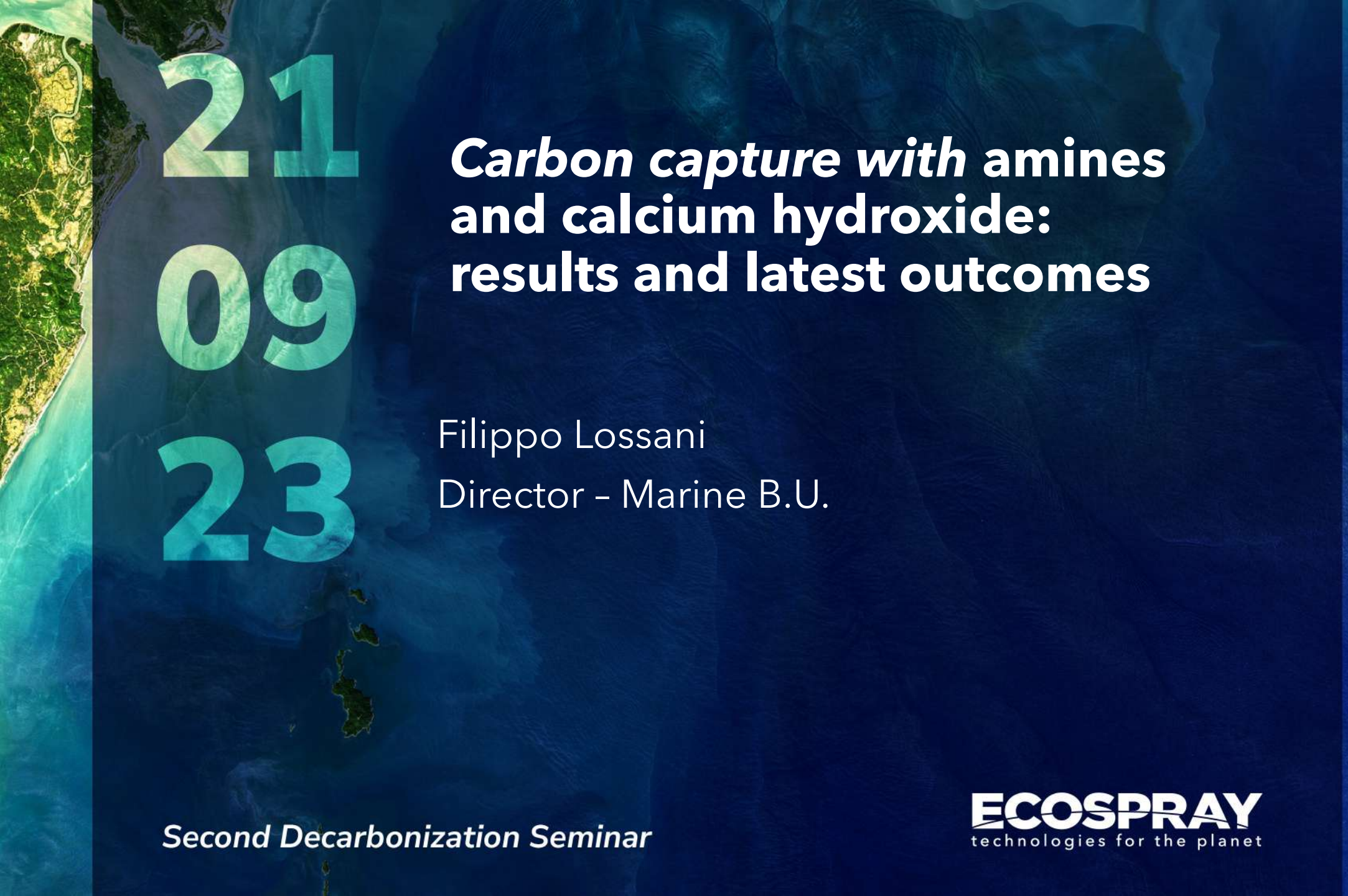

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Carbon capture with amines and calcium hydroxide: results and latest outcomes

Filippo Lossani
Director – Marine B.U.

Second Decarbonization Seminar

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Road to 2050

Amines and Lime milk-based Carbon Capture pilot plant

Assembling & testing

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Road to 2050 stories

Pilot plant target:

- Verify the process and the selected component when operating in real environment
- Deeply understand the reagent behavior: a finer characterization leads to a better system operation, maximizing the efficiency
- Better understanding of the pilot plant CO_2-capturing limits, defining the best operating conditions

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Carbon Capture with **Calcium Hydroxide**

Calcium hydroxide-based technology:

Goals achieved:

- The **applicability** of this technology in the **marine** flue gas treatment **has been proven**.
- CO_2 removal from the gas phase and conversion of the reagent (lime) are related by a **complex physics** that involves **reaction kinetics**, mass transfer and consequently process parameters. It is **now** more evident how the chemistry of the hydroxide-carbonate system influences the performance of the system and how it can be **controlled**.

$$CO_{2(gas)} + H_2O \leftrightarrow H_2CO_3 \leftrightarrow 2H^+ + CO_3^{=}$$

$$Ca(OH)_{2(Solid)} + H_2O \leftrightarrow Ca^{++} + 2OH^-$$

$$CO_3^{=} + Ca^{++} \rightarrow CaCO_{3(ppt)}$$

$$CaCO_{3(ppt)} + CO_3^{=} + 2H^+ \rightarrow Ca(HCO_3)_2$$

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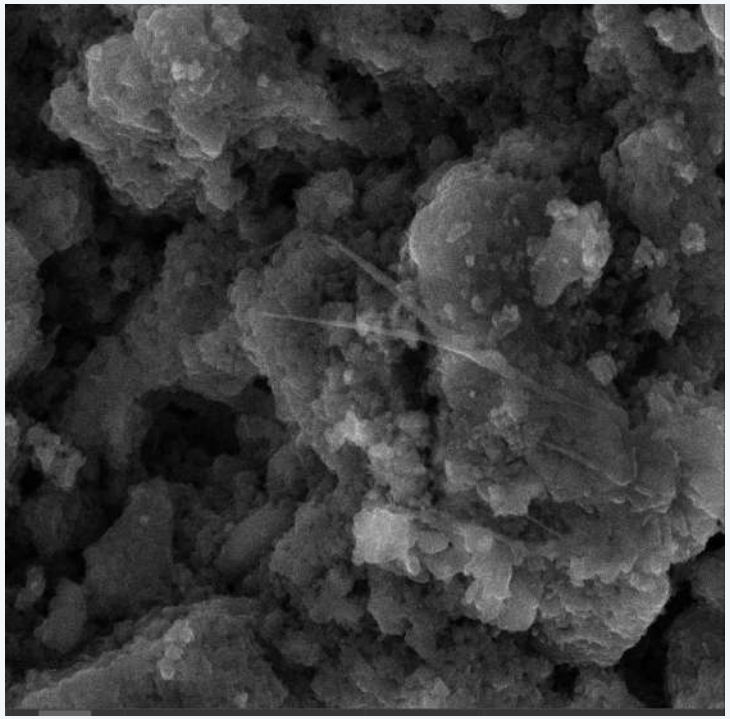
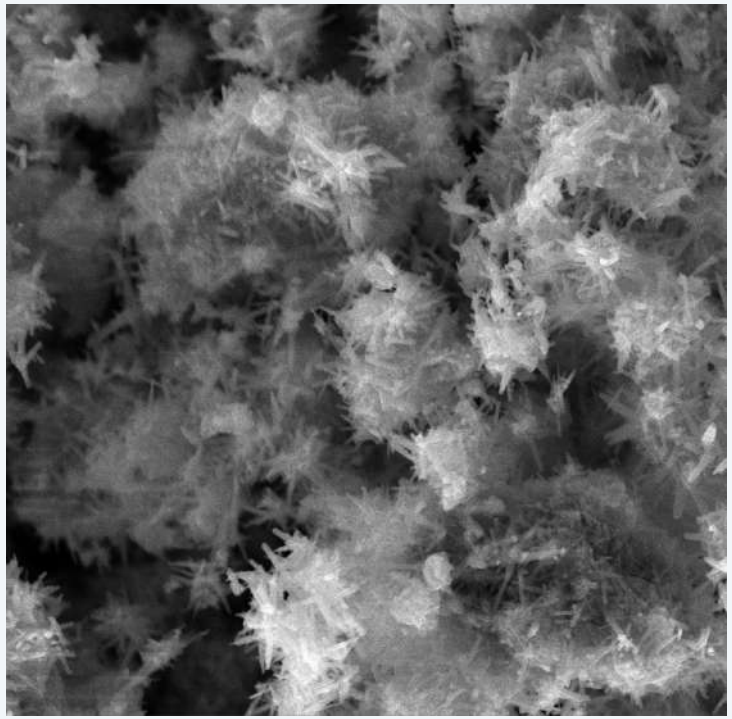
Carbon Capture with **Calcium Hydroxide**

Long-duration tests conducted onboard allowed us to observe the process until the **lime** is almost **completely converted** to limestone (90-95% conversion rate).

Scanning Electron Microscopy:



Agglomerates of **portlandite** – lime milk **before** the reaction with carbonates



Acicular crystal of **aragonite**, a crystalline form of calcium carbonate

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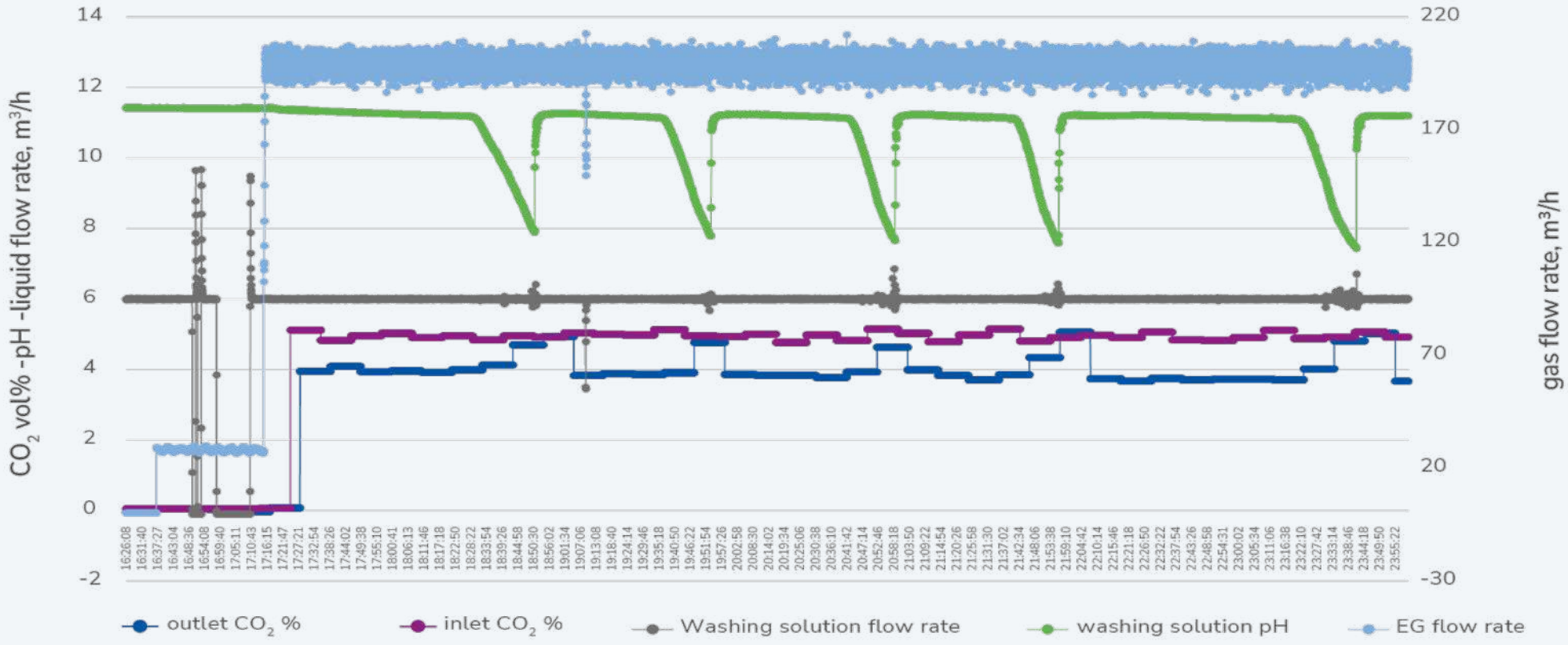
Carbon Capture with **Calcium Hydroxide**

pH control is **not reactive** enough to avoid a performance decline during the blow-down and make-up of the washing solution.



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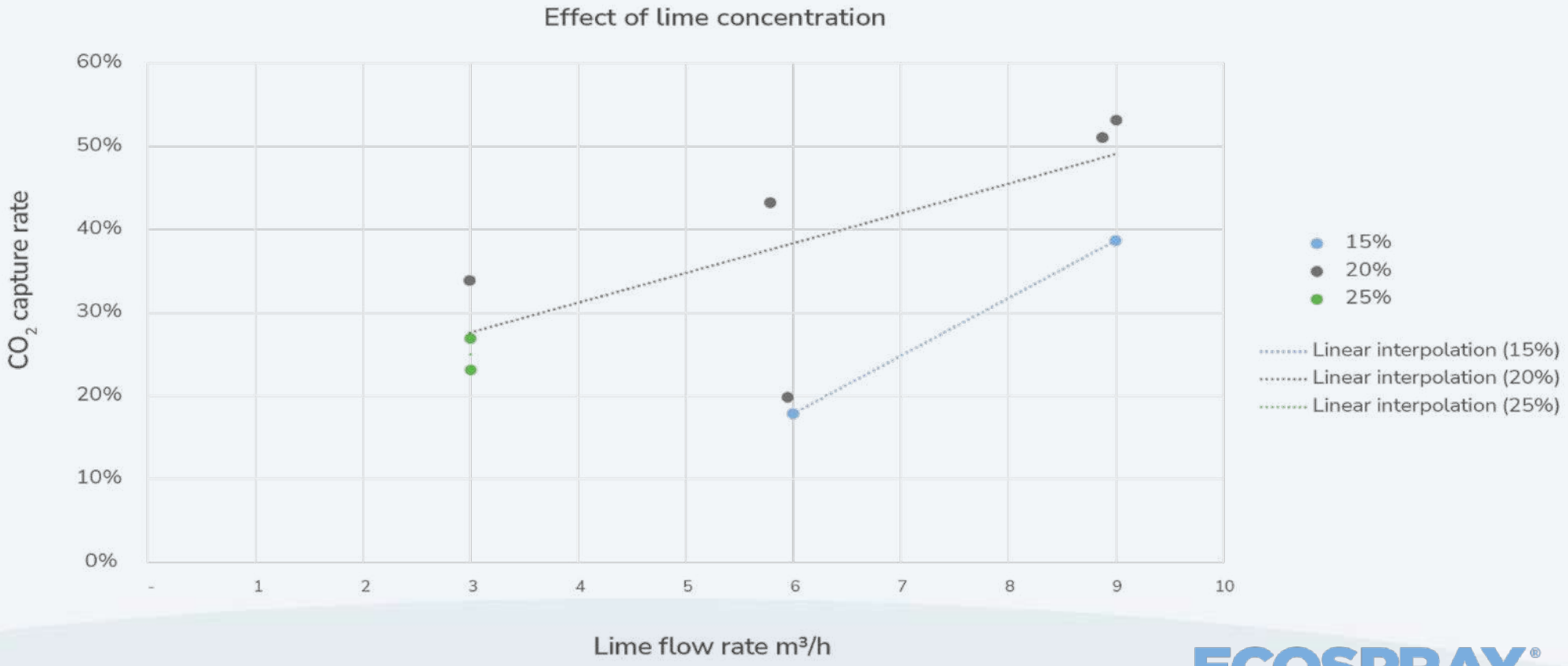
Carbon Capture with **Calcium Hydroxide**

CO_2 absorption: no advantage in using high-concentrated lime milk.

- Better results working with **15%-25**% concentration
- Clogging more likely



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Carbon Capture with **Calcium Hydroxide**

An **agitator** inside the scrubber tank would be more effective than the sparger to avoid sedimentation

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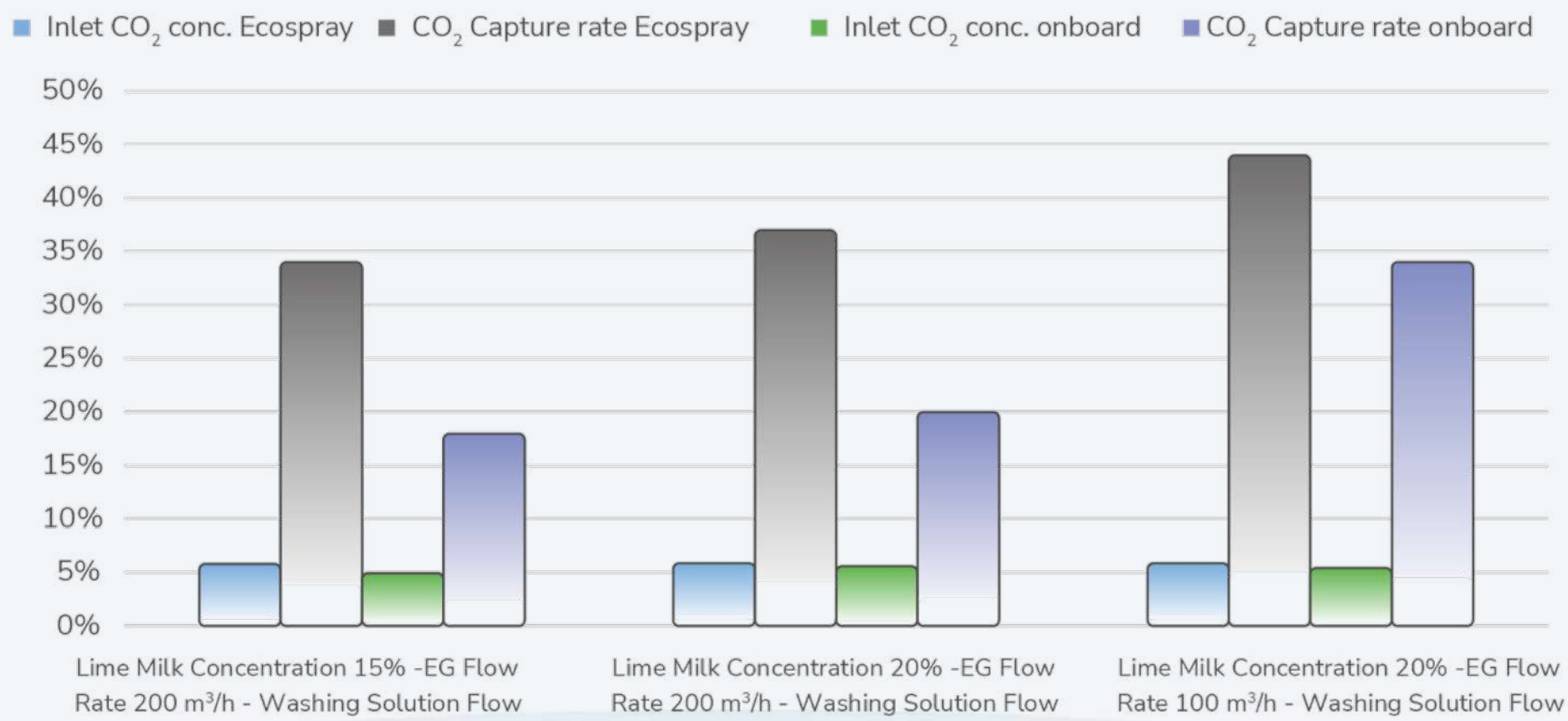
The **capture rate** onboard is always lower than at Ecospray. The difference could be related to the different solvent (i.e., **seawater** instead of tap water).

Carbon Capture with **Calcium Hydroxide**



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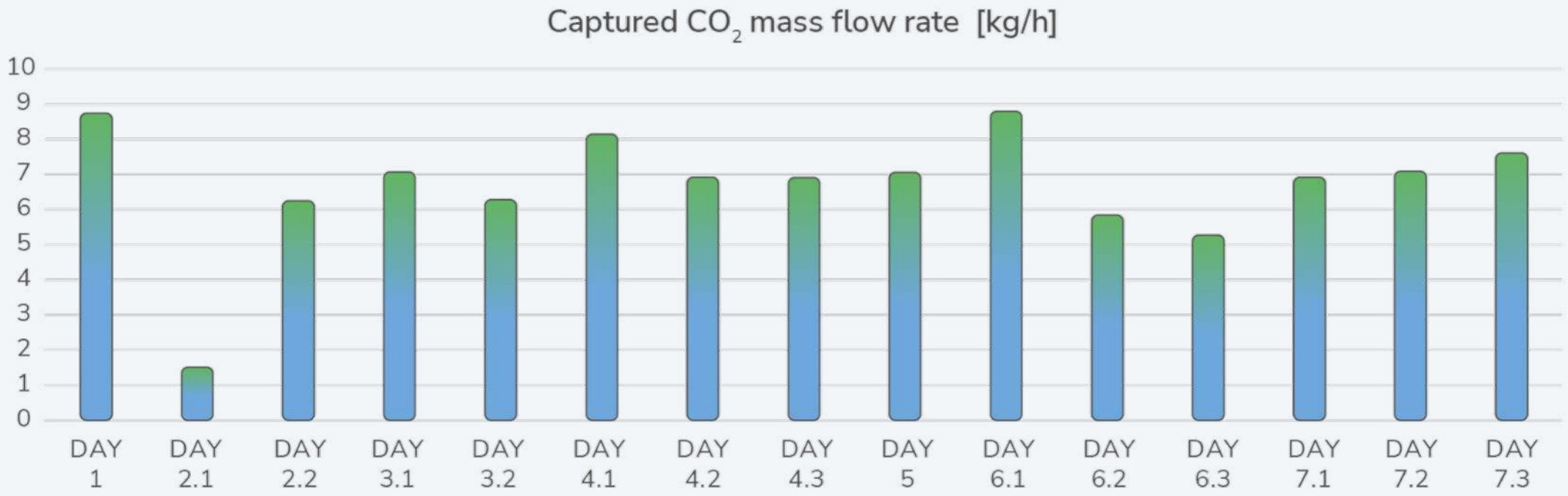
Carbon Capture with **Amines**

Amine- based technology:

In all onboard tested conditions, the pilot plant is able to absorb from 5 kg/h (on 9.9 kg/h CO_2 in exhaust gas from engine) to 8.7 kg/h (on 19.5 kg/h CO_2 in exhaust gas from engine) of **carbon dioxide**. Avg. **48% capturing rate**.



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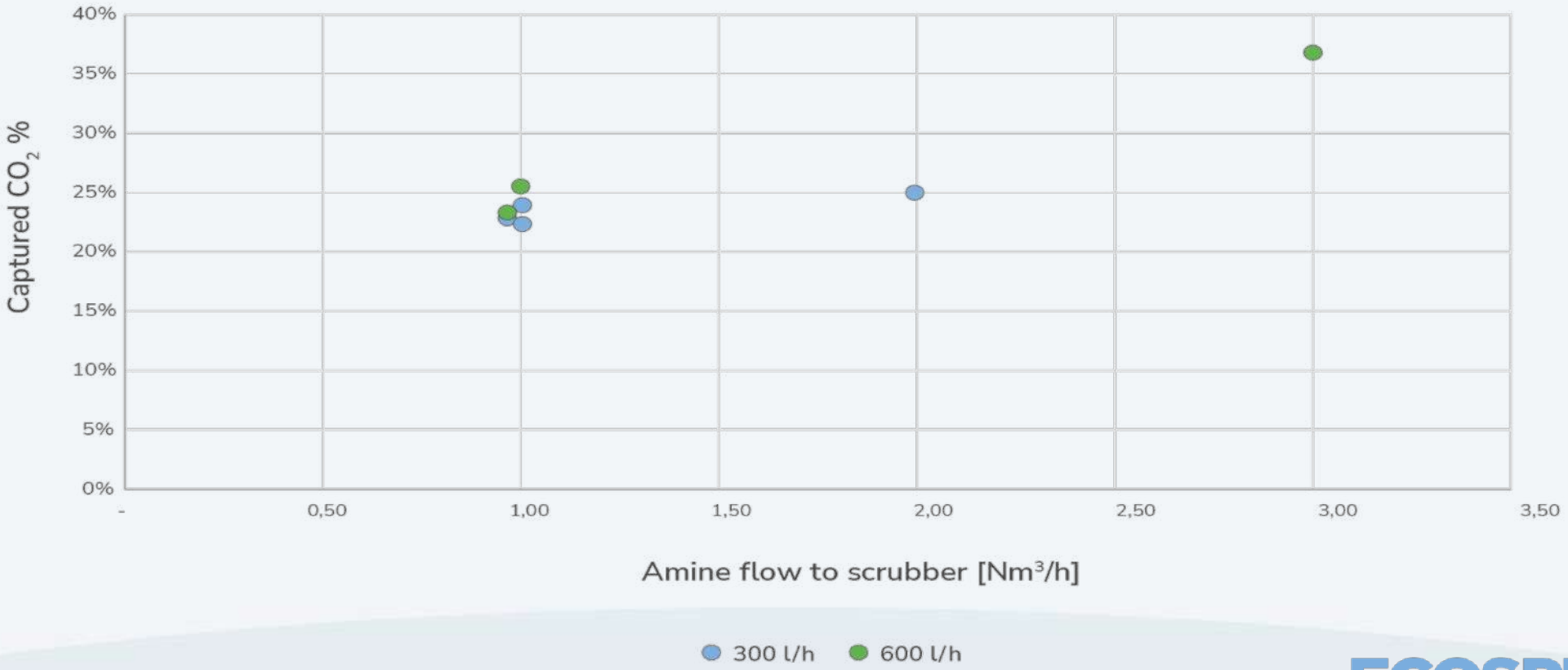
Carbon Capture with **Amines**

- **Increasing the flow rate** of amine recirculating on the absorber does not seem to improve significantly the carbon capture performance.
- Optimizations have been identified. e.g.: **improve the contact time** between the exhaust gas and amines by specific tower internals



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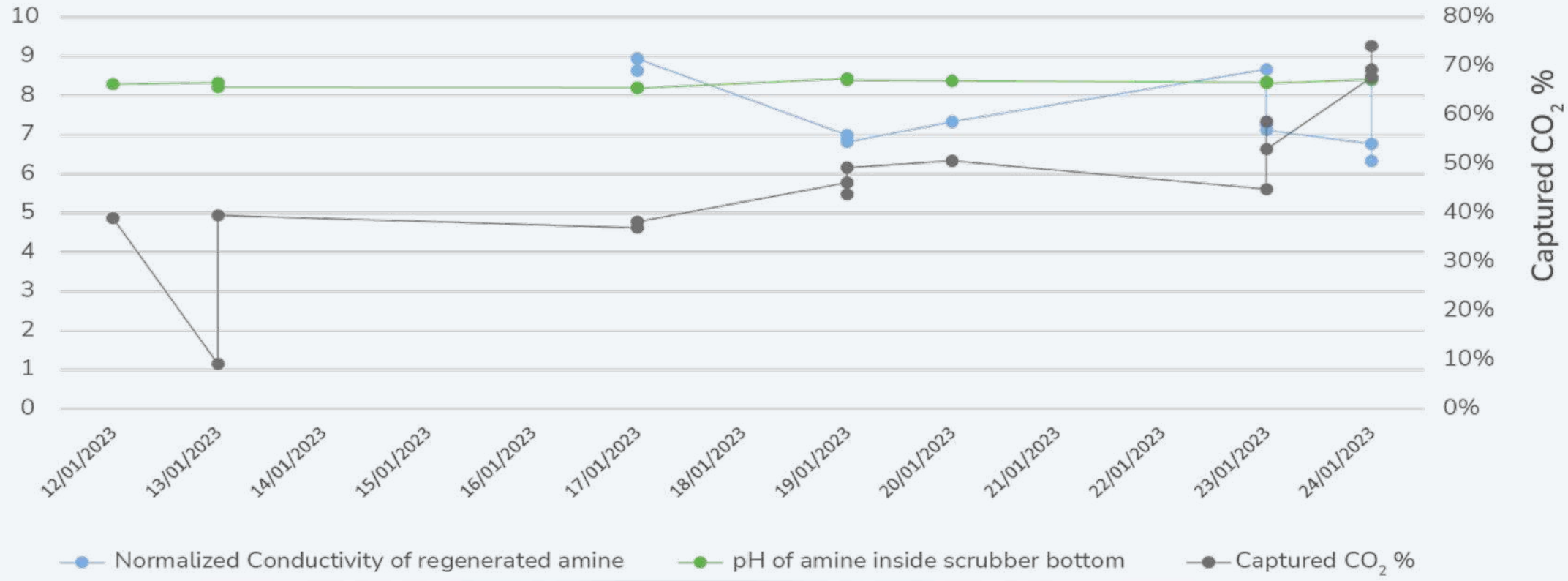
Carbon Capture with **Amines**

- **pH** cannot be considered a reliable parameter of correct system operation.
- **Conductivity**, even if influenced by temperature, could be a better indicator of regeneration performance



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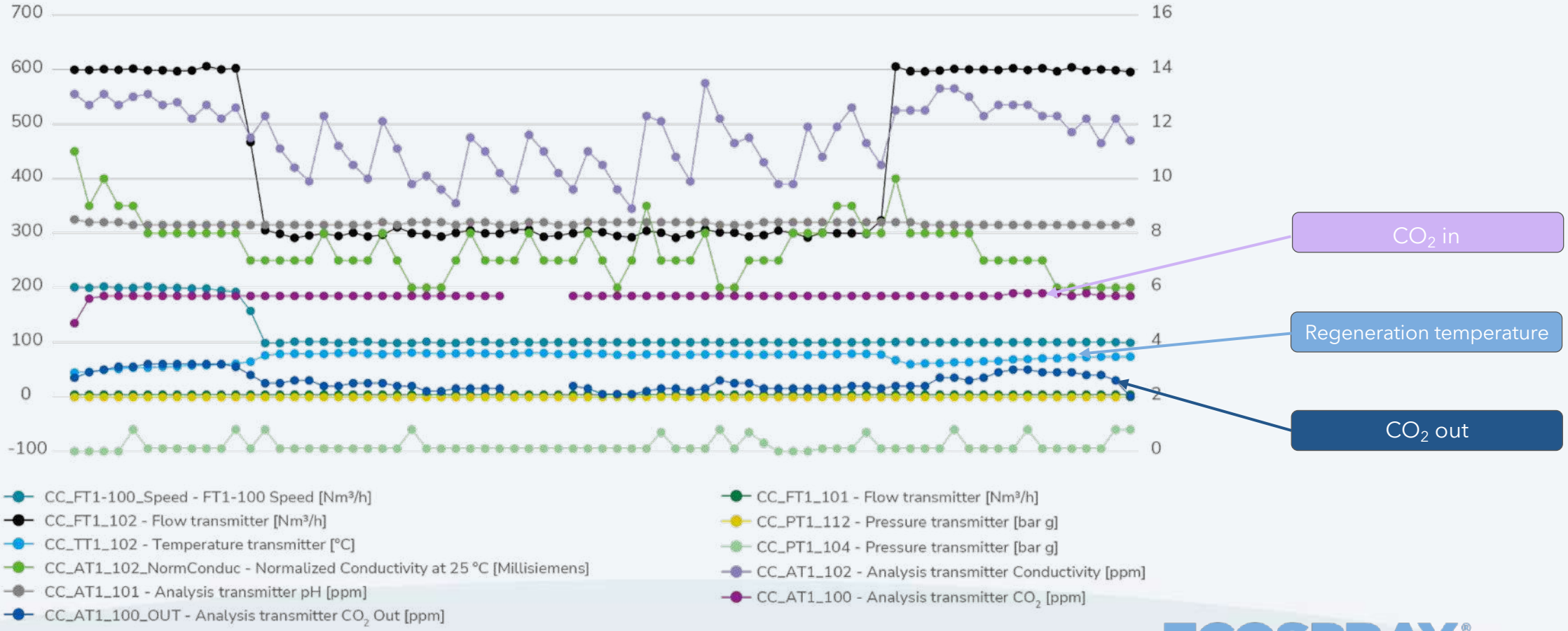
Carbon Capture with **Amines**

The pilot plant demonstrated the feasibility of **low temperature/low pressure regeneration** of the selected amine mixture. In the graph, capturing rate from 45% to 59% and regeneration temperature from 65 ° to 80 °C



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Energy efficiency

63,5K DWT Bulk Carrier – Gross 25% CCS		
Description	**Standard Amine capture process**	**Ecospray**
Effective Power [MW]	6,81	
Tot. exhaust gas flow [kg/h]	51518	
CO_2 Total capture rate [%]	25%	
CO_2 Captured [kg/h]	895	
Steam demand [kg/h]	1200	600
Amine regeneration heat demand [kWt]	/	1600
Electrical consumption [kW]	254	431
Additional CO_2 emission for steam generation [kg/h]	144,0	0 - (available steam capacity)
Additional CO_2 emission for heat generation [kg/h]	0	0 – (heat recovery from cooling system)
Additional CO_2 emission for Electrical Power [kg/h]	158,2	268,4
Fuel used for 1 Ton of captured CO_2 [kg]	**174,3**	**152,9**
Ratio Fuel used / Captured CO_2	**0,1743**	**0,1529**

Ecospray process is **10%-15% more energy-efficient** compared to conventional amine process.

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Thank you

Ecospray Technologies S.r.l.

Via Circonvallazione, 14/14A

15050 Alzano Scrivia (AL) Italy

Tel +39 0131 854611 - Fax +39 0131 854617

info@ecospray.eu

ecospray.eu

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