

# RESOLUTION CNPE 8/2024

Proposals to promote the decarbonization of oil and gas E&P activities

Decarbonization scenarios for E&P: methodology

Brazil / Rio de Janeiro, RJ – July 2025

E&P/SPG/DPG



# ABOUT EPE – ENERGY RESEARCH OFFICE



**State-owned company linked to the Brazilian Ministry of Mines and Energy (MME)**



**EPE aims at supporting MME energy policies with a wide range of information, analyses and reports on energy planning covering electricity, oil, natural gas and its derivatives, and biofuels**

# PUBLIC VALUE



**EPE conducts studies and research to underpin the formulation, implementation, and evaluation of Brazilian energy policy and planning**

**Through these studies, EPE fosters transparency and reduces information asymmetry by presenting data and facts that can support discussions on the energy transition efforts in Brazil and possible pathways for the oil and gas sector to support the emerging green economy**

# DISCLAIMER



This document is for informational purposes only and is intended to support the planning of the national energy sector. Any decisions regarding implementation (such as the formulation of public policies, definition of strategic guidelines, investment decisions, or business strategies) depend on other public and private institutions.

EPE disclaims any responsibility for any actions and decisions that may be taken by economic agents or any person based on the information contained in this document.

# CONTENTS



**CONTEXT**



**METHODOLOGY**



**RESULTS**



**FINAL REMARKS**

# CONTEXT



# CLIMATE CHANGE AND ENERGY TRANSITION

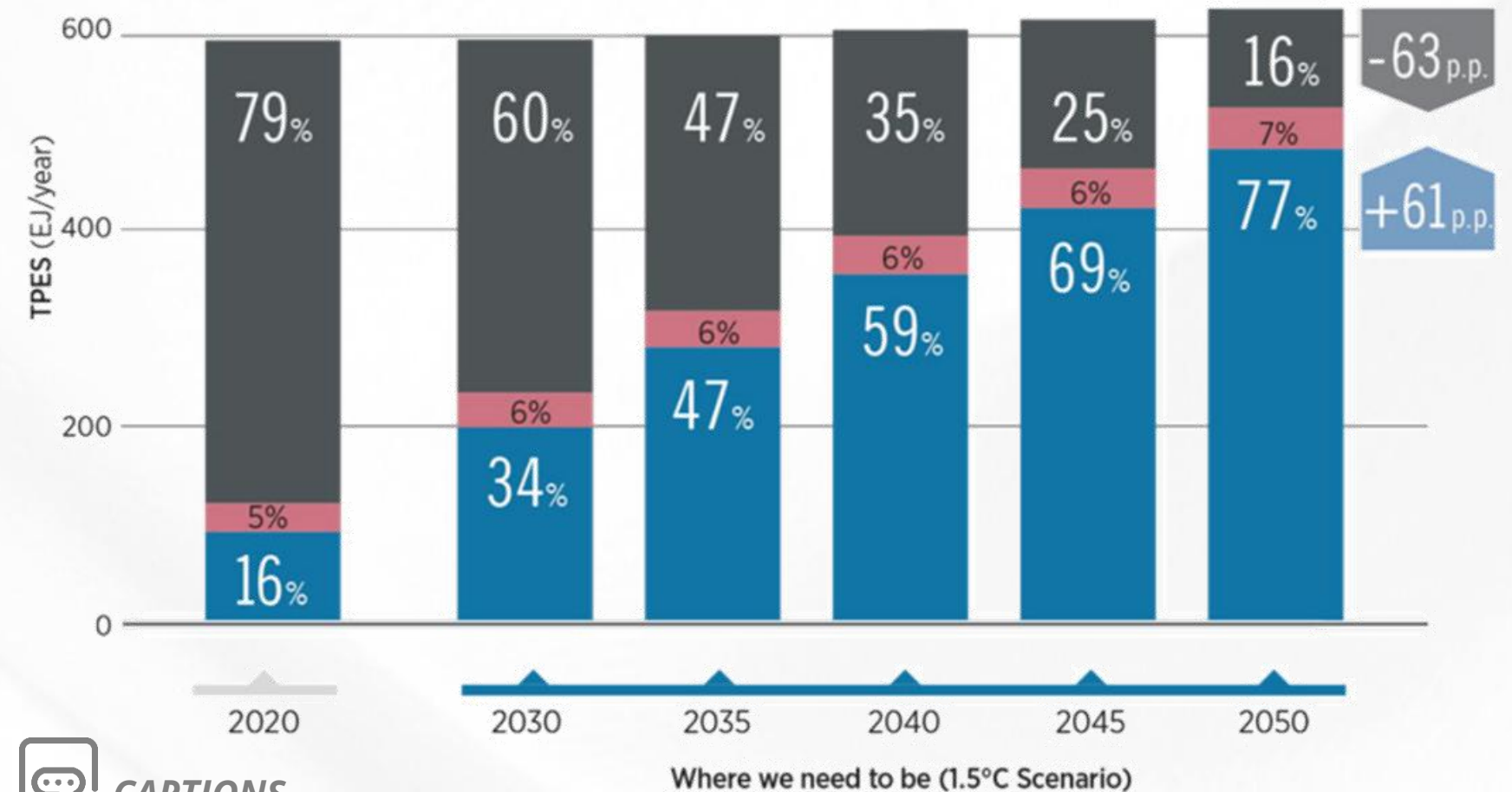


Over the past centuries, with the Industrial Revolution, **fossil fuels** have been the **foundation of the global energy system**, economic development, and societal lifestyle. In addition to shaping the current geopolitical landscape, they have had **a significant impact on the wealth and security of nations**.<sup>1</sup> However, their widespread use has caused an imbalance in the planet's ecosystem, resulting in **adverse effects**, such as **global warming** and **rising sea levels**, within the broader context of **climate change**.



Climate change needs an **energy transition** toward a **low-carbon economy** to **reduce environmental impact**. This transition encompasses not only increased energy efficiency but also **the replacement of high-carbon energy sources** with **lower-emission alternatives**, driving a **reduction in fossil fuel use** in favor of renewable energies and electrification.

Total primary energy supply by energy carrier group, 2020-2050 under the 1.5°C Scenario<sup>2</sup>



## CAPTIONS

- Fossil Fuels
- Nuclear
- Renewables

Total primary energy supply refers to the total amount of energy that is produced and consumed in various forms around the world. It includes all the energy sources that are used to produce electricity, power transportation, heat buildings and homes, and power industrial processes. This includes data from 2020 and highlights the necessary growth in the share of renewables in the energy mix to meet the 1.5°C target by 2050.

- TPES = Total primary energy supply.
- Renewables = hydro, solar, wind, bioenergy, geothermal and ocean energy.

<sup>1</sup> EPE, 2021. Caderno Especial: Ciclo de Debates com Instituto Brasileiro de Petróleo e Gás – IBP sobre Transição Energética, <https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/caderno-especial-ciclo-de-debates-com-instituto-brasileiro-de-petroleo-e-gas-ibp-sobre-transicao-energetica>.

<sup>2</sup> IRENA, 2024. World Energy Transitions Outlook, <https://www.irena.org/Publications/2023/Jun/World-Energy-Transitions-Outlook-2023>. Accessed 27 Jun 24.

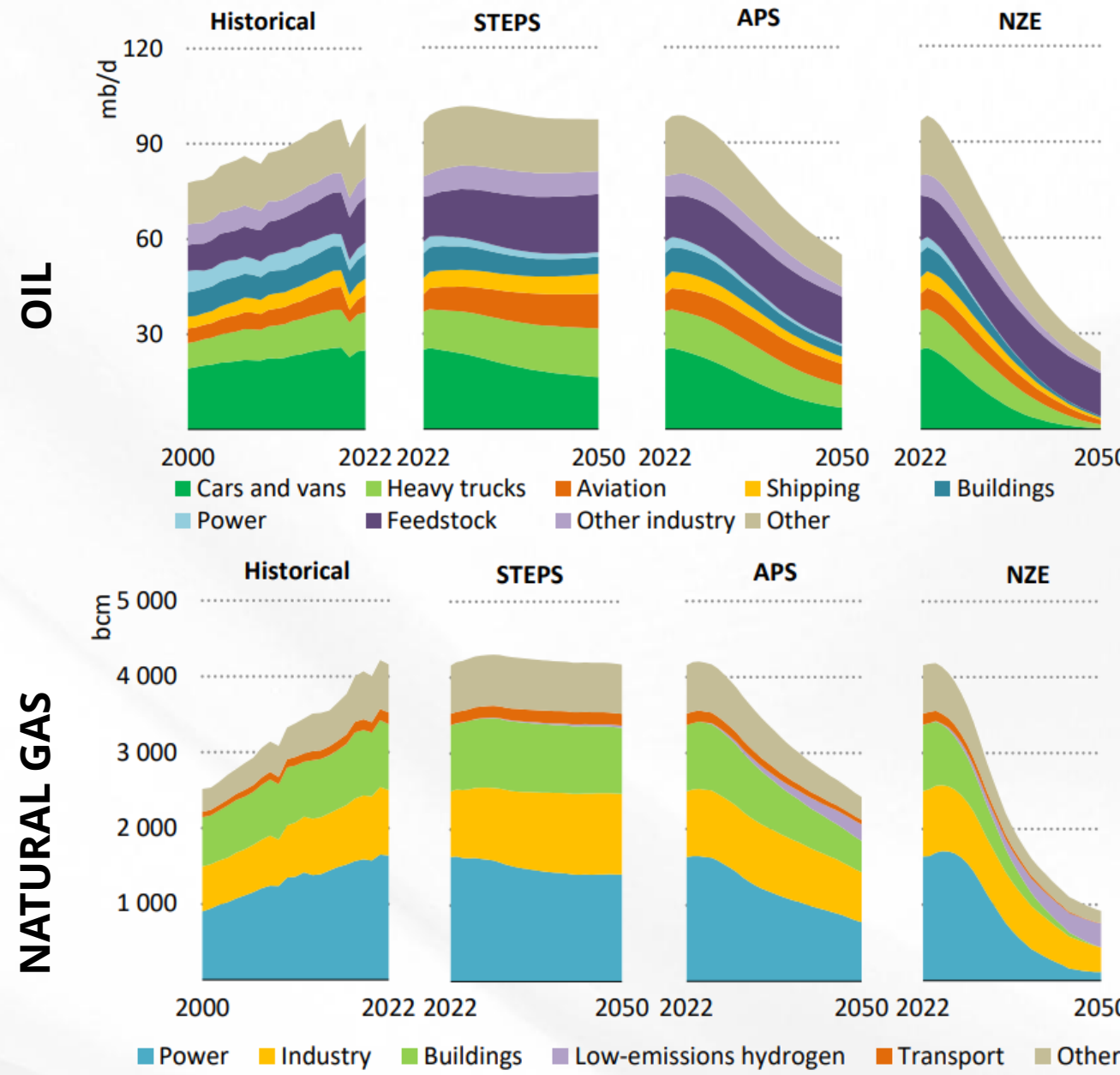
# FOSSIL FUELS IN A LOW-CARBON FUTURE

## But in this low-carbon future, what will be the role of fossil fuels?

Even in **the most ambitious** emission reduction scenarios - such as the IEA's NZE - **the oil and gas industry continues to supply part of the energy demand** up to the 2050 horizon, with a particular emphasis on the role of natural gas in the transportation and industrial sectors (especially chemicals and cement)<sup>1</sup>.

The outlook is for a **decline in the demand for oil and natural gas** amid **the growth of alternative sources**, forming a new, **lower-carbon, energy matrix**. Even so, the O&G industry will continue to be important in supplying **hard-to-abate sectors**, where the **complete replacement** of the energy sources used in their production processes is challenging, due to both technological and economic issues (e.g., **petrochemicals**)<sup>2</sup>.

Oil and Natural Gas demand by scenario, 2000-2050, IEA (2023)<sup>2</sup>



### CAPTIONS

mb/d = Million Barrels per Day

bcm = Billion Cubic Meters

STEPS (*Stated Policies Scenario*) looks at what governments are actually doing rather than what they say they will achieve.

APS (*Announced Pledges Scenario*) assumes that governments meet all of the climate-related commitments they have announced in full and on time. Pledges made by companies, businesses and industry organizations are also taken into account.

NZE (*Net Zero Emissions by 2050 Scenario*) describes a pathway for the global energy sector to reach net zero CO<sub>2</sub> emissions by 2050 without offsets from land-use measures.

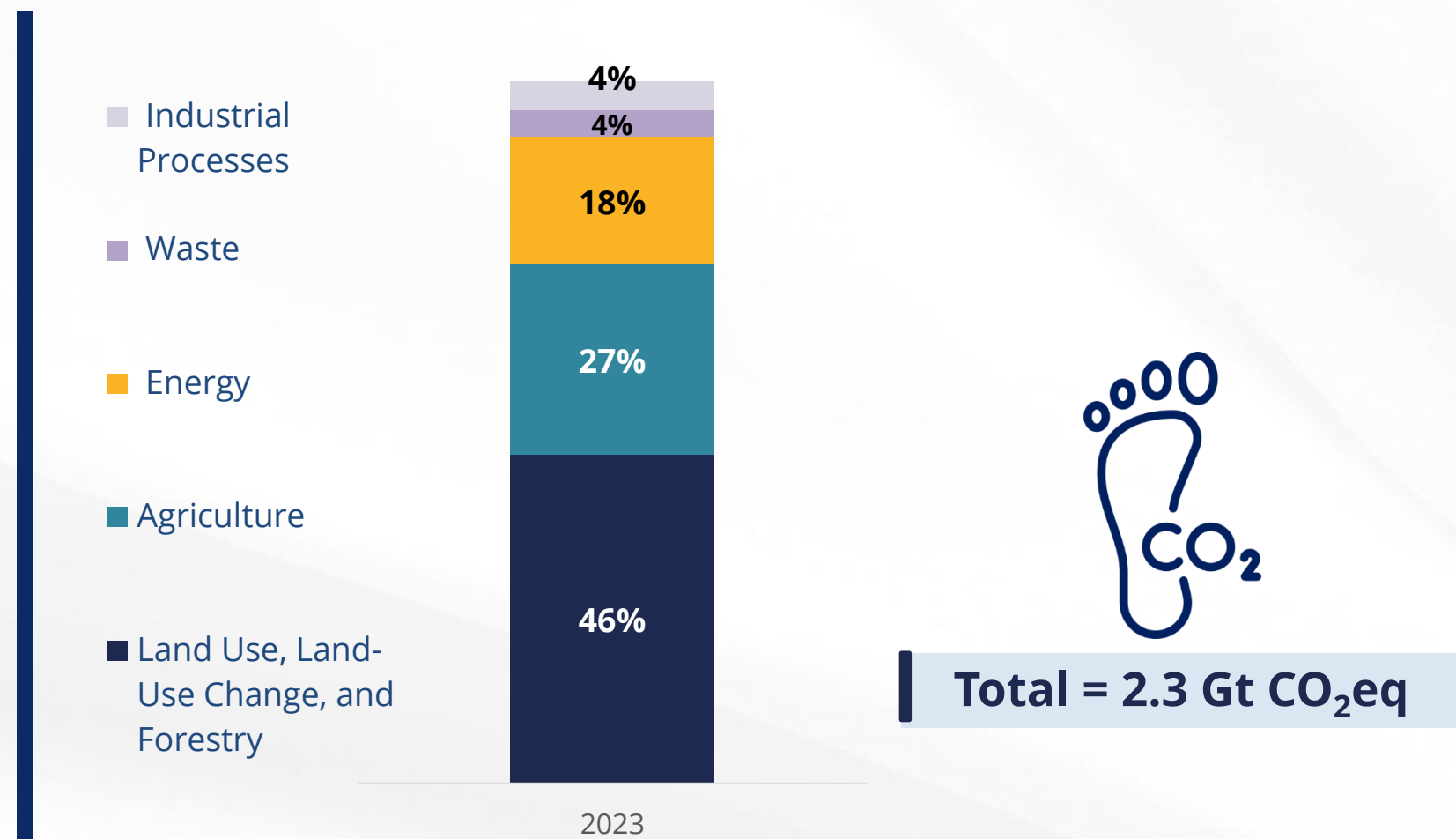


<sup>1</sup> IEA. 2023. Energy Technology Perspectives 2023, <https://iea.blob.core.windows.net/assets/a86b480e-2b03-4e25-bae1-da1395e0b620/EnergyTechnologyPerspectives2023.pdf>.

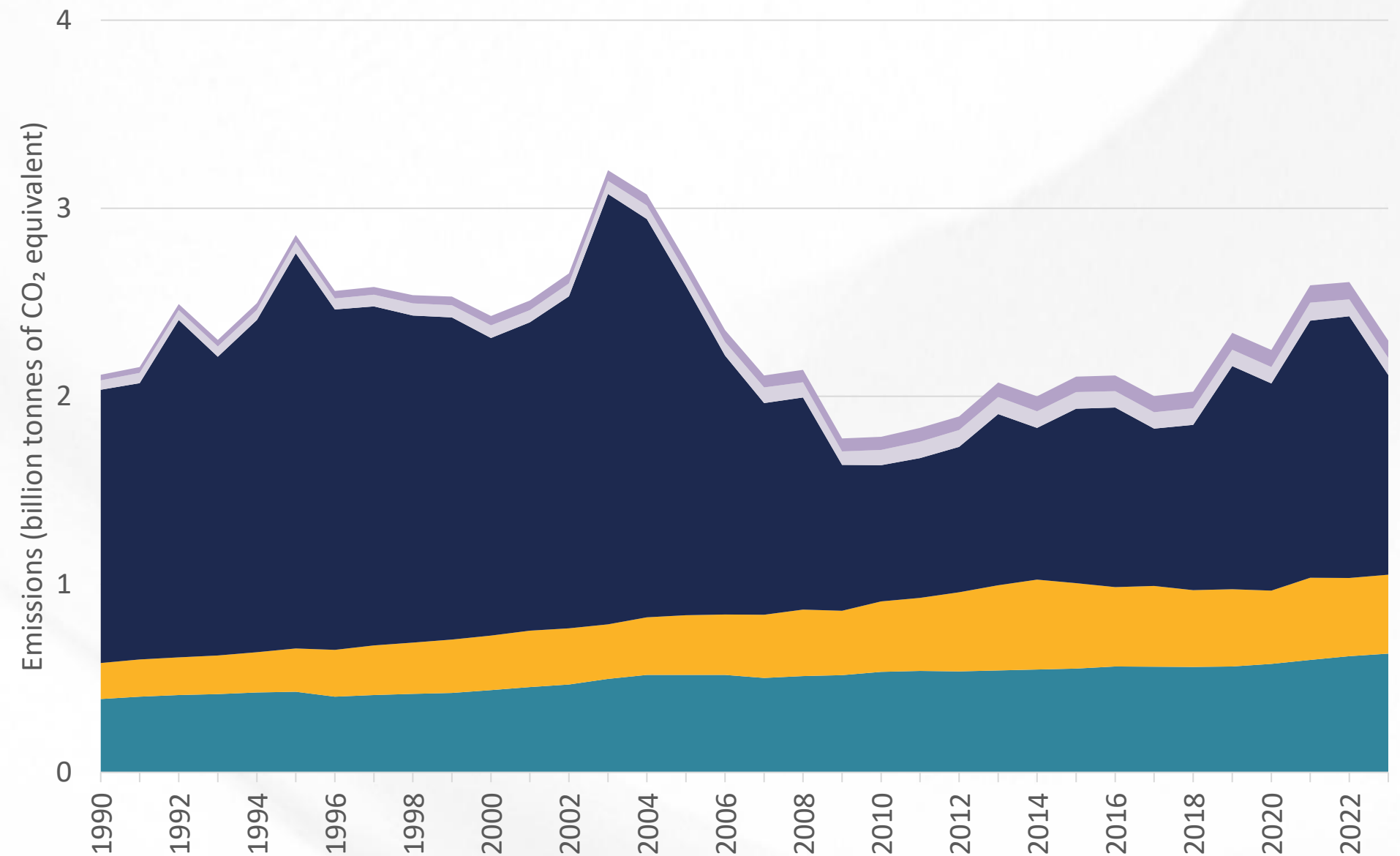
<sup>2</sup> IEA. 2023. The Oil and Gas Industry in Net Zero Transitions, <https://www.iea.org/reports/the-oil-and-gas-industry-in-net-zero-transitions#downloads>.

# BRAZILIAN EMISSIONS PROFILE

Brazilian emissions by sector<sup>1</sup>



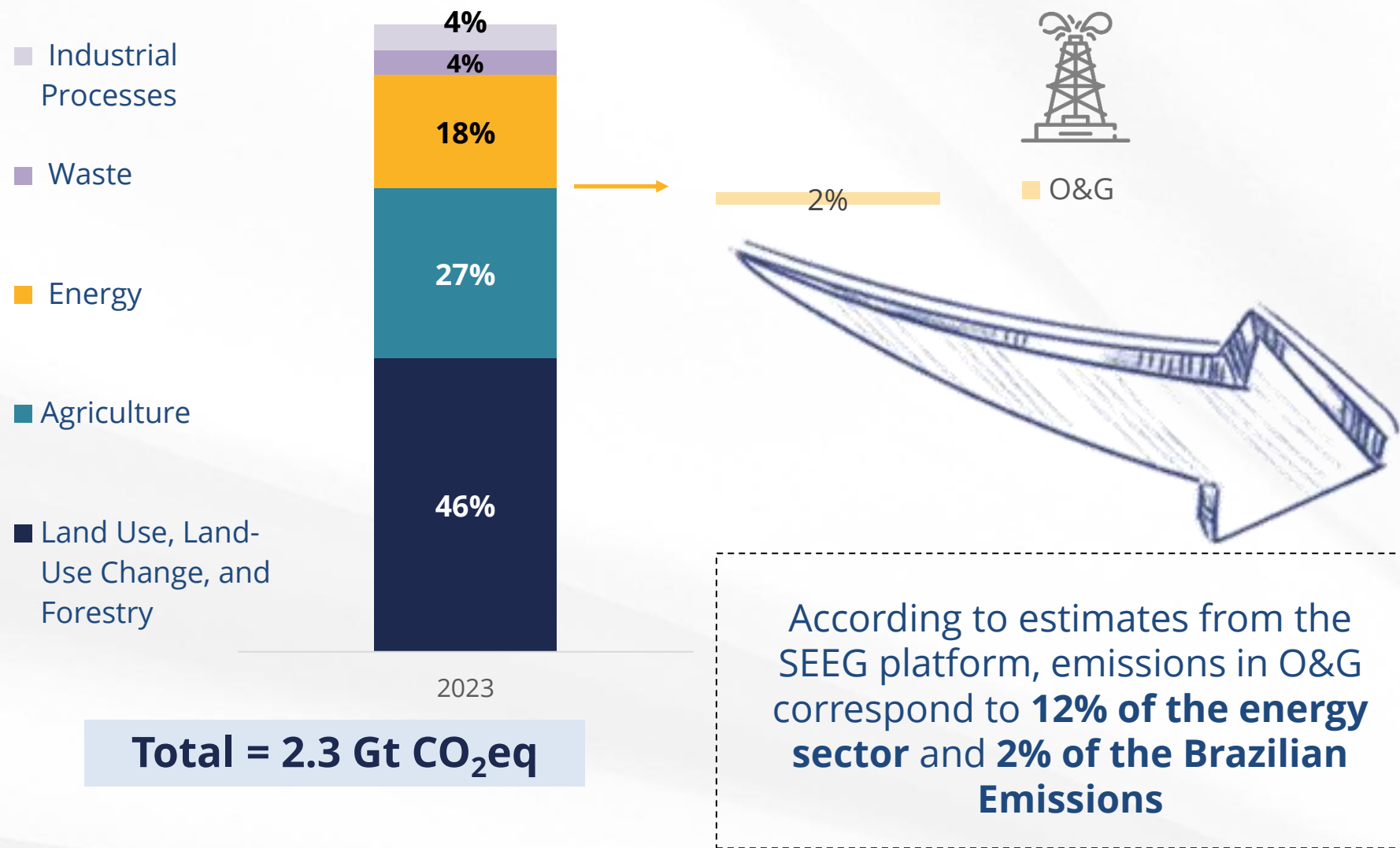
Brazil's Total Emissions in Tonnes of CO<sub>2</sub> Equivalent (1990–2023)<sup>1</sup>



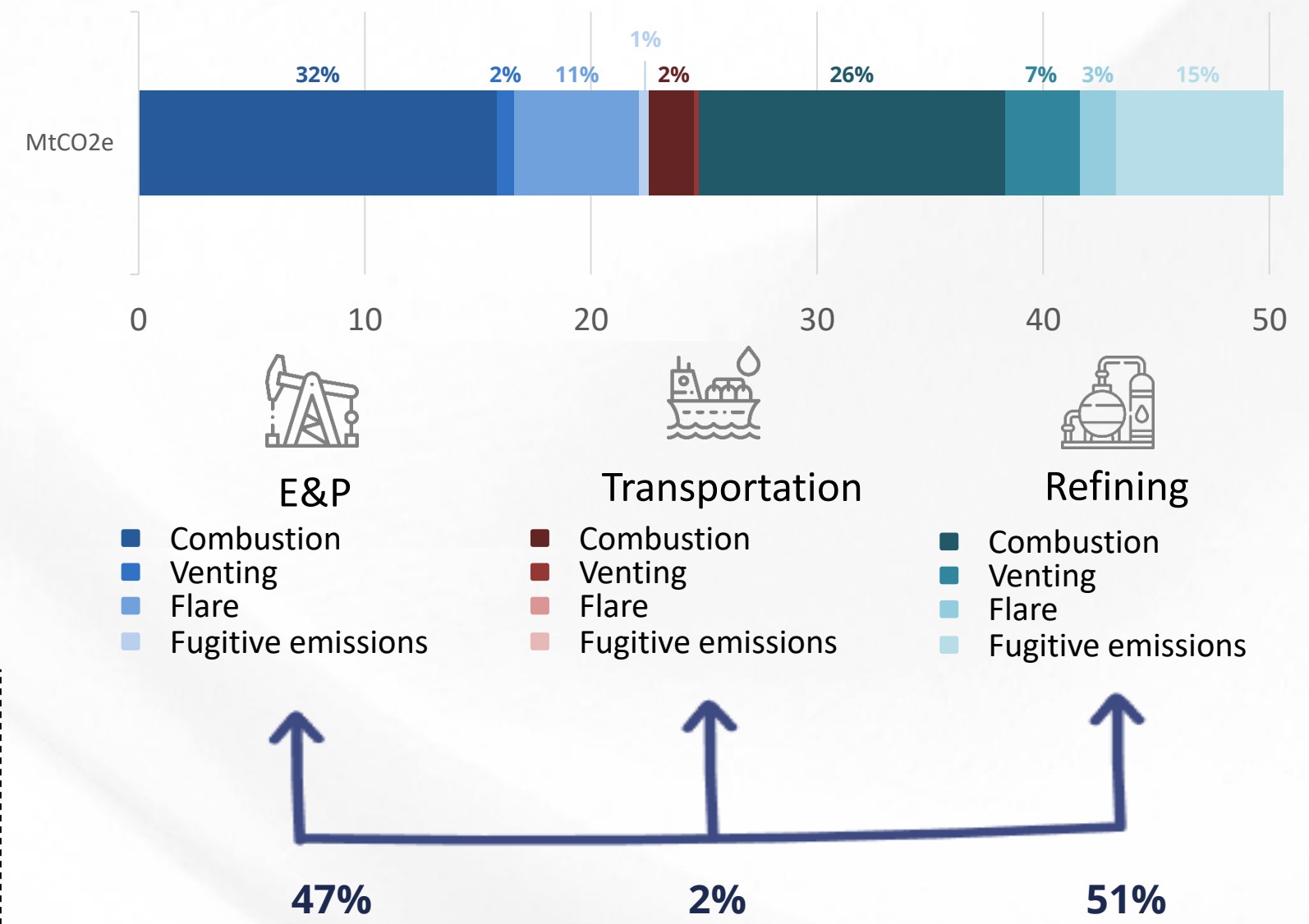
<sup>1</sup> Source: SEEG – Sistema de Estimativa de Emissões e Remoções de Gases de Efeito Estufa, Observatório do Clima. Available [online](#).

# GHG EMISSIONS FROM THE BRAZILIAN OIL & GAS SECTOR

Brazilian emissions by sector<sup>1</sup>



Emissions from Brazil's O&G sector in 2023<sup>1</sup>



<sup>1</sup> Source: SEEG – Sistema de Estimativa de Emissões e Remoções de Gases de Efeito Estufa, Observatório do Clima. Available [online](#).

# WHY DECARBONIZE THE BRAZILIAN O&G INDUSTRY?



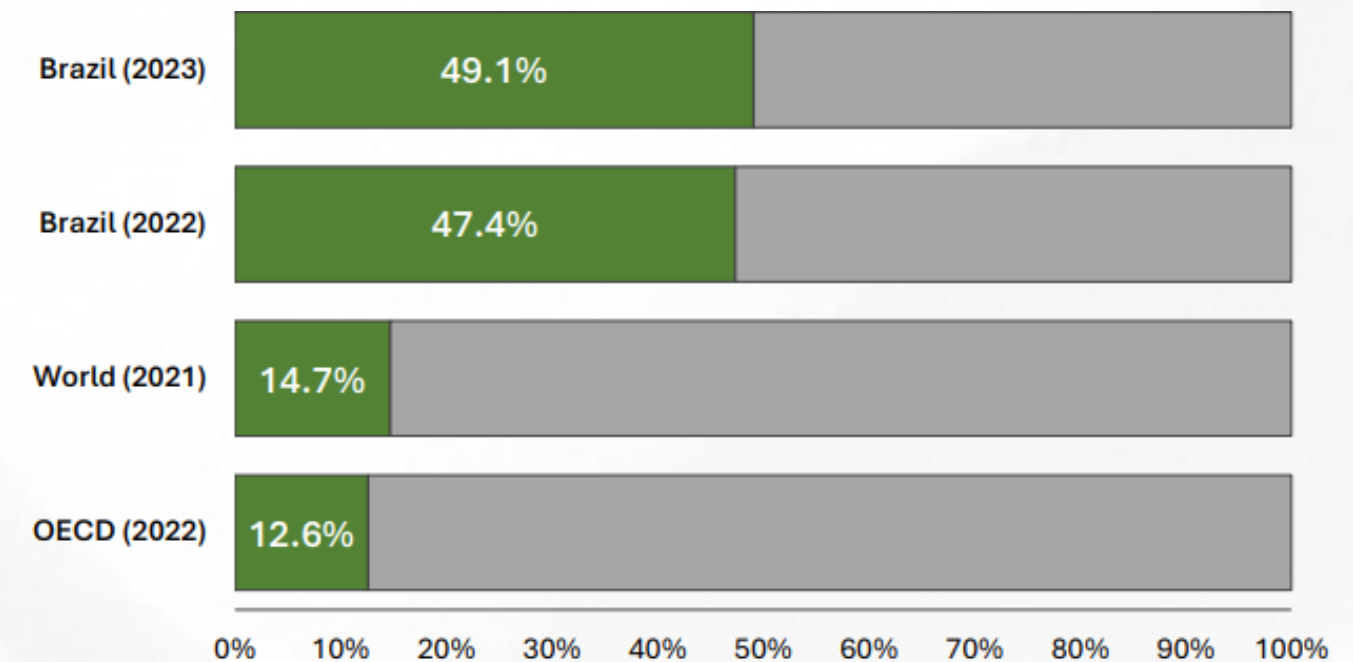
Brazil is the **5<sup>th</sup> largest emitter in the world**, accounting for **2.55% of global emissions** in 2024.<sup>1</sup> However, Brazil's emissions profile is quite peculiar. While the energy and industrial sectors are the largest emitters in the world's top 10 economies, in Brazil, **agriculture and LULUCF** (land use, land-use change and forestry) sectors are responsible for **about 73% of emissions**.



Thus, decarbonizing **Brazil's energy sector**, which already boasts **a strong share of renewables**, particularly in oil exploration and production (E&P), may not significantly impact **Brazil's emission targets**.

However, considering that, albeit reduced, there will still be **oil demand in the future**, the **oil and gas sector** should also aim to lower its **carbon intensity**, as there are indications that this factor will be **a value-adder** in the commodity market.<sup>3</sup>

Share of renewables in the Total Energy Supply (TES)<sup>2</sup>



CAPTIONS

Renewables

Non-renewables

<sup>1</sup> Climate Trace. [https://climatetrace.org/inventory?year\\_from=2022&year\\_to=2022&gas=co2e100](https://climatetrace.org/inventory?year_from=2022&year_to=2022&gas=co2e100). Accessed in 18 jul 25.

<sup>2</sup> EPE. 2024. BEN 2024: Summary Report. <https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/PublishingImages/Paginas/Forms/Publicaes/Summary%20Report%202024.pdf>.

<sup>3</sup> WEF. 2024. Carbon intensity: This overlooked metric is key to the green transition. <https://www.weforum.org/agenda/2024/02/carbon-intensity-a-key-and-overlooked-metric-for-the-climate-transition/>.

# CNPE RESOLUTION N° 08/2024

## Establishes guidelines for promoting the decarbonization of oil and natural gas exploration and production activities

“Article 3: EPE shall (...) propose the adoption of measures to incentivize the decarbonization of oil and natural gas exploration and production activities, presenting (...) **a study containing decarbonization scenarios** and the associated impacts of the proposed measures.”

A period of 180 (one hundred and eighty) days



### Executive Summary

An overview of the main findings

### Fact Sheet

Concise overview of the context and proposed measures, using accessible language and visual elements for broad audiences

### Final Report

Main document consolidating all analyses, methodologies, and discussions from the study

### Slide deck

Concise version focused on the methodology used in scenario development



<sup>1</sup> DESPACHO DO PRESIDENTE DA REPÚBLICA - DESPACHO DO PRESIDENTE DA REPÚBLICA - DOU - Imprensa Nacional

# METHODOLOGY



# METHODOLOGY



## MODEL ASSUMPTIONS<sup>1</sup>

- Model with integrated factors and a **top-down** approach:
  - It correlates the **energy demand** and sector's **historical emissions** with the **EPE's production curve**, refining the results through ad-hoc adjustments<sup>2</sup>;
  - Medium-term scenarios (**2037**)
  - Direct emissions
- Mitigation measures:
  - **Effort index matrix**: classification of mitigation measures related to **emissions reduction potential** and **effort level** for implementation
- Development of **medium-term emission reduction scenarios** (up to 2037) based on the implementation of GHG mitigation measures;
  - Baseline scenario;
  - Low, medium, and high effort scenarios;
  - Scenario sensitivity analysis;

<sup>1</sup> For this first version of the assessment of alternatives for E&P decarbonization, the model developed in 2022 by Green Domus — the consultancy awarded the contract for developing the modeling to estimate the potential for GHG emissions reduction in oil and natural gas E&P activities, as well as the related aspects — was used.

<sup>2</sup> Adjustments introduced by the analyst to adapt the model to the observed historical emissions, necessary due to changes in the Brazilian oil production profile and technological advancements recorded in recent years.

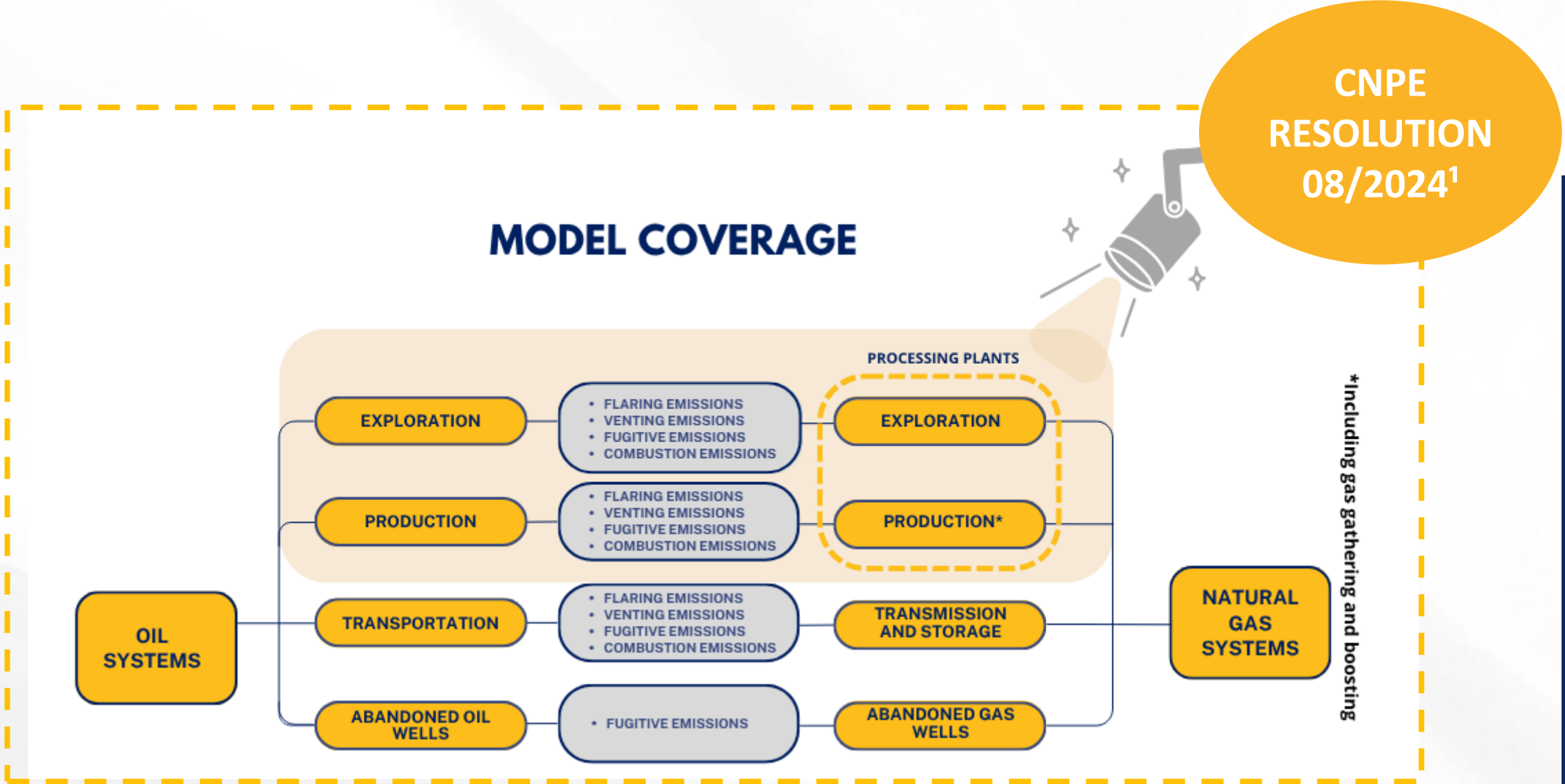


## STAKEHOLDERS ENGAGEMENT

- **Engagement with various sector stakeholders**, translating numerical results into practical, day-to-day actions for the industry



# SCOPE OF THE MODEL

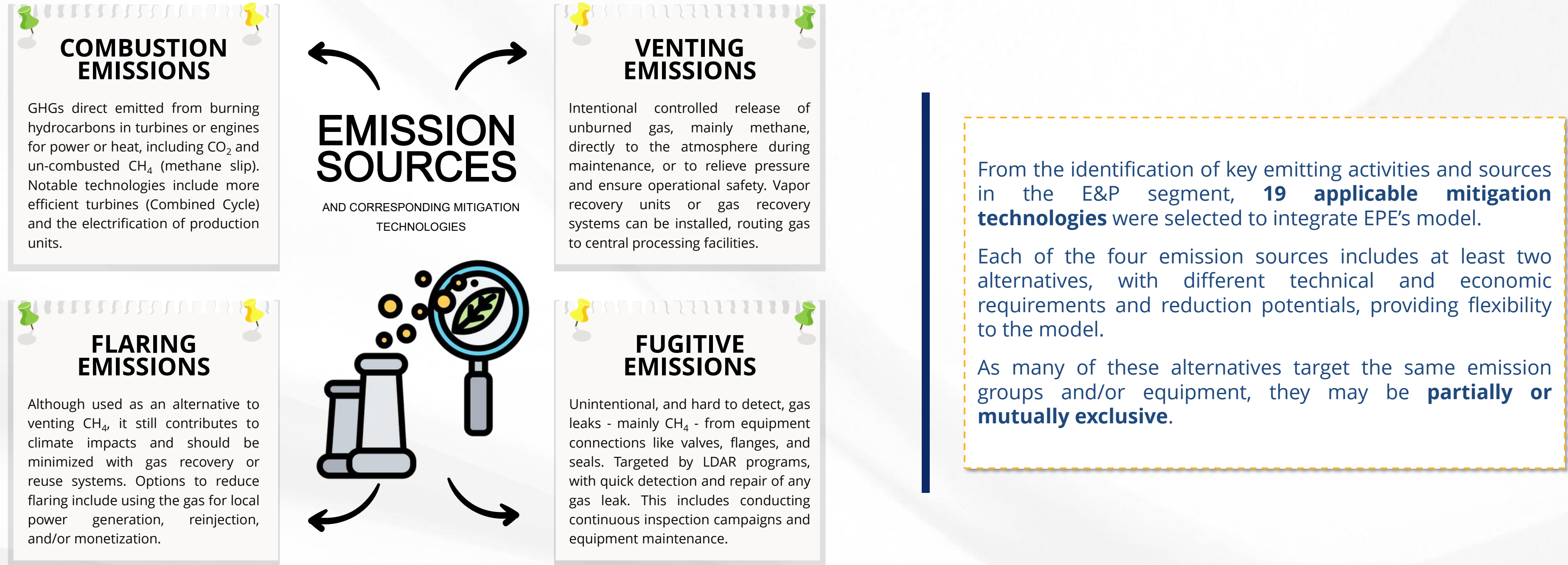


- **The model encompasses:**
  - Oil and natural gas systems
  - Different stages of the value chain:
    - Exploration and production (E&P)
    - Abandoned wells
    - Transportation
    - Maritime transportation
- Combustion, flaring, venting, and fugitive emissions

When estimating national and global emissions, only direct emissions are typically considered—that is, emissions from sources directly operated or controlled by companies in the sector. However, Scope 2 and Scope 3 emissions (indirect and supply-chain-related) included in corporate inventories also play a key role in achieving climate goals, even if they are not always reflected in broader estimation frameworks.

<sup>1</sup>To meet the requirements of CNPE Resolution No. 8/2024, only the highlighted areas were considered in the scenarios.

# IDENTIFICATION OF EMISSION SOURCES IN THE E&P SEGMENT



# EFFORT MATRIX FOR THE MAPPED MITIGATION MEASURES

To uniformly capture the varying levels of effort required to implement each mapped mitigation measure, a **Normalized Effort Index** was developed, ranging from 0 to 1. To calculate this index, the values of criteria C1 and C2 are summed and divided by the maximum possible effort value. When C1 data is not available, it is estimated by the simple average of the other three criteria (C3, C4, and C5).

Criteria used to assess the implementation effort of mitigation measures

Criterion	Category	Effort	Index
1) Marginal abatement cost	0 US\$/tCO <sub>2</sub> e	Very Low	1
	0 a 80 US\$/tCO <sub>2</sub> e	Low	2
	80 a 100 US\$/tCO <sub>2</sub> e	Medium	3
	100+ US\$/tCO <sub>2</sub> e	High	4
2) Technological barrier	Common practice with readily available operational technologies	Very Low	1
	Common practice requiring adaptation of existing technologies	Low	2
	New practice with available technological solutions	Medium	3
	New practice with most technologies under development or unavailable	High	4



Criteria used to estimate marginal abatement cost (C1) when quantitative data is unavailable

Criterion	Category	Effort	Index
3) Productivity loss	No production interruption required	Very Low	1
	Minimal production interruption	Low	2
	Temporary production shutdown	Medium	3
	Indefinite production shutdown	High	4
4) Investment return	Payback within 1 year	Very Low	1
	Payback within 2 years	Low	2
	Long-term payback	Medium	3
	No return on investment	High	4
5) Operational cost	Requires temporary mobilization of in-house staff for implementation	Very Low	1
	Requires temporary mobilization or hiring of staff for implementation and maintenance	Low	2
	Requires permanent mobilization of in-house staff for implementation and maintenance	Medium	3
	Requires permanent hiring of staff for implementation and maintenance	High	4

**Normalized Effort Index**



# TECHNOLOGY RANKING BY EFFORT LEVEL

CO<sub>2</sub> reinjection from natural gas processing involves separating co-produced CO<sub>2</sub> - especially from high-CO<sub>2</sub> fields like Brazil's pre-salt - then compressing and reinjecting it into reservoirs. This avoids atmospheric release and is often mandatory. In E&P, **reinjection also boosts oil recovery** by increasing reservoir pressure **and can serve as permanent storage**, reducing emissions and improving project economics.

Captures hydrocarbons vapors from low-pressure sources, like storage tanks and compressor. This practice **utilizes gas that would otherwise be vented or flared**, significantly reducing emissions and potentially generating revenue.

Replaces natural gas in pneumatic devices with compressed air, **eliminating methane emissions from the control process**. The recovered gas can be monetized, making the measure economically attractive.

LDAR programs **detect and repair unintended methane leaks** from equipment via periodic surveys. It is applicable to brown fields and often cost-effective, as recovered gas can generate financial return

**Leak Detection and Repair (LDAR)**

**Zero Routine Flaring**

**Replacement of NG - powered devices with Pressurized Air Systems**

**Installation of Vapor Recovery Units (VRUs)**

**CO<sub>2</sub> Reinjection from Natural Gas Processing**

**All Electric**

**Combined Cycle Turbines**

**Grid Electrification**

Connecting E&P facilities to the national grid replaces gas-powered systems with electric ones. In Brazil, this enables the use of low-carbon power, mostly renewable. **Despite high abatement potential**, offshore deployment requires **major investments in transmission and subsea infrastructure**.

By adding a Heat Recovery Steam Generator (HRSG) to open-cycle turbines used in extraction, combined-cycle systems recover waste heat to power a second steam turbine. This **raises efficiency** and **lowers emissions**, though it **may require retrofits and high capital investment**.

Replaces hydraulic or gas-driven equipment with electric systems on the platform, powered by a **centralized and more efficient gas-fired plant**. This reduces fuel use and emissions, but requires infrastructure investment. The model is already applied in Brazil, especially in green fields.

Eliminating continuous or intermittent flaring of associated gas is a priority due to its environmental impacts. These strategies can also result in **negative abatement costs when the gas is monetized**. The goal is to capture and utilize gas that would otherwise be burned due to **infrastructure or market limitations**.

**EFFORT**

# MITIGATION MEASURES IDENTIFIED FOR THE E&P SEGMENT

## GENERAL STRUCTURE

Total possible measures **08**

### Mutually exclusive group 1: combustion emissions Max 01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

### Mutually exclusive group 2: flaring emissions Max 01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
- Routine flaring and/or venting of associated gas limited to 2%

### Mutually exclusive group 3: fugitive emissions Max 01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions Max 02

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group Max 03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# MITIGATION MEASURES IDENTIFIED FOR THE E&P SEGMENT

## GENERAL STRUCTURE

### Mutually exclusive group 1: combustion emissions

Max  
01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

### Mutually exclusive group 2: flaring emissions

Max  
01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
- Routine flaring and/or venting of associated gas limited to 2%

### Mutually exclusive group 3: fugitive emissions

Max  
01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions

**Mutually Exclusive Groups** contain measures that act on the same technology or emission source. This means that only one measure from each group can be implemented at a time, as they are mutually exclusive.

- Reinjection of carbon dioxide from natural gas processing

# MITIGATION MEASURES IDENTIFIED FOR THE E&P SEGMENT

## GENERAL STRUCTURE

### Mutually exclusive group 1: combustion emissions Max 01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with distributed power generation
- Electrification of operations with renewable energy

The **Fully Compatible Group** includes measures that can be implemented simultaneously, as they target different and complementary technologies or emission sources. The **Partially Exclusive Group** is hybrid and allows up to two selected measures.

### Mutually exclusive group 2: venting emissions Max 01

- Elimination of venting emissions
- Elimination of venting emissions
- local use for electricity generation
- small-scale monetization using compressed natural gas
- large-scale monetization
- small-scale monetization using liquefied natural gas
- Routine flaring and/or venting of associated gas limited to 2%

### Mutually exclusive group 3: fugitive emissions Max 01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# STEPS FOR SCENARIO DEVELOPMENT

**STEP 1:** Evaluate up to **1 measure from each Mutually Exclusive Group** (1, 2, and 3), totaling between 0 and 3 measures

## Mutually exclusive group 1: combustion emissions

Max  
01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

## Mutually exclusive group 2: flaring emissions

Max  
01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
- Routine flaring and/or venting of associated gas limited to 2%

## Mutually exclusive group 3: fugitive emissions

Max  
01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

## Partially exclusive group: venting emissions

Max  
02

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

## Fully compatible group

Max  
03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# STEPS FOR SCENARIO DEVELOPMENT

**STEP 1:** Evaluate up to **1 measure from each Mutually Exclusive Group** (1, 2, and 3), totaling between 0 and 3 measures

**Mutually exclusive group 1: combustion emissions** Max 01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

**Mutually exclusive group 2: flaring emissions** Max 01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
  - Routine flaring and/or venting of associated gas limited to 2%

**Mutually exclusive group 3: fugitive emissions** Max 01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

**Partially exclusive group: venting emissions** Max 02

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

**Fully compatible group** Max 03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing
- 

To ensure industry alignment, selecting electrification measures automatically activates the electric equipment replacement measure, as the goal of electrifying E&P facilities is to replace natural gas-powered devices, reducing direct emissions on site

# STEPS FOR SCENARIO DEVELOPMENT

**STEP 2:** evaluate up to **2 measures among the 4 listed in the Partially Exclusive Group**, totaling between 0 and 2 measures

## Mutually exclusive group 1: combustion emissions Max 01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

## Mutually exclusive group 2: flaring emissions Max 01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
  - Routine flaring and/or venting of associated gas limited to 2%

## Mutually exclusive group 3: fugitive emissions Max 01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

## Partially exclusive group: venting emissions Max 02

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

## Fully compatible group Max 03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# STEPS FOR SCENARIO DEVELOPMENT

**STEP 3:** evaluate up to **3 measures from the Fully Compatible Group**. These are selected independently and can be combined, totaling between 0 and 3.

## Mutually exclusive group 1: combustion emissions Max 01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

## Mutually exclusive group 2: flaring emissions Max 01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
- Routine flaring and/or venting of associated gas limited to 2%

## Mutually exclusive group 3: fugitive emissions Max 01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

## Partially exclusive group: venting emissions Max 02

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

## Fully compatible group Max 03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# STEPS FOR SCENARIO DEVELOPMENT

## MAXIMUM MEASURES ALLOWED

Selected measures **08**

### Mutually exclusive group 1: combustion emissions Max 01

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

### Mutually exclusive group 2: flaring emissions Max 01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
  - Routine flaring and/or venting of associated gas limited to 2%

### Mutually exclusive group 3: fugitive emissions Max 01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions Max 02

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group Max 03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# MITIGATION MEASURES IDENTIFIED FOR THE E&P SEGMENT





**develop your mitigation**

EPE's emissions model (2023|v.0)

Effort [ ]Low | [ ]Medium | [ ]High



---

**up to 2 - venting emissions partially exclusive**

- Installation of VRU
- OR**
- Recovery of gas from pigging operations
- Installation of VRU in storage tanks
- OR**
- Flare installation

**up to 1 - flaring emissions**

- Zero routine flaring: reinjection
- Zero routine flaring: local use
- Zero routine flaring: small-scale monetization (GNC)
- Zero routine flaring: small-scale monetization (GNL)
- Zero routine flaring: large-scale monetization
- Routine flaring/venting of associated gas limited to 2%

**Fully compatible - free**

- Replacement of gas-powered pneumatic devices with instrument air systems
- Replacement of gas-powered devices with electric
- Reinjection of CO2 from natural gas processing

**up to 1 - fugitive emissions**

- Direct inspection and maintenance of NGPU, gates, seals...
- LDAR programs

**up to 1 - combustion emissions**

- Replacement of open-cycle gas turbines with combined-cycle turbines
- OR**
- Electrification\*\*
  - All-electric
  - grid
  - decentralized renewable system

**IMPORTANT**

**\*\*ELECTRIFICATION MEASURES ARE ONLY AVAILABLE UNDER THE HIGH-EFFORT OPTION AND MUST BE PAIRED WITH "REPLACEMENT OF GAS-POWERED DEVICES WITH ELECTRIC EQUIPMENT"**

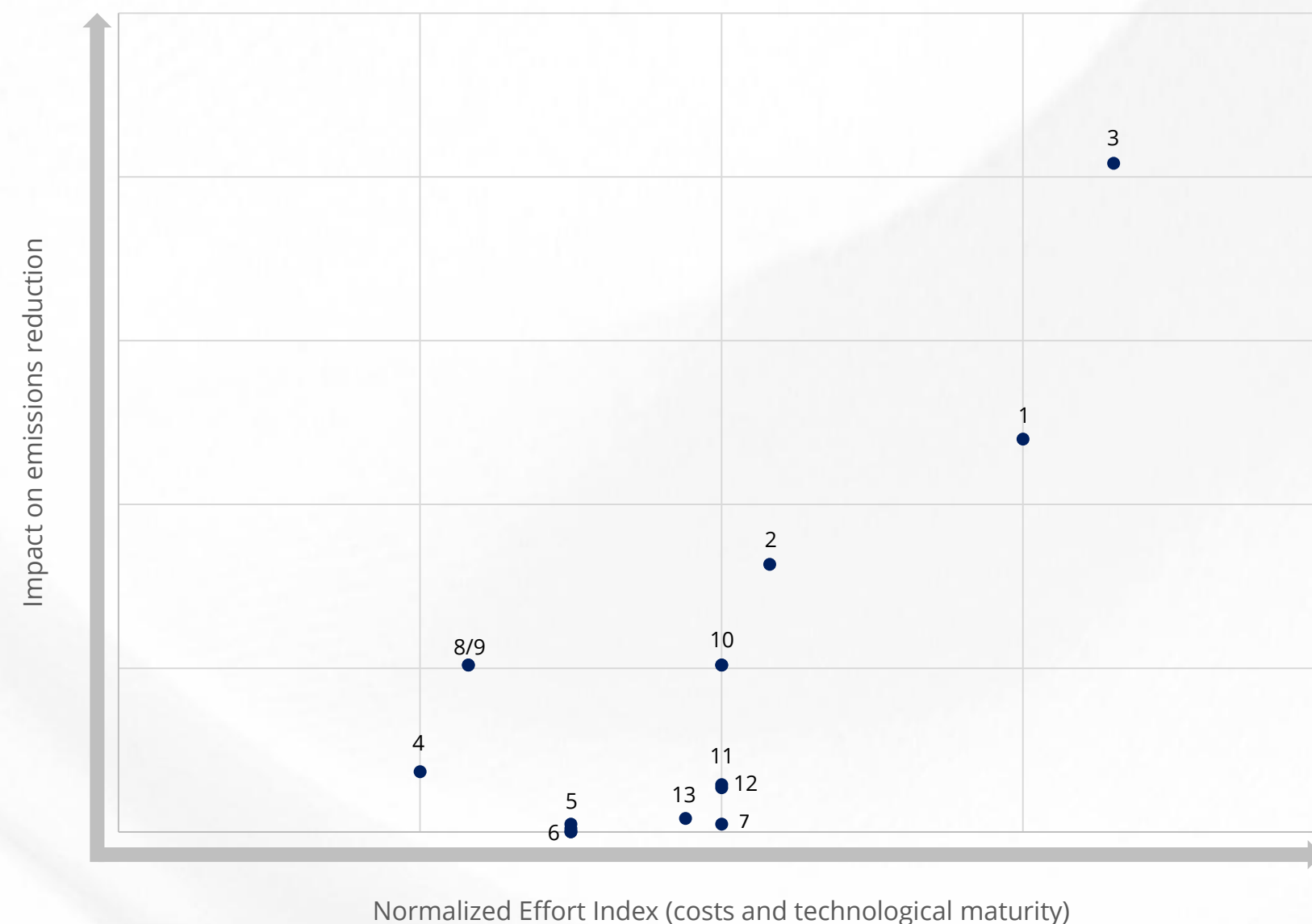


# RESULTS



# 13 MEASURES SELECTED TO BUILD MITIGATION SCENARIOS

1. Replacement of open-cycle gas turbines with combined-cycle turbines
2. Electrification of operations with centralized power generation (all-electric)
3. Electrification of operations with electricity sourced from the grid
4. Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves
5. Replacement of natural gas-powered pneumatic devices with instrument air systems
6. Installation of vapor recovery units
7. Replacement of natural gas-powered devices with electric equipment
8. Elimination of routine flaring through natural gas reinjection
9. Elimination of routine flaring by capturing and utilizing natural gas for productive purposes: local use for electricity generation
10. Elimination of routine flaring by capturing and utilizing natural gas for productive purposes: large-scale monetization
11. Flare installation
12. Reinjection of carbon dioxide from natural gas processing
13. Gas venting management: installation of vapor recovery units in storage tanks



Note: Among the mitigation technologies presented, 13 measures were selected to build emission scenarios. These scenarios aim to assess the reduction potential and the implementation effort required for the combined adoption of selected alternatives, chosen based on their relevance to the Brazilian context, mitigation potential, and/or technical and economic feasibility.

# EMISSION SCENARIO DEVELOPMENT

## MAIN SCENARIO 1

### Mutually exclusive group 1: combustion emissions

Selected measures

00

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

### Mutually exclusive group 2: venting emissions

Max  
01

- Elimination of venting from storage tanks
  - Elimination of venting from process units
  - Local use of gas
  - Small-scale flaring
  - Large-scale flaring
  - Small-scale venting
  - Routine flaring and/or venting of associated gas limited to 2%
- Step 1: no measures selected from Mutually Exclusive Group 1, aiming to focus on lower-effort alternatives**

### Mutually exclusive group 3: fugitive emissions

Max  
01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group

Max  
03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# EMISSION SCENARIO DEVELOPMENT

## MAIN SCENARIO 1

Mutually exclusive group 1: flaring emissions

Replacement of pneumatic tools with electric tools

Electrification of pneumatic tools

Electrification of pneumatic tools

Electrification of pneumatic tools

**Step 2:** the **zero routine flaring** measure with gas reinjection was selected for having the lowest effort among the listed options in Mutually Exclusive Group 2

Selected measures: 00

**Mutually exclusive group 2: flaring emissions**

Elimination of routine flaring through natural gas reinjection

Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:

- local use for electricity generation
- small-scale monetization using compressed natural gas
- large-scale monetization
- small-scale monetization using liquefied natural gas
- Routine flaring and/or venting of associated gas limited to 2%

Selected measures: 01

**Mutually exclusive group 3: fugitive emissions**

Max 01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

**Partially exclusive group: venting emissions**

Installation of vapor recovery units

OR

Recovery of gas from pigging operations

Installation of vapor recovery units in storage tanks

OR

Flare installation

**Fully compatible group**

Max 03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing
-

# EMISSION SCENARIO DEVELOPMENT

## MAIN SCENARIO 1

**Mitigation measure** **Step 3:** the **direct inspection measure** was selected in Group 3 for combining significant mitigation potential with comparatively low implementation effort

- Replacement of natural gas-powered pneumatic devices with electric equipment
- Electrification of operations with electricity sourced from a centralized renewable energy generation system
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

Selected measures

00

### Mutually exclusive group 2: flaring emissions

- Elimination of routine flaring through natural gas reinjection  
Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
  - Routine flaring and/or venting of associated gas limited to 2%

Selected measures

01

### Mutually exclusive group 3: fugitive emissions

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

Selected measures

01

### Partially exclusive group: venting emissions

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing
- 

Max

03

# EMISSION SCENARIO DEVELOPMENT

## MAIN SCENARIO 1

### Mutually exclusive group 1: combustion emissions

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

Selected measures

00

**Step 4:** the **VRU** measure was selected, preventing the selection of other gas or vapor recovery measures



- Elimination of routine flaring and/or natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
  - Routine flaring and/or venting of associated gas limited to 2%

Selected measures

01

### Mutually exclusive group 3: fugitive emissions

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions

Selected measures

01

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group

Max  
03

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- ReInjection of carbon dioxide from natural gas processing

# EMISSION SCENARIO DEVELOPMENT

## MAIN SCENARIO 1

### Mutually exclusive group 1: combustion emissions

Selected measures

00

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

### Mutually exclusive group 2: flaring emissions

Selected measures

01

- Elimination of routine flaring through natural gas reinjection
- Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:

- local use
- small-scale
- large-scale
- small-scale
- Routine

**Step 5:** only the **replacement with pressurized air systems** measure was selected from the Fully Compatible Group, as it presents the lowest relative effort in this group

### Mutually exclusive group 3: fugitive emissions

Selected measures

01

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions

Selected measures

01

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group

Selected measures

01

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# EMISSION SCENARIO DEVELOPMENT

## MAIN SCENARIO 1

Selected measures **04**

### Mutually exclusive group 1: combustion emissions

Selected measures  
**00**

- Replacement of open-cycle gas turbines with combined-cycle turbines
- Electrification of operations with centralized power generation (all-electric)
- Electrification of operations with electricity sourced from the grid
- Electrification of operations with electricity sourced from a decentralized renewable energy generation system

### Mutually exclusive group 2: flaring emissions

Selected measures  
**01**

- Elimination of routine flaring through natural gas reinjection  
Elimination of routine flaring by capturing and utilizing natural gas for productive purposes:
  - local use for electricity generation
  - small-scale monetization using compressed natural gas
  - large-scale monetization
  - small-scale monetization using liquefied natural gas
  - Routine flaring and/or venting of associated gas limited to 2%

### Mutually exclusive group 3: fugitive emissions

Selected measures  
**01**

- Leak detection and repair programs
- Direct inspection and maintenance of gas processing plants, pressurization stations, compressor stations, gates, seals, and valves

### Partially exclusive group: venting emissions

Selected measures  
**01**

- Installation of vapor recovery units
- OR
- Recovery of gas from pigging operations
- Installation of vapor recovery units in storage tanks
- OR
- Flare installation

### Fully compatible group

Selected measures  
**01**

- Replacement of natural gas-powered pneumatic devices with instrument air systems
- Replacement of natural gas-powered devices with electric equipment
- Reinjection of carbon dioxide from natural gas processing

# MAIN SCENARIOS DEVELOPMENT

## Main Scenario 1 (MS 1)



**develop your mitigation**  
EPE's emissions model (2023|v.0)

Scenario  MS 1 |  MS 2 |  MS 3

**up to 2 - venting emissions partially exclusive**

Installation of VRU

**OR**

Recovery of gas from pigging operations

Installation of VRU in storage tanks

**OR**

Flare installation

**up to 1 - flaring emissions**

Zero routine flaring: reinjection

Zero routine flaring: local use

Zero routine flaring: small-scale monetization (GNC)

Zero routine flaring: small-scale monetization (GNL)

Zero routine flaring: large-scale monetization

Routine flaring/venting of associated gas limited to 2%

**Fully compatible - free**

Replacement of gas-powered pneumatic devices with instrument air systems

Replacement of gas-powered devices with electric

Reinjection of CO2 from natural gas processing

**up to 1 - fugitive emissions**

Direct inspection and maintenance of NGPU, gates, seals...

LDAR programs

**up to 1 - combustion emissions**

Replacement of open-cycle gas turbines with combined-cycle turbines

**OR**

Electrification

All-electric

grid

decentralized renewable system



## Main Scenario 2 (MS 2)



**develop your mitigation**  
EPE's emissions model (2023|v.0)

Scenario  MS 1 |  MS 2 |  MS 3

**up to 2 - venting emissions partially exclusive**

Installation of VRU

**OR**

Recovery of gas from pigging operations

Installation of VRU in storage tanks

**OR**

Flare installation

**up to 1 - flaring emissions**

Zero routine flaring: reinjection

Zero routine flaring: local use

Zero routine flaring: small-scale monetization (GNC)

Zero routine flaring: small-scale monetization (GNL)

Zero routine flaring: large-scale monetization

Routine flaring/venting of associated gas limited to 2%

**Fully compatible - free**

Replacement of gas-powered pneumatic devices with instrument air systems

Replacement of gas-powered devices with electric

Reinjection of CO2 from natural gas processing

**up to 1 - fugitive emissions**

Direct inspection and maintenance of NGPU, gates, seals...

LDAR programs

**up to 1 - combustion emissions**

Replacement of open-cycle gas turbines with combined-cycle turbines

**OR**

Electrification

All-electric

grid

decentralized renewable system



## Main Scenario 3 (MS 3)



**develop your mitigation**  
EPE's emissions model (2023|v.0)

Scenario  MS 1 |  MS 2 |  MS 3

**up to 2 - venting emissions partially exclusive**

Installation of VRU

**OR**

Recovery of gas from pigging operations

Installation of VRU in storage tanks

**OR**

Flare installation

**up to 1 - flaring emissions**

Zero routine flaring: reinjection

Zero routine flaring: local use

Zero routine flaring: small-scale monetization (GNC)

Zero routine flaring: small-scale monetization (GNL)

Zero routine flaring: large-scale monetization

Routine flaring/venting of associated gas limited to 2%

**Fully compatible - free**

Replacement of gas-powered pneumatic devices with instrument air systems

Replacement of gas-powered devices with electric

Reinjection of CO2 from natural gas processing

**up to 1 - fugitive emissions**

Direct inspection and maintenance of NGPU, gates, seals...

LDAR programs

**up to 1 - combustion emissions**

Replacement of open-cycle gas turbines with combined-cycle turbines

**OR**

Electrification

All-electric

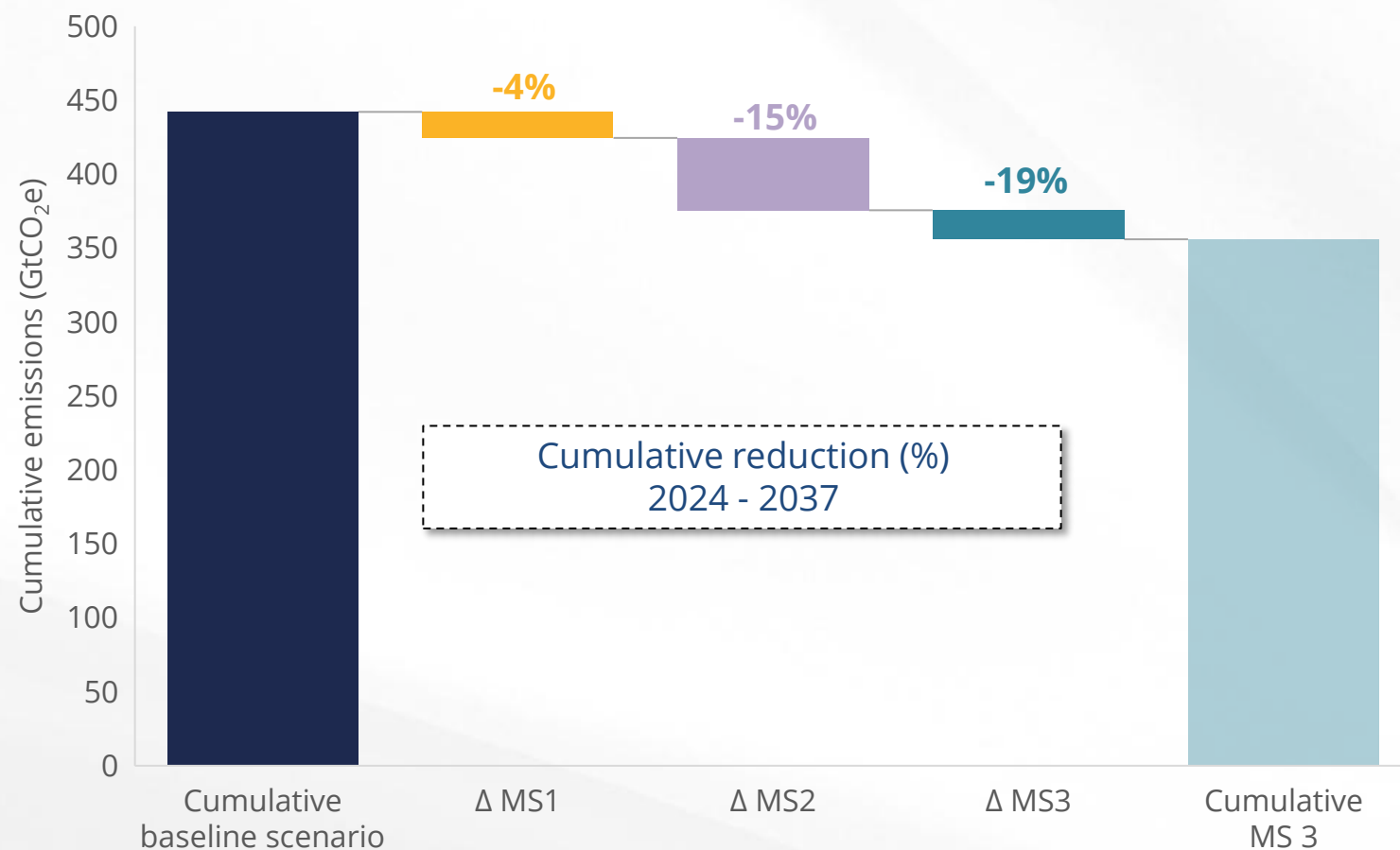
grid

decentralized renewable system



# FINDINGS FROM THE MAIN SCENARIOS

## Reduction between Baseline Scenario and the three Main Scenarios in projected cumulative emissions from 2024 to 2037



## Emissions reduction by scenario

### Main Scenario 3

High-effort measures with significant reduction potential. However, many projects still face technological and/or economic barriers.

### Main Scenario 1

Lower-effort measures with quick benefits. Can be applied to most projects, but reduction potential is limited.

Cumulative reductions by 2037

- 19%

- 15%

- 4%

### Main Scenario 2

Moderate effort measures with considerable impact. Although applied in some brownfield projects, they usually have greater technical and economic viability for new projects.

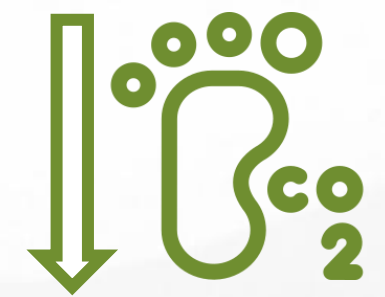
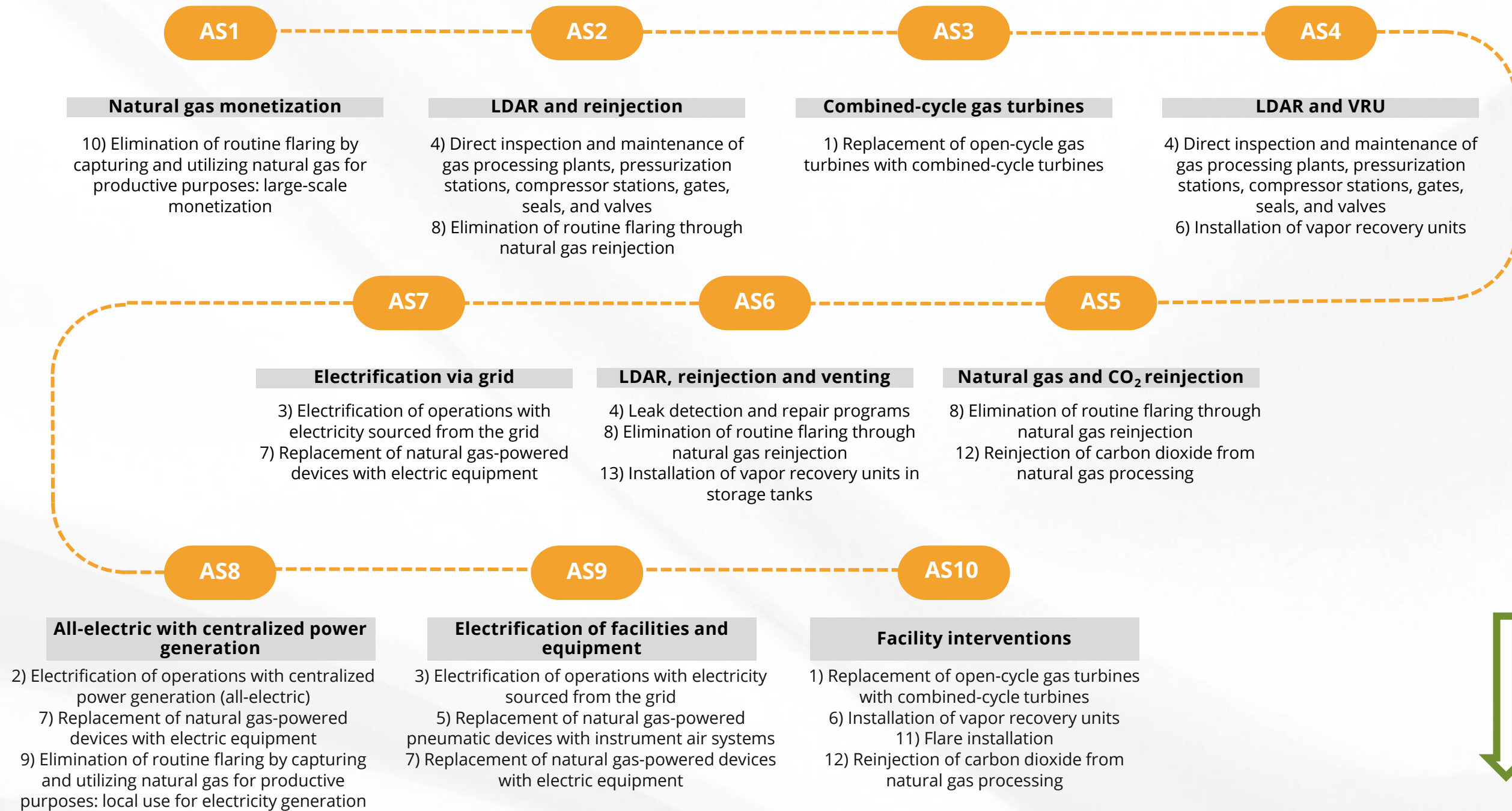
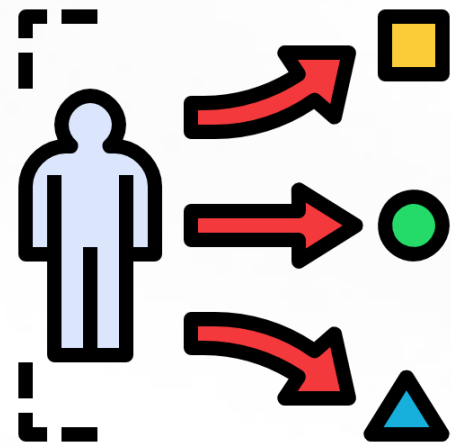
<sup>1</sup> Sistema de Estimativas de Emissões e Remoções de Gases do Efeito Estufa (SEEG), 2023. Emissões brutas de Gases do Efeito Estufa. Available in: [www.plataformaseeg.eco.br](http://www.plataformaseeg.eco.br). Accessed in: 11/04/2024.

<sup>2</sup> EPE, 2022. Plano Decenal de Expansão de Energia (PDE) 2021.

<sup>3</sup> Mboed = Million barrels of oil equivalent per day

<sup>4</sup> ANP, 2025. Anuário estatístico; EPE, 2024. Estudos do Plano Decenal de Expansão de Energia 2034: Previsão da Produção de Petróleo e Gás Natural.

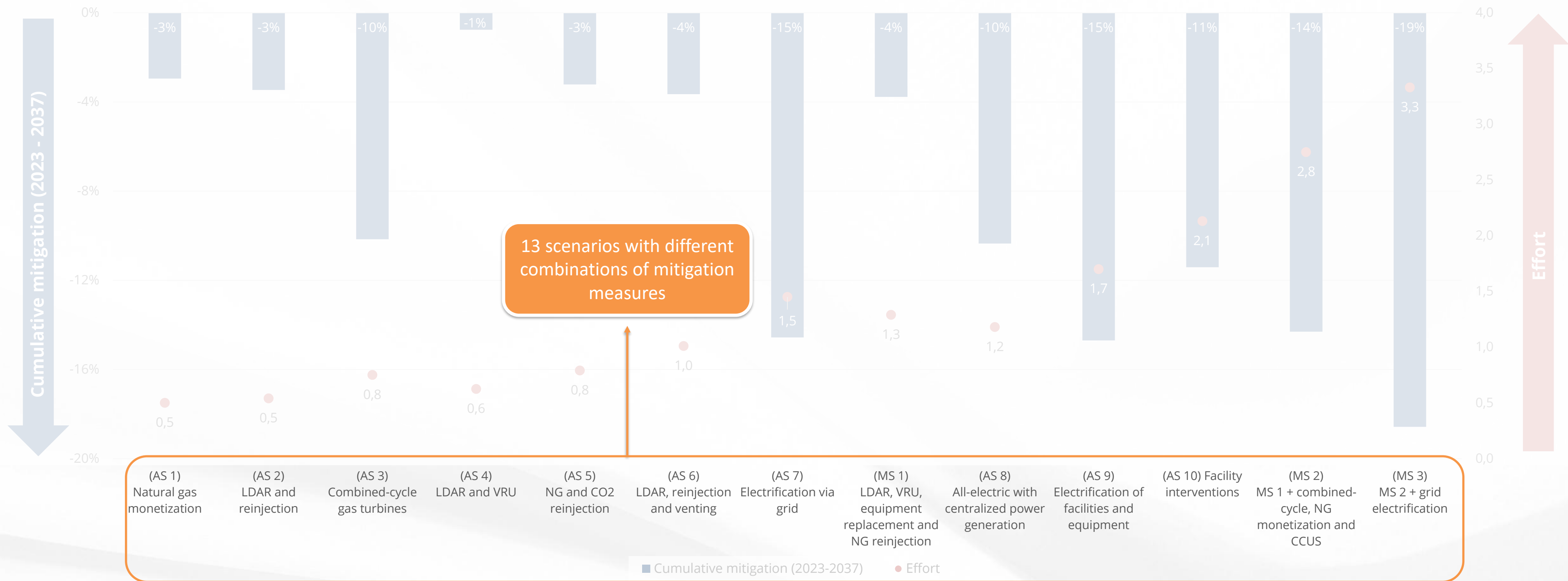
# MITIGATION MEASURES CONSIDERED IN THE ALTERNATIVE SCENARIOS



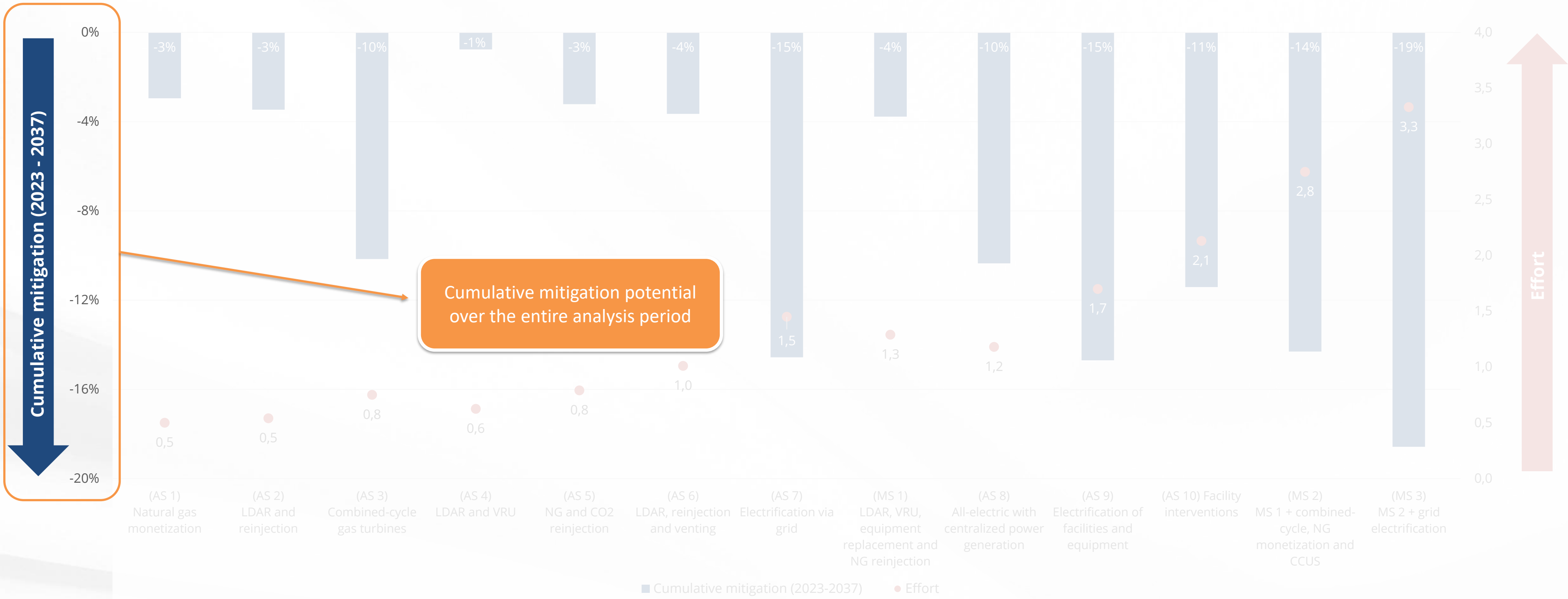
# SCENARIO SENSITIVITY ANALYSIS



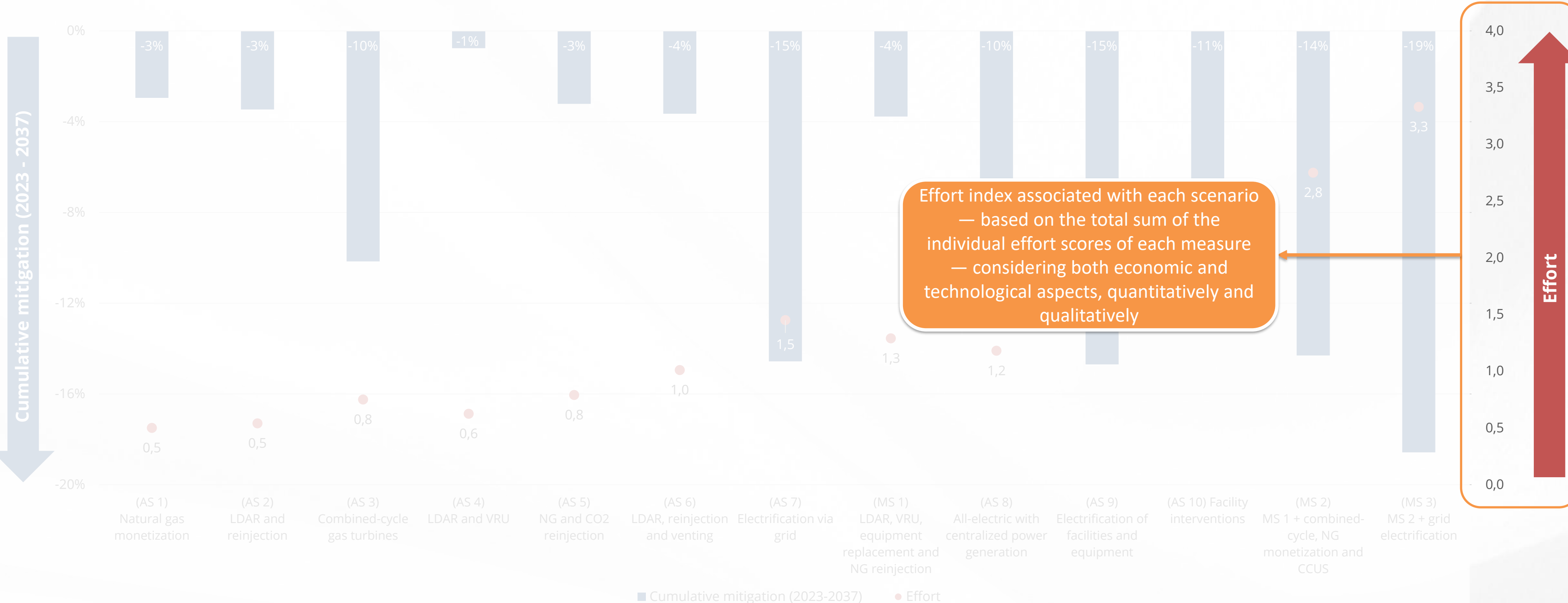
# SCENARIO SENSITIVITY ANALYSIS



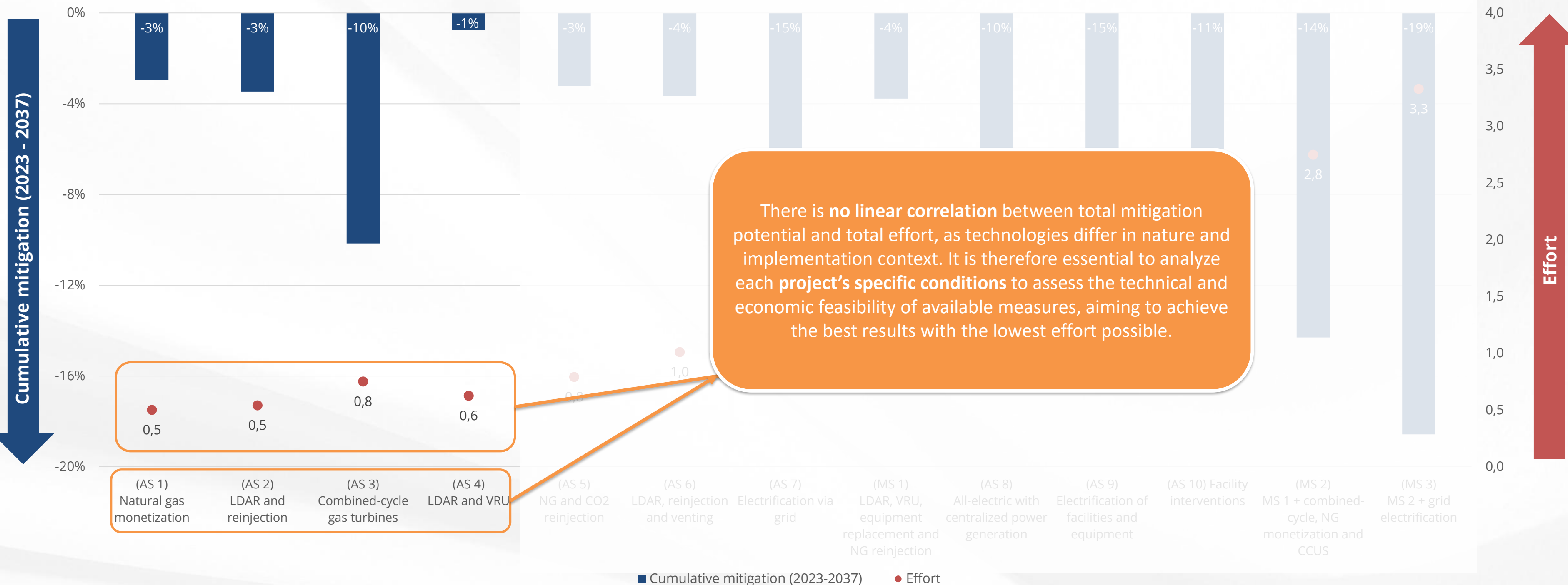
# SCENARIO SENSITIVITY ANALYSIS



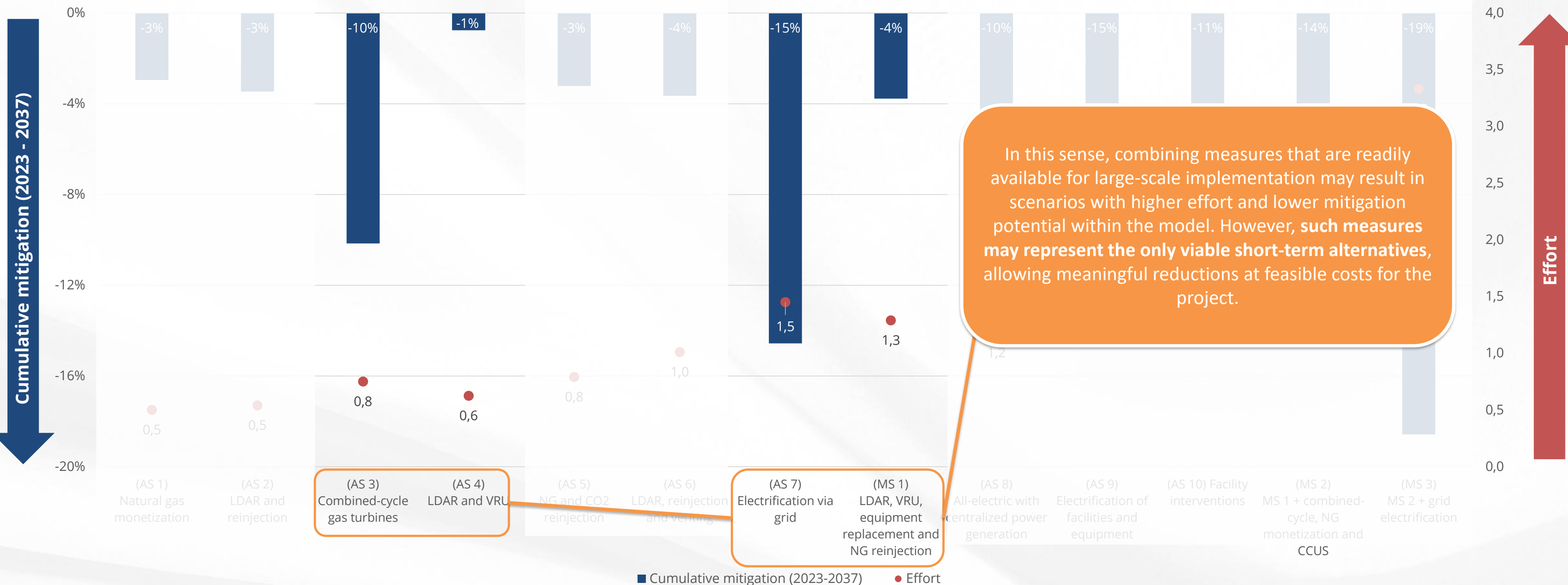
# SCENARIO SENSITIVITY ANALYSIS



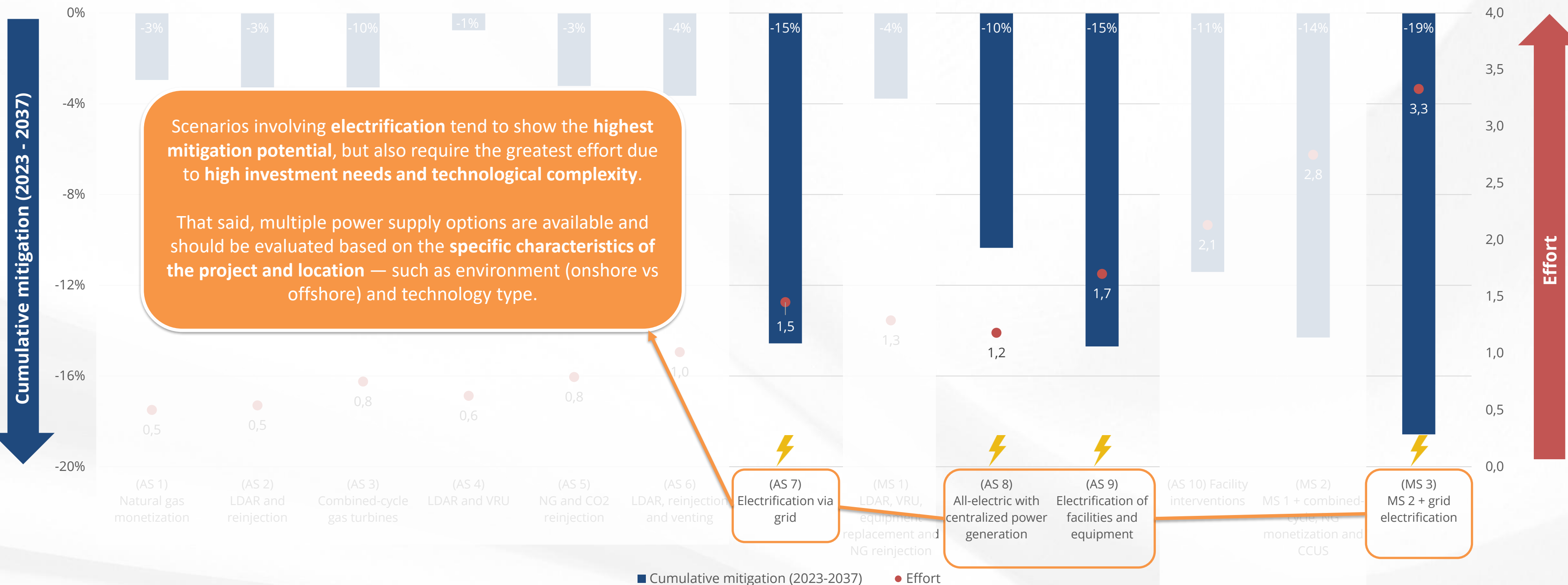
# SCENARIO SENSITIVITY ANALYSIS



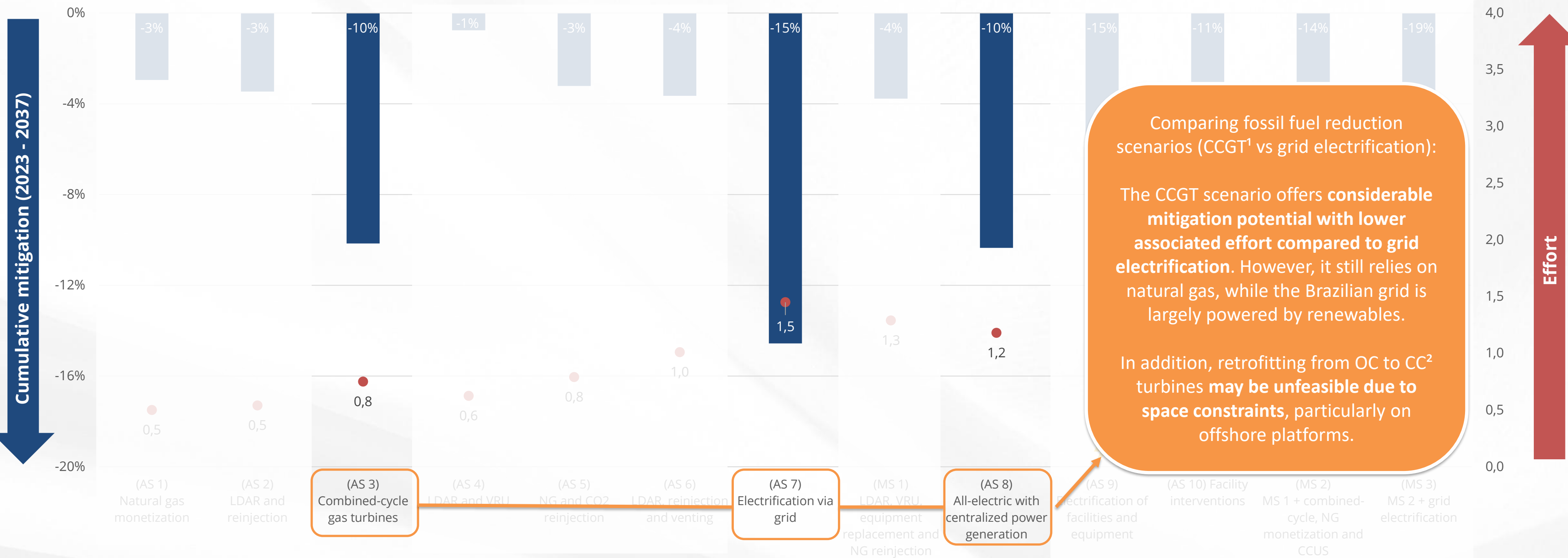
# SCENARIO SENSITIVITY ANALYSIS



# SCENARIO SENSITIVITY ANALYSIS



# SCENARIO SENSITIVITY ANALYSIS



Comparing fossil fuel reduction scenarios (CCGT<sup>1</sup> vs grid electrification):

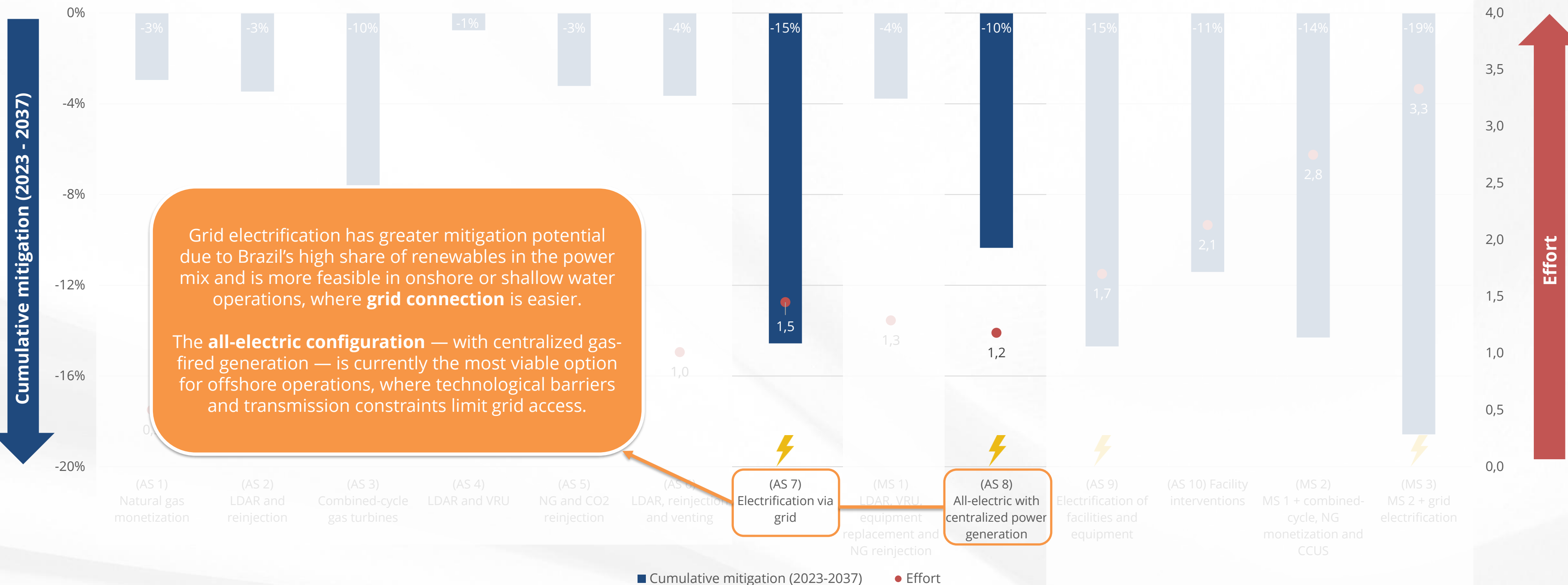
The CCGT scenario offers **considerable mitigation potential with lower associated effort compared to grid electrification**. However, it still relies on natural gas, while the Brazilian grid is largely powered by renewables.

In addition, retrofitting from OC to CC<sup>2</sup> turbines **may be unfeasible due to space constraints**, particularly on offshore platforms.

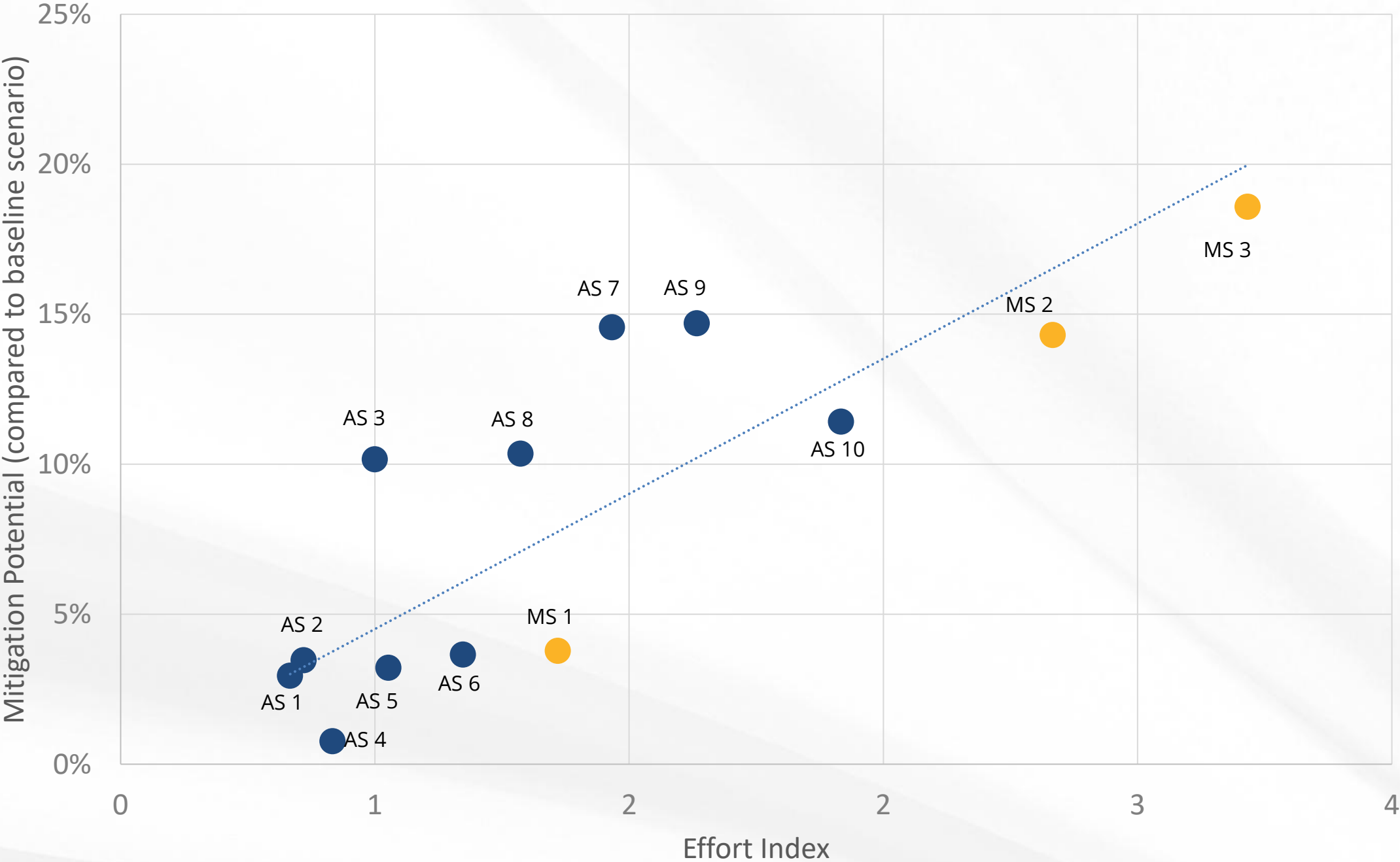
<sup>1</sup> Combined-cycle gas turbines  
<sup>2</sup> Open-cycle to combined-cycle

■ Cumulative mitigation (2023-2037) ● Effort

# SCENARIO SENSITIVITY ANALYSIS



# SCENARIO SENSITIVITY ANALYSIS



In summary, both the main and alternative scenarios highlight the **potential of electrification measures**, which show strong performance in emission reduction but are associated **with higher levels of effort**, due to technological barriers — especially in offshore operations — and higher costs.

Therefore, in addition to the importance of R&D initiatives in this area, it will be necessary to **increase funding to support the deployment of these technologies** and achieve greater emission reduction impact.

On the other end of the spectrum, scenarios involving **zero routine flaring and LDAR** represent comparatively **lower effort** and offer the opportunity for **quick wins** using available and cost-effective technologies.

In this regard, identifying and prioritizing high-emitting equipment, facilities, and activities becomes essential to improve the **efficiency between allocated resources and achieved results**.

# CHALLENGES AND SPECIFICITIES OF THE SCENARIOS

## ASSET DEVELOPMENT STAGE

### Greenfield projects

- More flexibility to adopt advanced technologies
- Challenges include higher investments and have longer financial payback periods

### Brownfield projects

- Allow the use of existing infrastructure
- Lower flexibility and operational shutdowns often required, with high costs — especially offshore

### Onshore

- Higher carbon intensity
- Limited use of associated gas so far
- High potential for generating regional socio-economic benefits

### Offshore

- High production and lower carbon intensity (in the pre-salt reserves, below the global average)
- High operational efficiency
- Leading the way in the adoption of disruptive techniques

## PROJECT ENVIRONMENT



## ELECTRIFICATION

### Opportunities

- Can improve energy efficiency and reduce emissions when supplied by renewable sources
- Greenfield projects offer greater flexibility

### Challenges

- Renewable power generation faces high costs and logistical, regulatory, and environmental barriers - particularly in remote offshore areas

### Current status

- Proven and already applied technology (e.g., EOR in pre-salt areas)
- Legal framework for storage approved in 2024
- Pilot regulatory phase ongoing until full regulation is consolidated

### Future outlook

- Growing interest from industry
- Public policies such as financing mechanisms and carbon pricing will play a crucial role
- Shared infrastructure can reduce implementation costs

## CCUS

# PROPOSALS



## Dissemination of Best Practices and Reduction of Information Asymmetry

- Expand knowledge on data and methodologies for GHG emissions accounting, enhancing the quality of public and sectoral inventories
- Standardize industry knowledge on technical aspects of flaring and venting
- Encourage adherence to public and corporate initiatives for emissions reduction
- Propose actions to minimize the impact of fields, facilities, and activities with higher total emissions and emission intensity



## Encouraging Capacity Building and Innovation

- Strengthen the mechanisms of the R&D Clause, with a focus on decarbonization
- Propose strategies and partnerships for training and capacity building within the supply chain, enhancing human capital qualification
- Structure mentoring and training programs for projects focused on reducing carbon intensity



## Incentives for Enabling Decarbonization Projects

- Facilitate access to international financing for emission reduction projects and expand national credit lines for decarbonization in E&P
- Identify opportunities to maximize low-carbon energy sources in E&P operations, including power supply
- Monitor the integration of sector companies into the carbon market



## Support for Regulatory and Oversight Activities

- Strengthen regulatory and oversight bodies responsible for GHG emissions in E&P
- Support the regulator in structuring LDAR campaigns to identify super-emitters (equipment and assets)
- Establish strategies for monitoring flare efficiency
- Encourage the development of an Emissions Reduction Action Plan by all companies operating in Brazilian E&P.

# FINAL REMARKS



# FINAL REMARKS

The CNPE's recognition of decarbonization aligns Brazil with global best practices, strengthening its position in the energy transition context

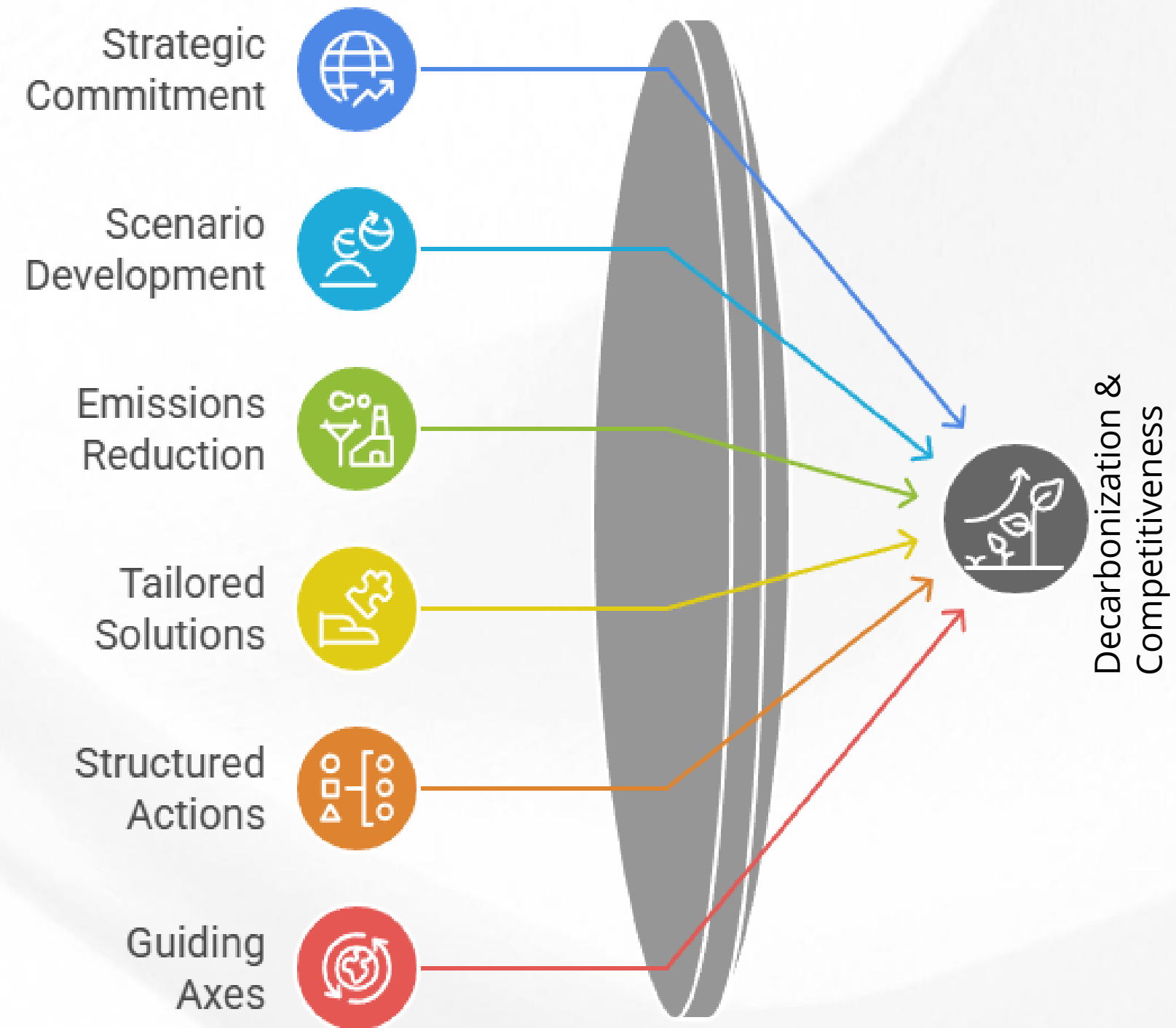
Scenario development supports impact assessment and strategic decision-making, enabling more effective, evidence-based policies

E&P emissions account for 1% of Brazil's total, yet there are clear opportunities to further reduce their intensity

Mitigation strategies must reflect the specific conditions of each operation - such as reservoir type, installation environment, and available infrastructure

Combining short-term actions, feasible with current technologies, and longer-term strategies that require innovation and investment is key. Priorities include identifying high-emitting assets and strengthening regulatory enforcement of best technologies

(I) Best practices & reduction of information asymmetry; (II) capacity building & innovation; (III) support for decarbonization projects; (IV) regulatory & oversight support



Energy Research Office – EPE

Chief Executive Officer

Thiago Guilherme Ferreira Prado

Division of Oil, Gas & Biofuel Studies | Oil & Gas Studies Department

General Coordination

Heloisa Borges Bastos Esteves

Executive Coordination

Marcos Frederico Farias de Souza

Technical Coordination

Regina Freitas Fernandes

Roberta de Albuquerque Cardoso

Technical Team

Bruna Silveira Guimarães

Isis de Oliveira Fernandes

Natália da Veiga Bonavita Teixeira

Nathália Oliveira de Castro

Rafael Freitas Funcia Lemme



The figures and icons used throughout this report were obtained from Canva and the Flaticon.com platform. Special thanks to Geotatah, bsd, and Iconjam.