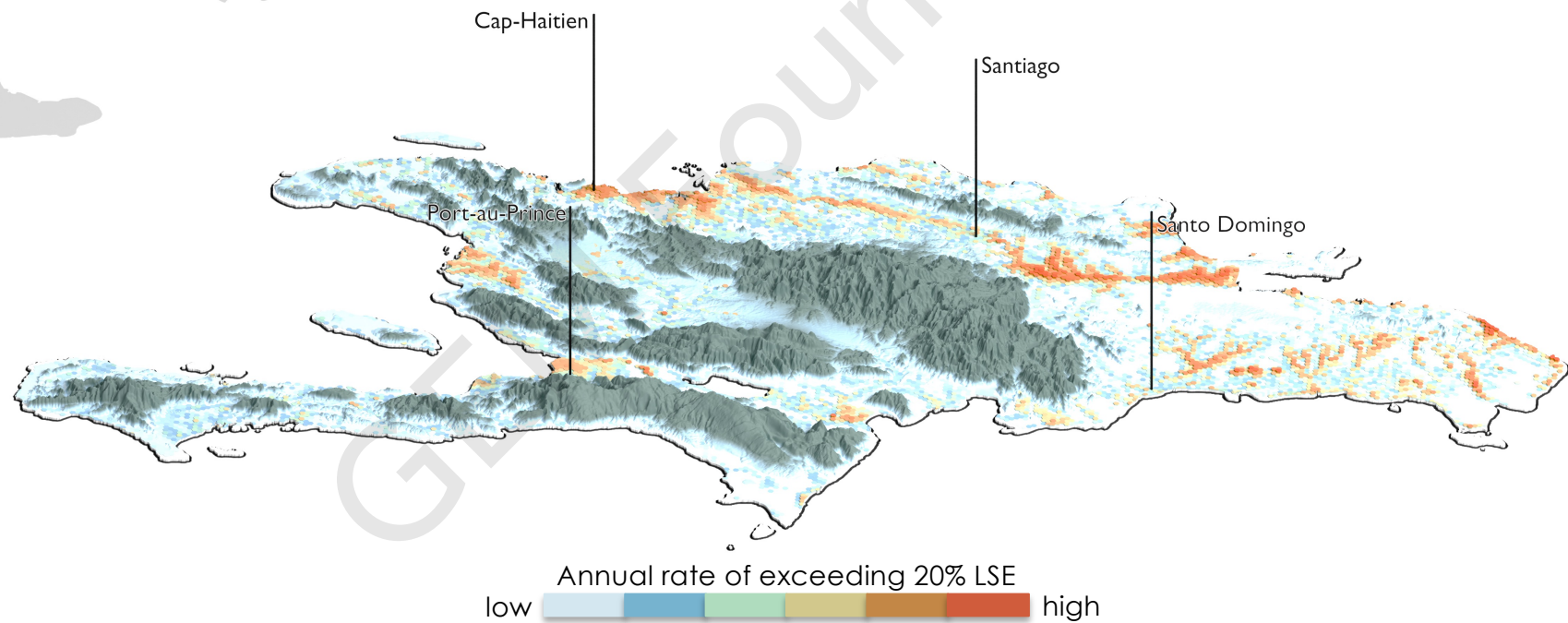


Source: RNZ



Photo credit: Jarg Pettinga

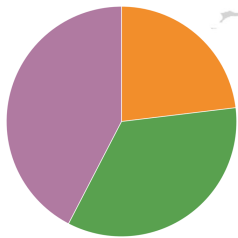
The case of Hispaniola - Rate of severe liquefaction



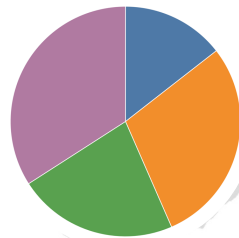
The case of Hispaniola - Roads in areas with high liquefaction rate

Road network distribution

Highways Primary Secondary Tertiary



Haiti



Dominican Republic

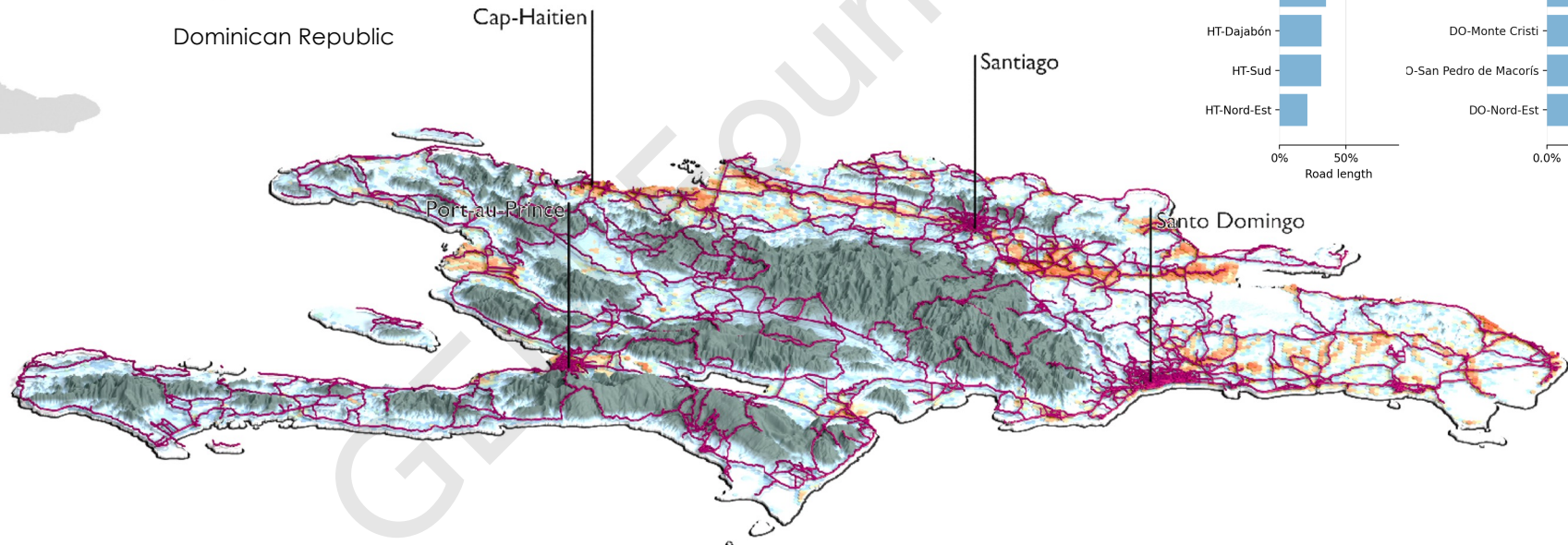
15,196 km

90%

Exposed to high ground shaking

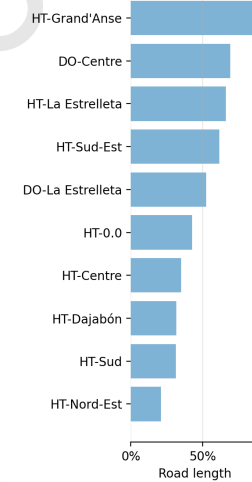
11%

Exposed to severe liquefaction

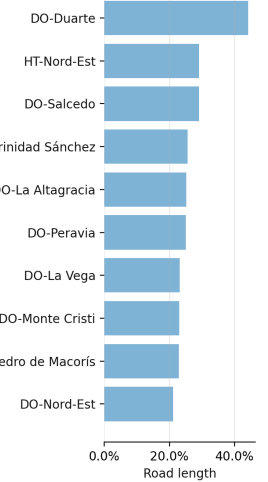


low Annual rate of exceeding 20% LSE high

Roads exposed to high PGA



Roads exposed to severe liquefaction



Behind and Beyond the Global Seismic Risk Model

SEISMIC VULNERABILITY

Al Mouayed Nafeh

Vulnerability Lead



LIQUEFACTION AND ROAD DAMAGE

Catarina Costa

Infrastructure Risk Lead



THE GLOBAL CARBON COST OF EARTHQUAKES

Linking seismic risk and life-cycle environmental impacts of buildings

Martina Caruso, on behalf of the risk team

Global Earthquake Model (GEM) Foundation

June 23 - 25, 2026

University of Zagreb, Croatia

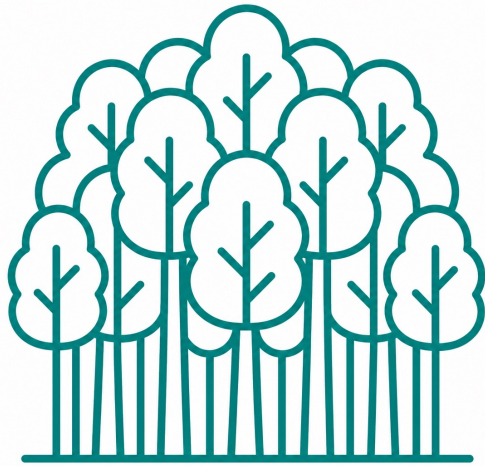
GEM CONFERENCE
FROM FAULTS TO FUTURE SCENARIOS



The 2023 Türkiye–Syria earthquake sequence generated around **17 million tonnes of CO₂-equivalent emissions** from building repair and reconstruction

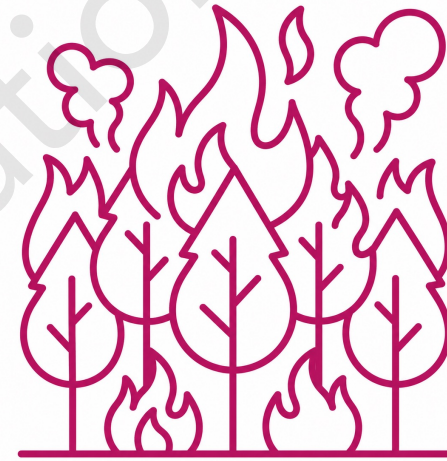
Do earthquakes have a carbon footprint?

Stored carbon vs released carbon



**The forest
(stored carbon)**

Like a forest that stores carbon through decades of growth, the global building stock represents the **cumulative embodied carbon of generations of construction activity**.



**The wildfire
(released carbon)**

Like a wildfire that releases the stored carbon, an earthquake can lead to a **sudden spike in carbon emissions through repair and reconstruction** of damaged buildings.

The hidden climate cost of earthquakes

Buildings are responsible for:



34%
of global CO₂e



32%
of global energy demand



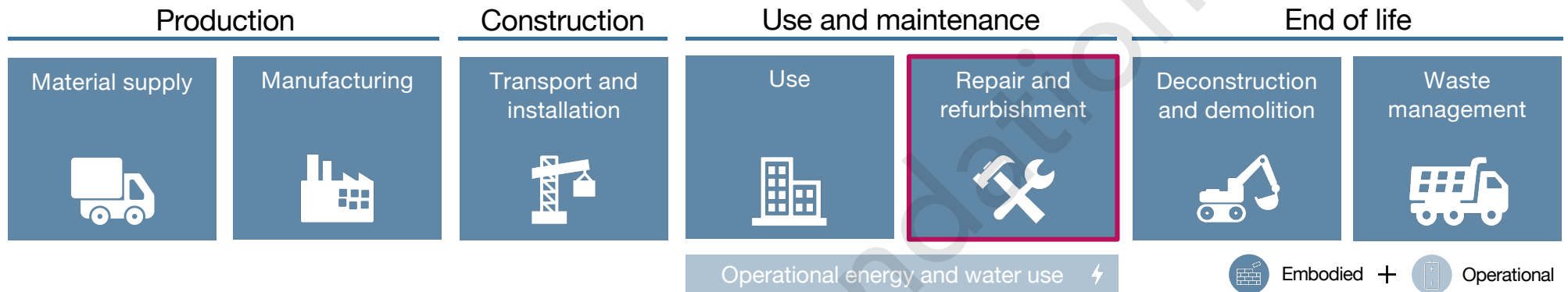
33%
of global waste



?

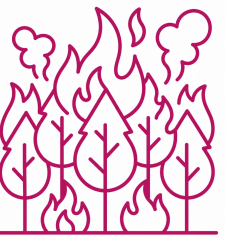
Rare but high-impact natural hazard events remain outside the scope of current environmental impact assessment and accounting frameworks, representing a **structural gap in building sector emissions reporting**.

Where earthquakes fit in a building's life cycle



Repair and refurbishment





Average annual embodied carbon (AAEC)

Aggregated carbon losses across multiple possible earthquake scenarios averaged into an annualised risk metric

Earthquake-induced building damage introduces an additional source of embodied carbon associated with repair and reconstruction activities during the building's life. These emissions can be interpreted as **risk-driven operations**.

The environmental dimension of seismic risk



Hazard

- ▶ Probabilistic models to describe the frequency of exceeding **ground shaking intensities** at any location



Exposure

- ▶ **1.7 billion buildings**, 281 billion m², 304 trillion USD
- ▶ Material type, number of storeys, structural system, occupancy, location

How much carbon is stored in the **global building stock**?

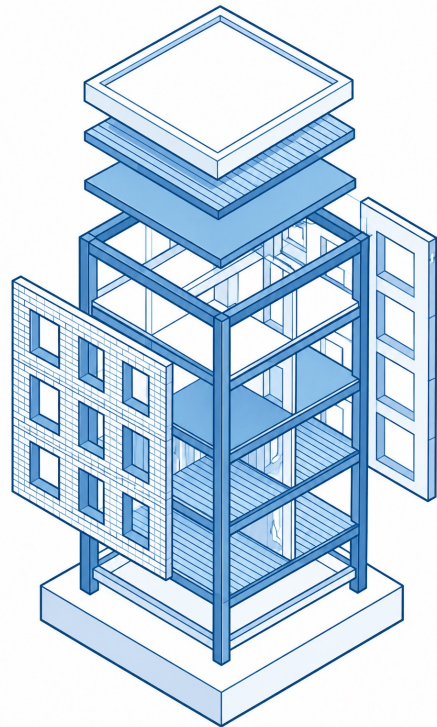


Vulnerability

- ▶ Functions linking ground shaking **intensity to impacts** for hundreds of building typologies

How does seismic damage translate into **carbon losses**?

How much carbon is stored in the global building stock?



Material/component quantities

- ▶ **Structural and non-structural components** sized via simplified design calculations for representative building archetypes

- ▶ Varying material type, structural system, and occupancy



Embodied carbon factors (ECFs)

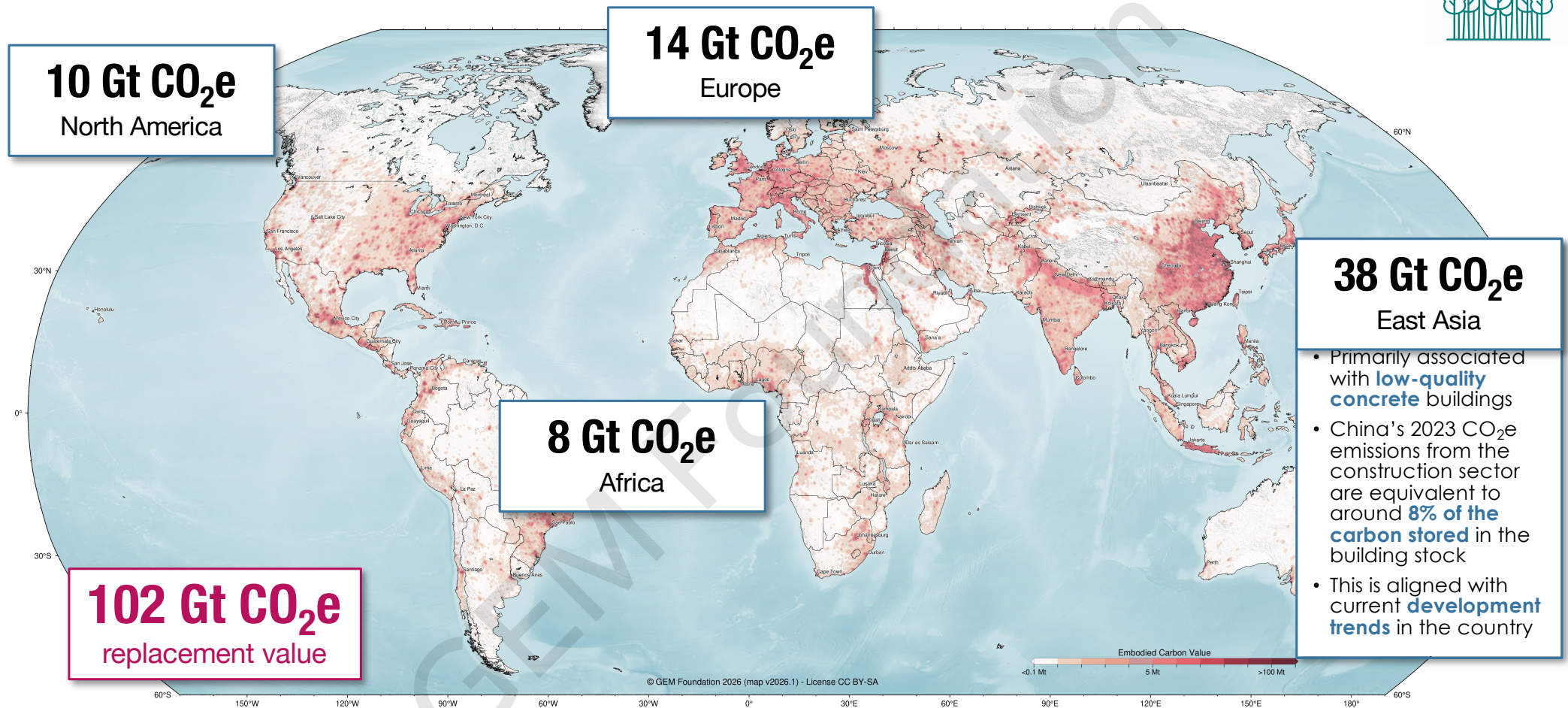
- ▶ Harmonised from 500+ Environmental Product Declarations (EPDs) and open databases, covering material supply and construction

- ▶ Regionalised based on electricity carbon intensity to capture **geographic variability**

= Replacement carbon value

The “**Build Back Better**” (BBB) approach is adopted in countries classified as high- and middle-income by the World Bank, where reconstruction is more likely to involve improvements in structural performance and material quality.

How much carbon is stored in the global building stock?

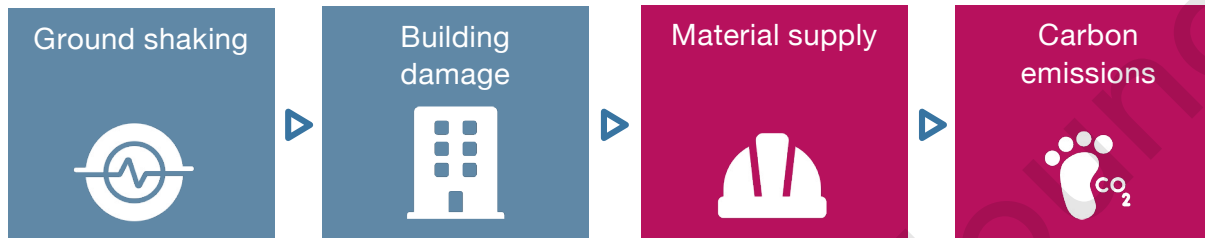


Estimated **embodied carbon (Mt CO₂e)** across the global building stock

How does seismic damage translate into carbon losses?

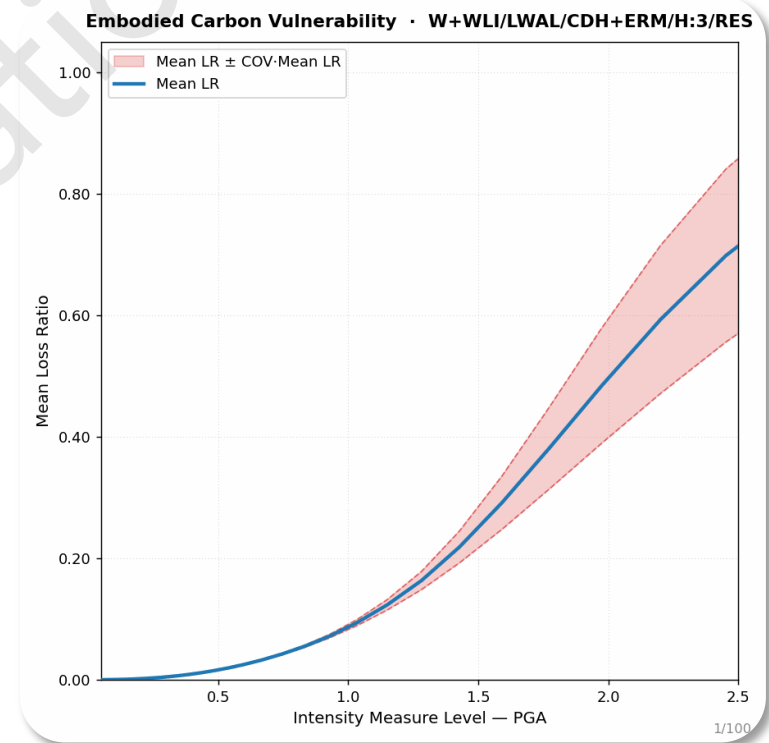


Embodied Carbon

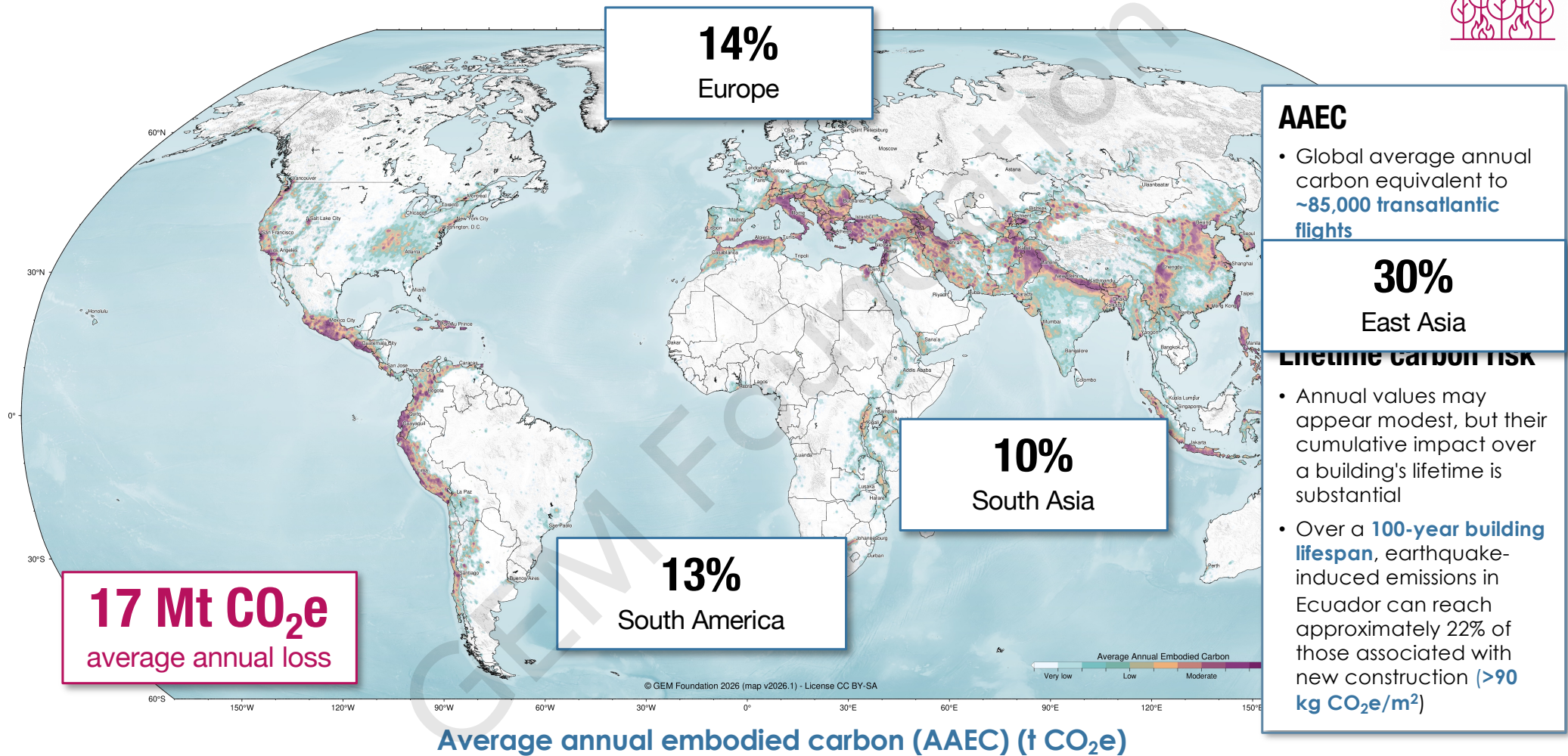


+2,000 building types
with individual vulnerability curves developed

The proposed database provides a robust and physically meaningful basis for **regional and continental assessments** of earthquake-induced environmental impacts.



Where is seismic carbon risk high?



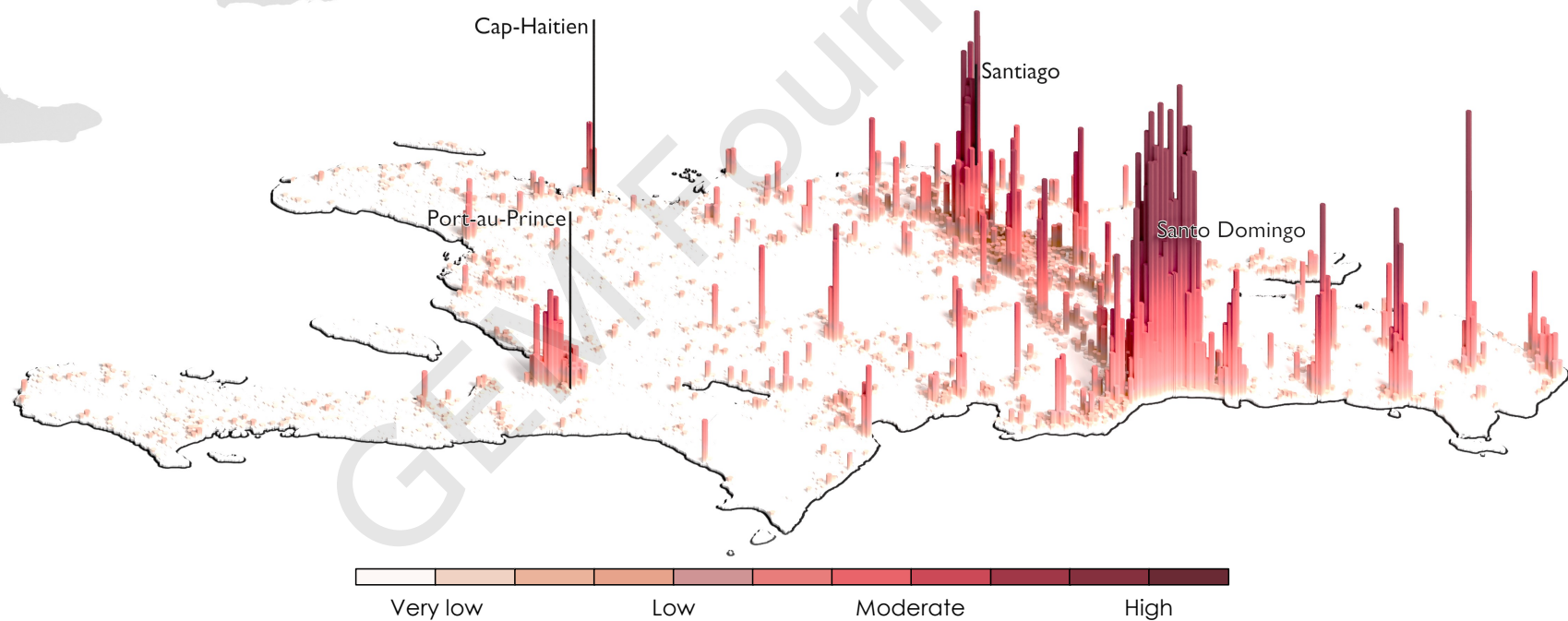
The case of Hispaniola - Replacement carbon value

Haiti

- 195 million m² of built-up area
- 46 Mt CO₂e of replacement carbon value
- 51% of carbon value associated with unreinforced masonry; 11% with adobe/stone/earth structures
- Average reconstruction carbon intensity: 235 kgCO₂e/m²

Dominican Republic

- 516 million m² of built-up area (>2.5× Haiti)
- 217 Mt CO₂e of replacement carbon value (>4.5× Haiti)
- 48% of carbon value associated with reinforced/confined masonry; 28% associated with unreinforced masonry
- Average reconstruction carbon intensity: 420 kgCO₂e/m²



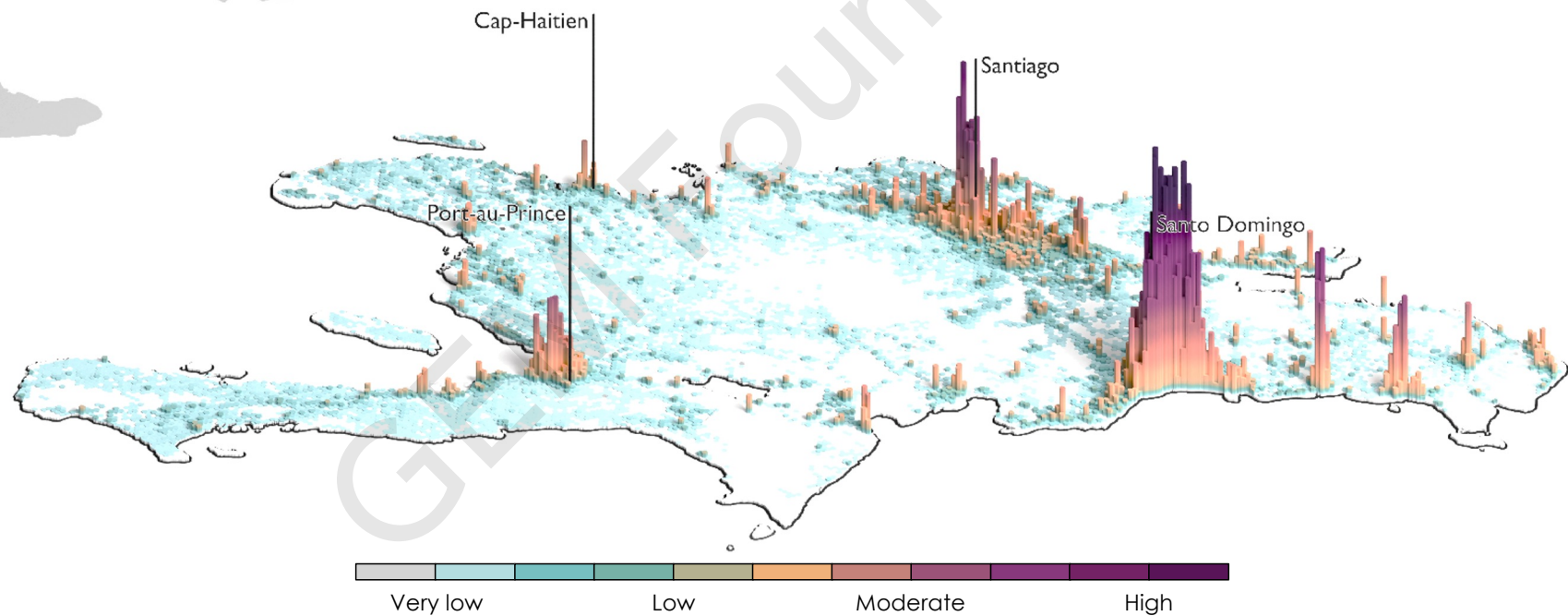
The case of Hispaniola - Average annual embodied carbon

Haiti

- 173,000 m² of built-up area destroyed
- 37,000 t CO₂e of annual carbon losses
- Carbon loss ratio: 0.08%
- 55% of carbon losses associated with unreinforced masonry;
21% with adobe/stone/earth structures

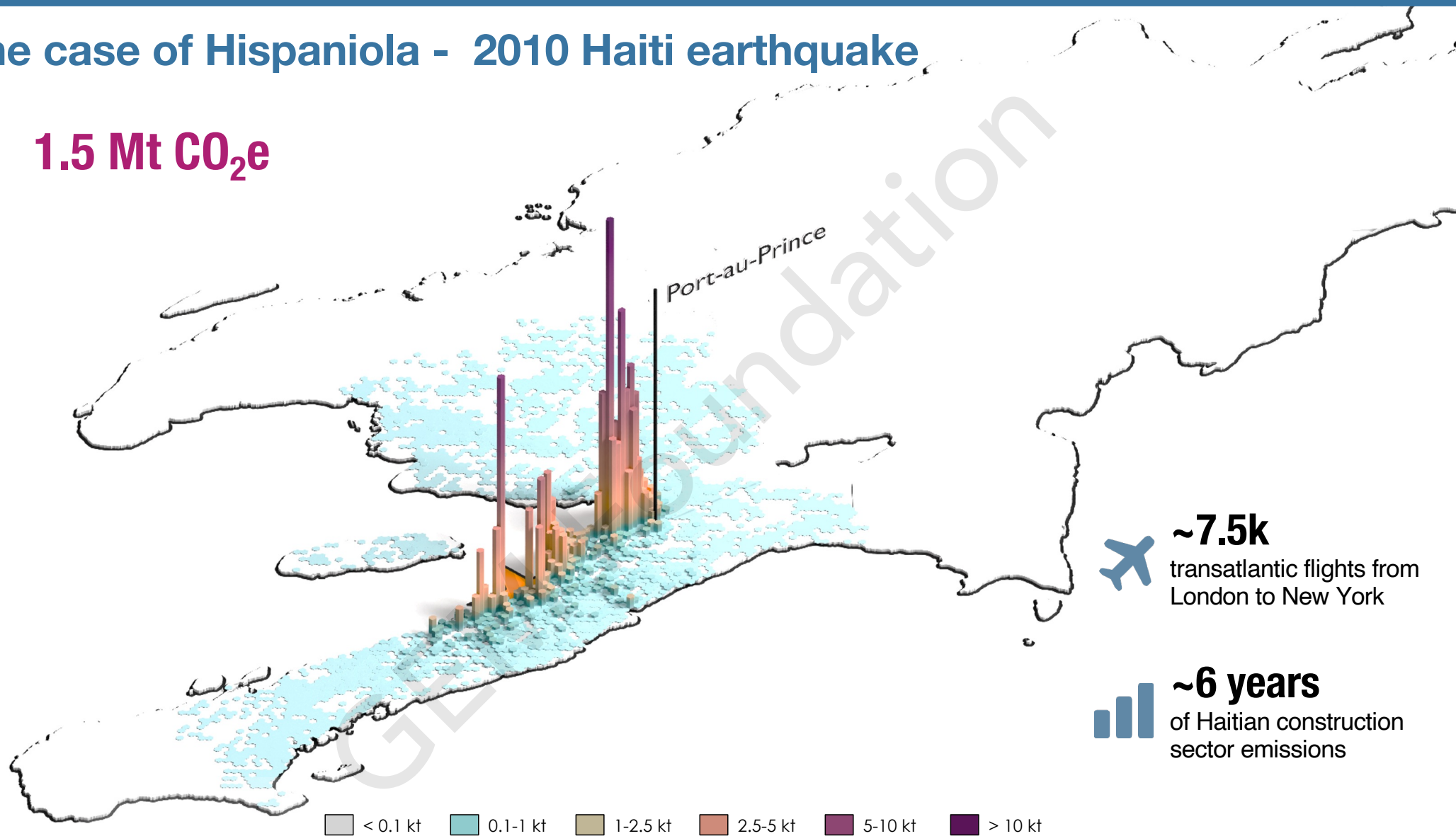
Dominican Republic

- 365,000 m² of built-up area destroyed (>2× Haiti)
- 165,000 t CO₂e of annual carbon losses (>4× Haiti)
- Carbon loss ratio: 0.07%
- 48% of carbon losses associated with unreinforced masonry;
27% associated with reinforced/confined masonry

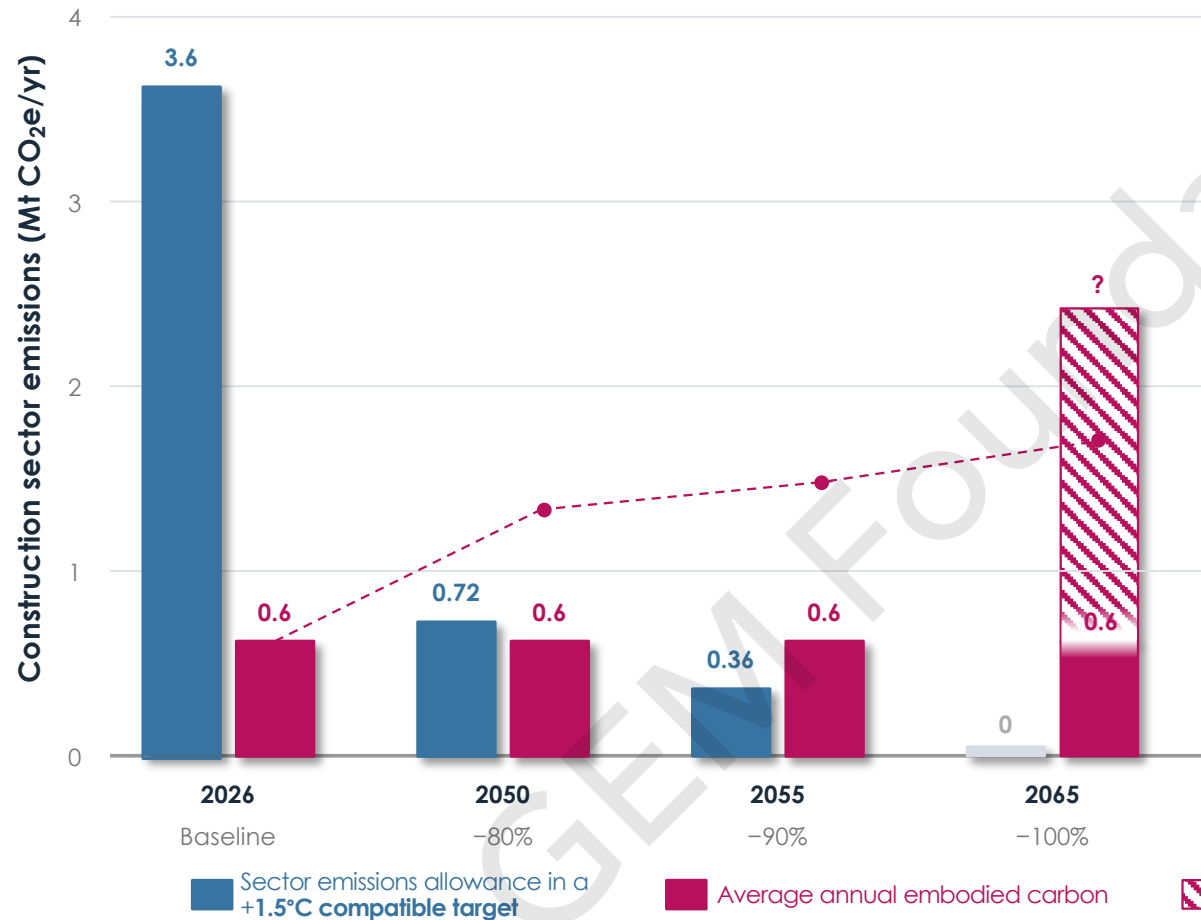


The case of Hispaniola - 2010 Haiti earthquake

1.5 Mt CO₂e



Seismic carbon losses and future emissions pathways in Ecuador



- ▶ We operate within a **finite carbon budget**, which is tight, especially under sustainable pathways
- ▶ Current budgets largely exclude **disaster-driven emissions**, including earthquake-related ones
- ▶ When **future construction activity and seismic risk evolution** are jointly accounted for, current climate targets are expected to be increasingly difficult to achieve

Behind and Beyond the Global Seismic Risk Model

SEISMIC VULNERABILITY

Al Mouayed Nafeh
Vulnerability Lead



LIQUEFACTION AND ROAD DAMAGE

Catarina Costa
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ENVIRONMENTAL IMPACT & EMBODIED CARBON

Martina Caruso
Risk Analyst



FORECASTING THE GLOBAL EXPOSURE TO EARTHQUAKES

Safety and Sustainability in Future Seismic Risk Assessments

Alejandro Calderón, on behalf of the risk team

Global Earthquake Model Foundation

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GEM CONFERENCE
FROM FAULTS TO FUTURE SCENARIOS

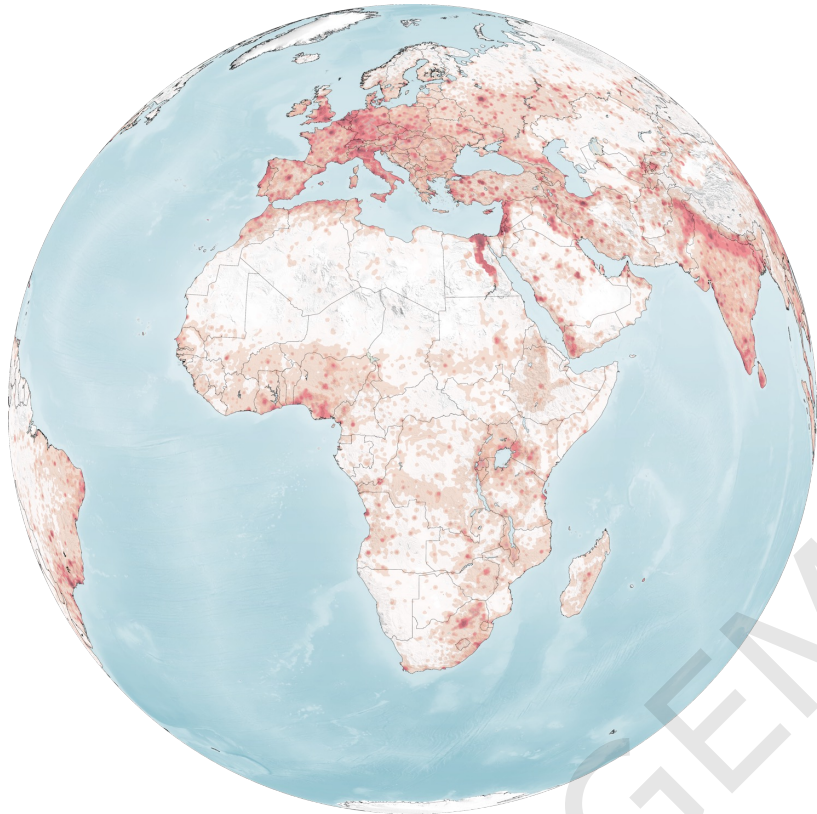
PROBLEM AND STAKES

Sustainability and Safety in
Future Seismic Risk Assessments



Safety and Sustainability in Seismic Risk Assessments

Global Exposure Map



Africa 2025: Total Exposure

Population	1.54 B. people
Buildings	340 M. units
Embodied Carbon	7,800 M. ton

→ ⌚ +40 years

Africa 2065: Total Exposure

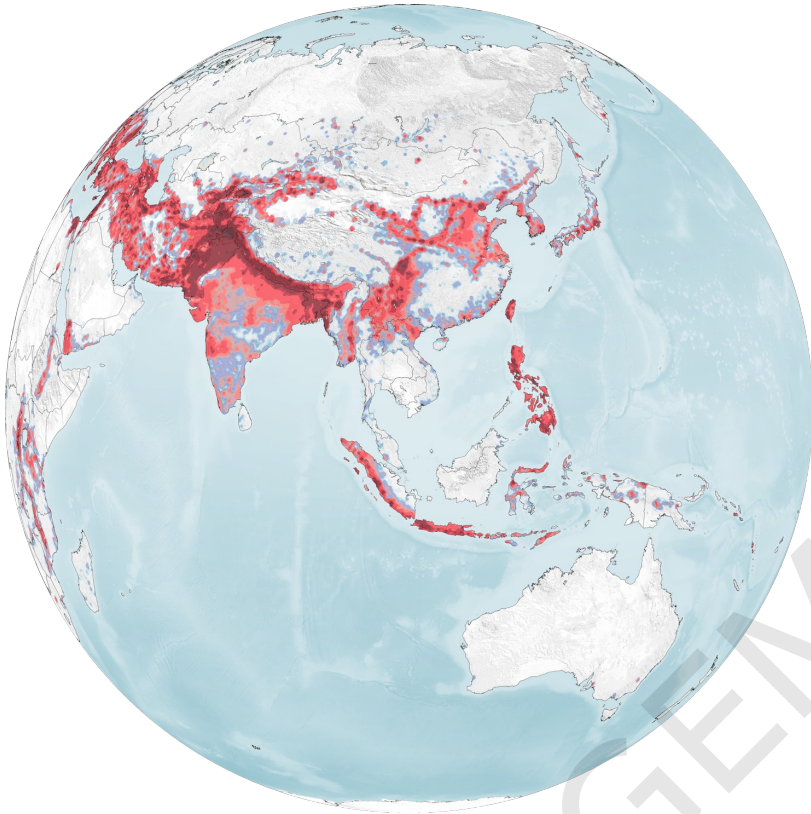
Population Forecast	2.5 - 3.4 B. people
Buildings	700 ?? M. units
Embodied Carbon	14.9 ? G. ton

Sustainability

Can we expand the building stock, and remain within the carbon budget?

Safety and Sustainability in Seismic Risk Assessments

Global Fatalities Map



Southeast Asia 2025: Average Annual Risk

Population 690 M. people

Fatalities > 300 people

B. In Complete Damage > 19,000 units

→ ⌚ +40 years

Southeast Asia 2065: Average Annual Risk

Population Forecast 700 - 830 M. people

Fatalities > 350 ?? people

B. in Complete Damage > 22,000 ?? units

Safety

Can we expand the building stock,
substantially reduce disaster mortality?

Design goals for a forecast framework



Main Goal

Develop **methods and tools** to project the forthcoming global exposure to earthquakes, using the **GEM's Global Exposure Model** as the foundation



Features

- ▶ Exposure datasets at different points in time: **2025 to 2065**
- ▶ Incorporate **demographic, socioeconomic and urban changes** that influence future exposure
- ▶ Have the capacity to simulate **multiple scenarios**



Requirements

- ▶ **OpenQuake ready** format
- ▶ **Parameter driven** and **easy testing** for risk mitigation strategies

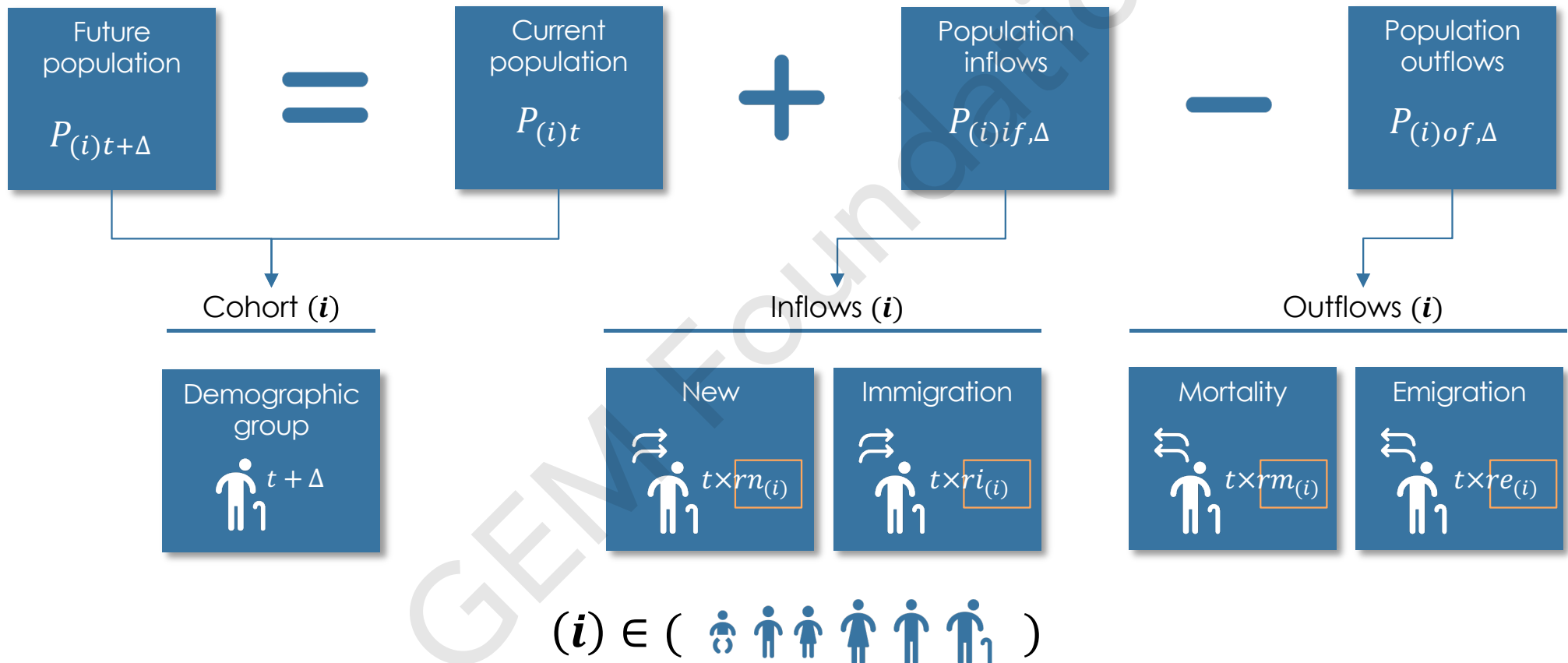
METHOD

Forecasting people and buildings



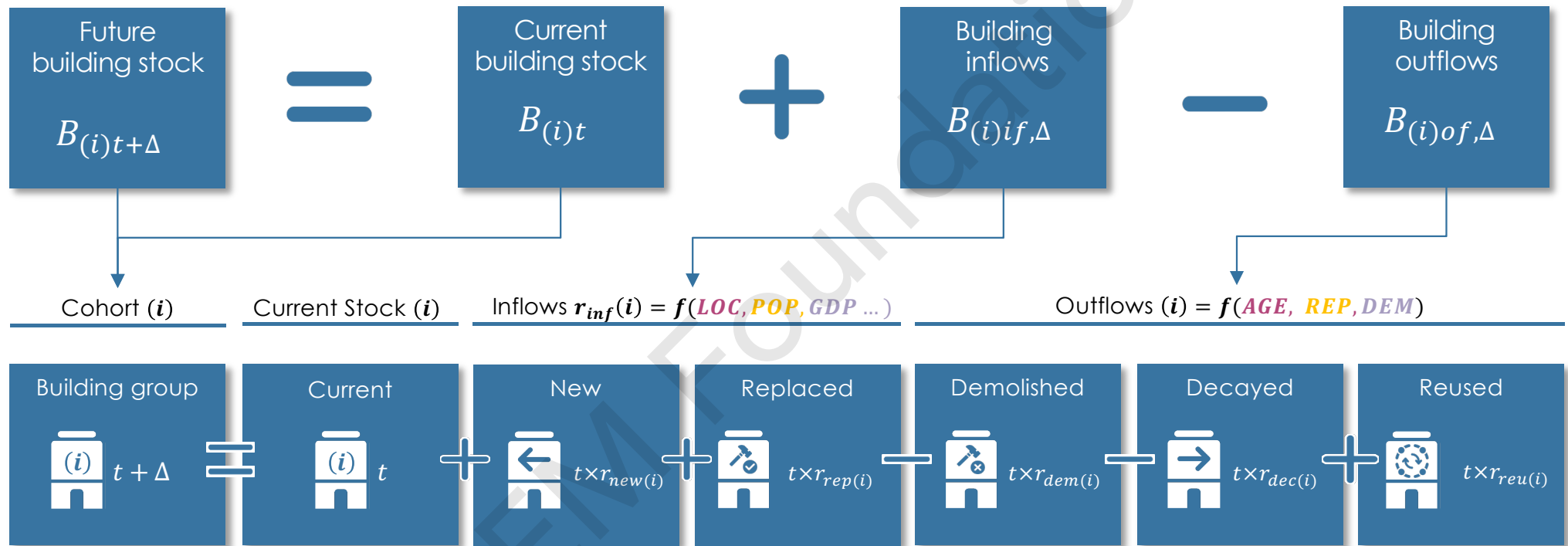
The cohort method: we project people by groups

Cohort component method



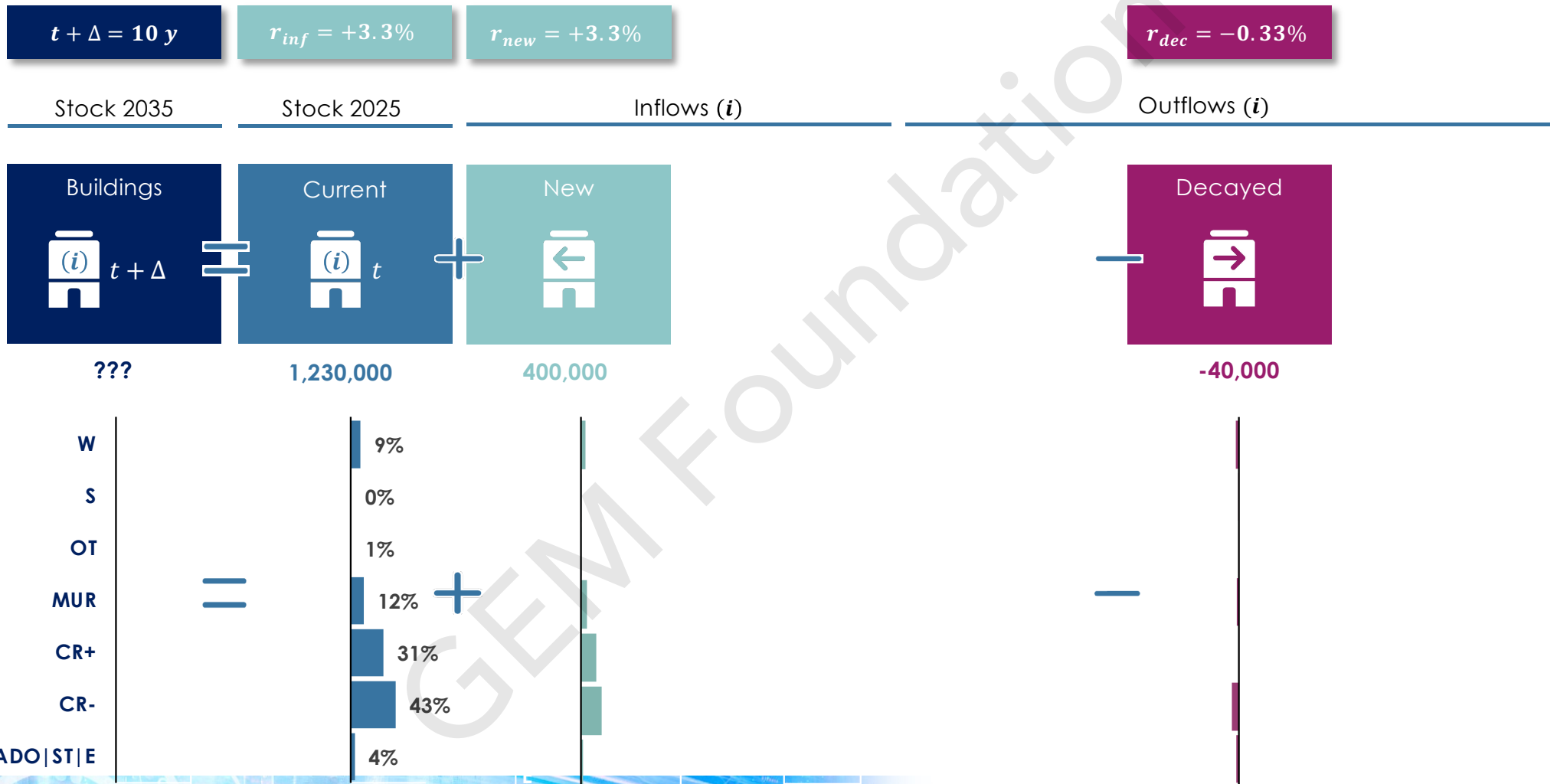
Our method: we project buildings by building classes

Building forecast method

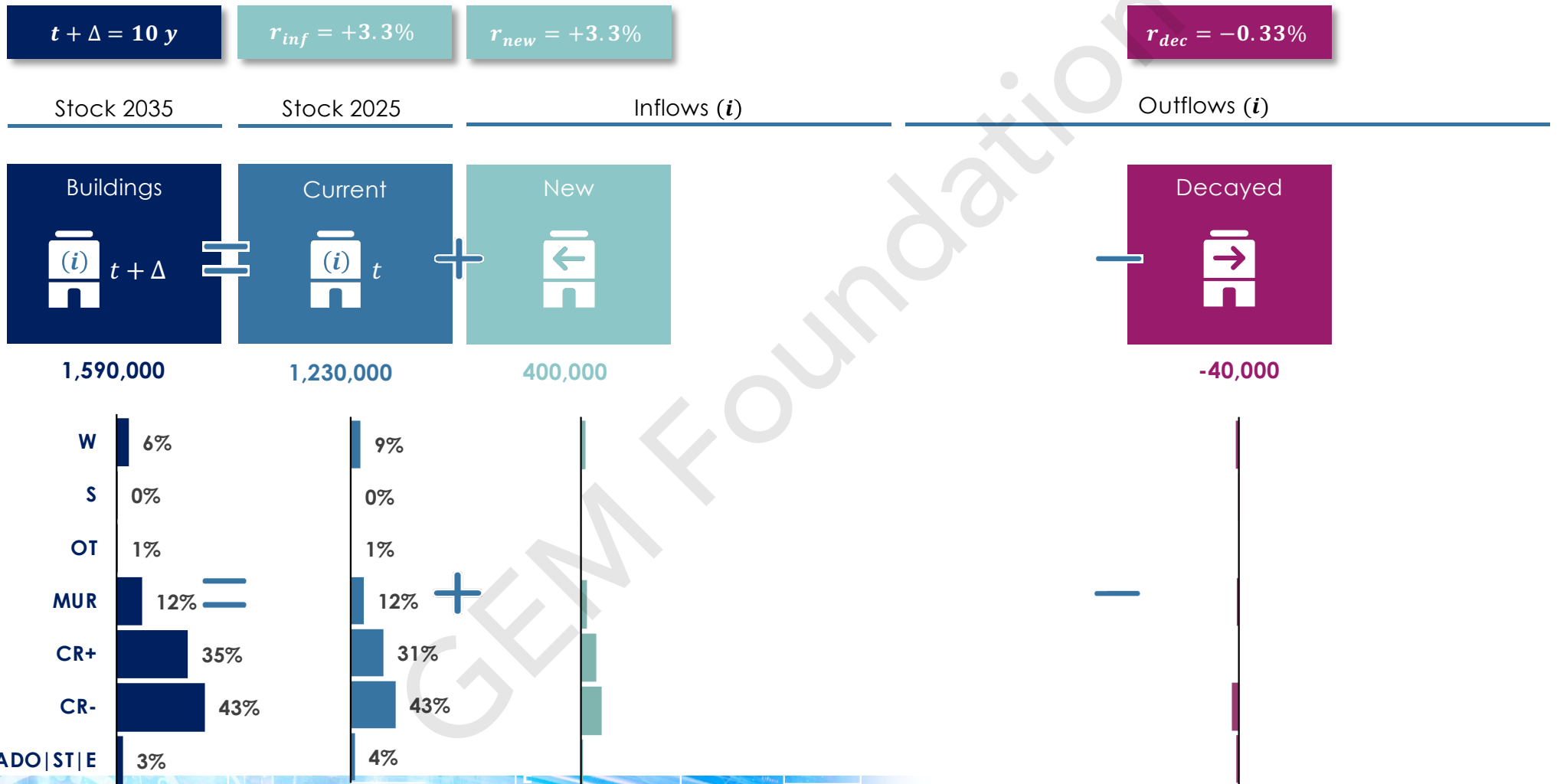


$$(i) \in (CR+, CR-, MR|MCF, MUR, ADO|ST|E, W, OT)$$

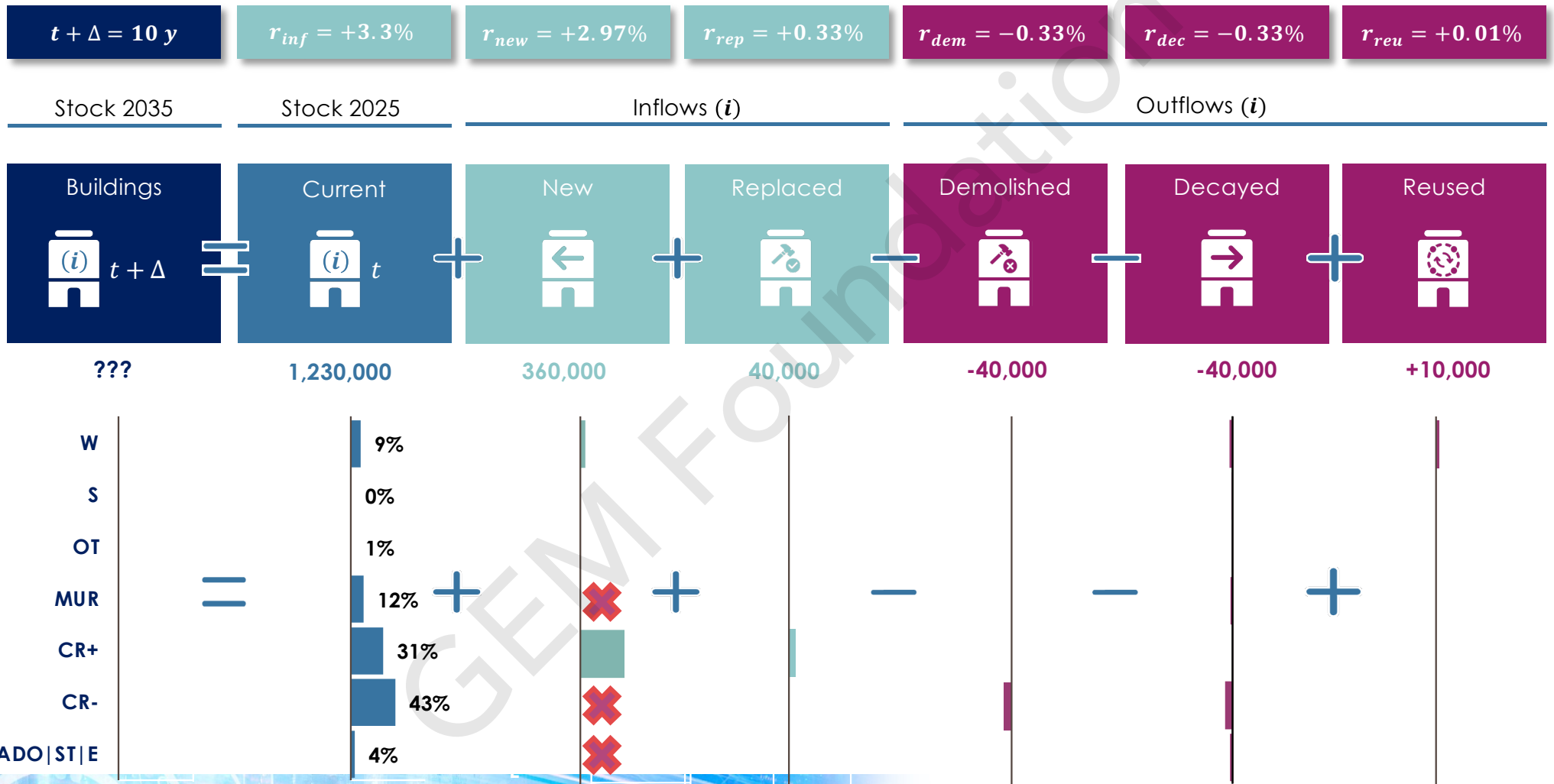
An unsafe and unsustainable scenario: Istanbul



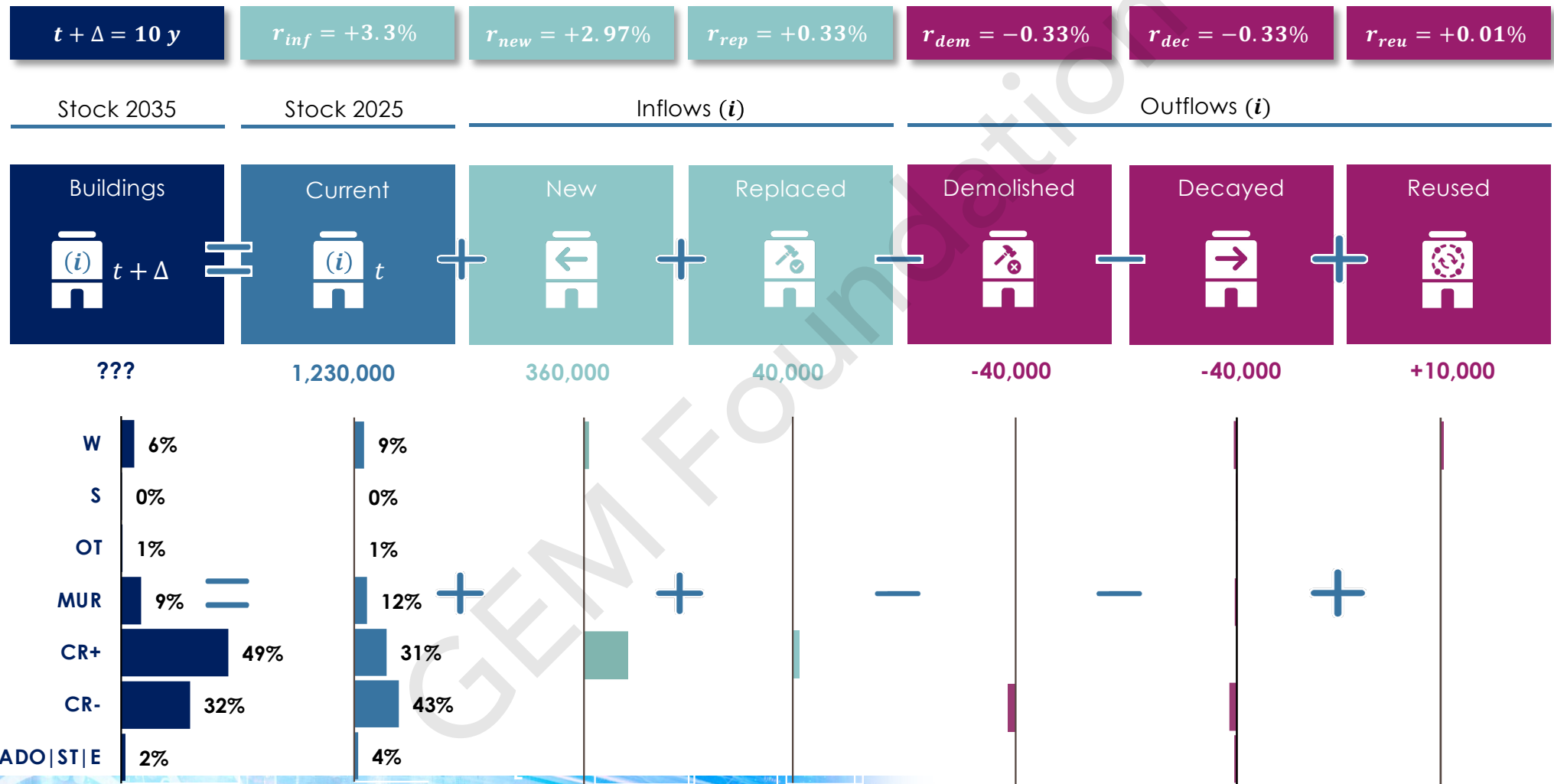
An unsafe and unsustainable scenario: Istanbul



A safer, more sustainable scenario for Istanbul

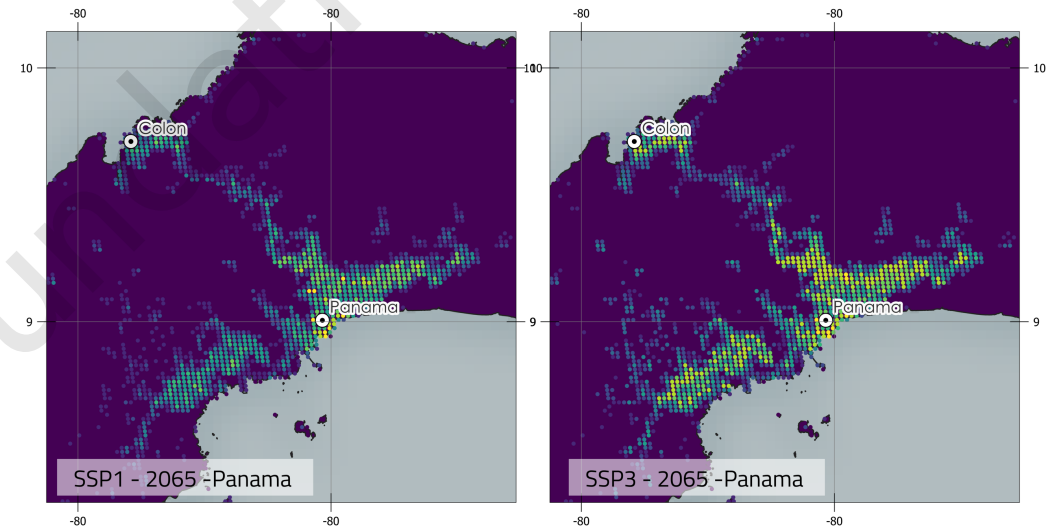


A safer, more sustainable scenario for Istanbul



EXPLORING NARRATIVES FOR THE FUTURE

The Shared Socioeconomic Pathways



The Shared Socioeconomic Pathways (SSPs)



SSP2	Business as usual:  ✓ Patterns continue ✓ Mixed progress ✓ No shifts	 Demographic transition  Human development  G.D.P. per capita  Governance  New  Replacements  Reused  Demolished  Decayed
------	--	--

The Shared Socioeconomic Pathways (SSPs)



SSP2	Building as usual										
		✓ Patterns continue ✓ Mixed progress ✓ No shifts	 Demographic transition 	 Human development 	 G.D.P. per capita 	 Governance 	 New 	 Replacements 	 Reused 	 Demolished 	 Decayed 

The Shared Socioeconomic Pathways (SSPs)

	Narrative	Impact on the input parameters								
SSP1	Safety and sustainability  ✓ Cooperative ✓ Equality ✓ Green transition	 Demographic transition 	 Human development 	 G.D.P. per capita 	 Governance 	 New 	 Replacements 	 Reused 	 Demolished 	 Decayed 
	Building as usual  ✓ Patterns continue ✓ Mixed progress ✓ No shifts	 Demographic transition 	 Human development 	 G.D.P. per capita 	 Governance 	 New 	 Replacements 	 Reused 	 Demolished 	 Decayed 

The Shared Socioeconomic Pathways (SSPs)

	Narrative	Impact on the input parameters								
SSP1	Safety and sustainability  ✓ Cooperative ✓ Equality ✓ Green transition	 Demographic transition 	 Human development 	 G.D.P. per capita 	 Governance 	 New 	 Replacements 	 Reused 	 Demolished 	 Decayed 
SSP2	Building as usual  ✓ Patterns continue ✓ Mixed progress ✓ No shifts	 Demographic transition 	 Human development 	 G.D.P. per capita 	 Governance 	 New 	 Replacements 	 Reused 	 Demolished 	 Decayed 
SSP3	A lack of code  ✓ Focus on growth ✓ Broken agreements ✓ Weak governance	 Demographic transition 	 Human development 	 G.D.P. per capita 	 Governance 	 New 	 Replacements 	 Reused 	 Demolished 	 Decayed 

Future scenarios – bounded by the present

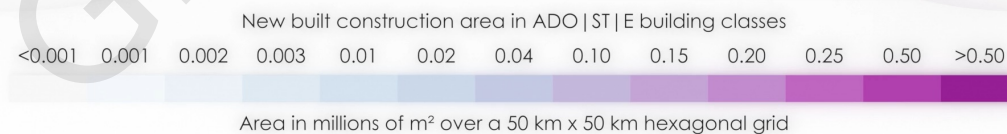
2025 2030 2035 2040 2045 2050 2055 2060 2065



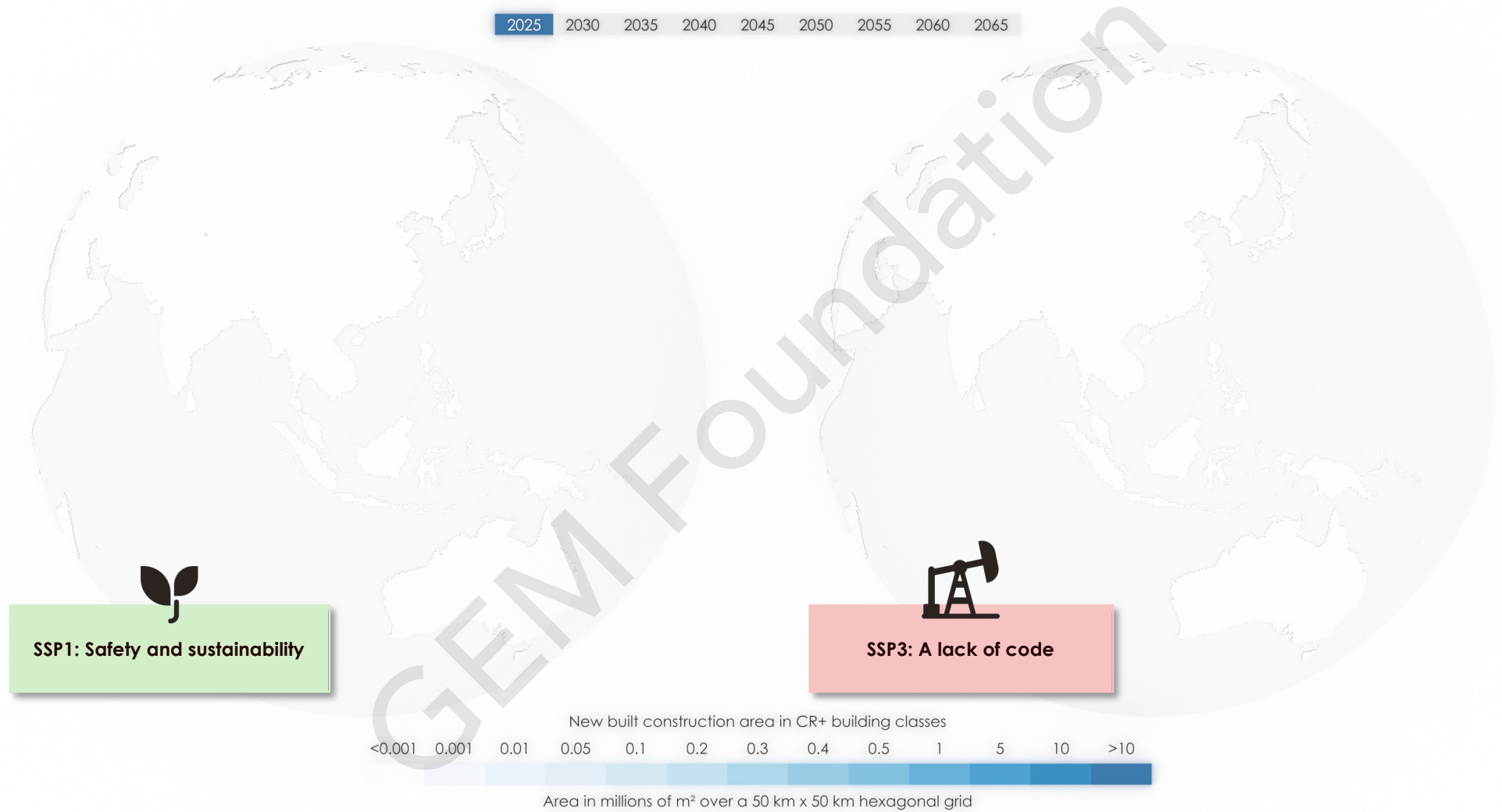
SSP1: Safety and sustainability



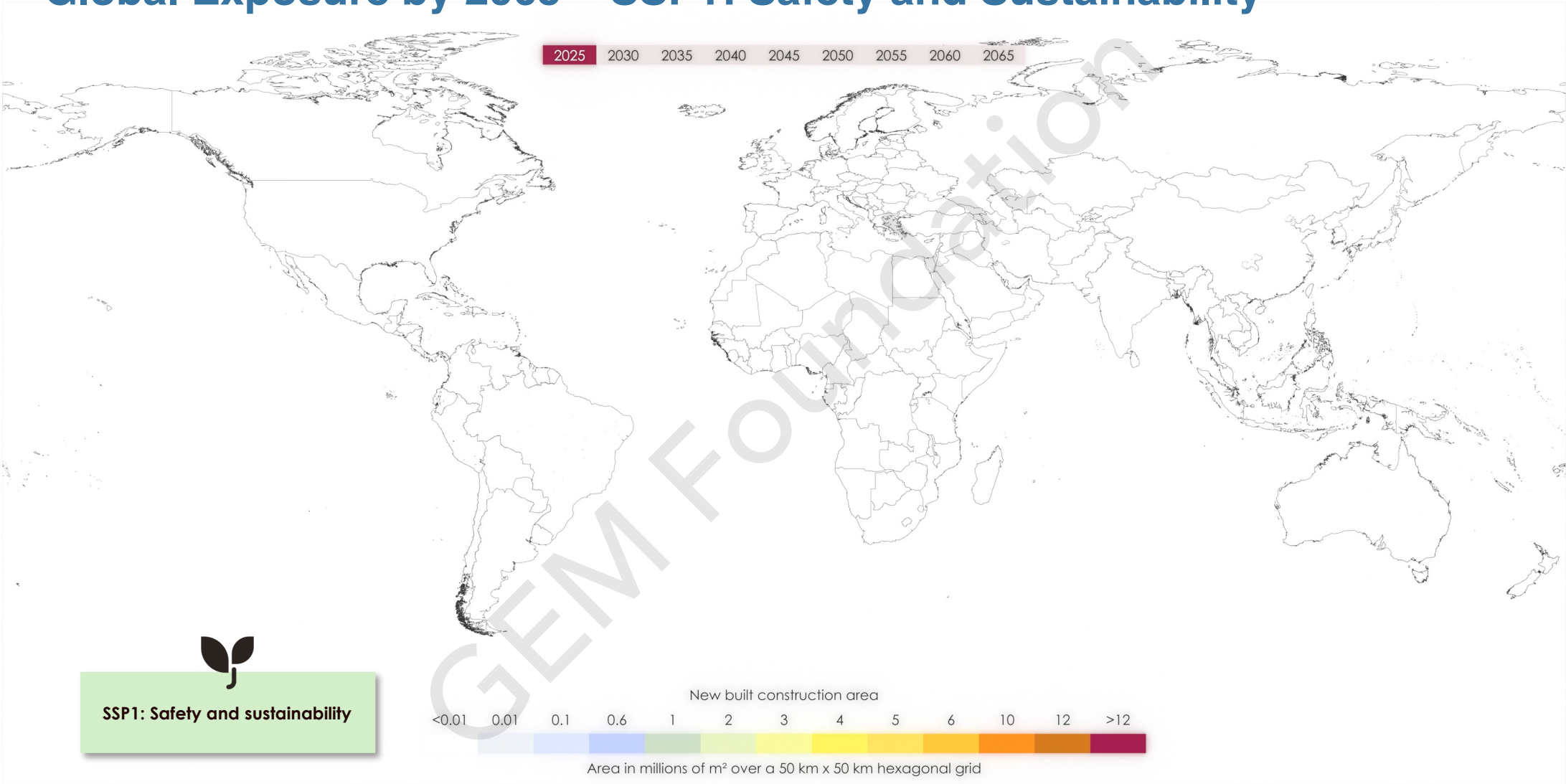
SSP3: A lack of code



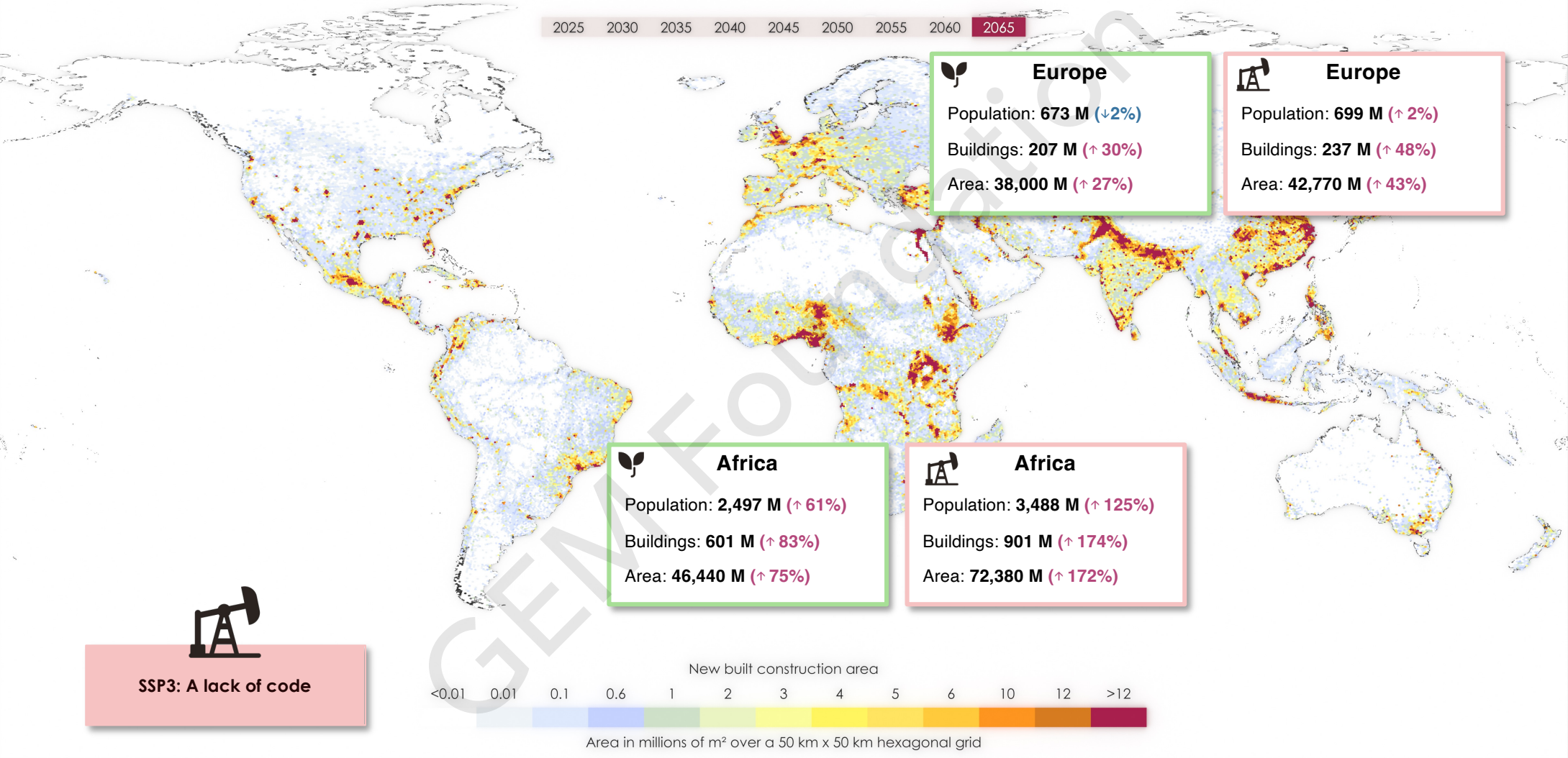
Future scenarios – bounded by the present



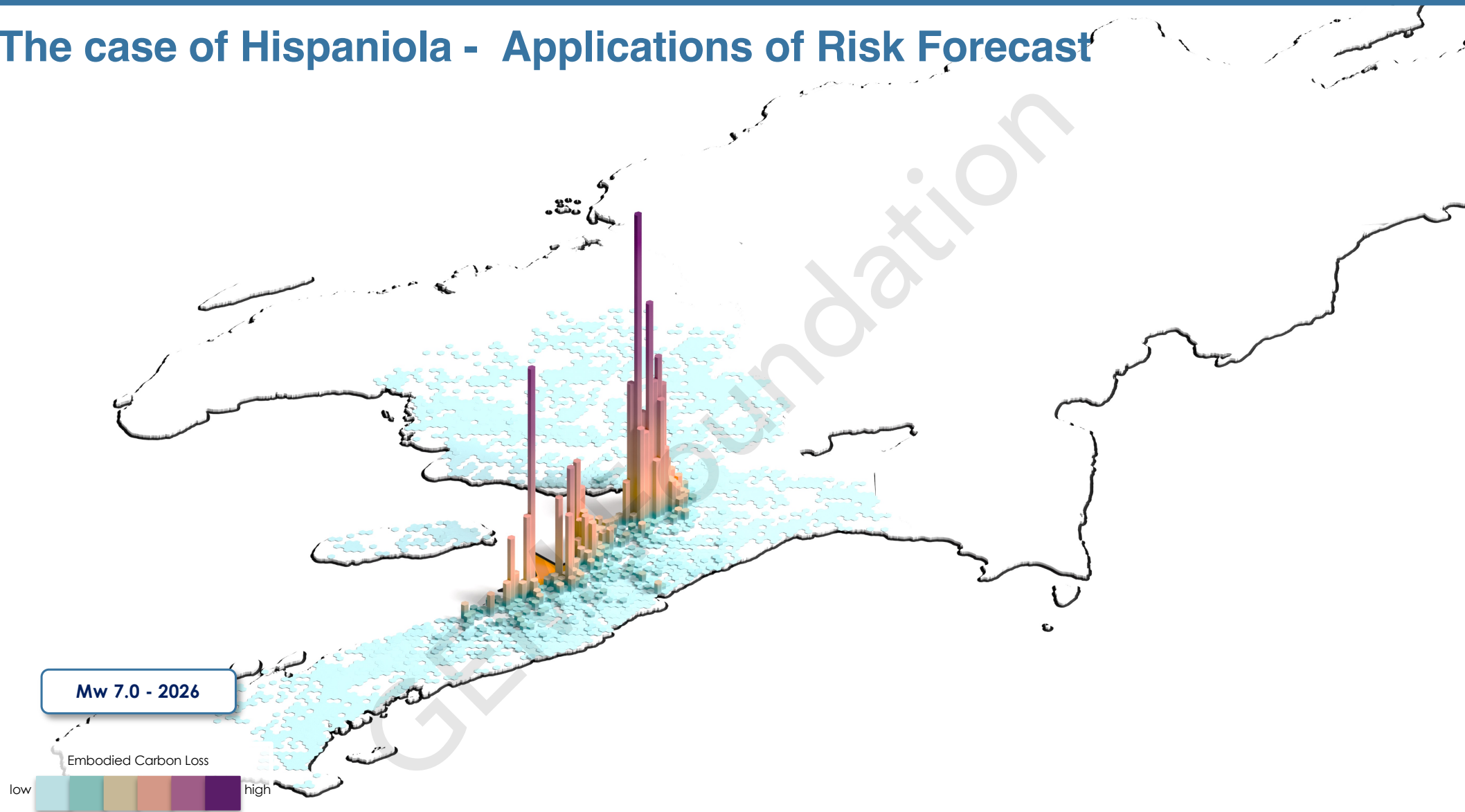
Global Exposure by 2065 – SSP1: Safety and Sustainability



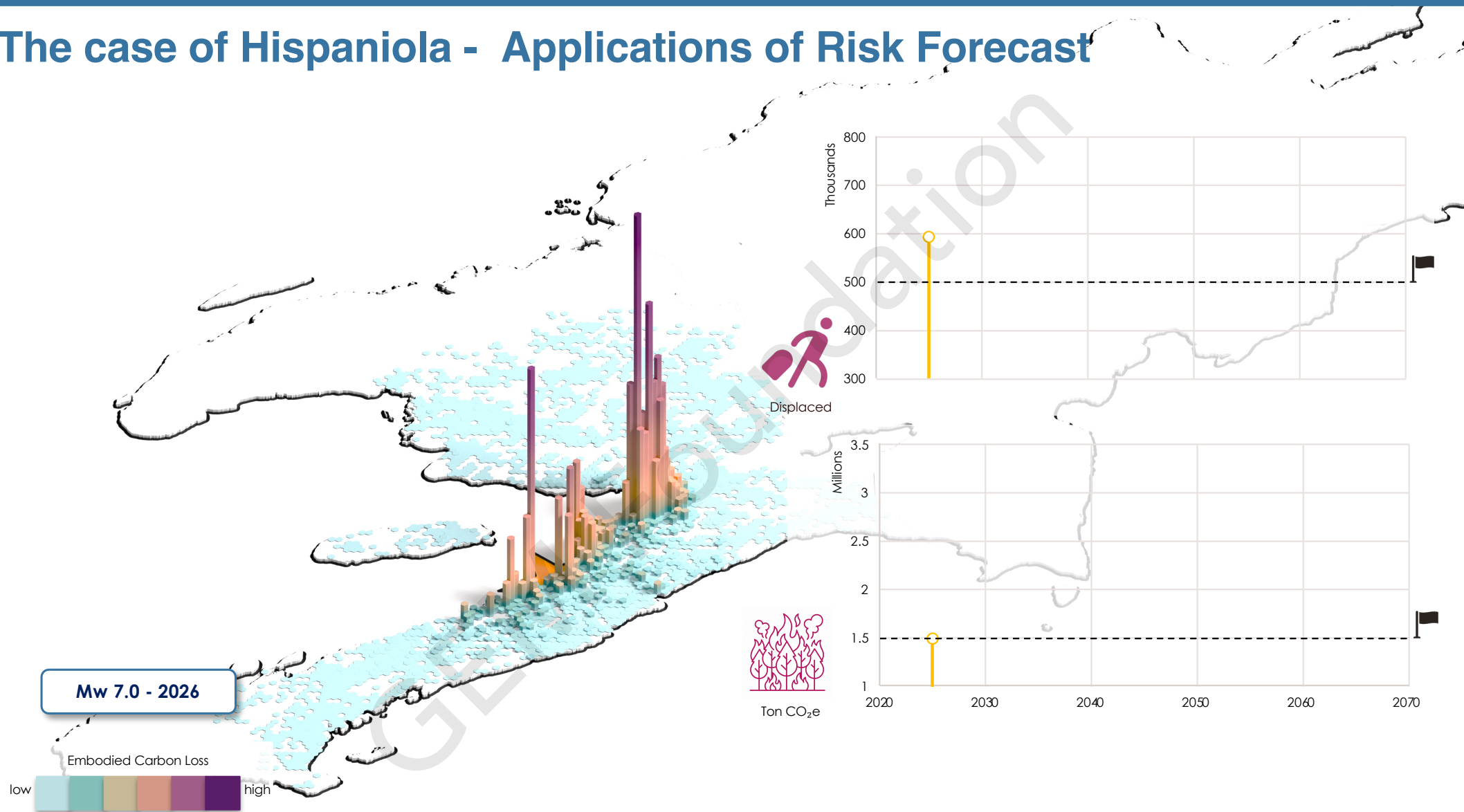
Global Exposure by 2065 – SSP3: A Lack of Code



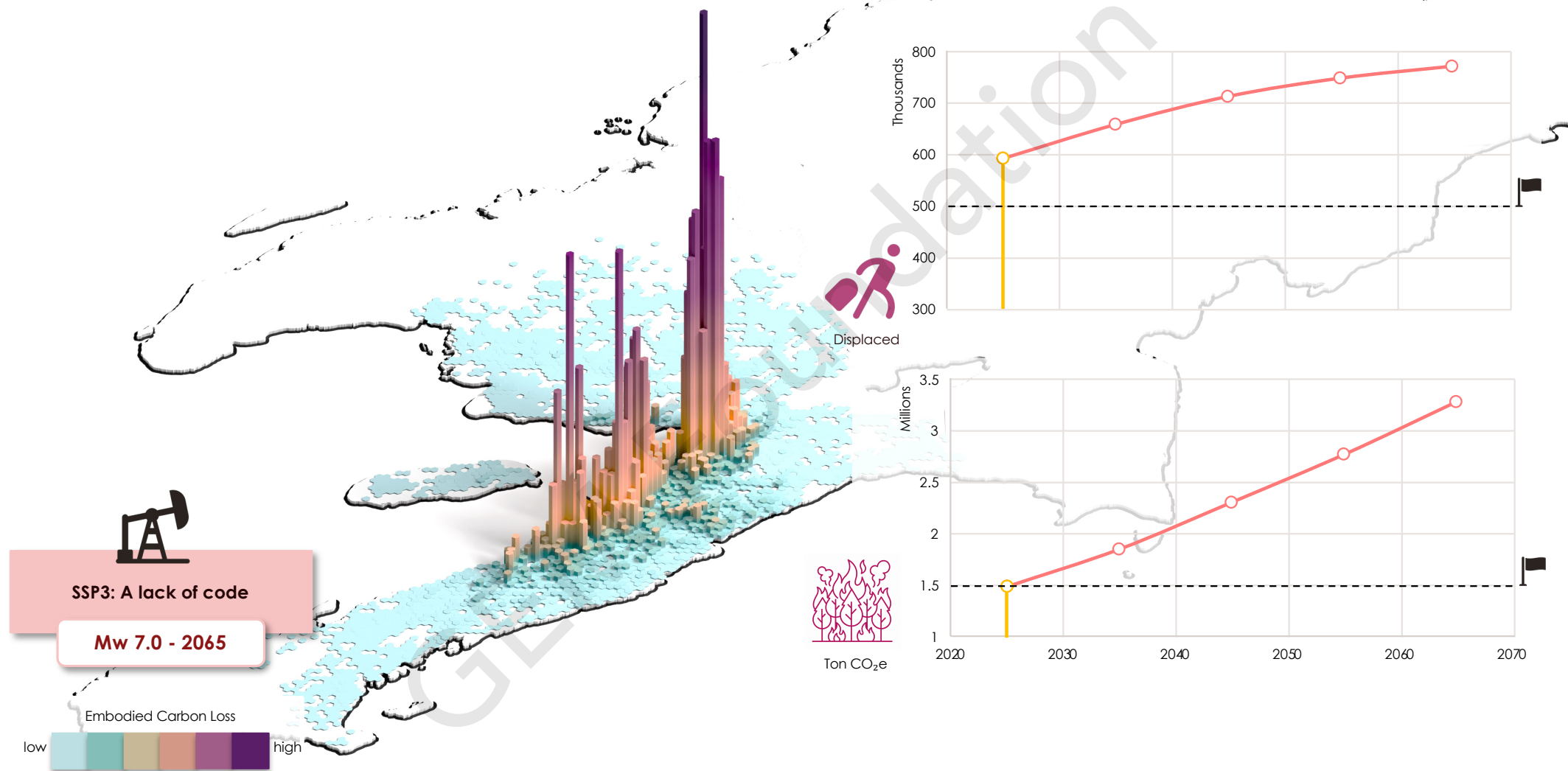
The case of Hispaniola - Applications of Risk Forecast



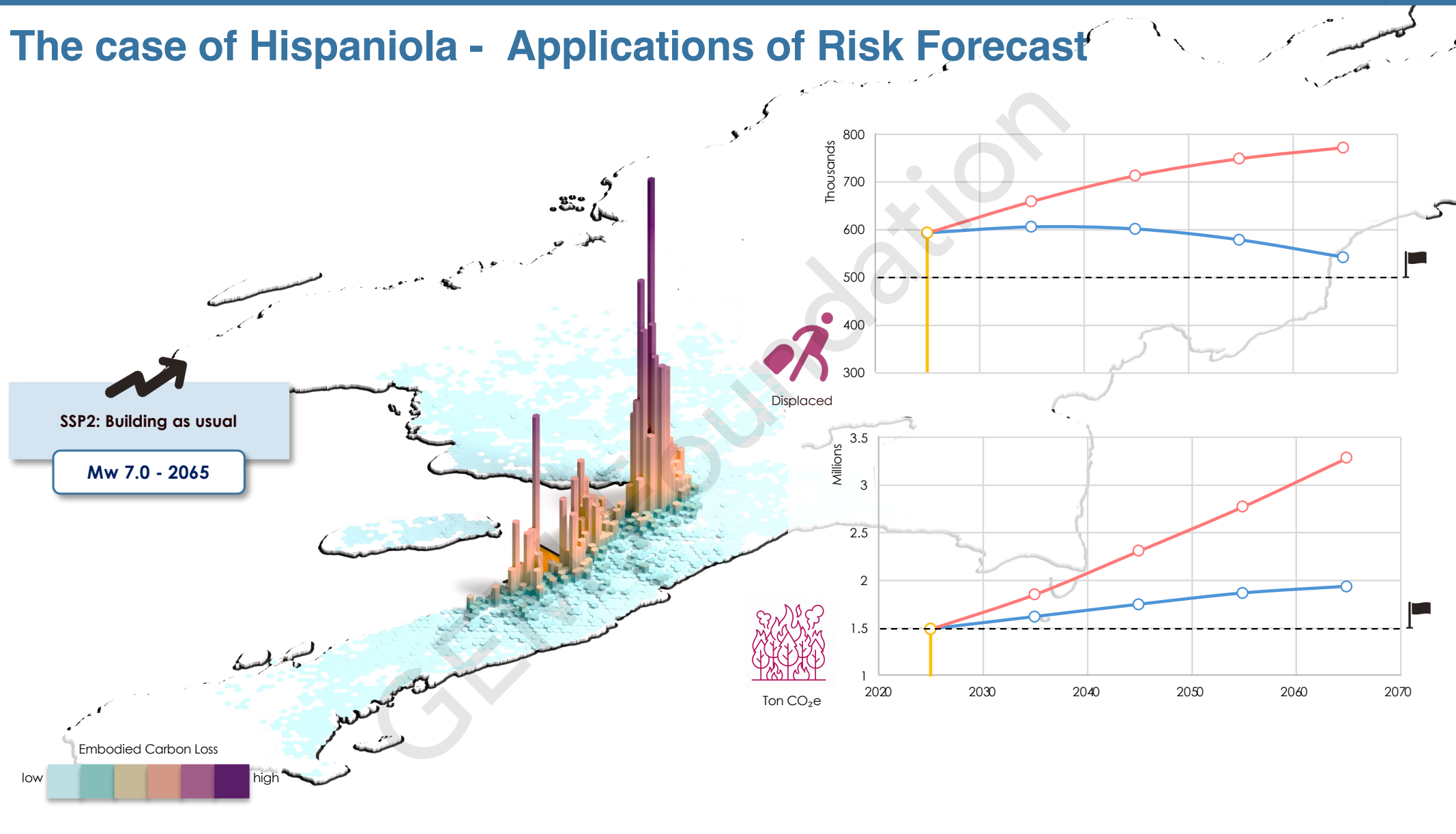
The case of Hispaniola - Applications of Risk Forecast



The case of Hispaniola - Applications of Risk Forecast



The case of Hispaniola - Applications of Risk Forecast



The case of Hispaniola - Applications of Risk Forecast

SSP1: Safety and sustainability

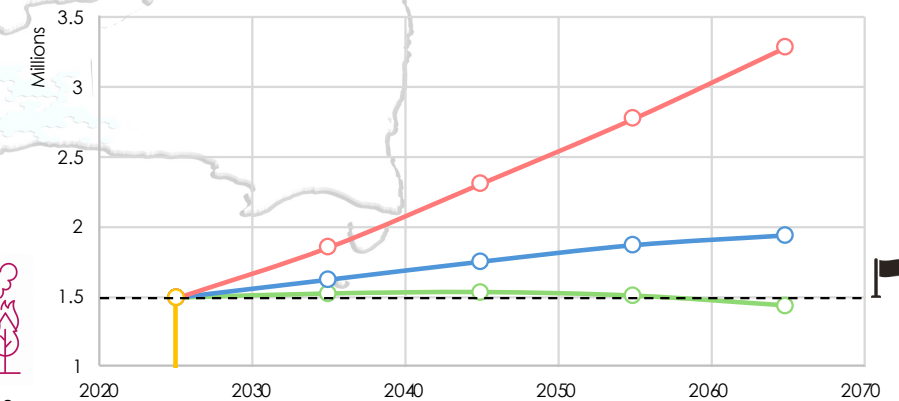
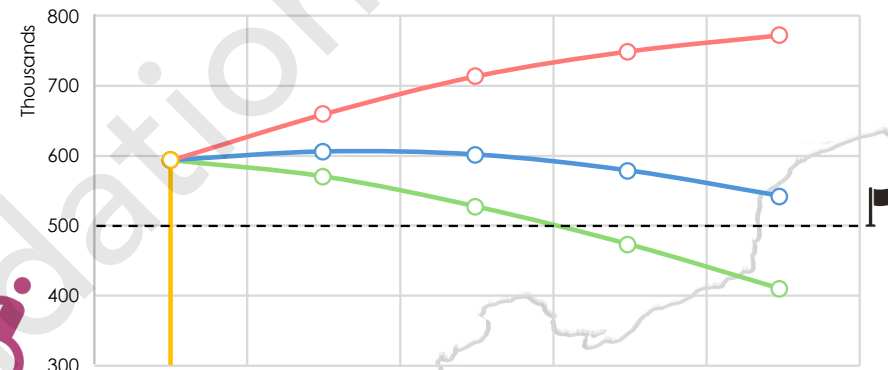
Mw 7.0 - 2065

Embodied Carbon Loss
low high

Displaced



Ton CO₂e



Behind and Beyond the Global Seismic Risk Model

SEISMIC VULNERABILITY

Al Mouayed Nafeh
Vulnerability Lead



LIQUEFACTION AND ROAD DAMAGE

Catarina Costa
Infrastructure Risk Lead



FUTURE RISK & URBAN EXPANSION

Alejandro Calderon
Exposure Research Lead



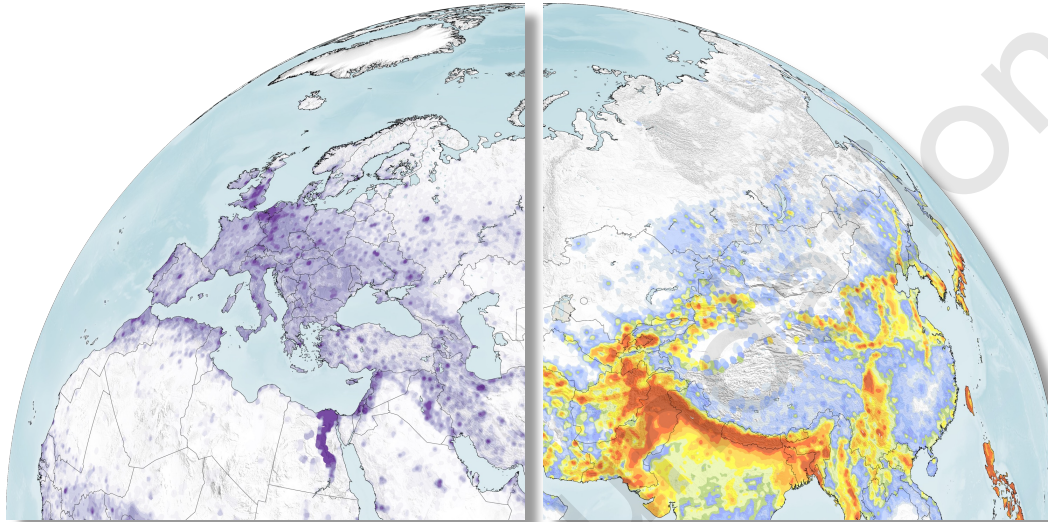
ENVIRONMENTAL IMPACT & EMBODIED CARBON

Martina Caruso
Risk Analyst



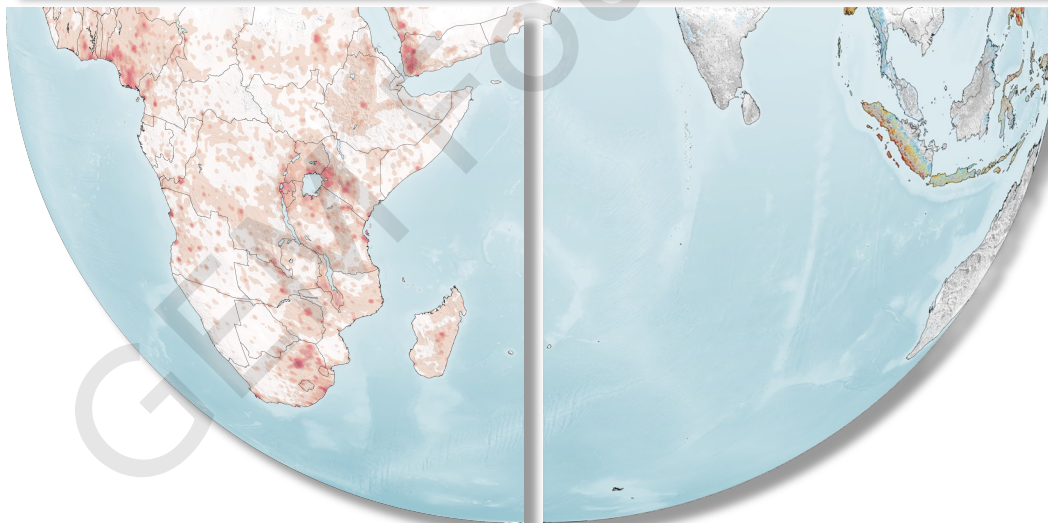
So what have we achieved in 2026?

**Updated Exposure Model
with new exposure attributes
A new Vulnerability Model**



**Updated seismic Risk metrics
New posters and updated
profiles and repositories**

**Enviromental impact of
earthquakes in terms of CO2e
Risk forecasting framework**



**A Global Liquefaction Model
Assessment of the impact on
roads and railways**

Beyond 2026

 Update of the Global Seismic Risk Model

 Expand risk to other infrastructure

 New visualization methods

 Consideration of other geohazards

 Global seismic risk forecast

 New AI and Big Data methods

Thank you!

Please attribute to the GEM Foundation with a link to:
<https://www.globalquakemodel.org>



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A stylized world map with black outlines of continents and a network of black lines representing tectonic plate boundaries. The map is set against a background of blue and white halftone dots. The entire image is overlaid with a complex digital pattern of blue and white lines, dots, and geometric shapes, creating a high-tech, futuristic aesthetic.

June 23 – 25, 2026

University of Zagreb, Croatia

GEM CONFERENCE

FROM FAULTS TO FUTURE SCENARIOS

