

## Climate footprint of LNG as a marine fuel: evidence from a high-resolution emission model for Spain

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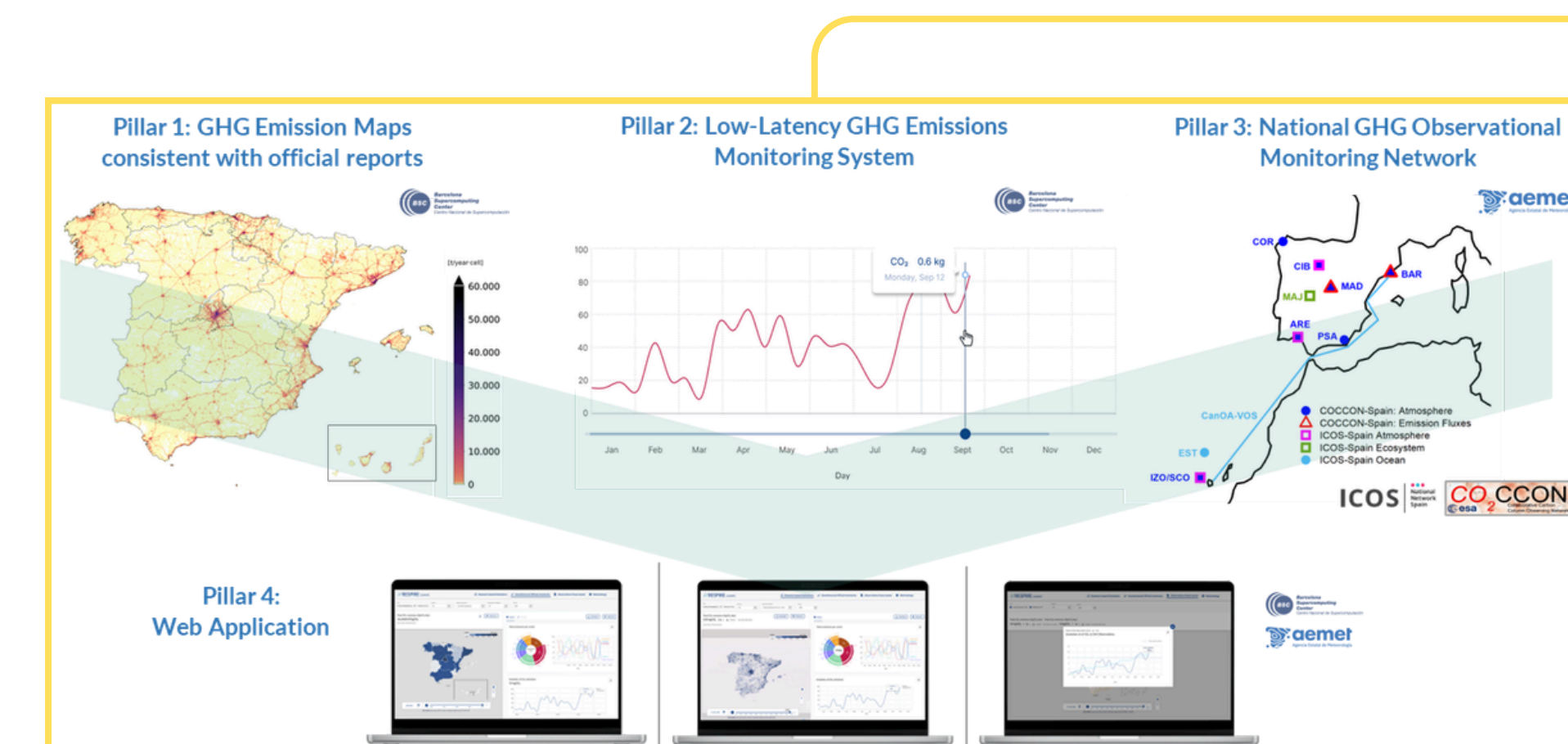
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We present results on shipping CH<sub>4</sub> emissions over Spain derived from a near-real-time, high-resolution Automatic Identification System (AIS)-based emission model developed within the RESPIRE-CLIMATE national project. Using AIS trajectories (2019–present), we quantify CH<sub>4</sub> slip from LNG-fuelled ships using engine-type- and load-dependent emission factors. The system is fully operational and generates daily outputs per ship type on a 1km×1km grid.

### RESPIRE CLIMATE High Resolution Emission System to Support Modelling and Monitoring Efforts in Spain

Four pillars integrating activity-based and observation-based high-resolution CO<sub>2,ff</sub> and CH<sub>4</sub> emissions

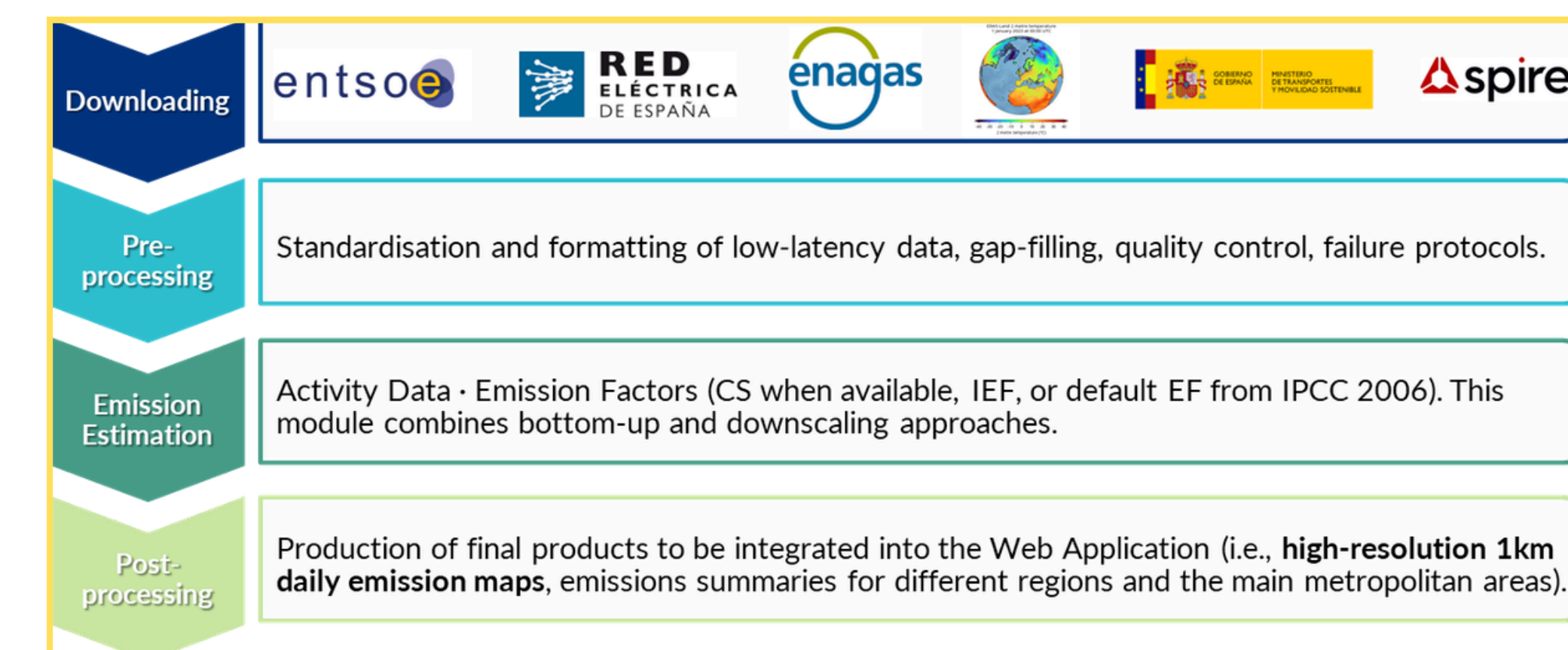
- Meeting diverse needs of policymakers, scientific communities, industries, and the public by providing comprehensive, high-resolution GHG emissions data.
- Facilitating data-driven decisions for emissions reductions across different scales.
- Contributing to identifying co-benefits and trade-offs with air quality.



#### Pillar 2

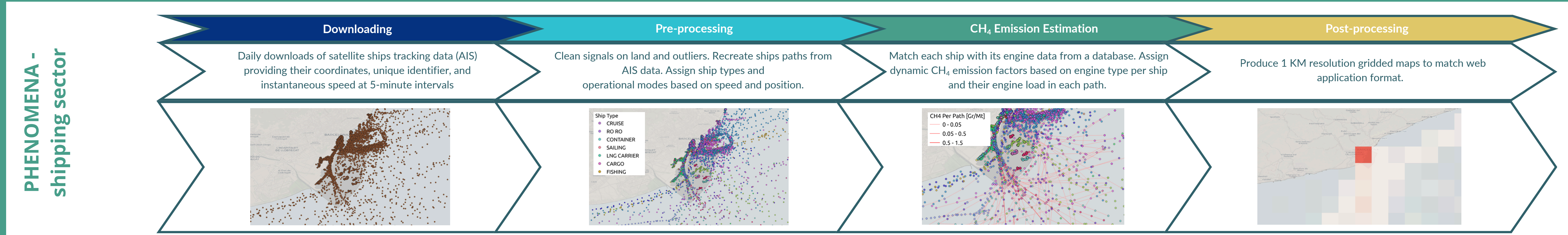
- **Low Latency GHG Emissions Monitoring System** (delay up to 3 months)
- **Species:**
  - CO<sub>2,ff</sub>, CH<sub>4</sub>
- **Sectors:**
  - Electricity Generation, Industrial Processes (Cement, Iron&Steel), Residential and Commercial, Fugitives, Road Transport, Shipping, Aviation.

### PHENOMENA: Spanish Emission Monitoring system for greenhouse gases



- Python-based, open-source system made up of four main modules.
- PHENOMENA delivers daily CO<sub>2</sub> and CH<sub>4</sub> emissions at up to 1km<sup>2</sup> resolution across 6 sectors in Spain.

### MARITIME TRANSPORT CH<sub>4</sub> EMISSION MODELLING



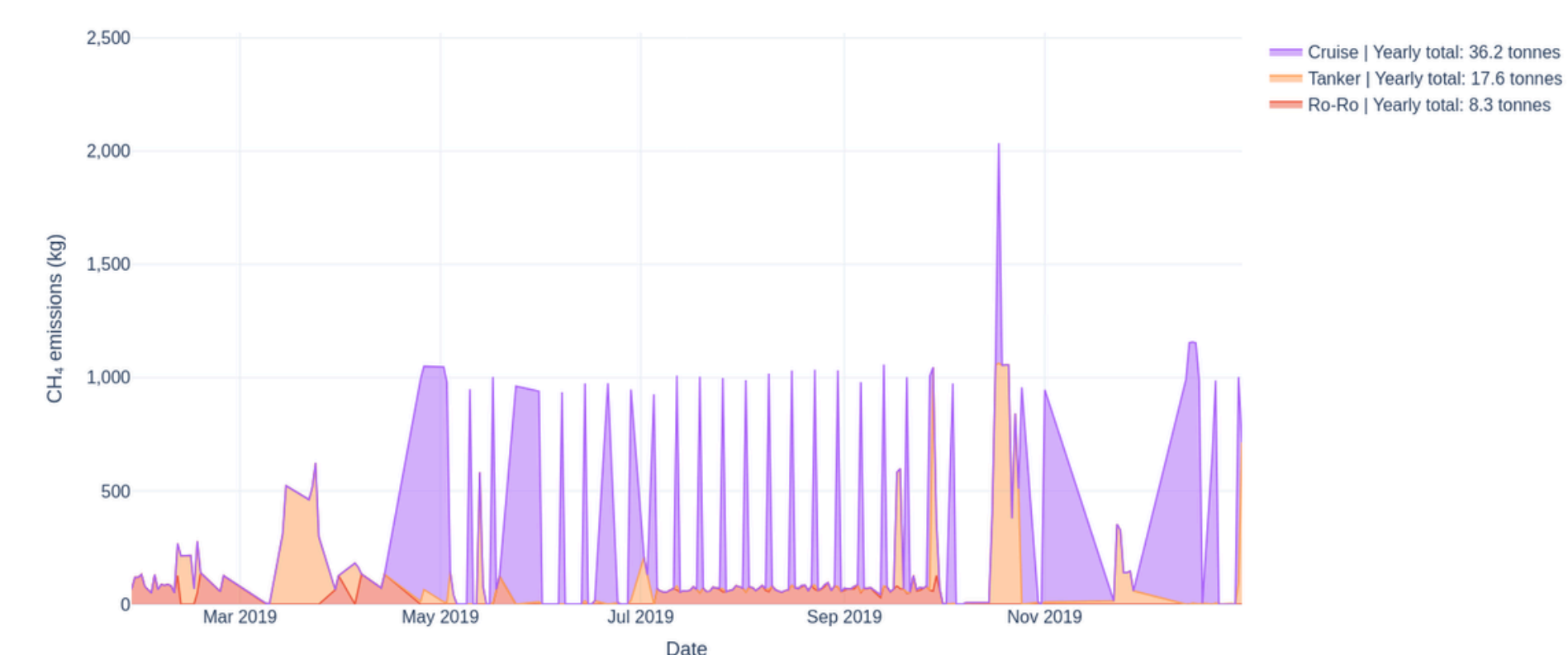
### LNG-FUELLED SHIPS CH<sub>4</sub> EMISSIONS TRENDS IN BARCELONA PORT

#### LNG Transition in Spain's Maritime Sector

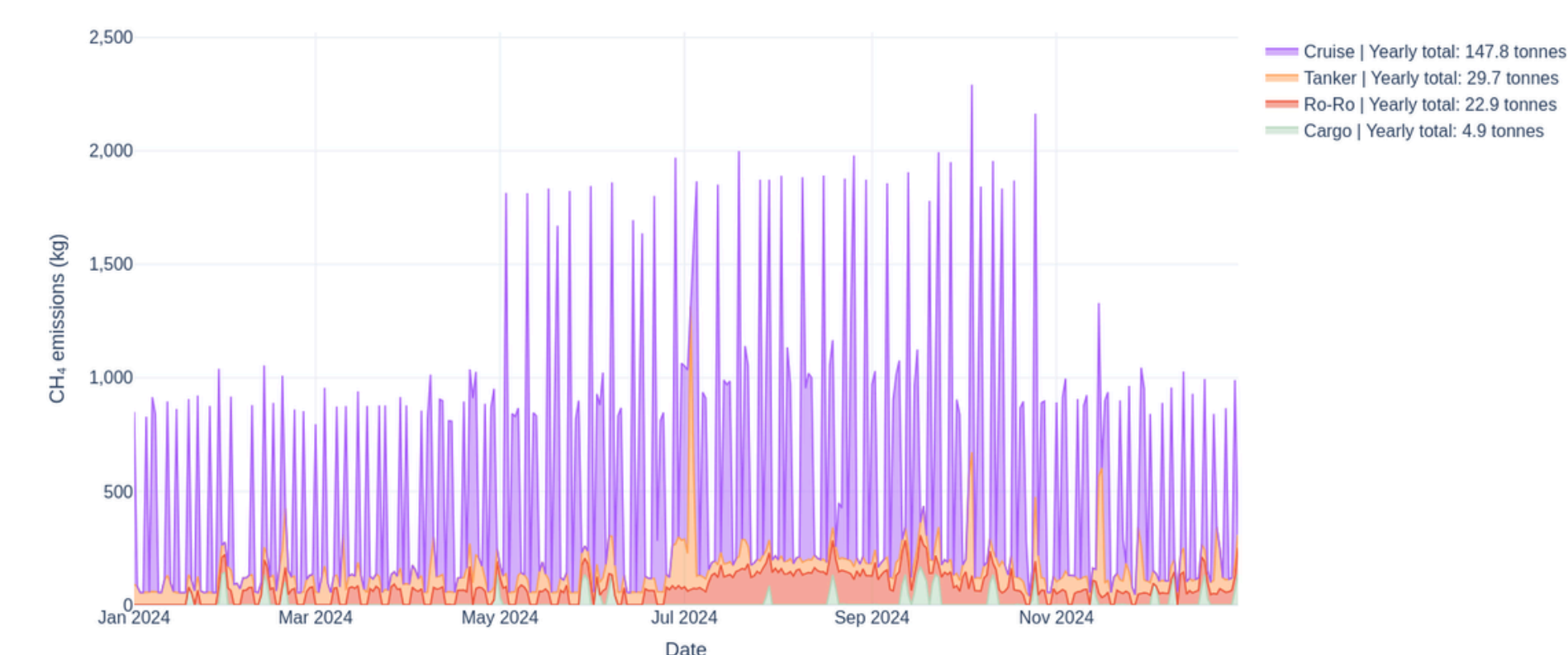
- After 2022, **LNG imports into Spain increased by roughly 20%** compared to 2019 levels, consolidating its role as a key entry point for Europe.
- In **Barcelona**, this shift did not translate into higher LNG import activity, but into an **increase of LNG-fuelled cruise and ferry traffic**. This led to the deployment of dedicated bunkering infrastructure after 2021. Because of this, bunkering, that refers to the refuelling of ships with LNG, increased almost six times, from ~37,500 m<sup>3</sup> in 2019 to ~230,000 m<sup>3</sup> in 2024.
- The trends in Barcelona mirror a **global expansion of LNG-fuelled fleets**, in part due to regulatory pressure to reduce sulphur emissions such as the 2025 IMO Mediterranean Low Emissions Area.

#### Daily annual CH<sub>4</sub> emissions in Barcelona Port (kg/day) by ship type

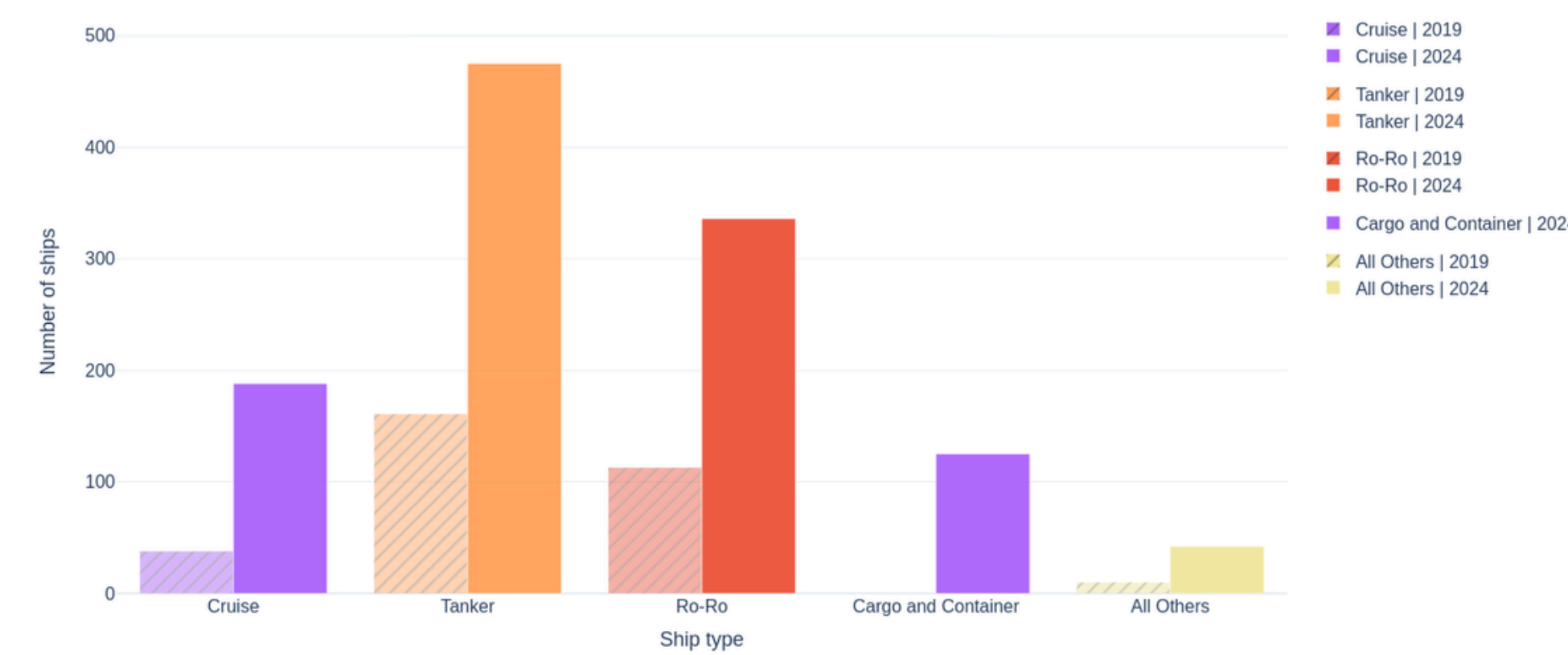
• 2019 - Total CH<sub>4</sub> Emissions 63 Tonnes



• 2024 - Total CH<sub>4</sub> Emissions 206 Tonnes

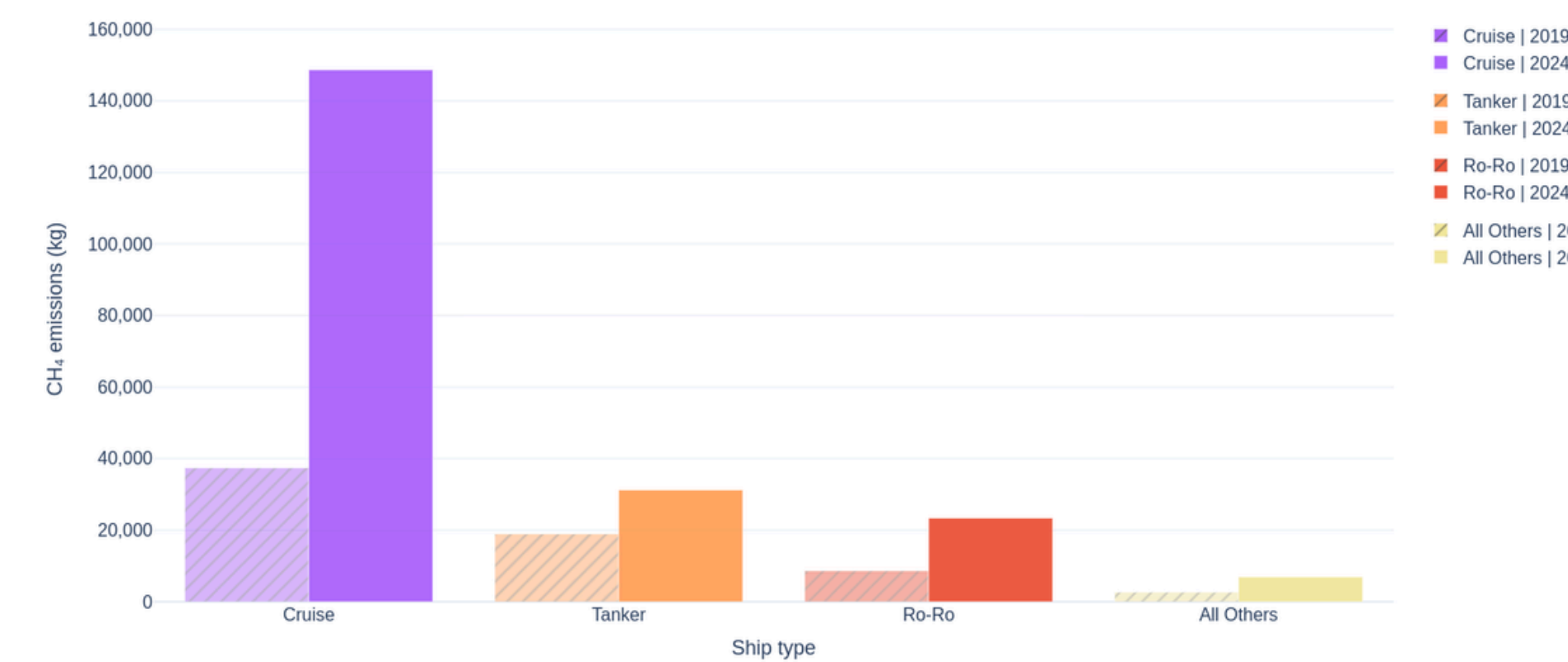


#### LNG-fuelled ships per month Barcelona Port 2019 vs 2024

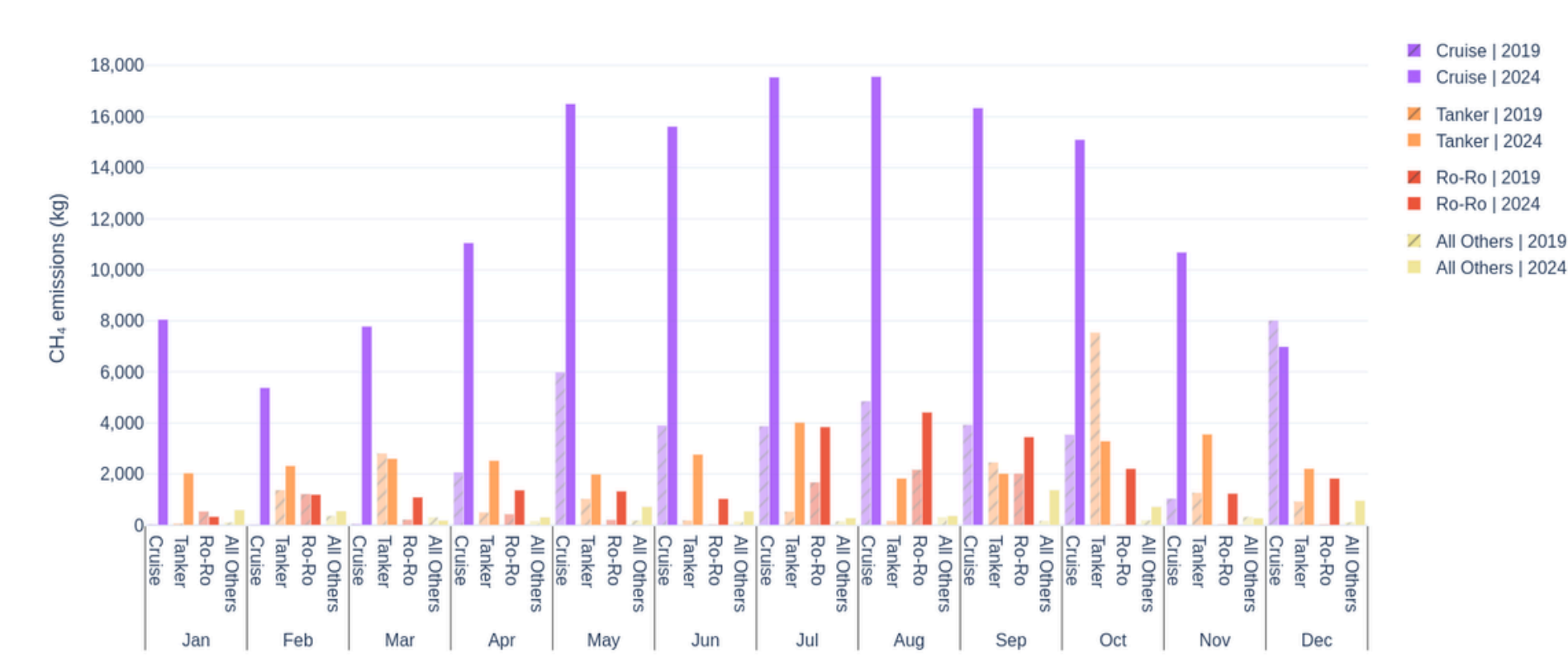


#### Accumulated CH<sub>4</sub> emissions (kg/day) by ship type - 2019 vs 2024

• Annual 2019 vs 2024



• Monthly 2019 vs 2024



- **Cruise ships are the main driver of the increase of CH<sub>4</sub> emissions in Barcelona**, and their activity in the port went from 38 vessels in 2019 to 188 in 2024.
- **Emissions show a strong seasonal pattern** linked to cruise traffic peaks in summer, while LNG tanker ships contribute a stable, year-round baseline of CH<sub>4</sub> emissions due to their relatively constant activity.