Power-to-X Colombia 2.0

ANDI-Naturgas Hydrogen and Renewable Gases Forum

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PtX Colombia 2.0 results

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Power-to-X Colombia 2.0

Project at a Glance

PtX Colombia 2.0 builds on the first project by moving from a nationwide screening to **concrete, techno-economically grounded first-mover concepts**. Phase 1 mapped the **Colombian H_2 landscape, resource base and EU/Colombian regulation**. Phase 2 translated these findings into structured concept ideas for three priority regions, focusing on **business models, cost levers, technical feasibility and regulatory readiness** to enable early PtX/BtX market entry.

Project goals

1. **Colombian H_2-project landscape**
2. **PtX/BtX-regulatory framework** in the EU and Colombia
3. **Resource, infrastructure and offtake potentials** (GIS-based)
4. **Methodology for H_2-project evaluation**
5. **≥ 3 first-mover project concepts** with a focus on business models, cost levers and technical feasibility

Project partners

- Fraunhofer ISE
- Federation of German Industries (BDI)
- CatalHyst
- ANDI-Naturgas Chamber of Hydrogen and Renewable Gases

Project timeline

- 10/25 – Kick-off
- 12/25 – Phase 1 - Webinar
- Phase 1 - End
- 02/26 – Phase 2 - Start
- 04/26 – Phase 2 – Industry interviews
- 06/26
- Phase 2 – Webinar

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Project Results – Phase 1

Phase 1 - Recap

Mapping and analysis of H_2-projects in Colombia

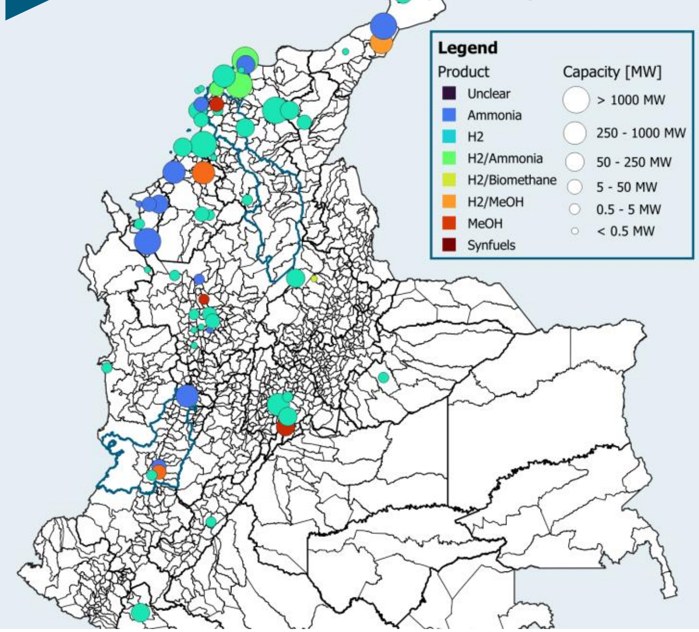
1 **The probability of projects becoming operational varies** due to current development stage, as well as further financial, technical, and regulatory challenges. This will lead to a **reduction and delay of the hydrogen ramp-up**.

2 **The Colombian National Hydrogen Roadmap** aims at an installed **electrolysis capacity of 1 – 3 GW by 2030**. Current projections exceed the target significantly but achieving it will be very challenging.

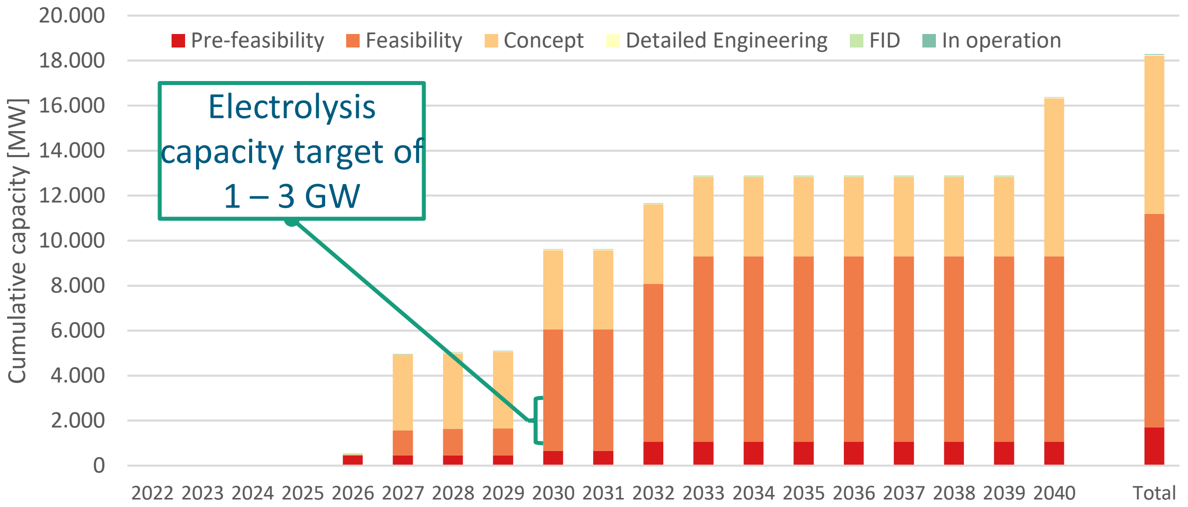
3 **Hydrogen projects are concentrated in northern Colombia,** including hybrid H_2/NH_3 projects. **Ammonia projects are mainly in the northeast,** while carbon-containing product projects are distributed around Colombia.

4 **Noticeable gap in MeOH & SAF projects** despite extensive access to biogenic carbon sources and high-value offtake markets in the maritime and aviation sector. **PtX-COL 2.0 project concepts directly target this gap.**

3/4 **Products & capacity**



1/2 **Announced ramp-up versus capacity goal***



* Contains data gaps and overreporting risk

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Phase 1 - Recap

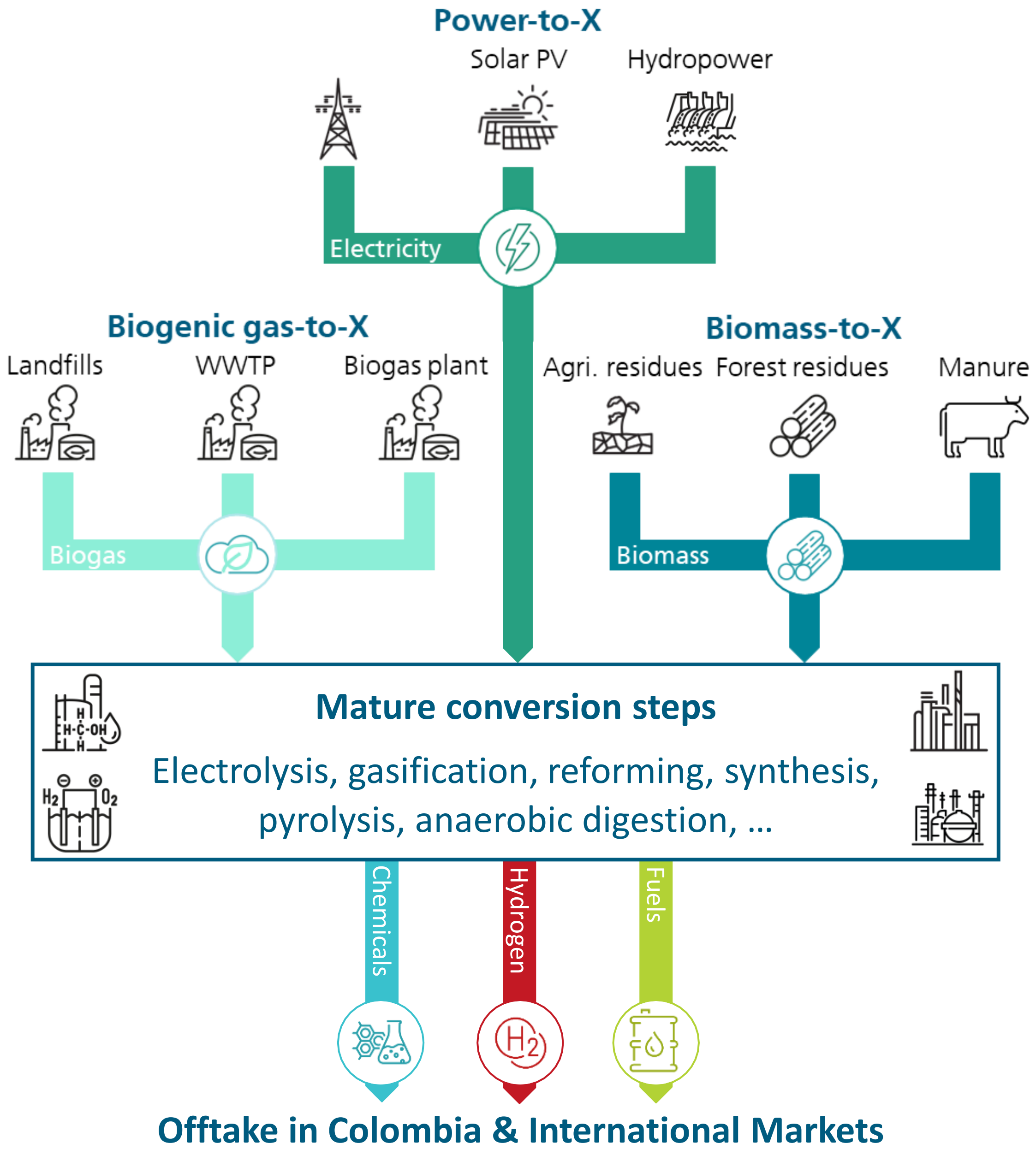
First-movers & hybrid concepts

1 **Leveraging low-cost feedstocks**
- Utilization of residue and waste biomass and biogenic gases
- Reduction in feedstock costs
- Biomass and biogenic gases bring carbon into the system

2 **Utilizing mature processes & existing infrastructure**
- Leverage mature production processes to minimize risks
- Integrate diverse processes into innovative supply chain designs
- Utilize or repurpose existing infrastructure to reduce costs

3 **Kick-start regional hydrogen hubs**
- Develop integrated hubs for production, distribution & offtake
- Reduce distances between production & end-users
- First step to create localized ecosystems to support hydrogen

4 **Targeting regulatory sweet spots**
- Leverage regulatory sweet spots for early market entry
- Take advantage of transitional periods in regulatory framework
- Align strategy with incentives and subsidy schemes



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Project Results – Phase 2

Conceptualization of first-mover projects

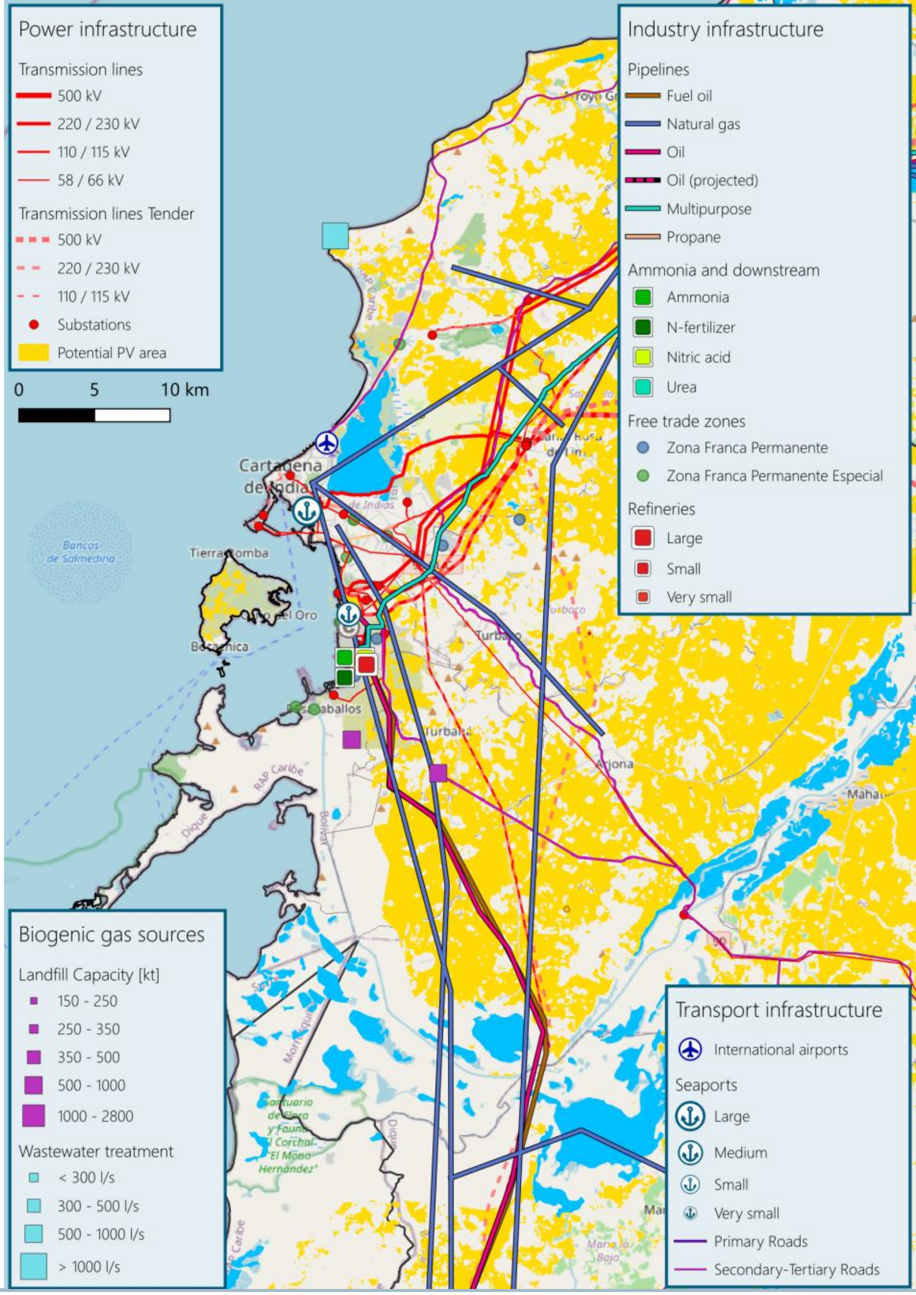
Bolívar

Bolívar (Cartagena hub)

- **Renewable base:** Solar PV is the main option (broad areas around Cartagena); onshore/offshore wind very limited, no local hydropower
- **Biogenic feedstock:** Landfills, Cartagena WWTP, cement-plant CO_2; relevant rice, corn and oil-palm residues concentrated in central/southern Bolívar
- **Infrastructure:** Dense gas + multipurpose pipeline to Reficar, several free-trade zones, and strong Port of Cartagena/Mamonal chemical-export and bunkering logistics
- **Offtake anchor:** Refinery, plus Rafael Núñez Airport (SAF) and maritime bunkering/export
- **Main constraint:** Grid capacity + renewable power cost, constrained water volume (Canal del Dique), and southern-Bolívar forest/peasant-reserve zones
- **Strategic focus:** One of the clearest first-mover regions via residue-based, industrially integrated, maritime projects

➢ **Selected concept: Medium-scale methanol from landfill gas**

➢ **Others:** Biomethane / SAF from LFG, renewable ammonia



Conceptualization of first-mover projects

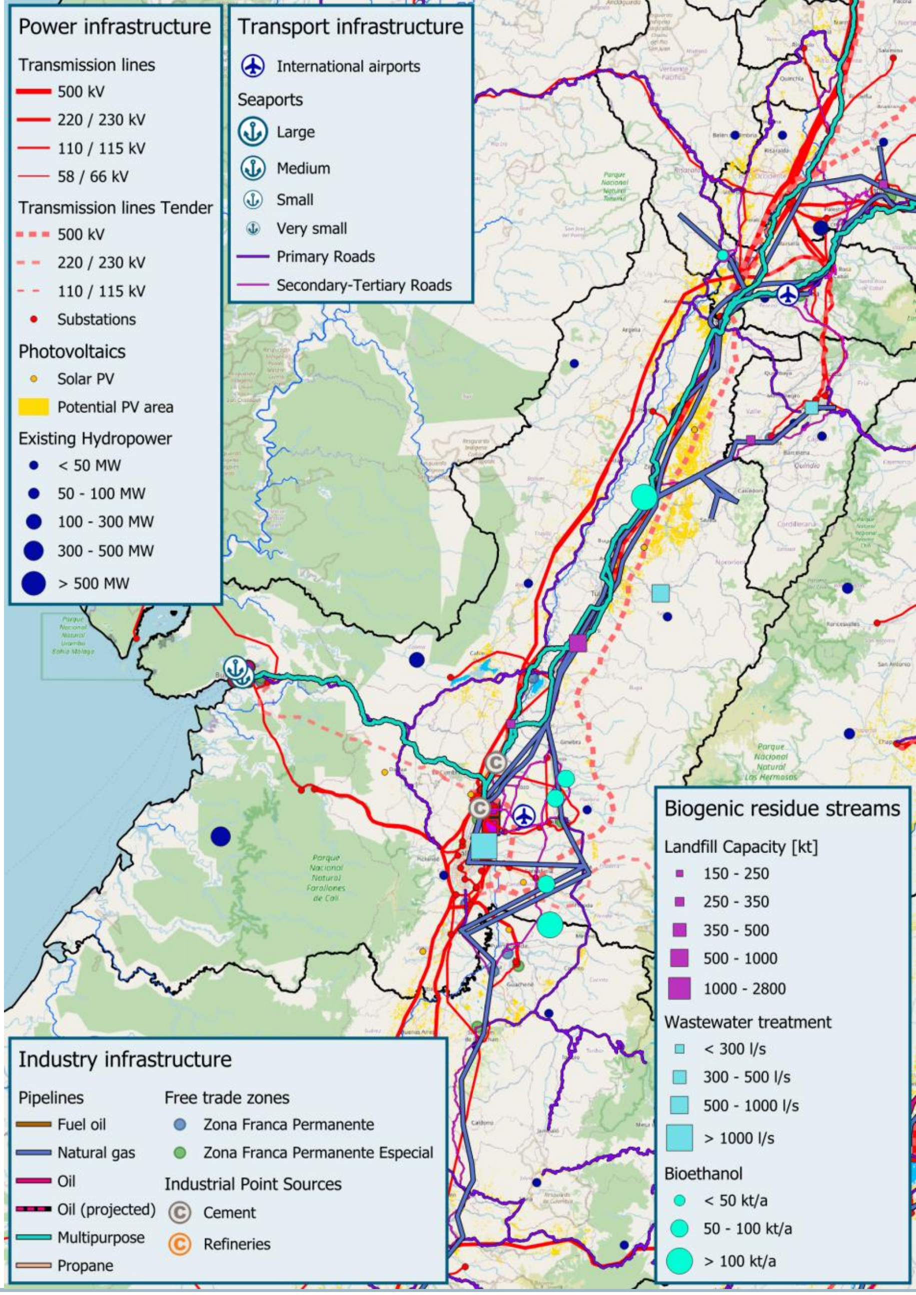
Valle del Cauca

Valle del Cauca (Cali–sugarcane belt)

- **Renewable base:** Extensive firm hydropower and biomass CHP; solar PV land- and grid-constrained along the Cauca corridor, onshore wind minimal
- **Biogenic feedstock:** Enormous sugarcane/bioethanol residue base (bagasse, RAC, vinasse, fermentation CO_2), landfills, Cali WWTP, plus corn/banana residues
- **Infrastructure:** Gas pipeline network, strong sugar-agroindustrial base with CHP, several free-trade zones, and export via Port of Buenaventura/Aguadulce — but less heavy-industry demand than the coast
- **Offtake anchor:** Regional agribusiness/fertilizer integration plus Alfonso Bonilla Aragón Airport (SAF) and Buenaventura export
- **Main constraint:** Energy cost, high socio-environmental/land-use complexity (protected/community/reserve zones + municipal zoning) and Río Cauca water/El Niño drought risk
- **Strategic focus:** SAF / biomass-based derivatives leveraging the ethanol cluster

➢ **Selected concept: SAF via Alcohol-to-Jet at existing mills**

➢ **Others:** SAF via gasification & FT, methanol from biogenic CO_2 and ren. H_2, methanol / biomethane from LFG, biochar-based fertilizers



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Conceptualization of first-mover projects

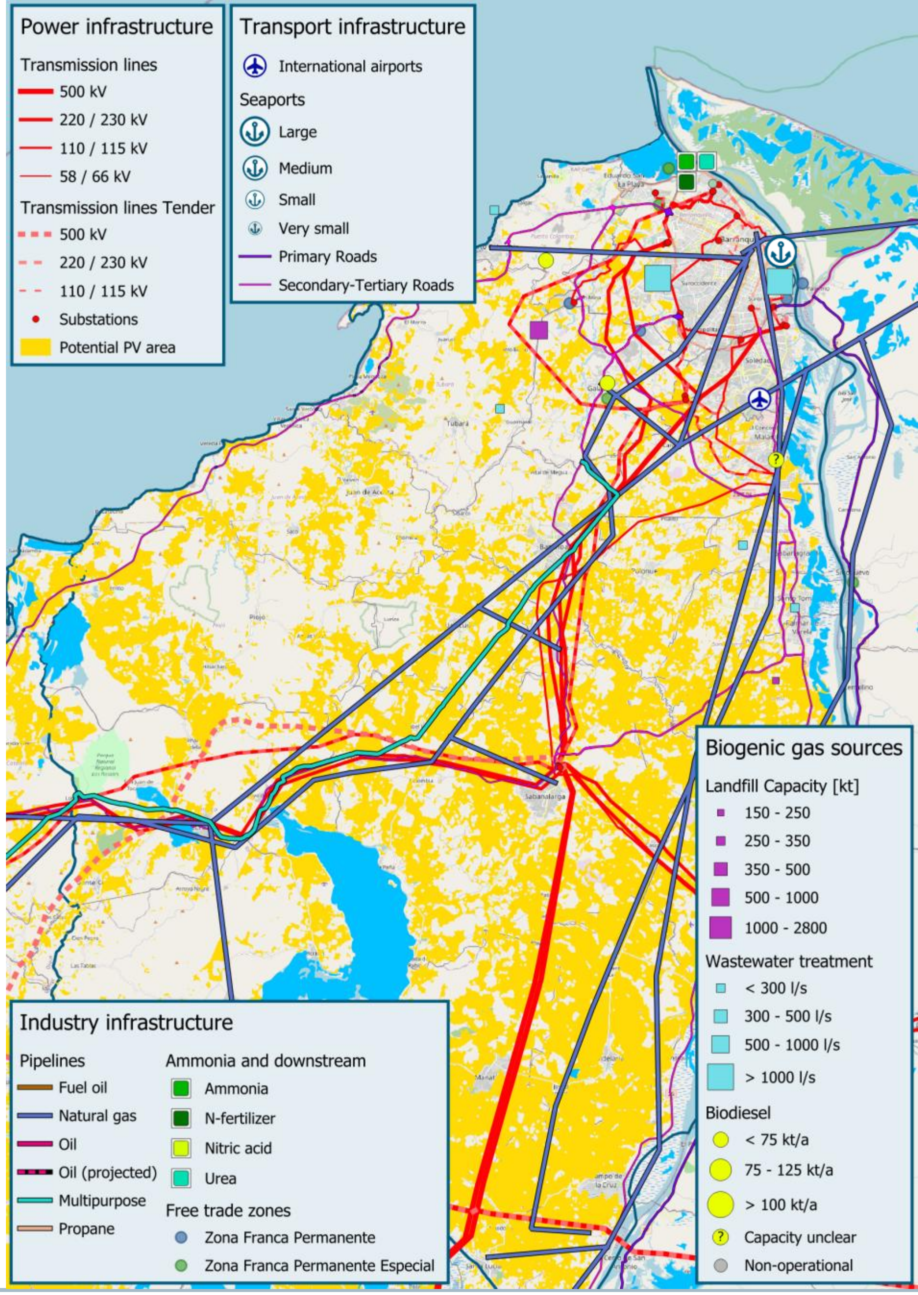
Atlántico

Atlántico (Barranquilla hub)

- **Renewable base:** Solar PV is the main option (broad but distributed areas around Barranquilla); onshore wind only small-scale, offshore wind post-2030, no local hydropower
- **Biogenic feedstock:** Limited — landfills, Barranquilla WWTP, biodiesel-glycerol residues and Smurfit paper-mill residues; very low agricultural-residue potential
- **Infrastructure:** Dense gas pipeline network, multipurpose pipeline to Reficar, well-developed HV grid, several free-trade zones, and a chemical port with existing ~10 kt ammonia storage/handling
- **Offtake anchor:** Ammonia/fertilizer integration plus Port of Barranquilla bunkering and Ernesto Cortissoz Airport (SAF)
- **Main constraint:** Renewable power cost/availability and a congested 220 kV grid requiring build-out
- **Strategic focus:** Domestic import-substitution of ammonia + maritime offtake via bunkering or export via large-scale PtX

➢ **Selected concept: Large-scale renewable ammonia**

➢ **Others:** Methanol from wastewater / landfill gas / glycerol residues



Bolívar – Concept 1a
Methanol from landfill gas

Medium Scale

High Impact

Medium Risk

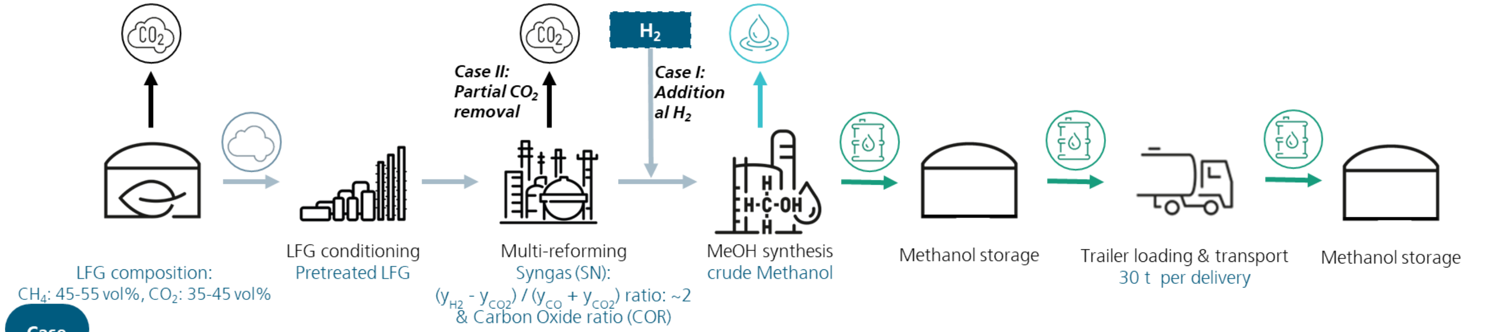
Medium CAPEX

Bolívar – Methanol from landfill gas

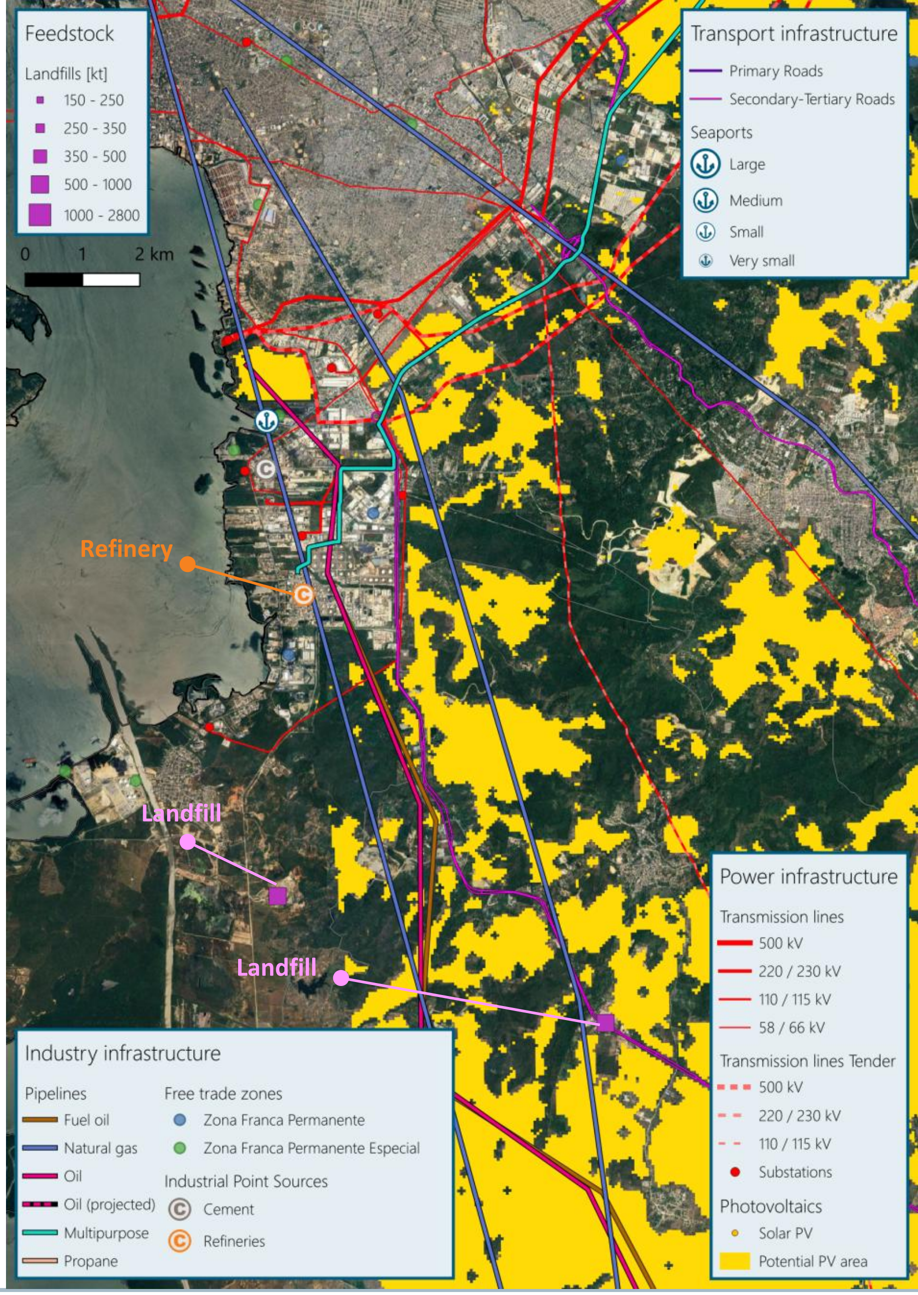
System layout & description

- **Scope:** Medium-scale low-carbon methanol at Cartagena from captured landfill gas; ~11.3 kt_{MeOH}/a (Case I) or ~7.35 kt_{MeOH}/a (Case II) with modular storage and trailer loading; target offtake at refinery
- **Feedstock:** ~9.6 M Nm^3/a landfill gas (CH_4 45–55 vol%, CO_2 35–45 vol%); pretreatment removes moisture, H_2S, siloxanes and particulates; required long-term gas-volume/quality prognosis before fixing plant size

- **Process:** LFG conditioning → multi-reforming to syngas → methanol synthesis → distillation → crude/fuel-grade methanol → storage → 30 t trailer loading (5–7 deliveries/week)
- **Production strategy (Case I vs. Case II):** Case I adds renewable H_2 (0.72 kt/a) via a 25–30 MWp PV park + ~20 MW PEM electrolyser to raise output (~11.3 kt/a) without CO_2 removal; Case II removes CO_2 upstream of reforming (no added H_2) for lower net conversion cost at reduced output (~7.35 kt/a)
  ➔ Cost-vs-volume trade-off to optimise



Case								
I	LFG 9.6 Mio. Nm^3/a	9.3 Mio. Nm^3/a	~15.82 kt/a	0.72 kt_{H2}/a	~11.32 kt/a	3 x 100 m^3	7 deliveries per week	3 x 200 m^3
II	LFG 9.6 Mio. Nm^3/a	9.3 Mio. Nm^3/a	~9.85 kt/a	-	~7.35 kt/a	2 x 100 m^3	5 deliveries per week	2 x 200 m^3



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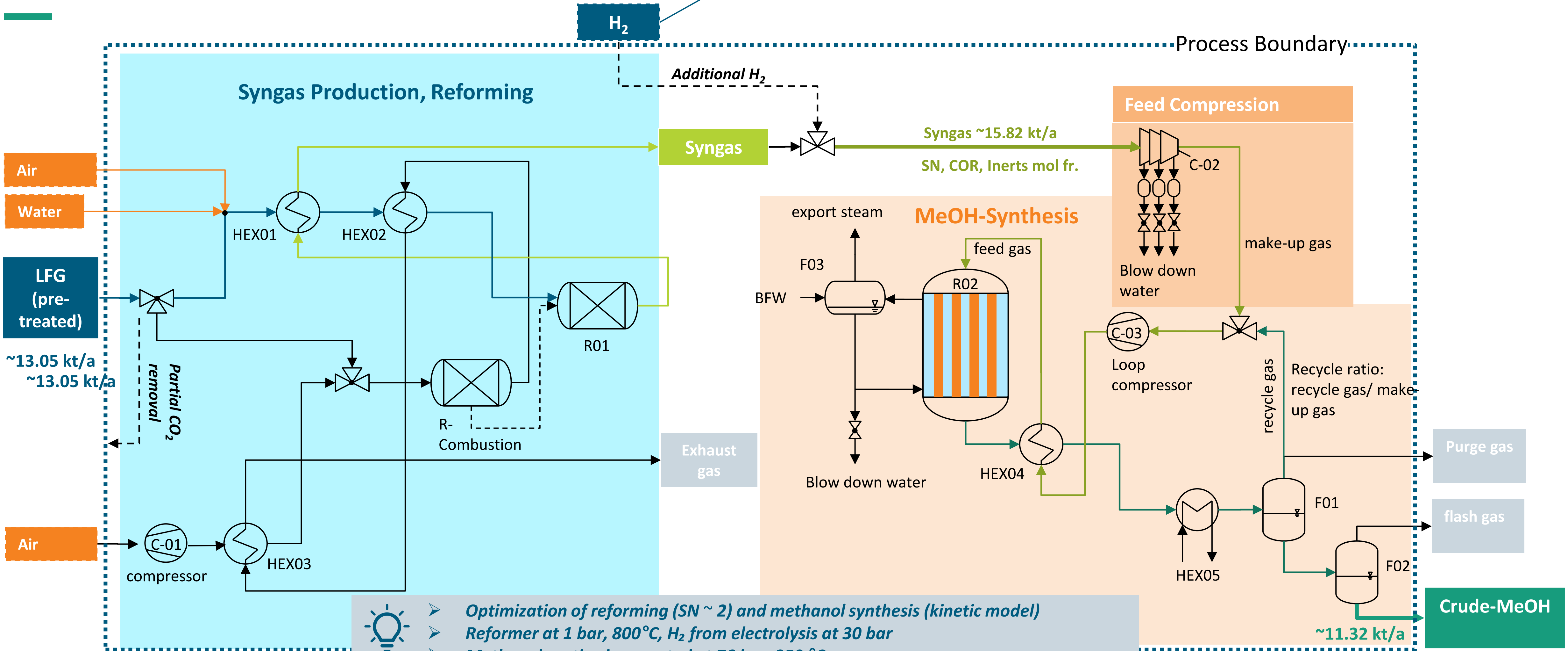
Bolívar – Methanol from landfill gas

Highlight – System overview Case I

Solar-powered electrolysis – Key figures

- H_2 demand: **0.72 kt/a** *(subject to actual LFG volumes)*
- Electricity demand: **~38 GWh/a**
- PV park: **25–30 MW$_p$**
- PEM electrolyser: **~20 MW$_{el}$**

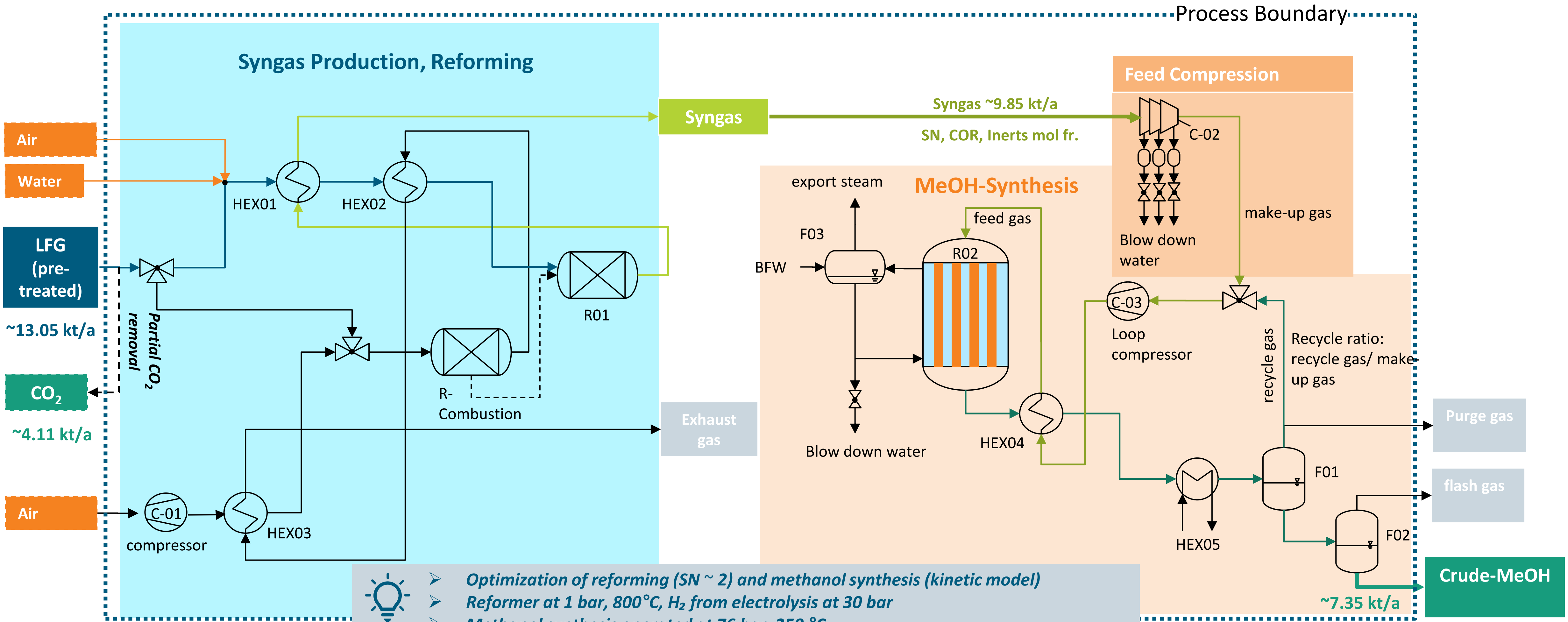


- *Optimization of reforming (SN ~ 2) and methanol synthesis (kinetic model)*
- *Reformer at 1 bar, 800°C, H_2 from electrolysis at 30 bar*
- *Methanol synthesis operated at 76 bar, 250 °C*

Bolívar – Methanol from landfill gas

Highlight – System overview Case II

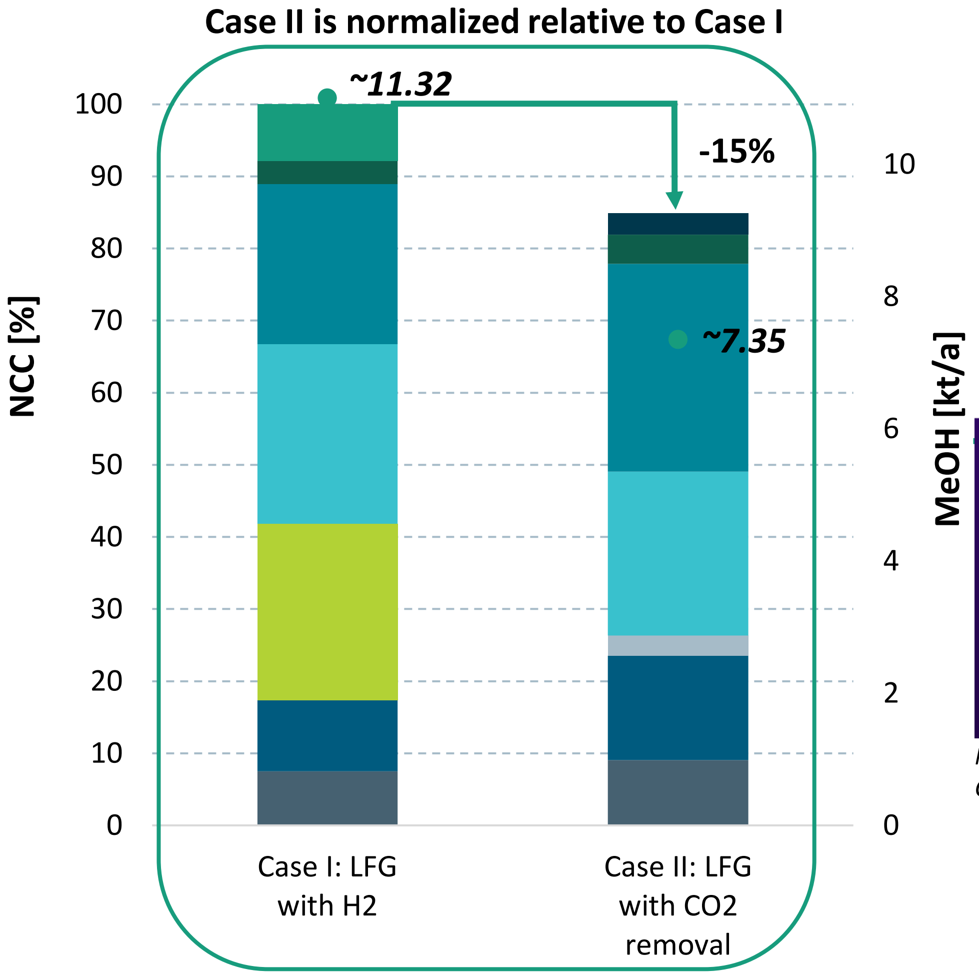
Feed | Utilities | Product | Purge

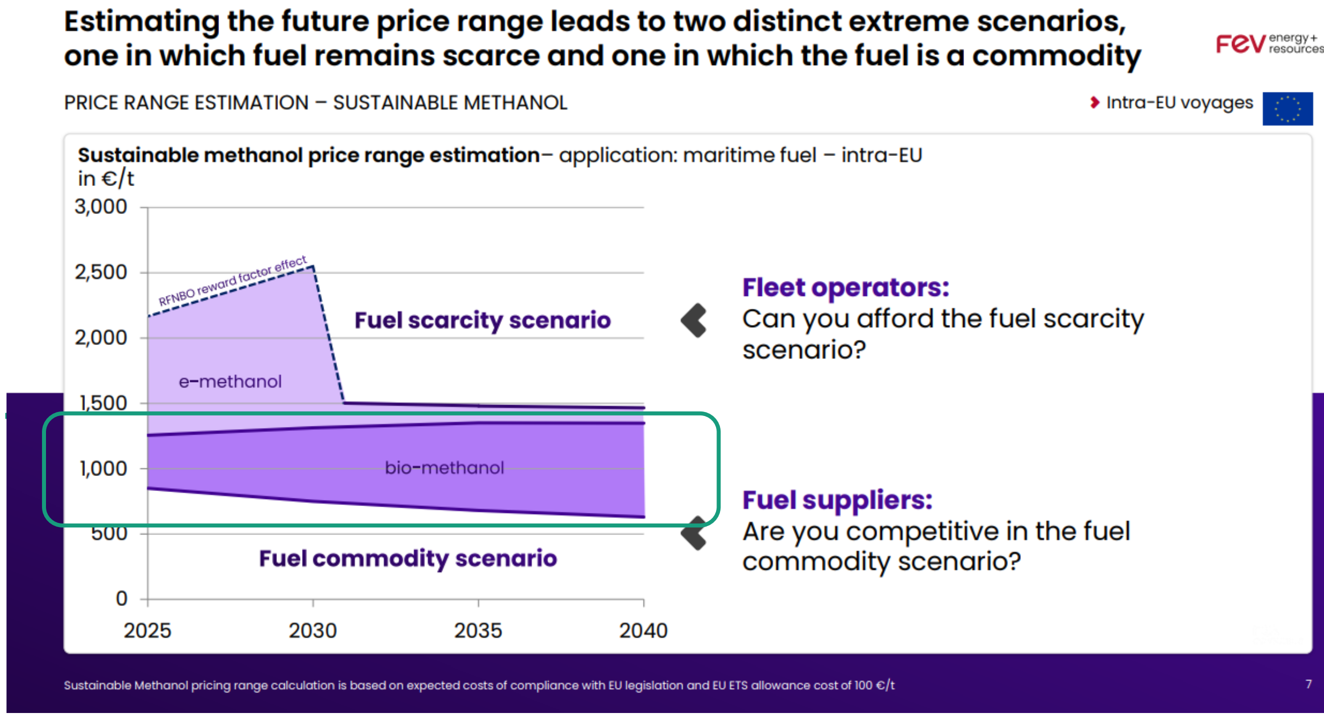


- *Optimization of reforming (SN ~ 2) and methanol synthesis (kinetic model)*
- *Reformer at 1 bar, 800°C, H_2 from electrolysis at 30 bar*
- *Methanol synthesis operated at 76 bar, 250 °C*

Bolívar – Methanol from landfill gas

Highlight – Net Conversion Costs (NCC) of MeOH in [%] w/o feedstock costs





Neumann, D. (2025). Green Methanol: Will There Be a Market and Customers Willing to Pay? Presentation at THE #P2X Conference 2025, FEV Consulting.

Bolívar – Methanol from landfill gas

Risks, maturity & market positioning

Project risks

- ⚠ **Feedstock & gas quality:** Volume, methane content and impurities are the economic foundation; landfill gas availability and contaminants must be specified before fixing plant size
- ⚠ **Power & renewable-H_2 cost (Case I):** PV-electrolysis is a major cost lever; grid backup adds reliability but tariff exposure
- ⚠ **Sub-process integration:** Multi-reforming + H_2/CO_2 adjustment + synthesis is the core risk; first-of-a-kind hybrid chain exposed to syngas control and ramp-up
- ⚠ **Offtake & certification:** Value hinges on certifiable landfill-gas origin; with no Colombian methanol/maritime mandate, demand relies on international (EU/IMO) signals, and uncertain offtake, policy and GHG classification can weaken bankability and delay financing

Technological maturity and integration risk

Sub-process	TRL 2026	TRL 2030	Integration risk
Solar PV / PEM electrolysis	9	9	Low
LFG collection & pretreatment	9	9	Low
CO_2 removal (PSA)	8–9	9	Medium
Multi-reforming (incl. dry reforming)	5–7	7–9	Medium-High
Methanol synthesis ($Cu/ZnO/Al_2O_3$)	9	9	Low
Purification & storage	9	9	Low
Full integrated LFG-to-Methanol	**7–8**	**8–9**	**Medium-High**

Advantages and market positioning

- **Low-cost residue feedstock:** Landfill gas with established collection; economics driven by conversion cost, not power (especially for Case II)
- **Two high-value offtake anchors:** Refinery integration + plus possible SAF via Methanol-to-Jet
- **Favorable site & infrastructure:** Cartagena combines broad solar PV, dense gas + multipurpose pipelines, free-trade zones and strong chemical-port logistics with manageable socio-environmental constraints
- **High maturity & learning-project fit:** Most sub-processes are proven (TRL 9); infrastructure-lean pilot subject to compliant-carbon certification

Valle del Cauca – Concept 1a

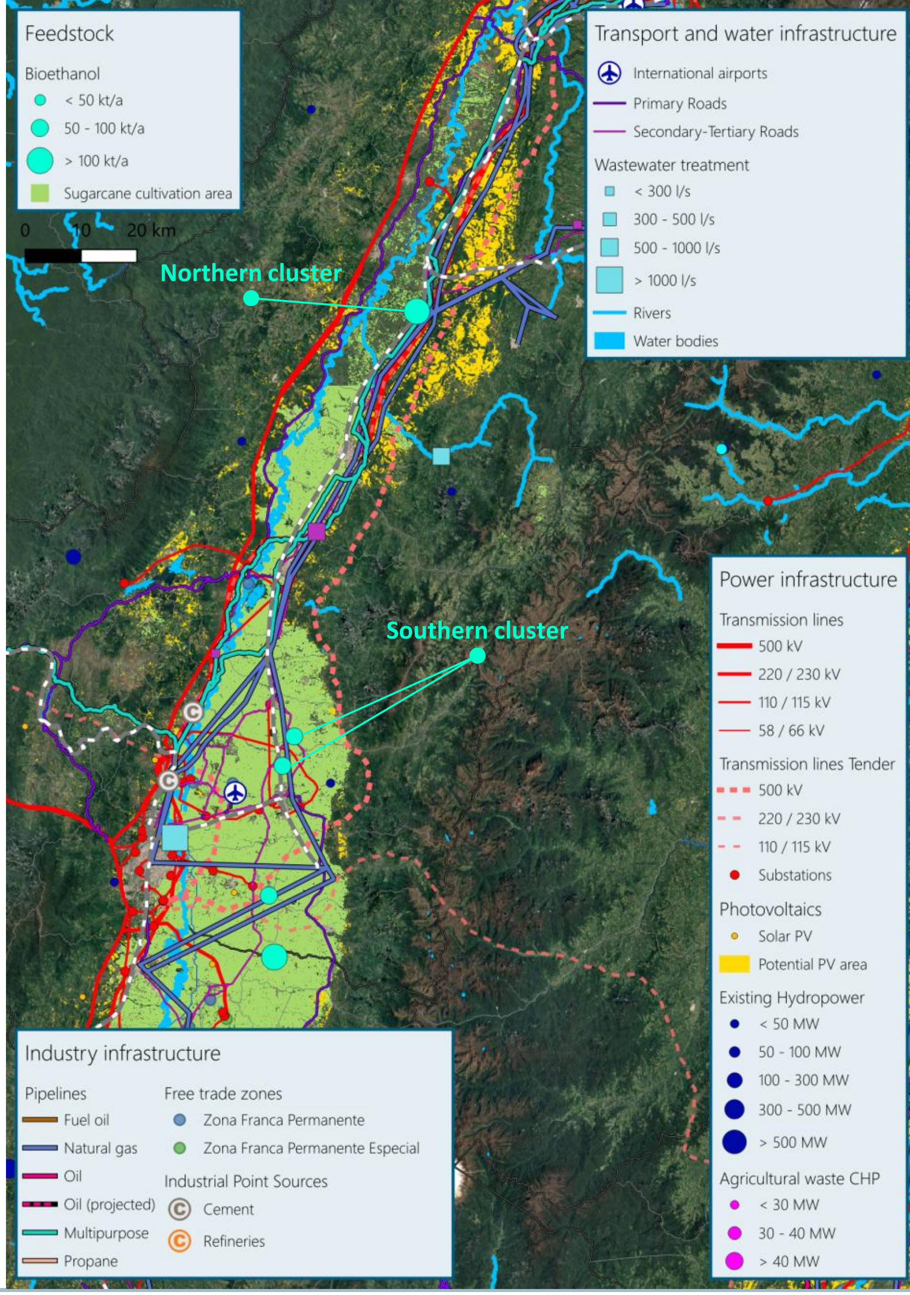
SAF from 1G / 2G sugarcane ethanol via Alcohol-to-Jet

Large Scale | High Impact | Medium-High Risk | High CAPEX

Valle del Cauca – SAF from bioethanol

Highlight – Site selection

	Southern-Cluster	Northern Cluster
Feedstock	• Two ISCC-certified mills • Dual-mill redundancy • Located in cane belt → direct RAC access	• Single largest mill • Lower combined 1G volume • Belt fringe → longer 2G residue haul
Water	• River Cauca is the primary source • Treated wastewater as backup • Slightly longer intake distance	• Closer proximity to River Cauca • Same permitting requirements • Relevant advantage in distance
Transport & offtake	• ~15 km to ABIA • Road/export via Buenaventura (~100 km) • No direct multipurpose pipeline nearby (~17 km)	• Adjacent to multipurpose pipeline • Short ~1–2 km tie-in → batch injection • Buenaventura ~170 km
Energy & utilites	• Onsite biomass CHP (LP steam for ATJ) • Grid access • Limited PV corridor	• Comparable CHP and grid access • Better large-scale PV access • PV advantage is secondary for ATJ
Summary	✅ **Preferred first-mover:** Dual feedstock redundancy, shortest path to ABIA, 2G extension feedstock proximity, and proven CHP integration, but no pipeline access exists for cost-efficient delivery to major airports	⚠️ **Viable alternative:** Pipeline proximity is a central benefit; becomes the preferred site if SAF volumes exceed ABIA absorption capacity or if pipeline tie-in can be developed easily; 2G logistics may provide a feasibility bottleneck

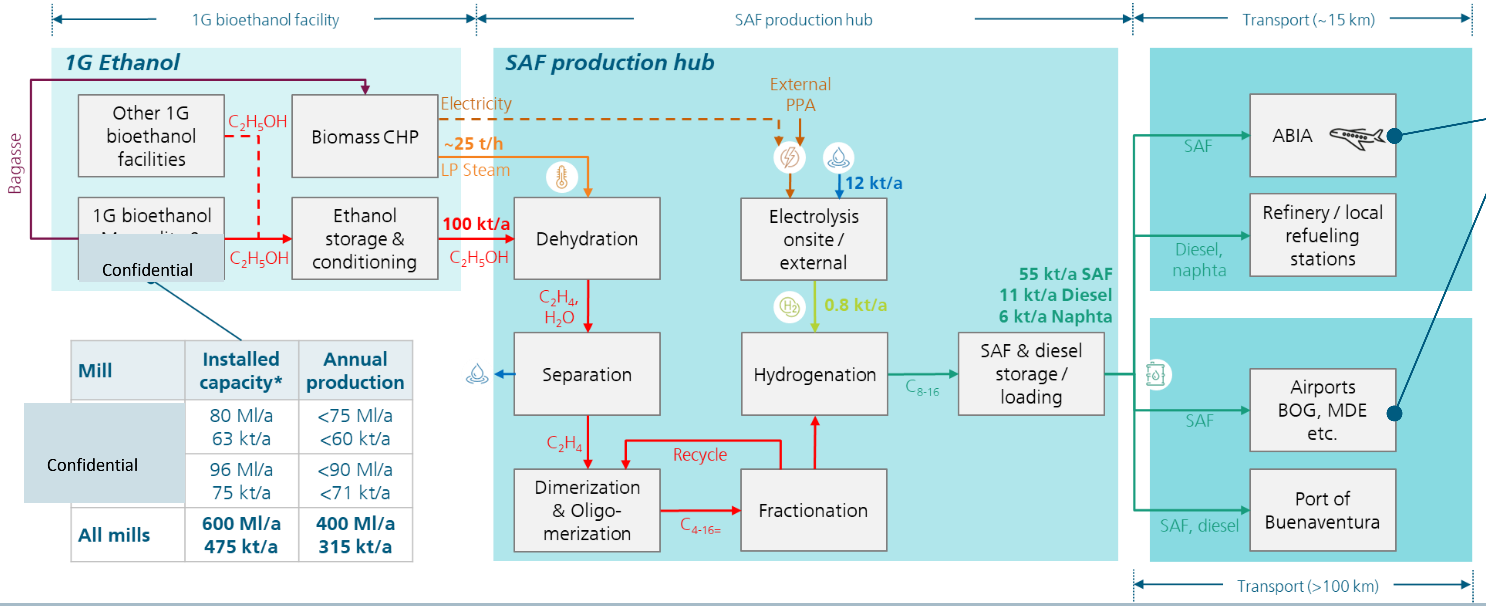


Valle del Cauca – SAF from bioethanol

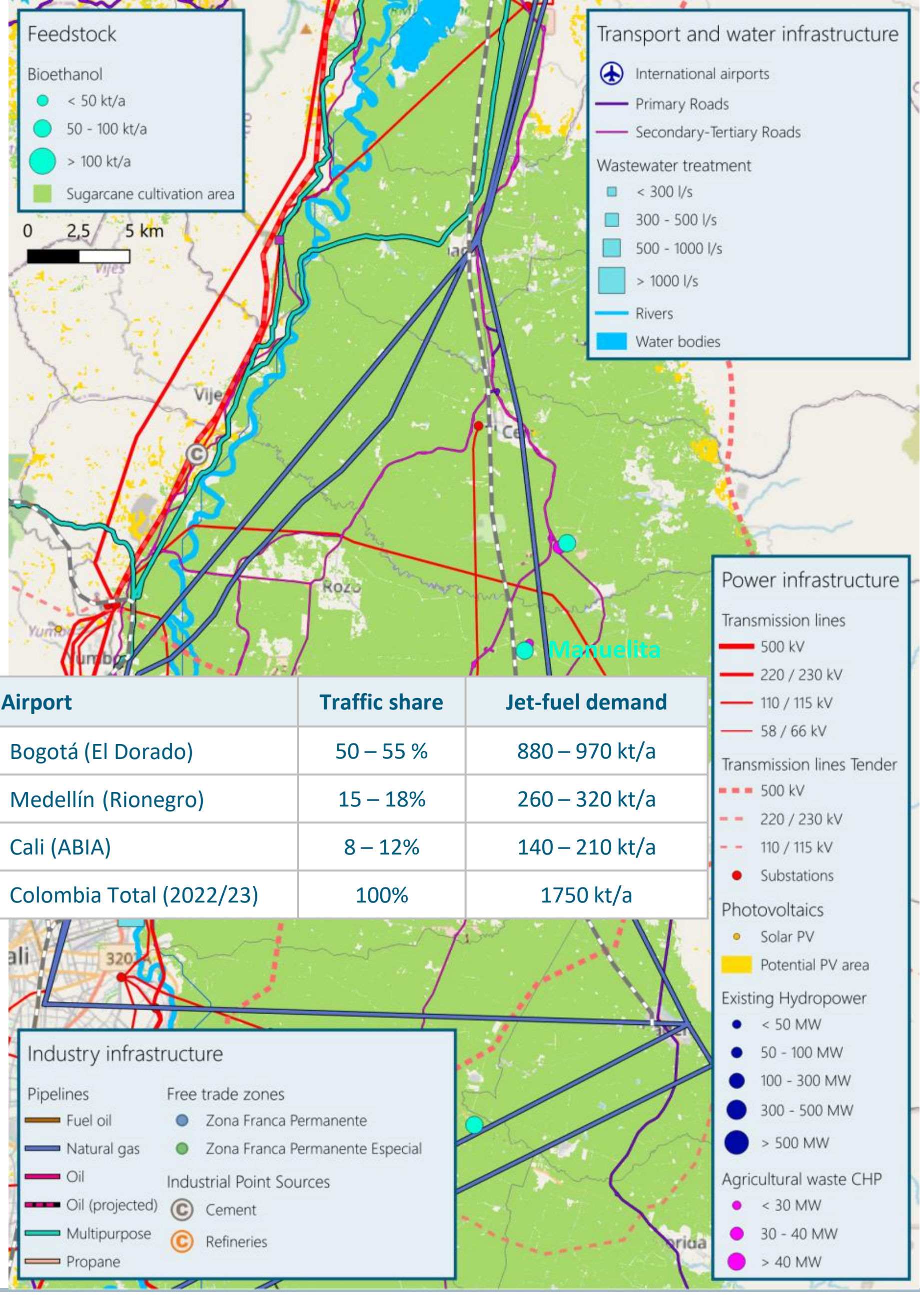
System layout & description

- **Scope:** Large-scale SAF plant on the Alcohol-to-Jet (ATJ) route, co-located at the dual-mill ethanol cluster; 1G base case and 2G extension raises input to 150 kt/a ethanol → 82 kt/a SAF; anchor offtake at Cali airport, scale-up via multipurpose pipeline or export via Buenaventura
- **Feedstock:** 1G anhydrous sugarcane ethanol from two ISCC-certified mills; 2G extension adds ~200 kt/a lignocellulosic residues (bagasse + RAC) within soil-conservation limits

- **Process:** Ethanol dehydration to ethylene → separation to ≥99.5 vol% C_2H_4 → oligomerization to C_8–C_{16} olefins → fractionation into jet/diesel/naphtha + recycle → hydrogenation with renewable H_2 to ATJ-SPK
- **Integration:** Leverages existing mill infrastructure and LP steam supply; shares ethanol storage, utilities and logistics; grid connection + PPA for power and hydrogen supply
- **Production strategy:** Launch as 1G ATJ for domestic/CORSIA-eligible and voluntary EU sales; transition to 2G to unlock EU mandate eligibility without cap and improve feedstock-cost exposure



Mill	Installed capacity*	Annual production
Confidential	80 Ml/a 63 kt/a	<75 Ml/a <60 kt/a
	96 Ml/a 75 kt/a	<90 Ml/a <71 kt/a
All mills	600 Ml/a 475 kt/a	400 Ml/a 315 kt/a



Airport	Traffic share	Jet-fuel demand
Bogotá (El Dorado)	50 – 55 %	880 – 970 kt/a
Medellín (Rionegro)	15 – 18%	260 – 320 kt/a
Cali (ABIA)	8 – 12%	140 – 210 kt/a
Colombia Total (2022/23)	100%	1750 kt/a

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Valle del Cauca – SAF from bioethanol

Risks, maturity & market positioning

Project risks

- ⚠ **Ethanol price & availability:** Depends on spare ethanol from a regulated, sugar-linked market (~75–80% of OPEX); mitigated via long-term contracts
- ⚠ **EU 1G cap & export access:** 1G sugarcane ATJ cannot count toward the ReFuelEU mandate (food-crop cap) ➔ targets domestic/CORSIA market, with a 2G extension (bagasse/RAC) essential to unlock EU eligibility
- ⚠ **2G feedstock logistics & technology:** RAC logistics don't yet exist and surplus bagasse is limited by CHP use, ➔ feedstock logistics complexity and lower technological readiness with no local reference; may be mitigated by a bagasse-led start
- ⚠ **Water, siting & offtake logistics:** Large-scale water supply relies mainly on the Río Cauca, rural zoning delays, and without pipeline batch injection SAF distribution beyond ABIA raises transport cost / offtake concentration; Riopaila being a pipeline-adjacent alternative

Technological maturity and integration risk

Sub-process	TRL 2026	TRL 2030	Integration risk
1G ethanol supply / H_2 delivery	9	9	Medium
Ethanol dehydration / separation	9	9	Low
Oligomerization (ATJ)	8	8–9	Low-Medium
Fractionation / hydrogenation	8–9	9	Low-Medium
ATJ-SPK cert. (ASTM D7566 Annex 5)	9	9	Low
2G residue collection & logistics	4–6	6–8	Medium-High
2G pretreatment & hydrolysis	6–7	7–8	Medium-High
Full 1G integrated system	**8**	**8–9**	**Low**
Full system with 2G extension	**6**	**7–8**	**Medium-High**

Advantages and market positioning

- ⊕ **Unmatched feedstock & CHP:** Two ISCC-certified mills + onsite CHP steam directly to ATJ ➔ avoids boiler, cuts CAPEX
- ⊕ **Strong anchor + strategic location:** Cali airport anchor offtaker, plus potential for pipeline integration scale-up, co-products and Buenaventura export
- ⊕ **High maturity & existing certification:** Proven 1G ATJ (ASTM D7566 Annex 5); main work is execution, not validation
- ⊕ **Strong EU demand pull + phased pathway:** SAF mandate (2%→6%→20%→70%) enable transitioning to 2G which unlocks the EU compliance market

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Atlántico – Concept 2a
Renewable ammonia

Large Scale

High Impact

Medium-High Risk

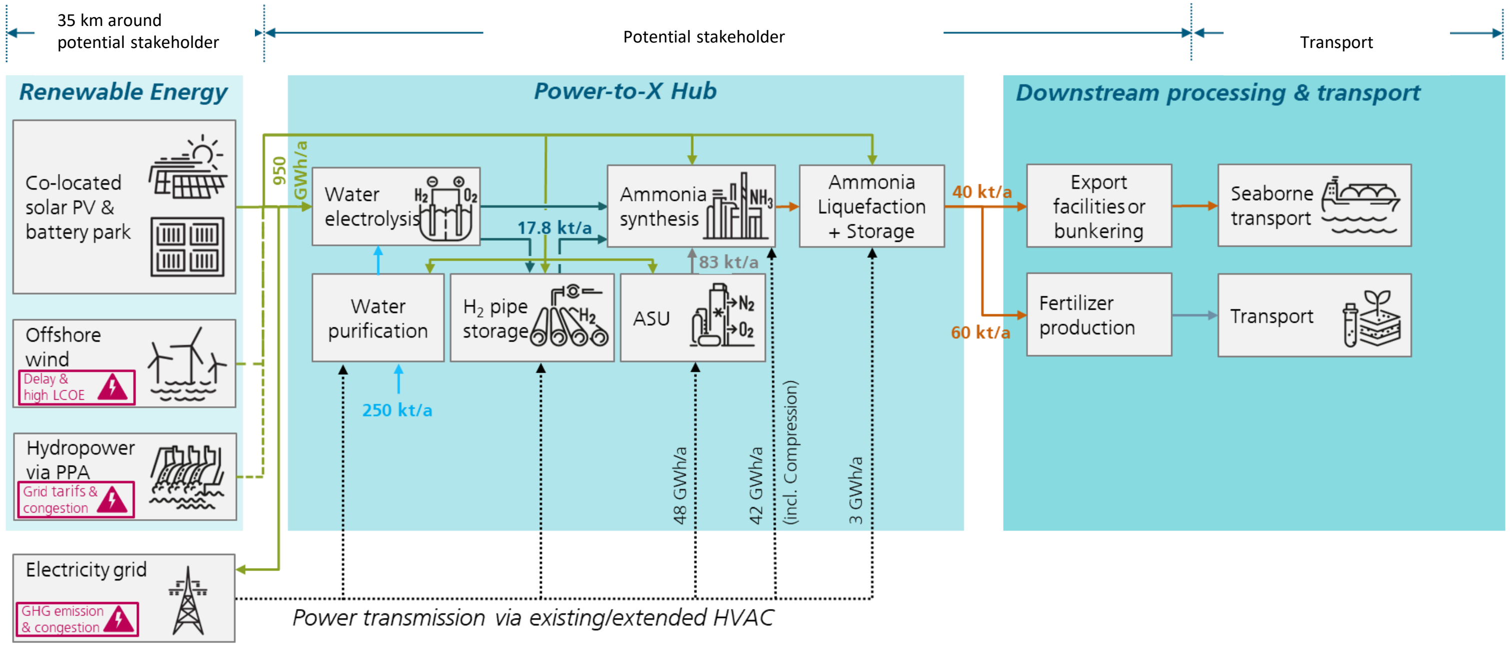
Very High CAPEX

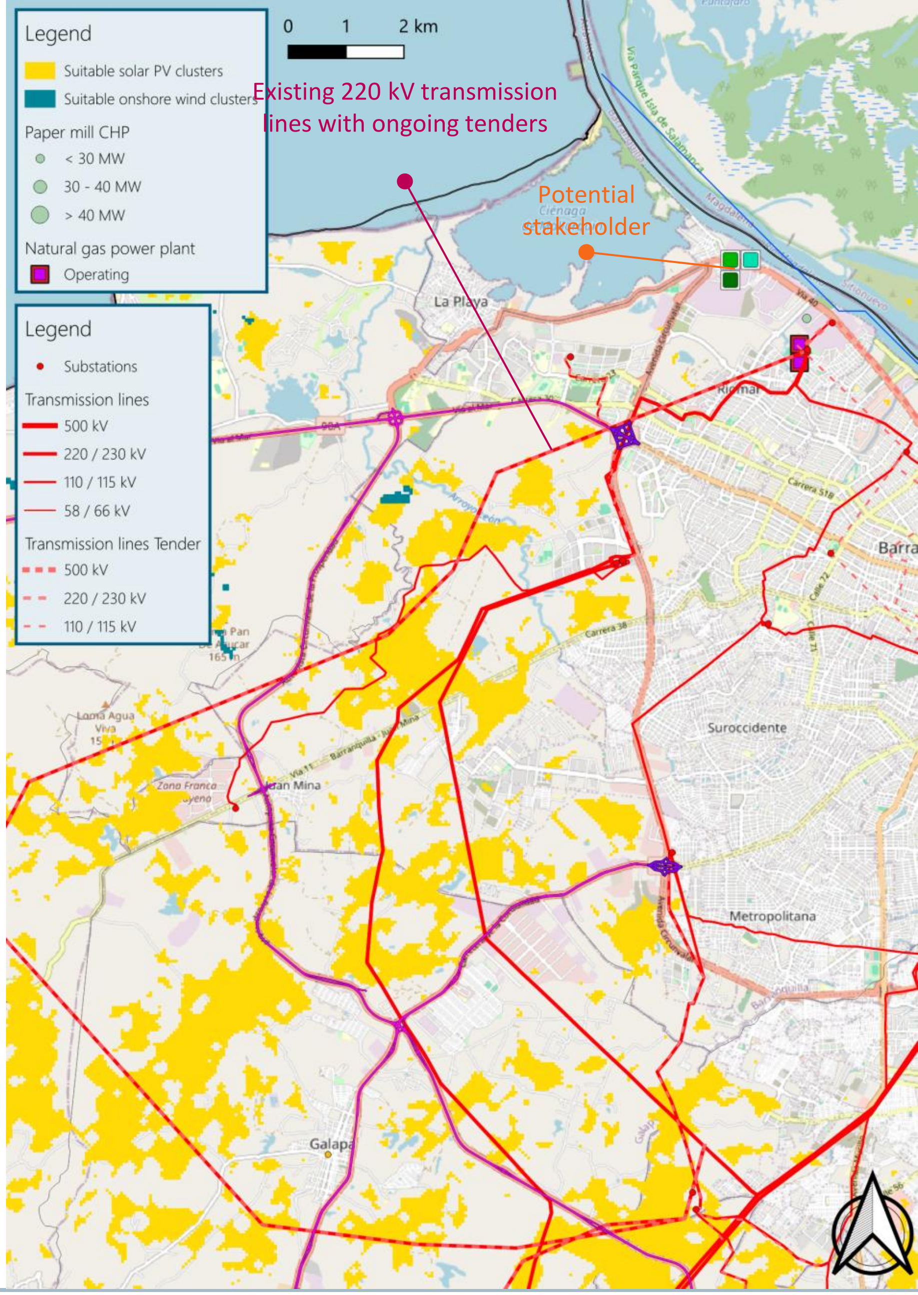
Atlántico – Renewable ammonia

System layout & description

- **Scope:** 100 kt/a renewable ammonia at Barranquilla; ~60 kt/a substitutes fossil ammonia imports, ~40 kt/a for export/bunkering
- **Power:** Co-located solar PV + battery park (preferred), offshore wind as post-2032 complement; grid connection for utilities
- **Integration:** Leverages existing ammonia storage, bagging, blending & port logistics at the host site

- **Process:** Large-scale ALK/PEM electrolysis → H_2 pipe storage → Cryogenic ASU (N_2) → Flexible Haber-Bosch loop (150–200 bar, 350–400 °C) → Liquid NH_3 at −33 °C, 99.98 mol%
- **Production strategy:** Mass-balance split via RFNBO-conform (hourly-matched) electrolysis for the ~40 kt/a export share; Colombian balancing rules for the ~60 kt/a domestic share to raise electrolyzer full-load hours and lower LCOA





Atlántico – Renewable ammonia

Risks, maturity & market positioning

Project risks

- ⚠ **Power cost & competitiveness:** Green NH_3 stays above grey-import cost viability hinges on low-cost PV-led power and grid constraints; other potentially lower-cost ammonia projects (e.g. in La Guajira) introduce competitiveness risk
- ⚠ **Offshore wind timing:** The offshore wind farm near Barranquilla is not available soon and can only serve as a post-2032 complement; over-reliance on it in the power concept would jeopardize schedule and elevate LCoA
- ⚠ **Grid & water delivery:** Substantial third-party grid/transmission upgrades are a key COD schedule risk; a dedicated water concept must be defined in feasibility
- ⚠ **Regulatory & certification:** Depends on EU RFNBO compliance while Colombia's GHG threshold / matching rules remain uncertain ➔ probably delaying financing and complicating bankability

Technological maturity and integration risk

Sub-process	TRL 2026	TRL 2030	Integration risk
Solar PV + BESS	9	9	Low
HVAC transmission / grid connection	9	9	Medium-High
ALK & PEM electrolysis (individually)	9	9	Low
Hybrid ALK/PEM (shared interface)	7–8	8–9	Medium
Cryogenic ASU (N_2)	9	9	Low
Flexible Haber-Bosch loop	7–8	8–9	Medium
Ammonia storage (−33 °C)	9	9	Low
Full integrated PtA	**7–8**	**8–9**	**Medium**

Advantages and market positioning

- **Existing downstream & port infrastructure:** Direct integration into an operating ammonia/fertilizer chain lowers entry barriers and CAPEX
- **Domestic anchor + import substitution:** Sizeable demand anchor gives commercial pull independent of volatile export economics
- **Favorable site:** Ample land, competitive PV, port access, low socio-environmental complexity and good water access
- **High maturity & dual-market fit:** Proven sub-processes; mass-balance split captures EU premiums while raising FLH and lowering LCOA

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Next steps

1 **Decide what to advance**
Select the most promising first-mover concept, site, and target market

2 **De-risk the critical assumptions**
Confirm feedstock, power, water, logistics, certification, and offtake conditions

3 **Optimize the concept to bankability**
Refine design, run sensitivities, and validate the main techno-economic levers

4 **Build the Phase III implementation package**
Launch feasibility / pre-FEED, partner commitments, and funding roadmap

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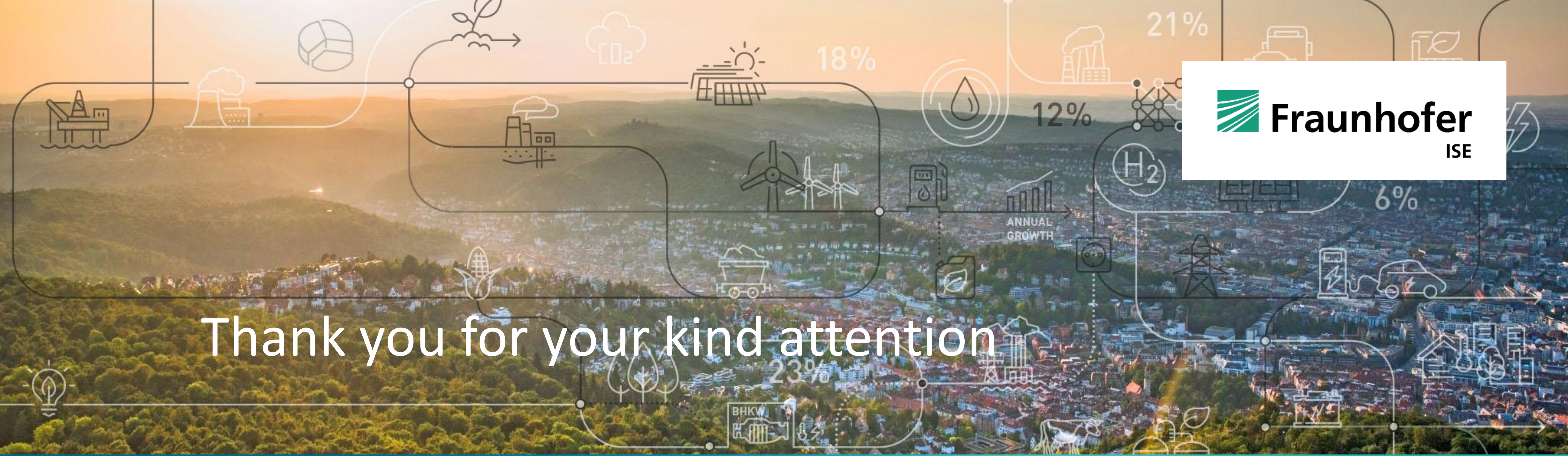

Thank you for your kind attention

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