CARBON INTENSITY HAS BECOME A FIRST-ORDER FEASIBILITY TEST IN ENERGY PROJECT DEVELOPMENT

A market-facing guide to why lifecycle carbon intensity now shapes project access, incentives, and value — especially in Europe, but increasingly elsewhere too.

EU RFNBO threshold ≥70% GHG savings	**FuelEU Maritime reference** 91.16 gCO_2e/MJ
U.S. 45V upper qualification limit ≤4 $kgCO_2e/kg\ H_2$	**UK low-carbon hydrogen threshold** 20 gCO_2e/MJ (LHV)

WHAT THIS MEANS IN PLAIN ENGLISH

- Carbon intensity now affects whether a project can enter a market, qualify for incentives, avoid penalties, and reach final investment decision — not just whether it can be engineered.
- The earliest commercial choices increasingly sit upstream: electricity sourcing, feedstock choices, plant siting, and chain-of-custody design can decide whether a project is bankable.
- The commercial test is becoming numeric and auditable: rulebooks such as RED / RFNBO, FuelEU Maritime, 45V, LCFS, and the UK hydrogen standard all translate carbon performance into thresholds that buyers and regulators can verify.

WHY CI NOW DETERMINES VIABILITY, NOT JUST COMPLIANCE

The change is structural: the "product" increasingly includes not only molecules (H_2, NH_3, LNG, SAF, e-fuels) but also a **verified emissions attribute**. Several policy systems now encode this explicitly via (i) **lifecycle GHG saving thresholds**, (ii) **CI benchmarks that tighten over time**, and/or (iii) **border or downstream carbon costs** that scale with embedded emissions.

In practical terms, two things changed first.

First, **electricity sourcing** becomes an economic lever, not an engineering detail—because grid intensity can make or break threshold compliance. In the EU's RFNBO framework (as an example), the delegated act governing renewable electricity criteria includes rules on **direct connection**, **temporal/geographic correlation concepts**, and additionality-style constraints such as renewable installations coming into operation **not earlier than 36 months** before the fuel plant (for direct connection), plus a transitional regime for certain requirements. [3]

Second, **supply-chain design must be audit-native**. For RFNBO compliance evidence, the EU delegated act explicitly allows using **national or international voluntary schemes recognized by**

the Commission to demonstrate compliance—meaning documentation architecture is part of the product. [4]

THE RULEBOOK NUMBERS THAT NOW SHAPE COMMERCIAL GO / NO-GO DECISIONS

The table below focuses on **explicit numeric CI thresholds or quantitative compliance tests**, plus effective dates, in the EU and other major demand centers.

REGULATORY THRESHOLDS AND COMPLIANCE TESTS

Market	Regulation or scheme	What it tests	Numeric CI / GHG thresholds	Effective timing
EU	Revised RED framework (RFNBO threshold) + RED fossil comparator	Lifecycle GHG saving threshold for RFNBOs and implied CI cap	RFNBOs must achieve ≥70% GHG savings under the revised RED framework. Using the RED fossil comparator of 94 gCO_2e/MJ[1] to translate that threshold implies an effective cap of 28.2 gCO_2e/MJ. [5] [6]	
EU	RED II sustainability criteria for biofuels/bioliquids/biomass fuels	Minimum GHG saving vs comparator, with thresholds varying by installation start date	For example: **50% / 60% / 65%** minimum GHG savings depending on when installations started operating (RED II Article 29). [7]	
EU	RED III (amending RED II)	Strengthens targets and extends approach; developers still must build to delegated-methodology rules	Sets updated renewable targets and policy context; entered into force and requires national transposition	Entered into force **Nov 2023**; transposition deadline **May 2025**. [8]
EU	Delegated Regulation	When electricity	Direct connection: renewable	

[1] The 94 gCO_2e/MJ comparator applies to certain transport fuels under RED II; developers should verify the correct comparator for their specific pathway and target year.

Market	Regulation or scheme	What it tests	Numeric CI / GHG thresholds	Effective timing
	(RFNBO electricity rules) 2023/1184	used for RFNBO can be treated as renewable; certification route	electricity plant must come into operation **≤36 months** earlier than fuel plant in specified cases. [9] Evidence can be shown via Commission-recognized voluntary schemes. [4] Transitional provisions apply for some requirements. [4]	
EU	FuelEU Maritime (Reg. 2023/1805)	**Well-to-wake GHG intensity** limit for energy used onboard	Uses reference **91.16 gCO_2e/MJ** and requires progressive reductions: **2% (2025), 6% (2030), 14.5% (2035), 31% (2040), 62% (2045), 80% (2050)**. [10] Applies from **Jan 2025**.	
EU	EU ETS extension to maritime transport	Carbon cost applied to verified emissions from shipping	Compliance obligation phases in (surrender shares ramp up by year), covering 100% intra-EU and 50% extra-EU legs	Maritime included from **Jan 2024** with phased surrender obligations. [11]
EU	CBAM (Reg. 2023/956)	**Embedded emissions reporting** and (from 2026) financial adjustment for imports	Transitional reporting started **Oct 2023**; substantive CBAM obligations apply from **Jan 2026**; scope includes **hydrogen** and **fertilisers** (relevant to ammonia value chains). [12]	
EU	EU Taxonomy (Delegated Reg. 2021/2139)	"Sustainable finance" eligibility for hydrogen manufacturing activity	Hydrogen requires lifecycle GHG savings **73.4%** ⇒ lifecycle emissions **<3 tCO_2e/tH_2**. [13]	
US	IRA clean hydrogen PTC (45V) – IRS final regs	Eligibility and credit tiering	Hydrogen qualifies if lifecycle emissions **≤4 $kgCO_2e/kg\ H_2$**; tier	

Market	Regulation or scheme	What it tests	Numeric CI / GHG thresholds	Effective timing
		based on lifecycle CI	thresholds at **0.45 / 1.5 / 2.5 / 4 $kgCO_2e/kg$** defining credit levels. [14] Final regs effective **Jan 10, 2025**. [15]	
UK	Low Carbon Hydrogen Standard	CI threshold for “low-carbon” hydrogen	Threshold: **20 gCO_2e/MJ (LHV)** (≈ **2.4 $kgCO_2e/kg\ H_2$** WtG).	
Canada	Clean Fuel Regulations	Annual CI limits (gasoline/diesel pools) and crediting	Gasoline CI limits decline **91.5 → 81.0 gCO_2e/MJ (2023→2030+)**; diesel **89.5 → 79.0 gCO_2e/MJ**; baselines **95 (gasoline)** and **93 (diesel)**. [17]	
California	LCFS (post-2024 amendments)	CI benchmark schedule and credit/deficit economics	Benchmarks for gasoline in 2025 transactions from **July 1, 2025**: **76.60 gCO_2e/MJ**; for diesel: **81.70 gCO_2e/MJ**. [18] For 2025 transactions **before July 1**, benchmarks **85.77 (gasoline)** and **86.64 (diesel)** apply. [19] Effective date **July 1, 2025**. [20]	
Japan	METI hydrogen strategy / CI thresholds used for support framing	CI threshold definitions for “clean/low-carbon” hydrogen and ammonia	Hydrogen: 3.4 $kgCO_2/kg\ H_2$ (well-to-gate). Ammonia: ~0.87 $kgCO_2e/kg\ NH_3$ (well-to-gate; older materials also cite 0.84 kg/kg with a different boundary). [21]	
South Korea	Clean hydrogen certification	Threshold for certification	Threshold: 4 $kgCO_2e/kg\ H_2$ (well-to-gate). [22]	

Practical translation into CI caps. Under the revised RED framework, RFNBOs must achieve at least 70% GHG savings. Separately, the RED fossil comparator of 94 gCO_2e/MJ is the reference value commonly used to translate that threshold into an implied CI cap. On that basis, the maximum lifecycle CI is 28.2 gCO_2e/MJ (94 × (1−0.70)). For hydrogen (≈120 MJ/kg LHV), this is ≈ 3.38 $kgCO_2e/kg\ H_2$ - often the difference between “marketable” and “stranded.”

THE BENCHMARK RANGES BUYERS AND REGULATORS WILL ASK ABOUT

CI values vary by boundary (well-to-gate vs well-to-wake), methane leakage, capture rates, and electricity sourcing. Below are **representative benchmarks** in the units teams are now debating in diligence.

REPRESENTATIVE CI BENCHMARKS AND NOTES

Commodity / pathway	Representative CI (range)	Unit / boundary	What drives the range	Key sources
Hydrogen, grey (SMR, no CCS)	~9–12	$kgCO_2e/kg\ H_2$ (≈75–100 gCO_2e/MJ)	Natural gas supply chain and process CO_2	Review reporting ~11 $kgCO_2e/kg$ as benchmark. [23]
Hydrogen, blue (SMR/ATR + CCS)	~3–8+	$kgCO_2e/kg\ H_2$	Capture rate, **methane leakage**, energy for CCS/compression, gas basin differences	ATR example ~3.91 $kgCO_2e/kg$; other routes higher. [24] Basin-specific modelling: **3.3 (Marcellus) vs 7.4 (Permian)** $kgCO_2e/kg\ H_2$. [25]
Hydrogen, green (electrolysis)	~0.6–2.5+	$kgCO_2e/kg\ H_2$	Electricity CI (wind vs solar vs grid), electrolyser utilization, upstream manufacturing	Wind-based ~0.6; solar-based ~2.5 $kgCO_2e/kg\ H_2$ in lifecycle analysis. [26]
Ammonia, conventional (natural gas)	~2.4–2.6	$tCO_2e/t\ NH_3$ (≈130–140 $gCO_2e/MJ\ NH_3$ LHV)	Process CO_2 from reforming dominates	IEA cites ~**2.4 tCO_2/t** direct emissions intensity. [27] Lifecycle-to-plant-gate estimate **2.6 t/t**. [28]
LNG as marine fuel (illustrative WtW, excluding slip uncertainty)	~75 (best case) to ~90+	gCO_2e/MJ (well-to-wake)	WtT intensity + CO_2 combustion; methane slip can erode benefits	FuelEU default factors show WtT **18.5 gCO_2e/MJ** and CO_2 combustion factors by engine class (basis for WtW calculations). [29] ICCT finds LNG's maximum lifecycle benefit can be limited and slip/leakage is pivotal. [30]

Commodity / pathway	Representative CI (range)	Unit / boundary	What drives the range	Key sources
E-kerosene (PtL with renewable power + DAC CO_2)	~1–28	gCO_2e/MJ (GWP100)	Electricity source (PV vs wind), process design	Reported PtL-kerosene range **1–28 gCO_2e/MJ** for DAC + wind/PV configurations. [31]

Methodology note that keeps coming up in reviews: regulators are converging on **lifecycle** framing (WtT/TtW/WtW), but the *allowed* system boundaries and default factors differ. For example, FuelEU Maritime explicitly structures default **WtT and TtW** factors in Annex II as the basis for the ship energy GHG intensity index. [29] So "we calculated CI" is not enough; the only question that matters is "did we calculate CI exactly the way the destination rulebook tests it?"

WHY CARBON INTENSITY QUICKLY SHOWS UP IN PROJECT VALUE

To make the shift concrete, here is a **stylized export project** (illustrative, pre-tax, real dollars) where CI affects value through (a) **carbon price exposure** and (b) the implied **need for low-CI electricity**.

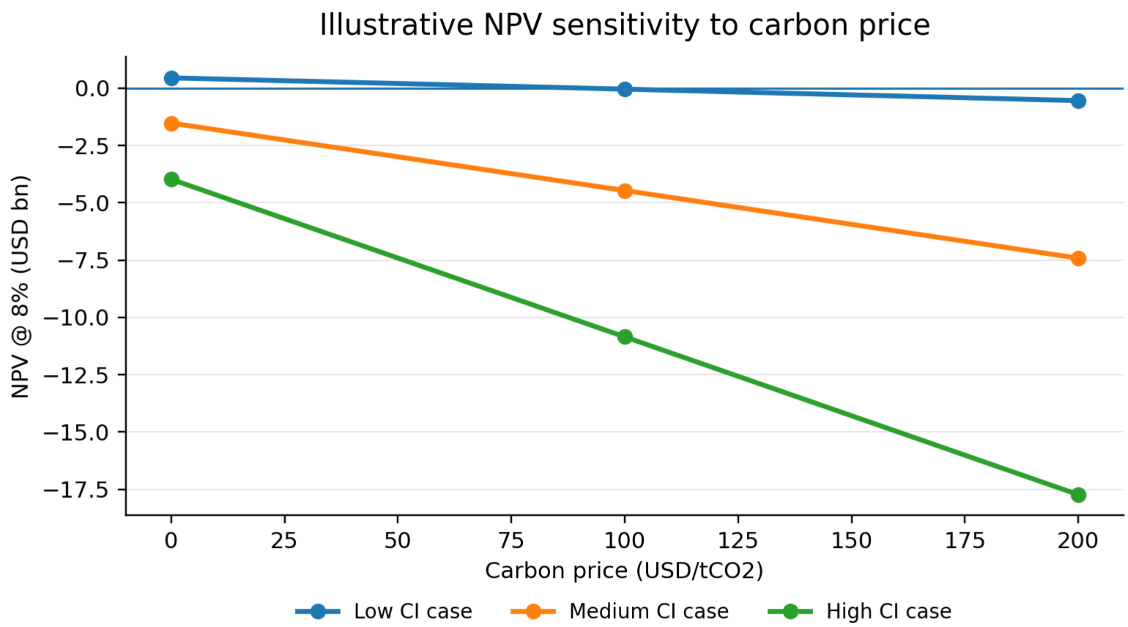
MODEL ASSUMPTIONS

We model an e-ammonia project (1 Mt/y) over 20 years. CAPEX is incurred at year 0; annual cash flows are simplified operating margin minus fixed OPEX and sustaining capex.

Assumptions (illustrative): CAPEX \$3.0bn; price \$800/t; electricity use 10 MWh/t; non-power OPEX \$80/t; shipping \$40/t; fixed OPEX \$50m/y; sustaining capex \$30m/y; discount rate 8%. CI is expressed as $tCO_2e/t\ NH_3$; carbon prices shown at \$0/\$100/\$200 per tCO_2.

SENSITIVITY CHART

Illustrative NPV sensitivity to carbon price under low-, medium-, and high-CI cases.



As carbon prices (or carbon-linked penalties/adjustments) rise, **CI becomes a first-order NPV driver**. Even without assigning a "green premium," rising carbon cost alone can destroy value at elevated CI.

SCENARIO TABLE

Low/medium/high scenarios illustrate how **grid intensity and power price jointly** shape CI and economics.

Scenario	Carbon price (USD/tCO2)	Power cost (USD/t)	CI (tCO2e/t NH3)	NPV @8% (USD bn)	IRR (%)
Low	0	250	0.50	0.44	9.9
Low	100	250	0.50	-0.05	7.8
Low	200	250	0.50	-0.55	5.5
Medium	0	450	3.00	-1.53	0.0
Medium	100	450	3.00	-4.47	n/a
Medium	200	450	3.00	-7.42	n/a

Scenario	Carbon price (USD/tCO2)	Power cost (USD/t)	CI (tCO2e/t NH3)	NPV @8% (USD bn)	IRR (%)
High	0	700	7.00	-3.98	n/a
High	100	700	7.00	-10.85	n/a
High	200	700	7.00	-17.73	n/a

The lesson matches what I see in diligence: **you do not "optimize" CI late**. If CI requires different electricity contracting, different routing, different plant siting, different logistics, or a different certification stack, those choices must be locked early or the economics will not converge.

CASE SNAPSHOTS: WHERE CI CHANGED MARKET ACCESS OR BANKABILITY

THE EU RFNBO THRESHOLD VERSUS "WHICH GAS BASIN?"

Under the revised RED framework, EU RFNBO eligibility hinges on achieving at least 70% GHG savings. The RED fossil comparator of 94 gCO_2e/MJ is then the reference value used to translate that threshold into an implied CI cap. [32] Measurement-informed analysis shows blue hydrogen can vary dramatically by natural gas supply chain: 3.3 $kgCO_2e/kg\ H_2$ using Marcellus gas versus 7.4 $kgCO_2e/kg\ H_2$ using Permian gas in one recent study. [25] In practice, the gas basin and methane-management performance can therefore determine whether a pathway clears an EU threshold before a buyer ever discusses price.

THE US 45V "CREDIT CLIFF" AND WHY SUPPLIERS NOW START WITH CI

Under the IRS final rules implementing 45V, hydrogen is only "qualified clean hydrogen" if lifecycle GHG emissions are **≤4 $kgCO_2e/kg\ H_2$**, and the credit tiers step at **0.45 / 1.5 / 2.5 / 4 $kgCO_2e/kg\ H_2$**. **[33]** This makes CI a financing variable: missing the best tier by a small margin can mean losing most of the per-kg incentive, which can erase equity returns. The final regulations are effective **Jan 10, 2025**, so this is already a live bankability test. [34]

CALIFORNIA LCFS BENCHMARK STEP-CHANGE AND THE "PAPERWORK RISK"

California's amended LCFS tightened 2025 benchmarks mid-year: gasoline benchmark **76.60 gCO_2e/MJ** and diesel **81.70 gCO_2e/MJ** apply for 2025 transactions starting **July 1, 2025**, while earlier-2025 benchmarks were **85.77** and **86.64** respectively. [35] For low-CI fuels, that benchmark shift changes credit/deficit volumes immediately—and critically, it raises the cost of any CI calculation or traceability failure because errors are applied against a tighter benchmark.

A CONCEPT-SELECT CHECKLIST YOU CAN ACTUALLY USE

A CI-led development process is not "more reporting." It is **front-loading the right constraints** so you don't build a technically elegant but commercially stranded asset.

Use this early-stage checklist:

- Define the rulebook first: target markets, use-cases, and compliance tests. Map each product/offtake pathway to the governing CI test (e.g., RED RFNBO threshold, FuelEU maritime intensity, 45V tier, Japan/Korea certification thresholds). [36]
- Lock system boundaries and functional units. Decide whether your decision variable is gCO_2e/MJ (WtW), $kgCO_2e/kg$, or tCO_2e/t product—and align to the actual regulation's test method and default factors (e.g., FuelEU Annex II structure). [29]
- Treat electricity as a regulated feedstock. Under RFNBO rules, whether electricity "counts" as renewable is constrained by criteria such as direct connection timing (36-month rule) and recognized certification pathways. [3]
- Engineer the supply chain for audit from day one. Build chain-of-custody documentation, metering, fuel attribute tracking, and data retention so you can credibly use recognized schemes where allowed (e.g., Commission-recognized voluntary schemes for RFNBO evidence). [4]
- Quantify sensitivities before equipment selection. Run CI sensitivity against grid intensity, methane leakage assumptions, capture rates, transport distance/mode, and load factors—then translate into "eligibility/not eligible" and NPV/IRR implications.
- Design for verification pathways, not just internal KPIs. Verification standards and third-party review requirements (seen across multiple schemes) mean "close enough" CI is often not financeable—only defensible, reproducible CI is.

SOURCE TRAIL: THE PRIMARY REFERENCES WORTH KEEPING CLOSE

EU primary texts: RED II (Directive 2018/2001) including the 94 gCO_2e/MJ comparator and biofuel sustainability framework. [37] RED III amending directive and timing. [8] FuelEU Maritime (Reg. 2023/1805) including reference intensity 91.16 gCO_2e/MJ and Annex II default factors. [38] CBAM (Reg. 2023/956) transitional and definitive dates. [12] EU Taxonomy hydrogen technical screening criterion. [13]

US primary texts: Federal Register final rule implementing 45V thresholds and effective date. **[39]**

UK/Japan/Korea reference thresholds: UK Low Carbon Hydrogen Standard. [16] Japan METI threshold framing for hydrogen (3.4 kg/kg) and ammonia (~0.87 kg/kg, well-to-gate; older strategy materials also cite 0.84 kg/kg with a different boundary). [21] Korea clean hydrogen certification threshold (4 $kgCO_2e/kg\ H_2$, well-to-gate). [22]

North America fuel CI schemes: Canada Clean Fuel Regulations CI limits table. **[17]** California LCFS benchmark tables and effective date. **[40]**

Peer-reviewed / research CI benchmarks: basin-specific blue H_2 variability. **[25]** Hydrogen lifecycle comparisons (grey/blue/green). **[41]** Conventional ammonia emissions intensity benchmarks. **[42]** PtL e-kerosene CI range. **[31]**

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