

Understanding Natech risks from earthquakes

Characterisation of seismic hazard for fixed industrial facilities of Ecopetrol

MEng Emilio Tinoco, PhD Felipe Muñoz, MSc Julián Camargo, PhD Cristina Dimate, MSc Nelson Pérez
Seminar on effective management of technological risks of accidents triggered by natural hazards (Natech).
29 November 2022



Ecopetrol: Present and Future

Integrated energy group participating in all segments of the hydrocarbon chain.



Present

Upstream



679,000 bpd
+250 fields

71% Crude Oil
29% Gas

Midstream



1,010 kbpd
9,000 km

Oil and Gas
pipeline transport

Downstream



2 refineries
354 kbd

Max. 400 kbd

Renewables

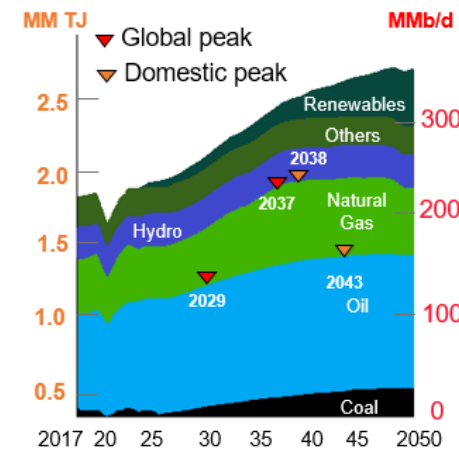


112 MWp

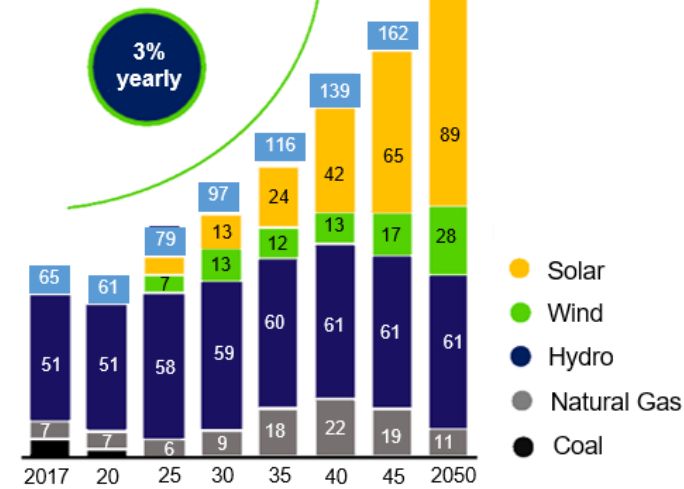
Largest self-
generator
in Colombia

Future

Energy demand in Colombia

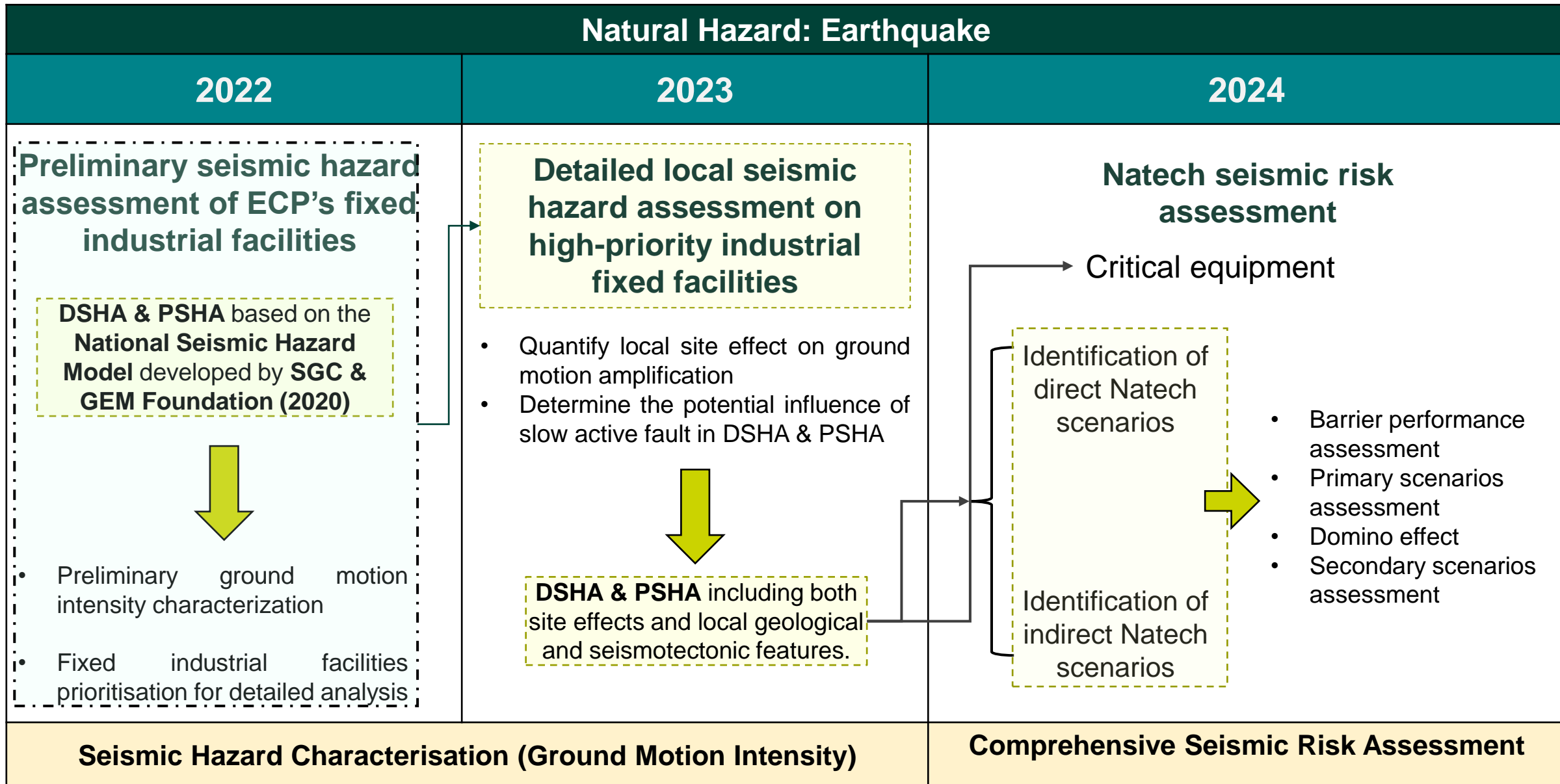


Electric power generation TWh



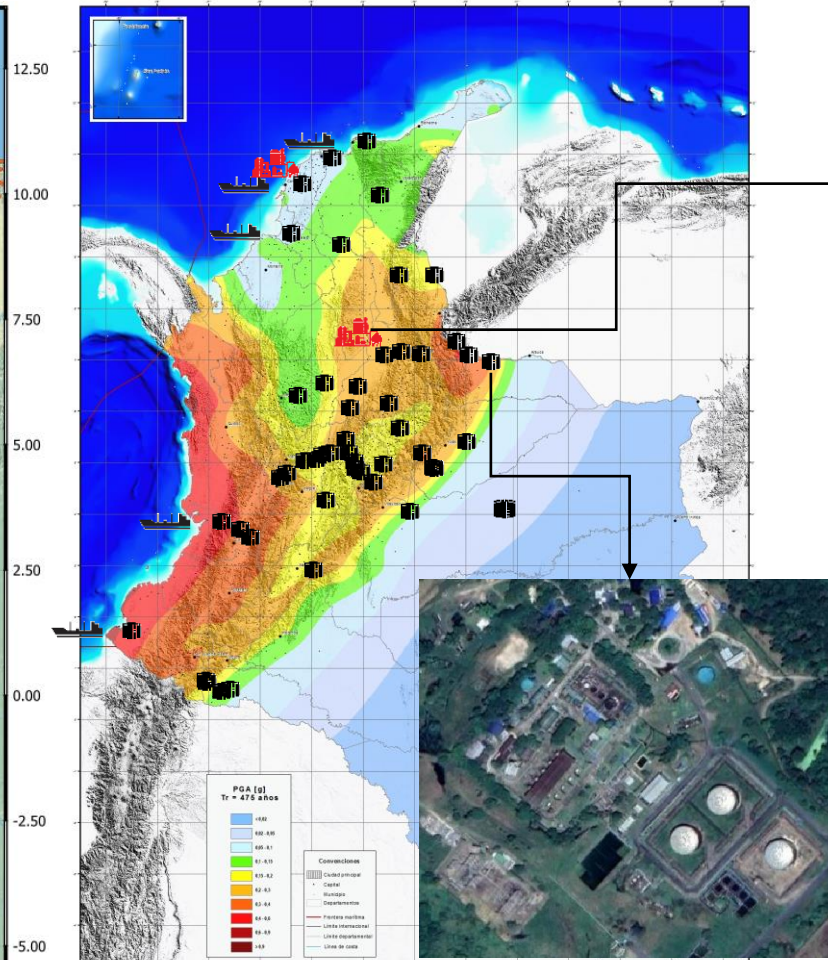
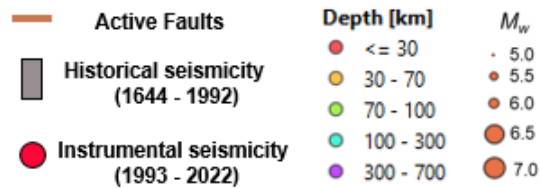
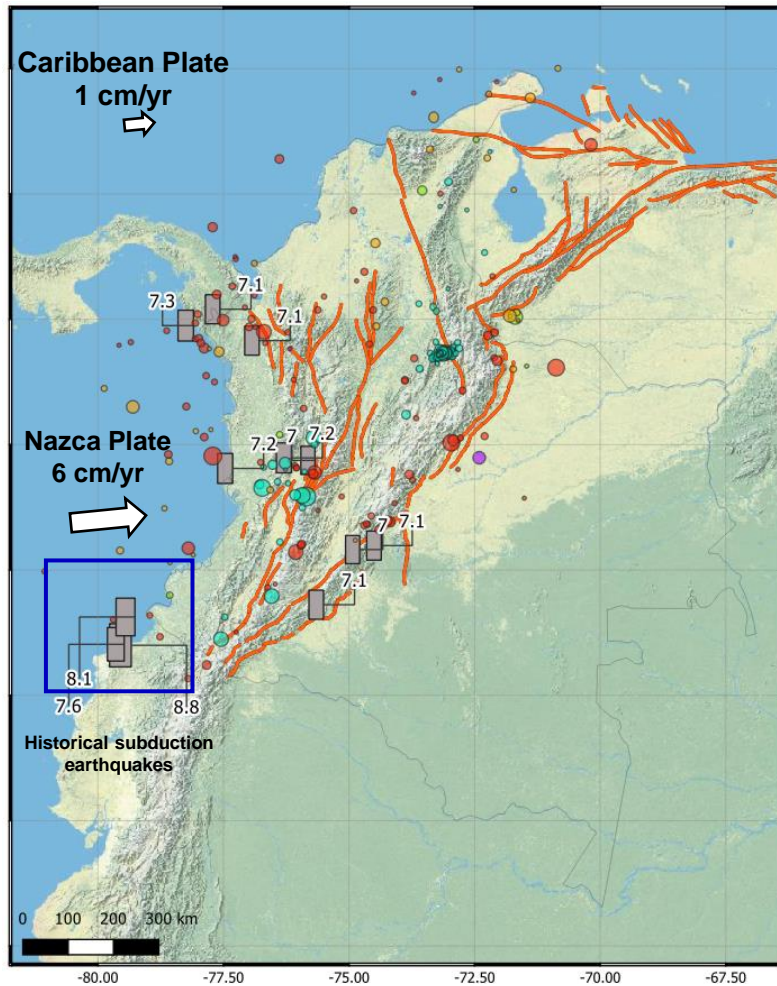
Ecopetrol's Natech risk assessment from earthquakes

Two-stage work plan: 1) Seismic hazard assessment, 2) Natech event assessment



National seismic hazard and Ecopetrol's fixed facilities

Ecopetrol's fixed facilities are placed mainly in moderate-to-high seismic hazard zones.



Peak ground acceleration map for rock sites conditions and a return period of 475 years (SGC & GEM Foundation, 2020).



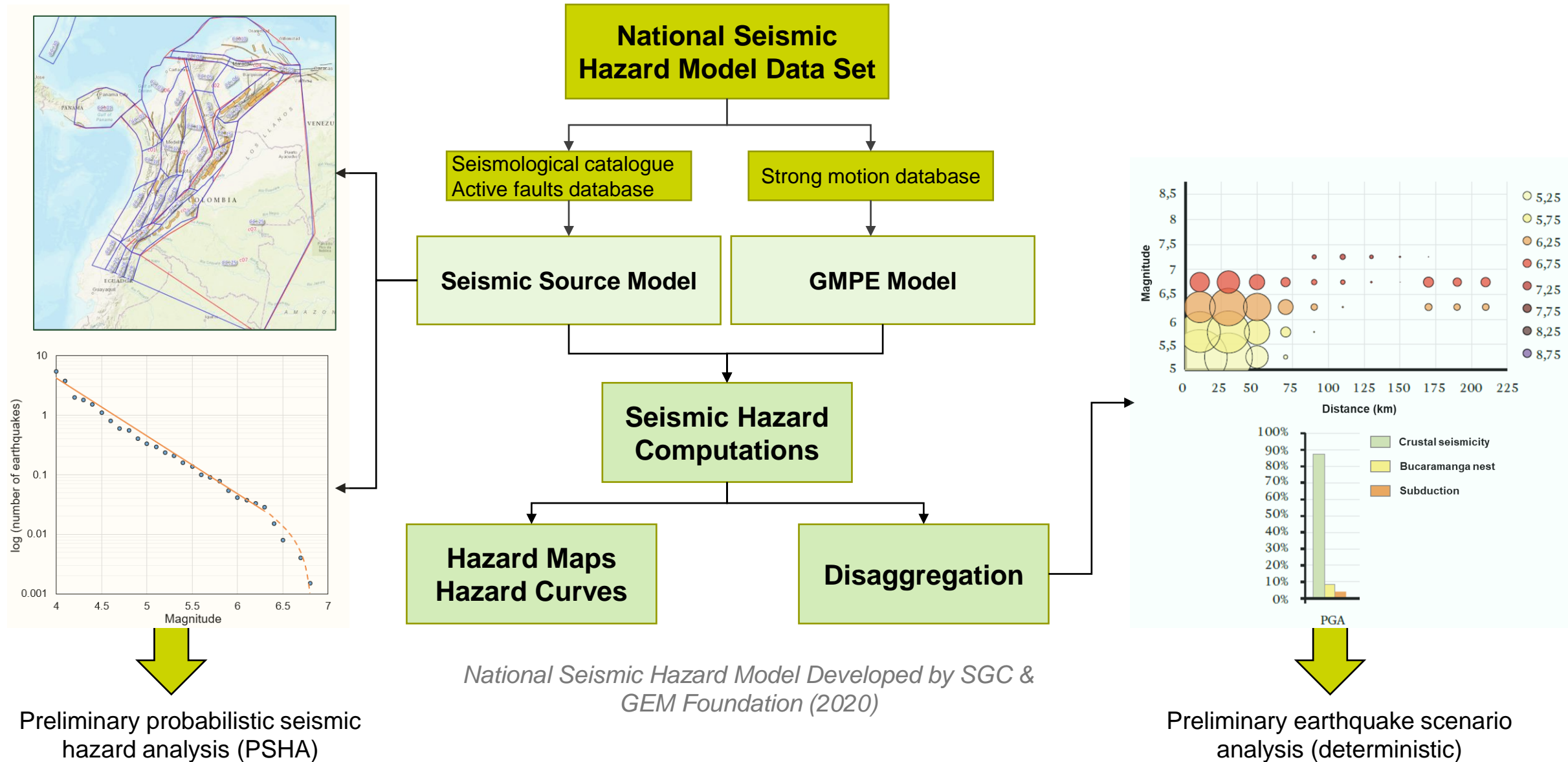
The direct use of the national seismic hazard model for **Natech** events (or other local scale projects) has the **following limitations**:

1. Non-mapped active local faults capable of generating earthquakes of moderate sizes.
2. Seismic hazard results do not include the evaluation of site effects (ground shaking amplification)
3. The seismic hazard analysis for Natech events should also consider earthquake scenarios based on the different seismogenic sources in Colombia:

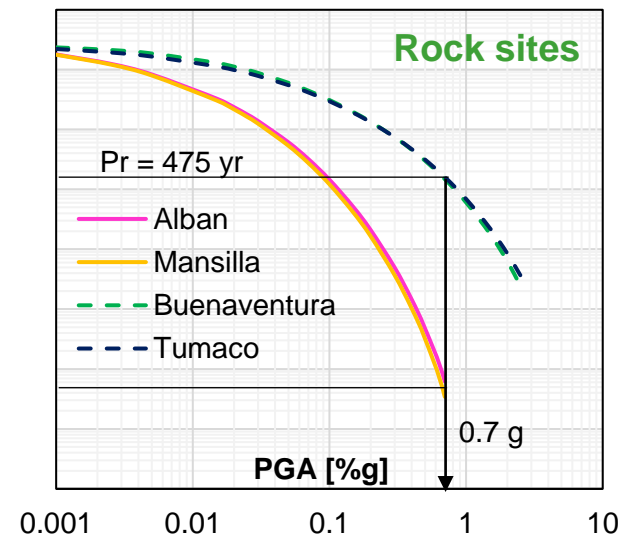
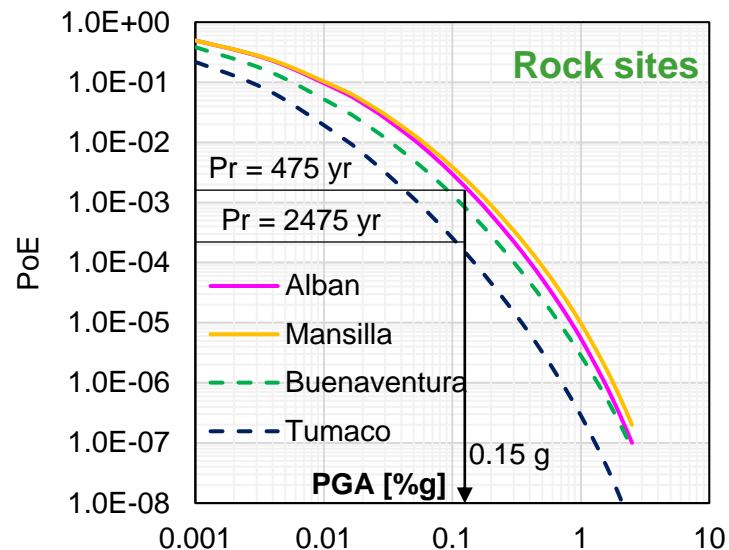
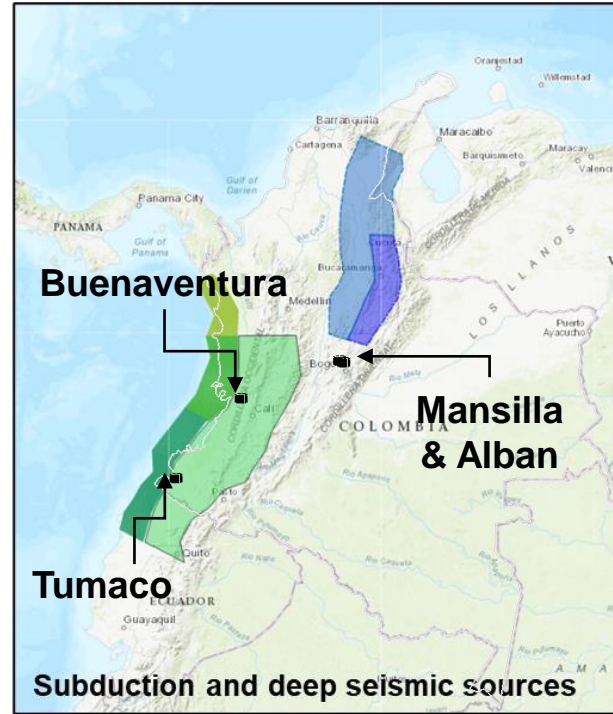
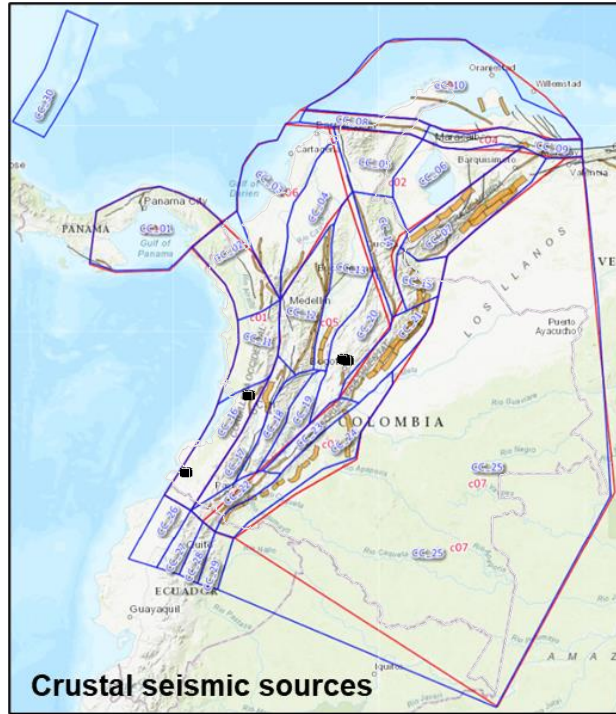
- Interplate subduction
- Intraplate subduction
- Active faults and continental crust
- Bucaramanga Seismic Nest

Using the seismic hazard model for preliminary calculations at the local scale

Based on the inputs and results of the national model we perform local scale preliminary calculations.



Seismic hazard assessment of fixed industrial facilities through the PSHA national model

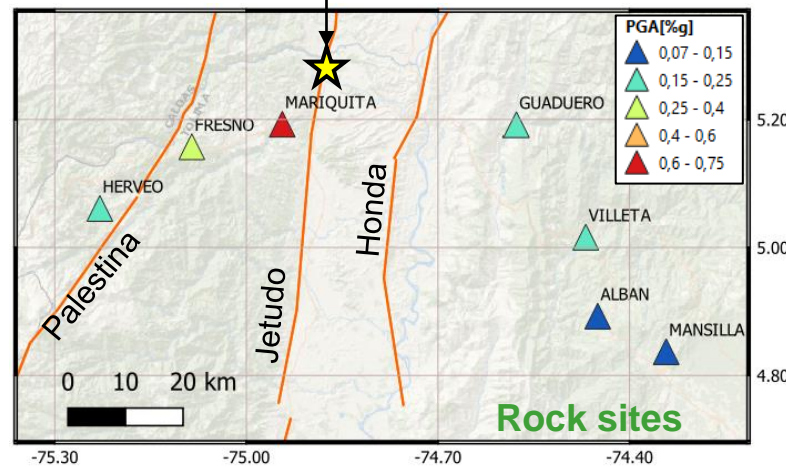
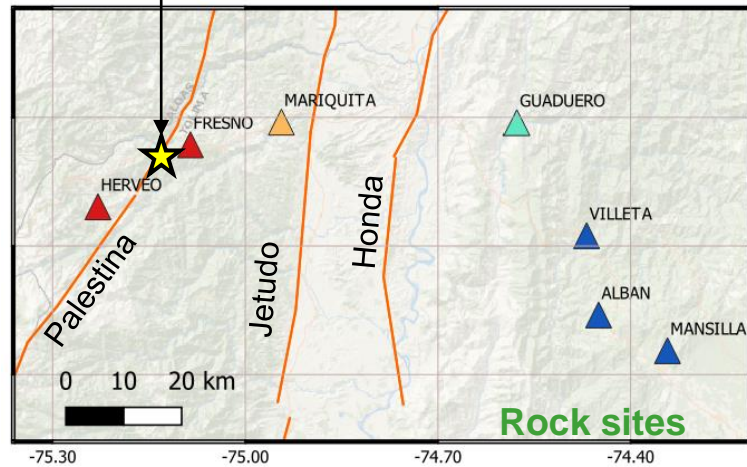
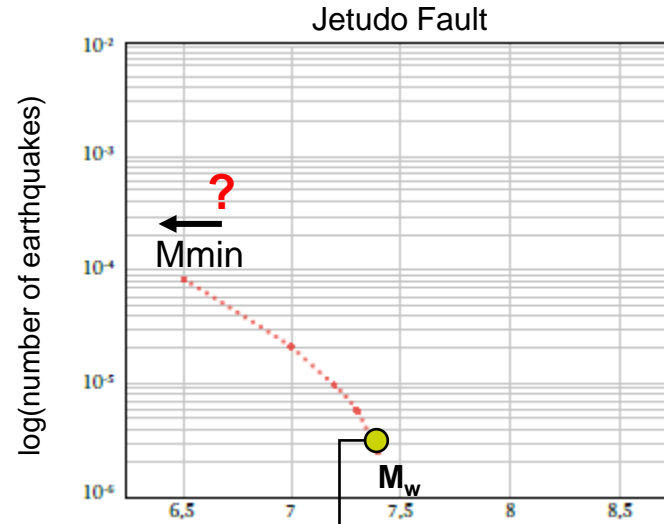
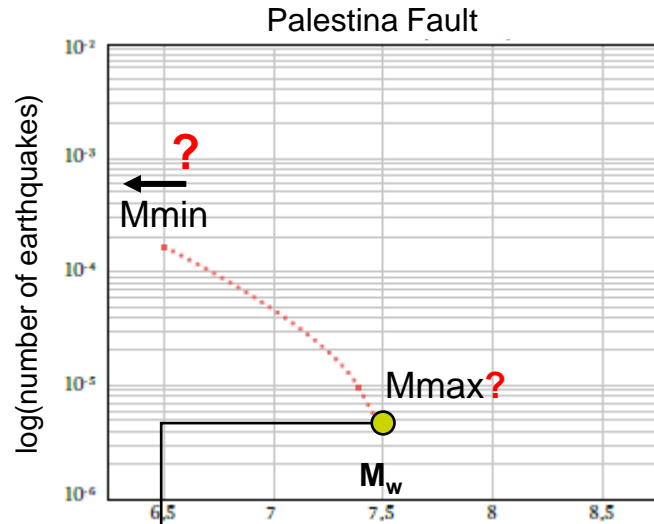


Insights

- The PSHA considers the contribution of all combinations of magnitude and distance of each seismic source.
- Towards the Pacific zone the largest contribution to the hazard is from subduction seismic sources (mainly from large historical subduction earthquakes). In the Andean zone the seismic hazard is dominated by cortical sources.
- Some active faults at intermediate distances (about 40 km) from some fixed installations on the Pacific coast can generate significant ground motion levels (e.g., Buenaventura).
- Different levels of ground motion can be estimated for various return periods and according to the importance of the facilities.

Deterministic hazard calculations based on seismic Hazard disaggregation

Earthquake scenario approach based on the maximum earthquake of an active fault



Insights

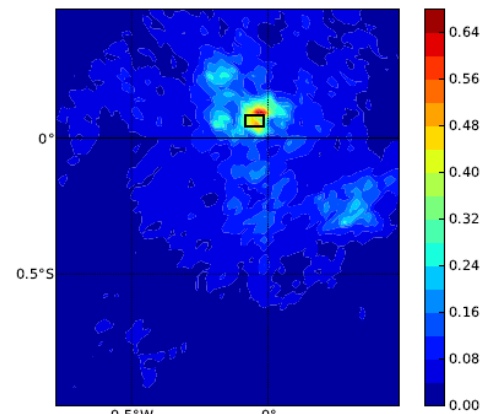
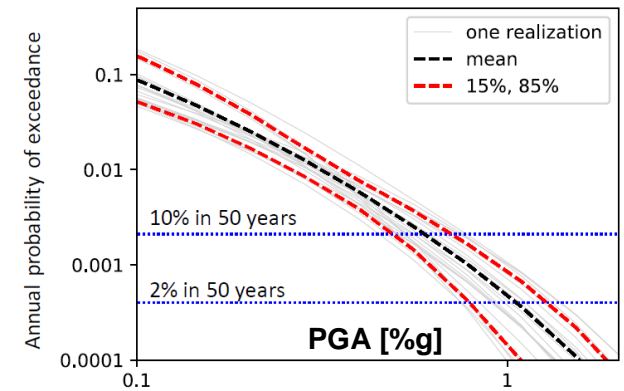
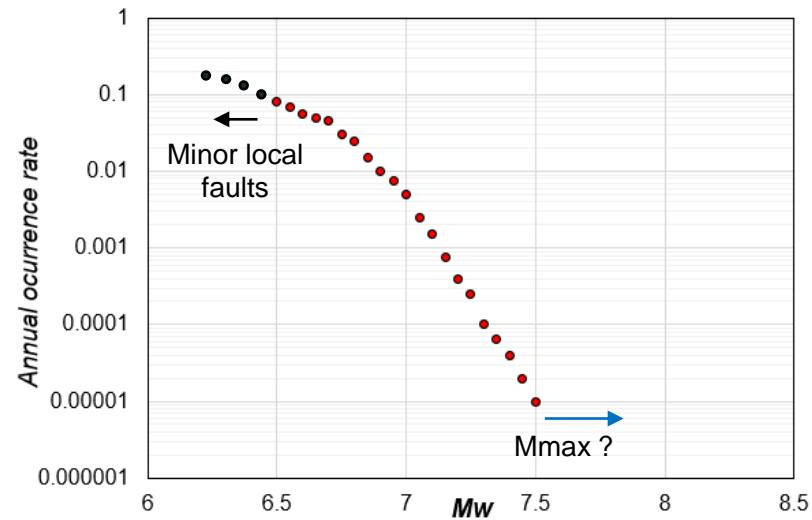
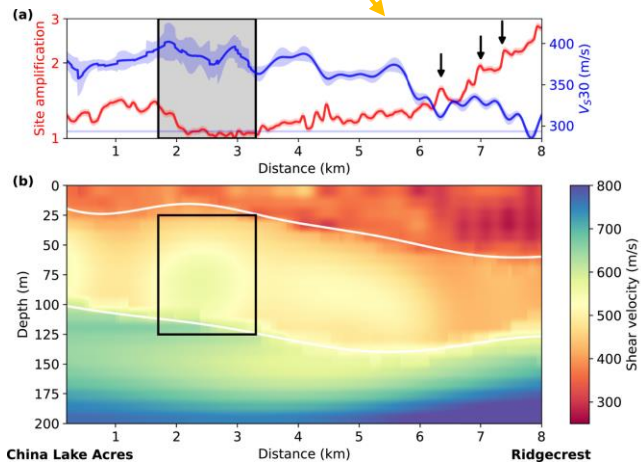
- With the scenario-based approach we are faced with a situation in which there are multiple sites near seismic sources.
- This begs the question, which scenario controls the seismic hazard?
- Are there non-mapped local structures capable of generating earthquakes of magnitude less than $M_{6.5}$?

Detailed studies on high-priority industrial fixed facilities

Local-scale studies on site effects and to reduce uncertainty in seismic sources - 2023

Hazard sites and seismic source models

Update local seismic hazard



Local site conditions

Reducing uncertainty in slip rate of near active faults
 Reducing uncertainty in M_{max}
 Reducing epistemic uncertainty in the seismic source logic tree

Update seismic hazard calculations

Conclusions and recommendations

- Most of Ecopetrol's fixed installations are in the Andean zone, where an **intermediate to high seismic hazard** predominates.
- The scenario-based approach reveals that ground shaking **can affect several fixed installations simultaneously**. Reducing the epistemic uncertainty in the earthquake that controls the seismic hazard is necessary.
- In fixed installations where specific studies are performed, the local conditions must be characterised to **estimate ground motion amplification**.
- Local probabilistic seismic hazard analysis allows identifying the influence of different seismotectonic environments. For example, **in the Andean zone, active faults and cortical seismicity** are the main contributors to seismic hazard, while in the Pacific zone, **subduction (and deep earthquakes) seismic sources predominate**.
- In fixed installations, it is recommended to develop fragility curves for **aged** structures.
- **A close relationship with the SGC** (Colombian Geological Survey) is essential to **reduce uncertainty about nearby active faults**.
- The assessment of potential Natech events promotes territorial resilience as it allows us to identify the limitations of **emergency responders in dealing with disasters** and the **social and environmental extent of the impacts** on hazardous infrastructure.
- We are **open to cooperating and working** together with other companies and organisations.

USAMOS NUESTRA ENERGÍA PARA
CONSTRUIR UNA **EMPRESA Y UN PAÍS**
———— **DE TODOS, PARA TODOS** ————

