

Is Green Steel Within Reach in India?

Green DRI economics, policy drivers and site feasibility in Andhra Pradesh

FULL REPORT

transitionasia.org/storage/2026/09/TA_India_Report_Oct2026.pdf

OPEN-SOURCE MODEL

github.com/transition-asia/green-steel-dri-model



Concept illustration, AI-generated. Not a facility design.

A joint Transition Asia and TERI study

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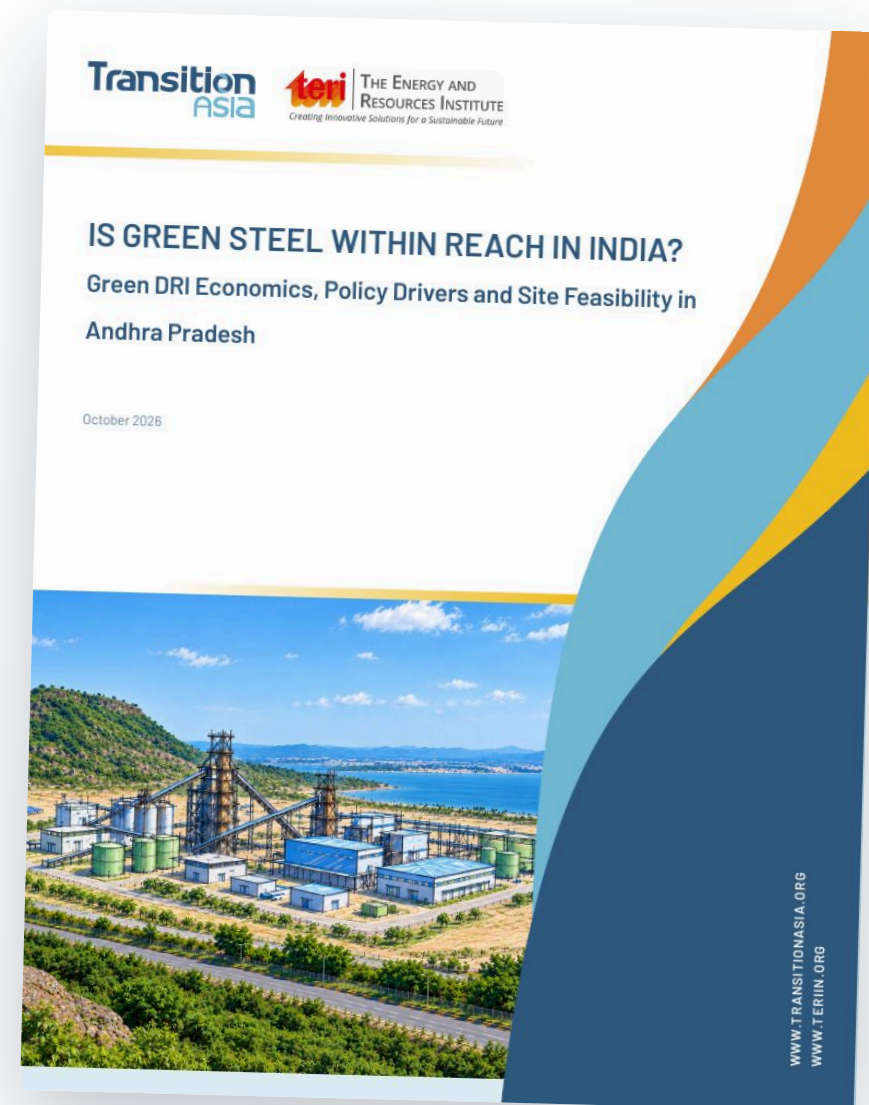
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India's steel emissions will be set by the capacity it has not yet built

42% of the world's steel capacity under development is in India¹

93% of planned ironmaking is coal-based². A blast furnace built now **emits into the 2060s**.

5% has started construction². **The route is still open.**

THE ANCHOR CASE

AM/NS India greenfield

Rajayyapeta, Anakapalli district, Andhra Pradesh

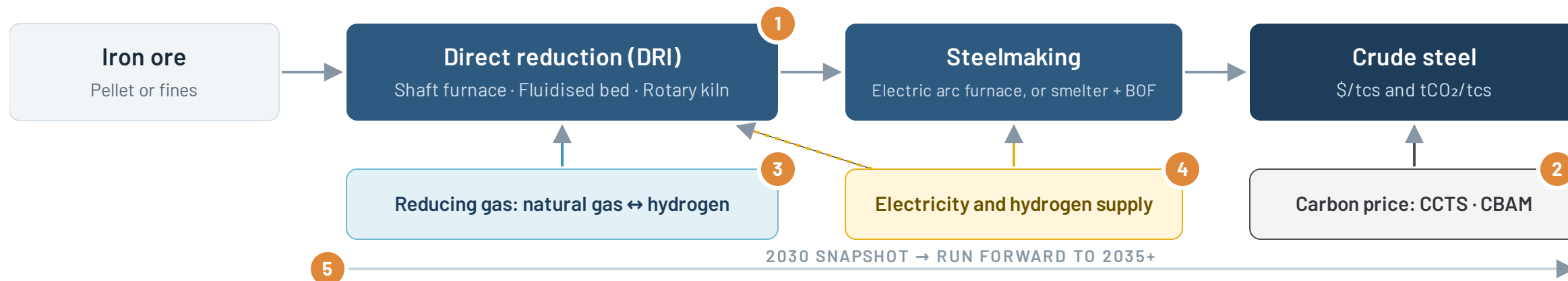
2029 ○ **Phase 1 starts production**
8.2 Mtpa, BF-BOF **LOCKED IN**

~2030 ● **Phase 2 decision**
9.6 Mtpa, no route yet

THIS REPORT

➔ **Why it matters beyond this site.** Every new primary plant in India's pipeline faces the same questions of ore, power, hydrogen and carbon. Phase 2 is an early, real test of the answers.

Five decision questions, asked along the value chain of one real plant



1

Technology choice

What does green steel cost by route, and against the blast furnace?

2

Carbon-price pressure

How much do India's CCTS, then the EU's CBAM, close the gap as they tighten?

3

The fuel choice

How do cost, emissions and risk move from natural gas to 100% hydrogen?

4

Power and hydrogen

How should the plant contract power, and should it make or buy hydrogen?

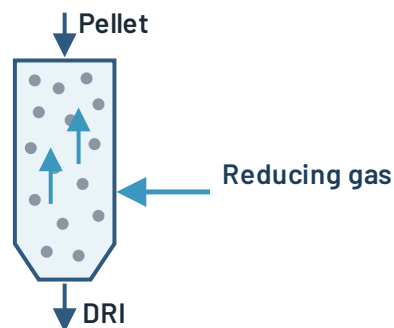
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The time dimension

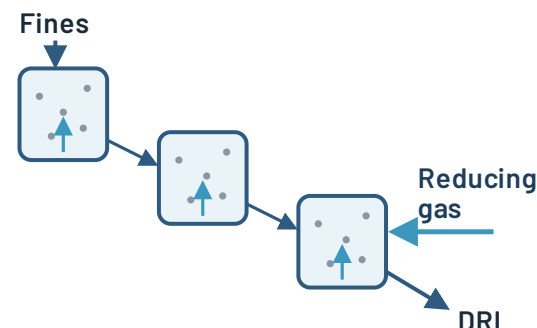
How do the answers shift as carbon prices rise and hydrogen gets cheaper?

Three direct-reduction reactors: the ore each one takes decides the rest of the plant

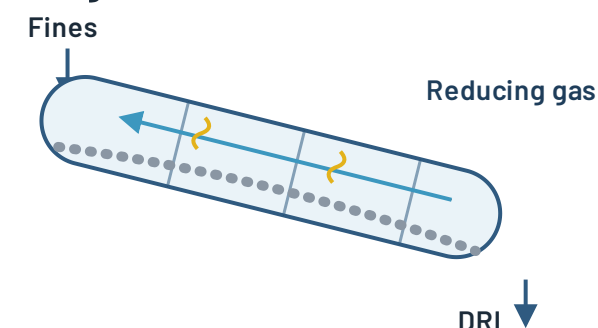
Shaft furnace



Fluidised bed



Rotary kiln



IRON FEED

Expensive high-grade pellet

Cheap low-grade fines, no pelletising

DOWNSTREAM
PLANT

Straight to an electric arc furnace (EAF)

An extra electric smelter (ESF), then a basic oxygen furnace (BOF)

Fines carry about 1/5 gangue: more power, more lime, added carbon

MATURITY

COMMERCIAL

PILOT

EARLY COMMERCIAL

Same chemistry, three vessels. All three run on hydrogen, natural gas or any blend. On natural gas alone they already emit about half the CO₂ of a BF-BOF.

A detailed, site-specific in-house model: process by process, hour by hour

OPEN-SOURCE MODEL



Process by process

Bottom-up engineering of every step, from iron ore to crude steel.



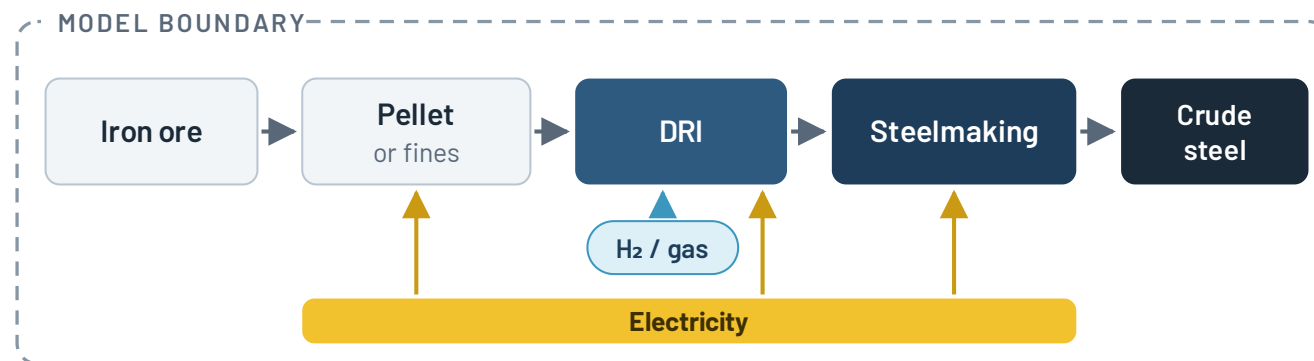
Hour by hour

Optimises how power is supplied, stored and dispatched in every hour of the year, at least cost.



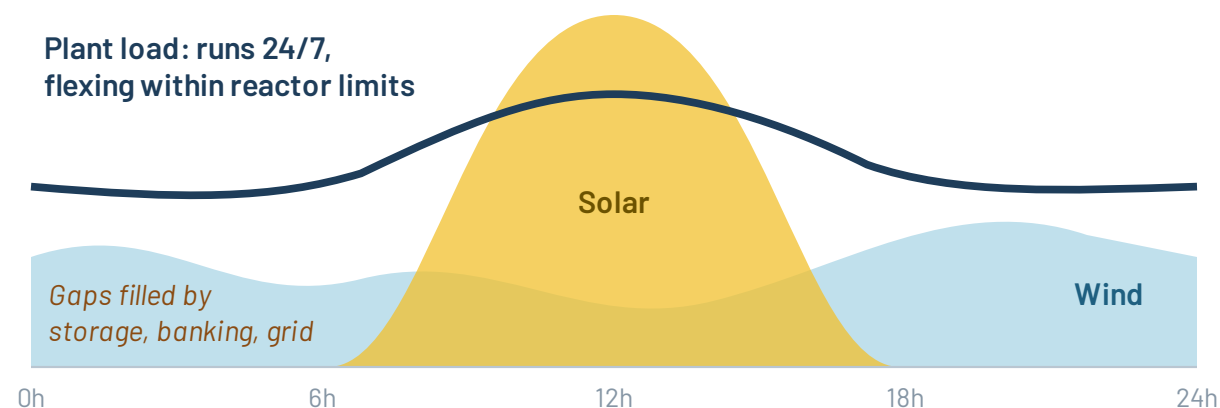
Built for this site's choices

- Power and hydrogen options
- Different policies



Compared with a new blast furnace: **\$536/tcs** and **2.6 tCO₂/tcs** (UC Berkeley, 2026)

ONE DAY AT THE PLANT *illustrative*



WHAT WE FOUND

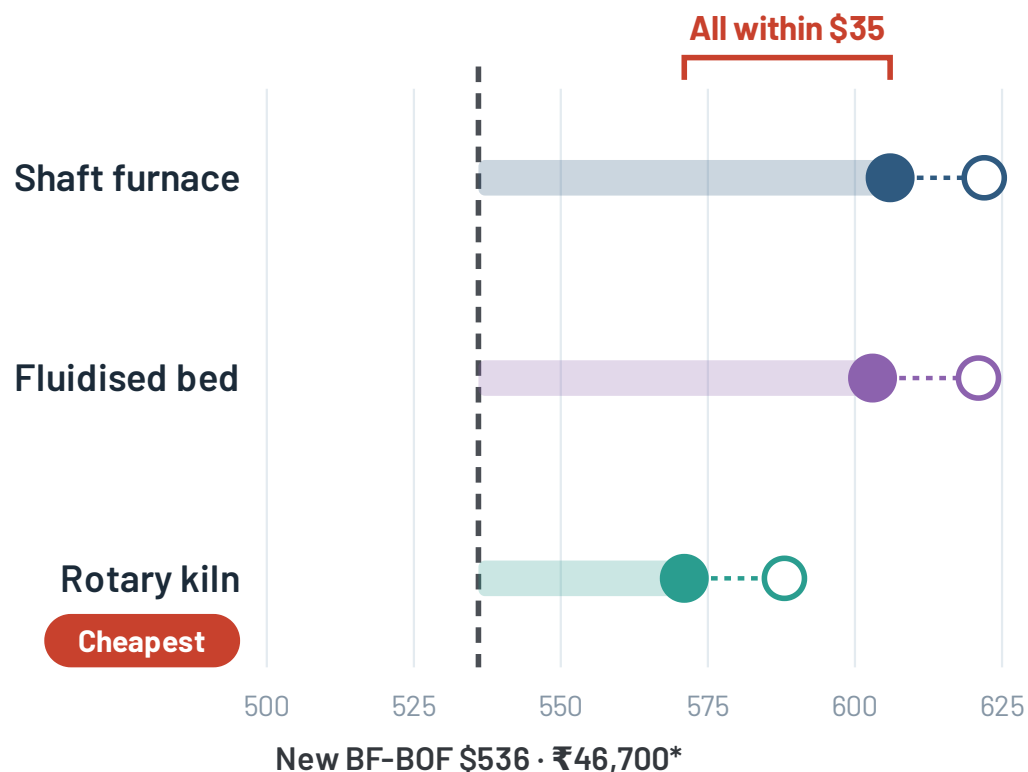
Six findings

Following the five questions; the time dimension runs through all of them.

- 1 Technology choice
- 2 India's carbon market
- 3 The EU border
- 4 The fuel choice
- 5 Buying power
- 6 Making or buying hydrogen

At 100% hydrogen, green steel costs 6–13% more than a new BF-BOF

Levelised cost, \$/tcs (2025 USD) ● 100% H₂, with support ○ without support



100% H₂ · \$ · ₹ · PREMIUM

\$606 ₹52,800 +13%
no support: \$622 · +16%

\$603 ₹52,600 +13%
no support: \$621 · +16%

\$571 ₹49,800 +6%
no support: \$588 · +10%

AT 100% GREEN HYDROGEN

\$571–606 /tcs
₹49,800–52,800/tcs

A 6–13% premium over a new BF-BOF, with India's hydrogen support:

- SIGHT production incentive, ₹50/40/30 per kg in years 1–3
- Andhra Pradesh's 25% capital subsidy on electrolyzers

SIGHT + electrolyser subsidy: **\$16–18/tcs**

SO CHOOSE THE ROUTE ON

Iron feed

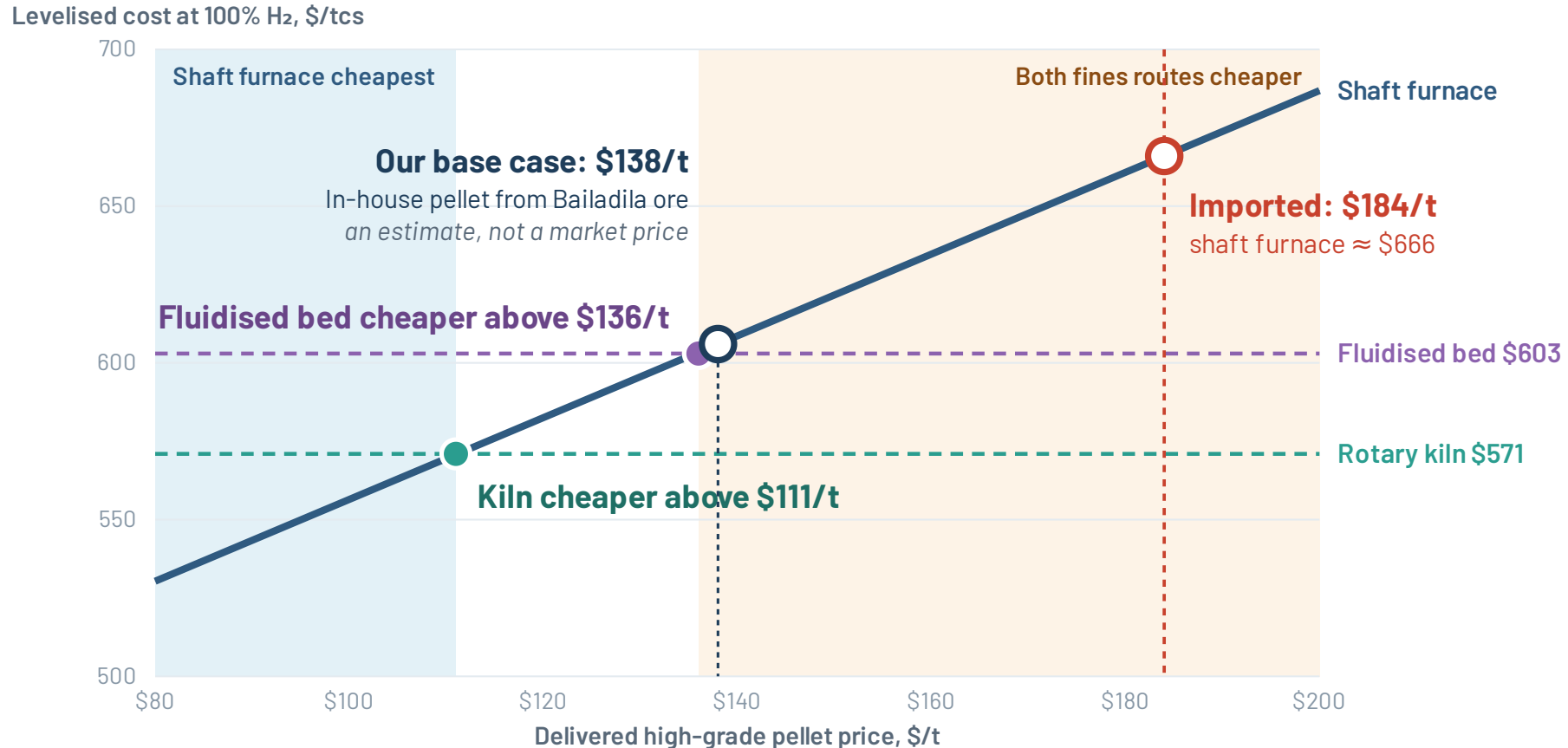
Emissions

Maturity

not headline cost

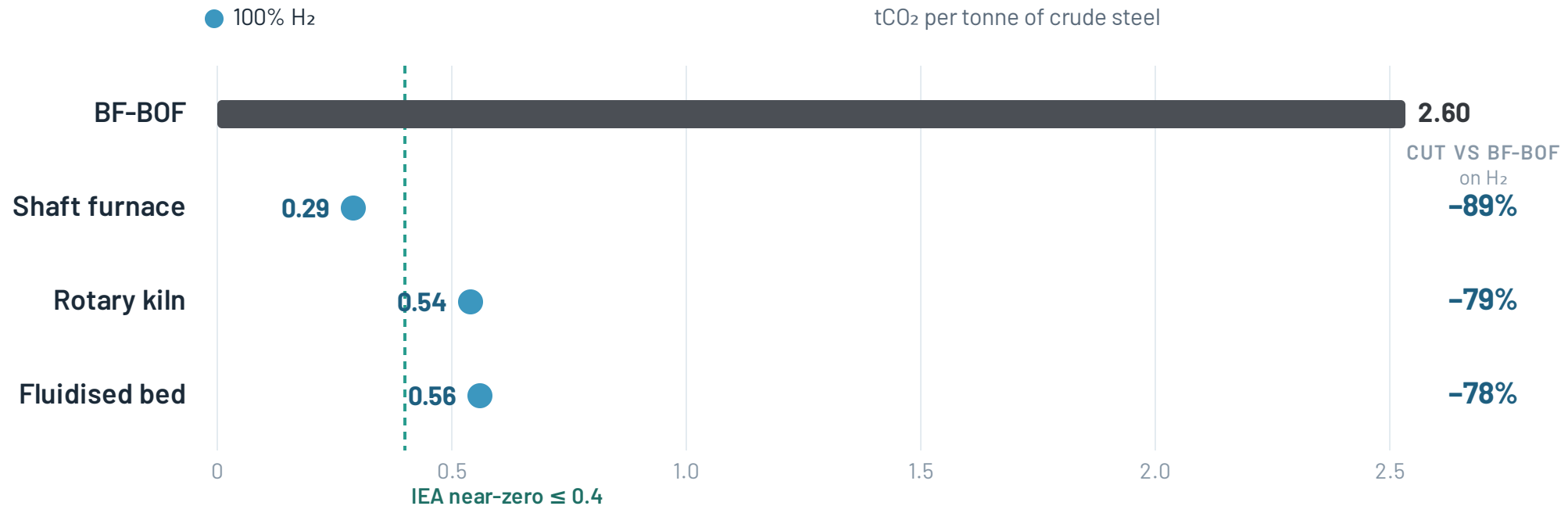
* BF-BOF comparator (\$536/tcs, 2.6 tCO₂/tcs): UC Berkeley (2026). Rupees at ₹87.16 per US dollar.
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The shaft furnace wins on cost only if its pellet is cheap



The shaft furnace's economic case rests on the **pellet price**.

On hydrogen, every route cuts emissions by at least three quarters



Why the fines routes sit higher

The smelter needs added carbon to make hot metal: about 0.2 tCO₂/tcs.

Near-zero needs clean power

On grid power alone, the hydrogen shaft furnace would emit about 2.2 tCO₂/tcs.

Cheapest, cleanest and most mature are three different reactors

	Shaft furnace	Fluidised bed	Rotary kiln
COST AT 100% H ₂	\$606/tcs	\$603/tcs	CHEAPEST \$571/tcs
EMISSIONS AT 100% H ₂	CLEANEST 0.29 tCO ₂ /tcs	0.56 tCO ₂ /tcs	0.54 tCO ₂ /tcs
MATURITY	MOST MATURE Proven at Phase 2 scale	Pilot	Early commercial; ~50 kilns needed
ROLE FOR PHASE 2	Build, designed for hydrogen	No lead on any test	Pilot on the site's own fines

WHAT WOULD SHIFT THE BALANCE

Pellet below \$111/t or a rising carbon price → favours the shaft furnace

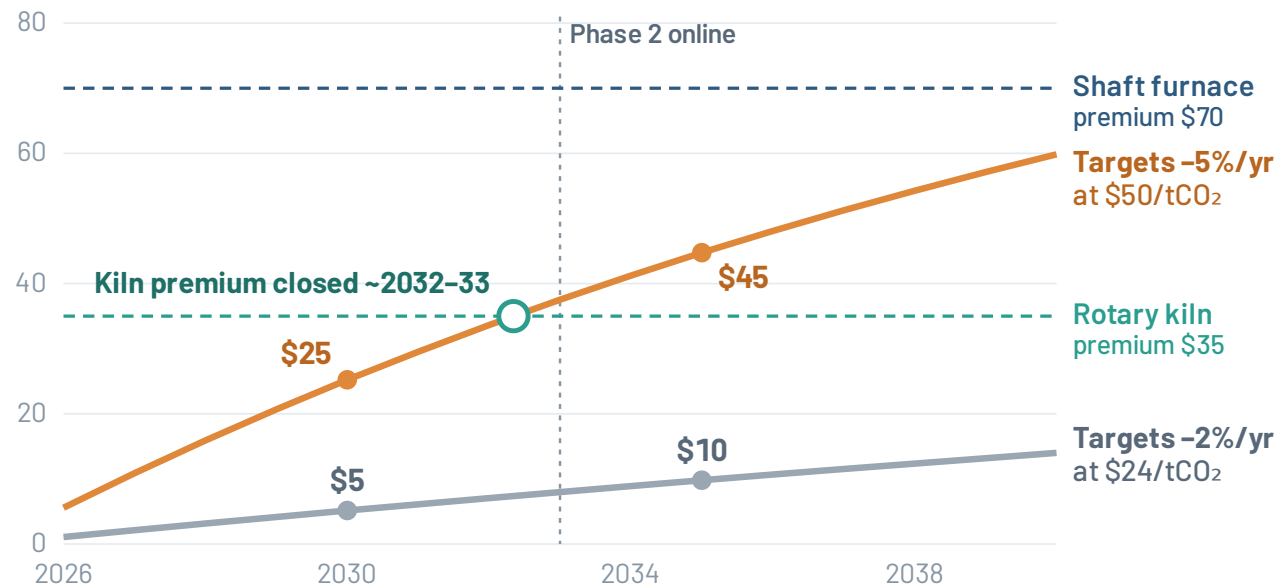
Cheaper fines reactors or higher-grade fines → favours the fines routes

OUR READING

Build Phase 2 on a **fuel-flexible shaft furnace designed for hydrogen**, and **pilot the rotary kiln** on the site's own fines.

India's Carbon Credit Trading Scheme (CCTS) narrows the gap through the pace of its targets

Value to a green plant, \$/tcs · lines: how fast BF-BOF targets tighten each year, and the carbon price



HOW IT HELPS A GREEN PLANT

Targets are set plant by plant from historical emissions. A new green plant sits **outside the scheme** in its first years, so we count **no** credit for it. Its gain is the **certificate cost** the BF-BOFs carry as their targets tighten.

WORTH BY 2035

\$10–45 /tcs

The **pace of the targets** matters more than the price, but **no long-term path** has been published.

OUTLOOK

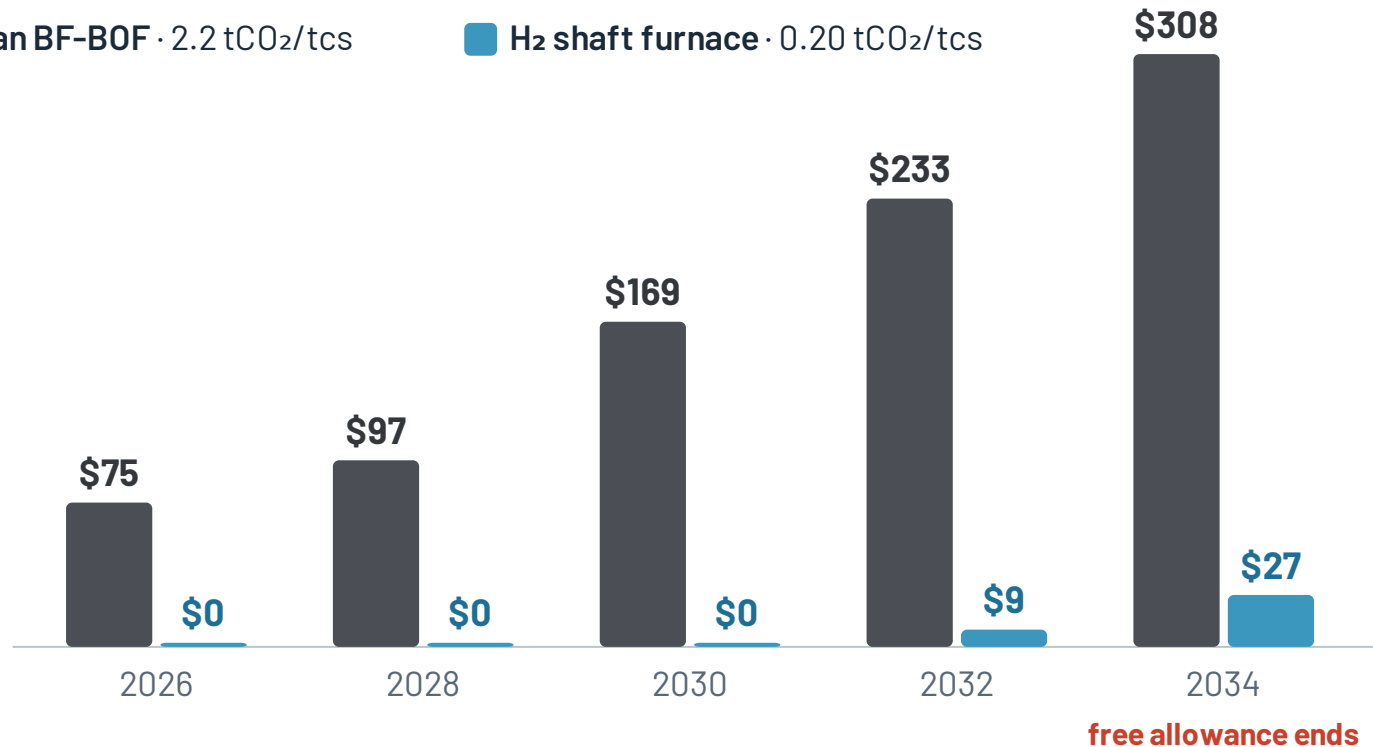
The current design offers a greenfield green plant **little direct incentive**. A common emission-intensity threshold would reward such a plant directly: at **1.6 tCO₂/tcs**, a price of **\$25–50/tCO₂** would **cover the whole premium**.

The EU border favours green steel, but only on exported tonnes

EU border charge (CBAM), \$ per tonne of steel · emissions on the CBAM boundary

Indian BF-BOF · 2.2 tCO₂/tcs

H₂ shaft furnace · 0.20 tCO₂/tcs



LANDED IN THE EU AT COMMISSIONING, 2033

\$179–209 /tcs cheaper
than Indian blast-furnace steel

But India exports only **3–5%** of its steel, and the EU import quota does not tell green from conventional.

The border supports the case; the domestic market must carry it.

FOR AM/NS

Report Phase 2 as **its own installation**. Blended with Phase 1, its 2034 charge rises from **\$27 to ~\$155/t**.

Why not start on gas? India does not have the gas to spare

3–4% of India's entire gas use would go to **this one plant**, if Phase 2 ran on natural gas

All imported LNG

Domestic gas goes to city gas and fertiliser, not steel.

None built since 1994

No greenfield gas-based DRI plant in India, for want of gas.

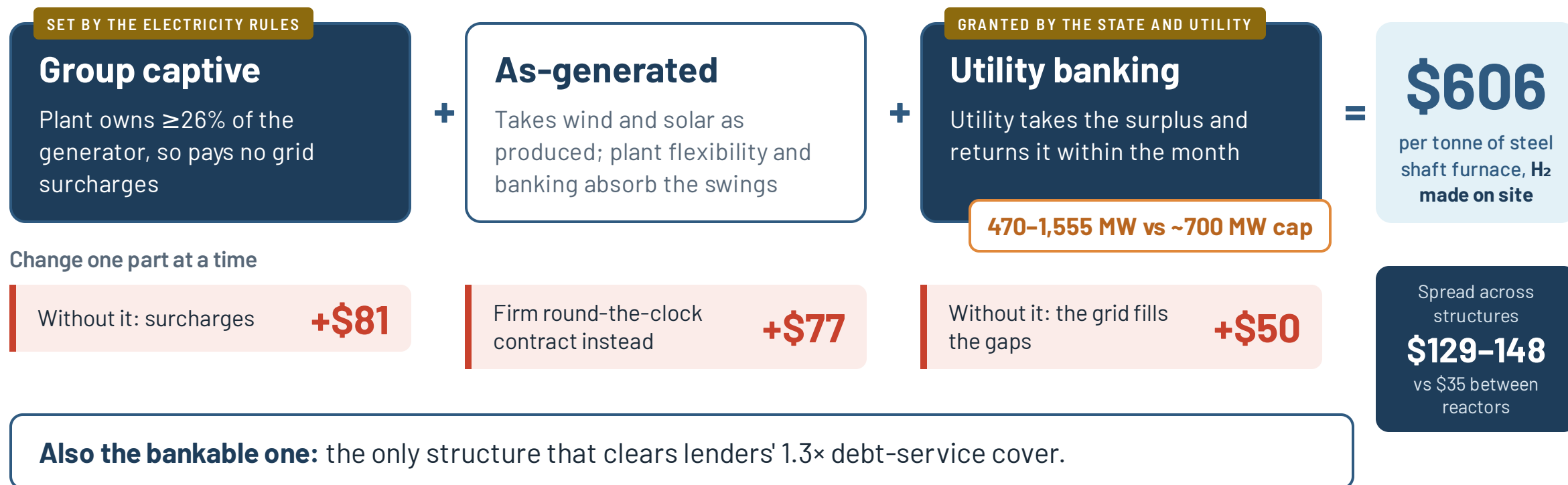
Supply shocks bite

AM/NS India's output fell ~13% in the 2022 LNG spike; the 2026 Hormuz crisis halted Qatar's exports.

DESIGN FOR HYDROGEN FROM DAY ONE

Gas is **insurance on timing**, not the plan. Hydrogen supply, whether made on site or bought from the hub, has to be lined up **before the plant is built**.

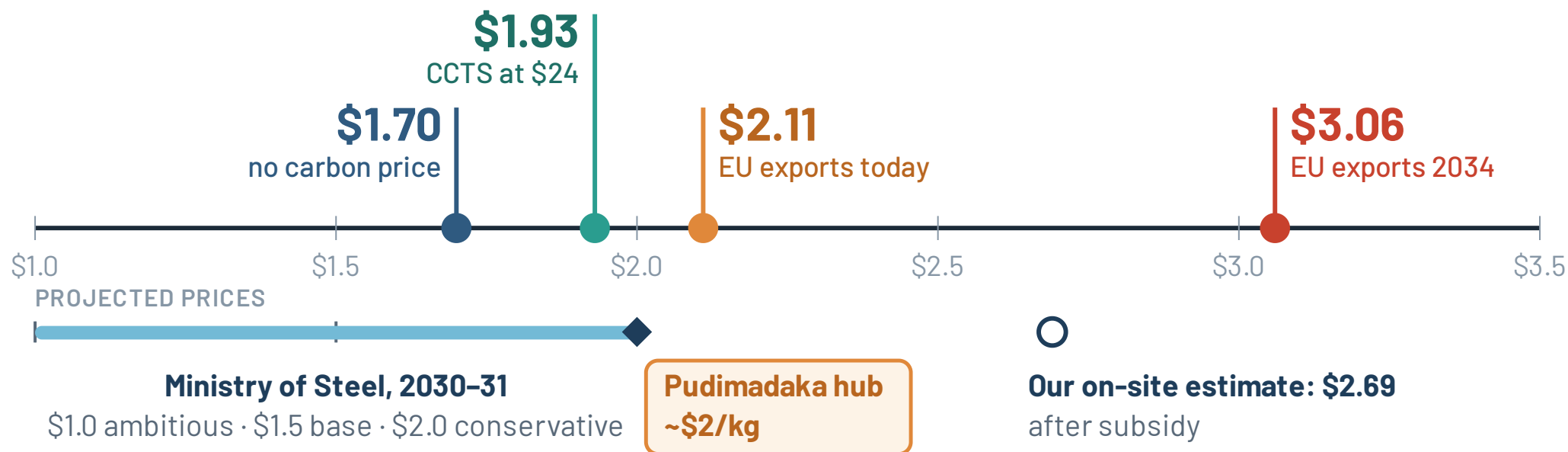
How the plant buys its power moves the cost more than the choice of reactor



Group-captive status and banking need to be secured before the investment decision.

What hydrogen must cost to beat gas: the hub at ~\$2/kg comes close, on-site at \$2.69 does not yet

Delivered green hydrogen, \$/kg · hydrogen beats gas below each threshold



PUTTING IT TOGETHER

What it means

What decides the outcome, what each actor can do, and when.

- 1 What decides the outcome
- 2 What to do
- 3 The decision calendar

Three conditions outside the plant fence

1

Carbon-market targets and price

\$10–45 /tcs by 2035

Depends on how fast targets tighten on the highest emitters.

2

BEST OPTION

Hydrogen hub delivery

~\$2/kg by 2032

With Phase 2's 1,200 t/day offtake secured. Also cuts the banking need to **~470 MW**.

3

NEEDED EITHER WAY

The energy-banking envelope

470–1,555 MW needed

~470 MW with hub hydrogen, ~1,555 MW made on site, against **~700 MW** state-wide.

Each moves the cost of steel more than the reactor.
None is in the steelmaker's hands alone.

Three actors, and what each can do now

AM/NS India

- Commit Phase 2 to a **fuel-flexible shaft furnace designed for hydrogen**; pilot the kiln
- Register Phase 2 as its **own CBAM installation**
- Secure **group-captive power and banking** before the investment decision
- Protect the **captive pellet** supply

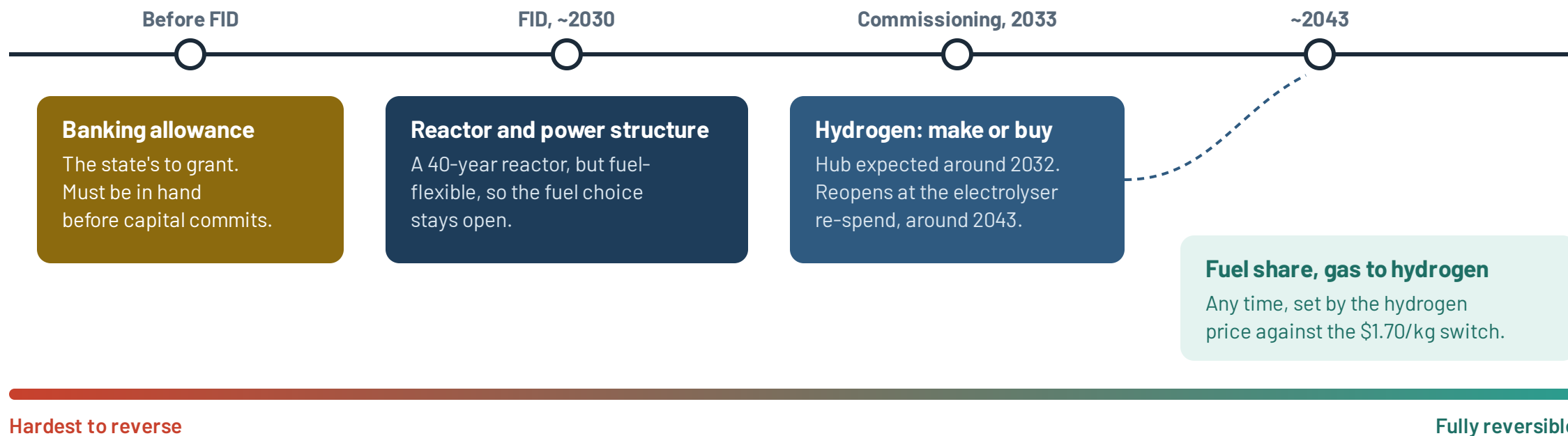
Policymakers

- Publish a **long-term path** for carbon-market targets
- Turn the Green Steel Taxonomy into **demand** through procurement
- **Expand the banking envelope**, or support storage
- Deliver the **hub near \$2/kg by 2032**

Financiers

- Underwrite on **debt cover**, not levelised cost
- Steel price for 1.3× cover: **\$590** with hub hydrogen, **\$692** on open access
- Price the **stranding risk** of another blast furnace: a \$308/t border charge by 2034

Decide in order of irreversibility: the concessions bind hardest, not the vessel



IS GREEN STEEL WITHIN REACH IN INDIA?

Yes. The gap is 6–13%, and what closes it sits outside the plant fence.

The pace of the carbon market's targets, the hydrogen hub and the state's banking envelope each move the cost of steel more than the choice of reactor.

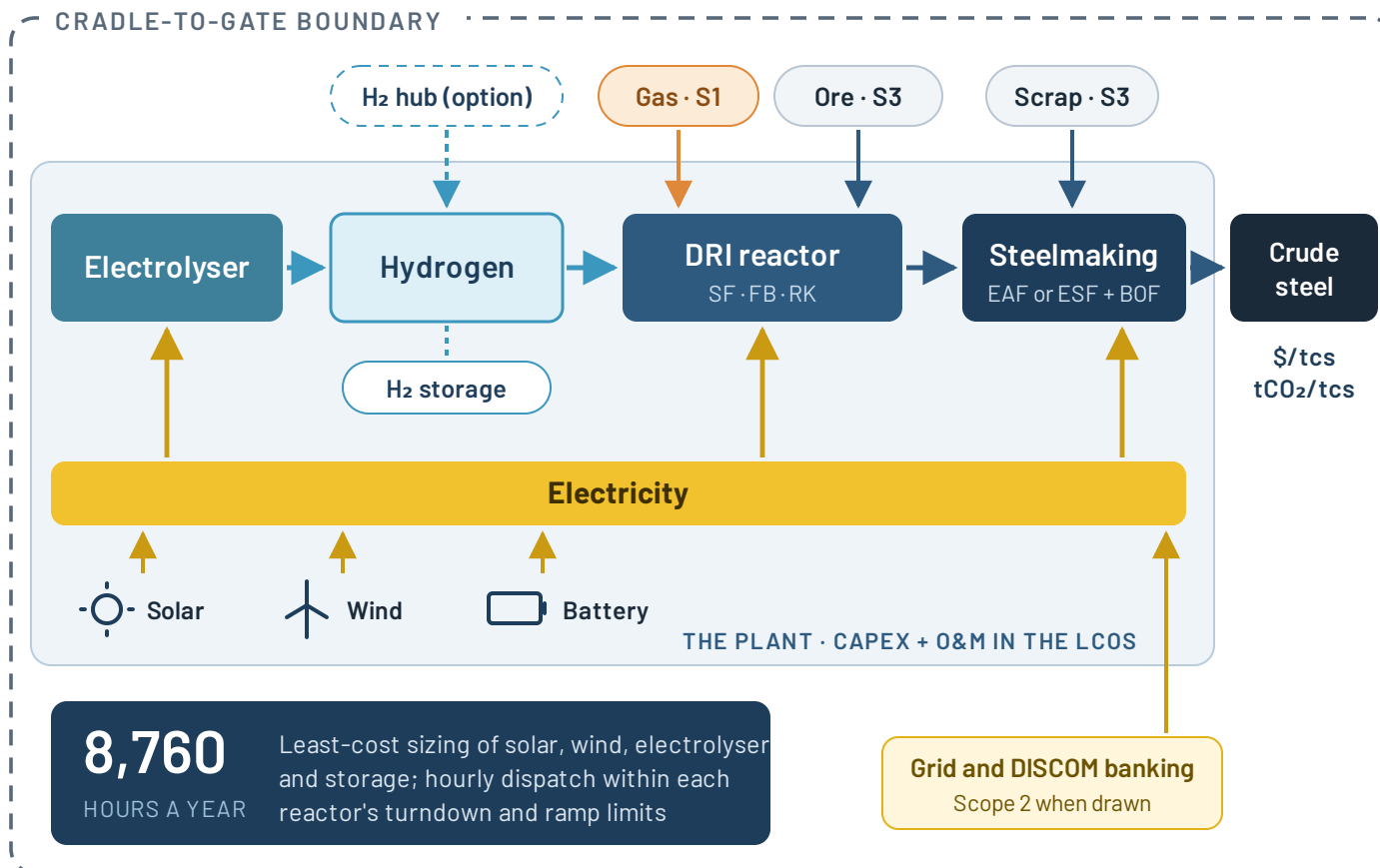
Thank you

Transition
ASIA



Full report, model,
inputs and results

Boundary and base case: a cradle-to-gate levelised cost from an hourly least-cost plant model

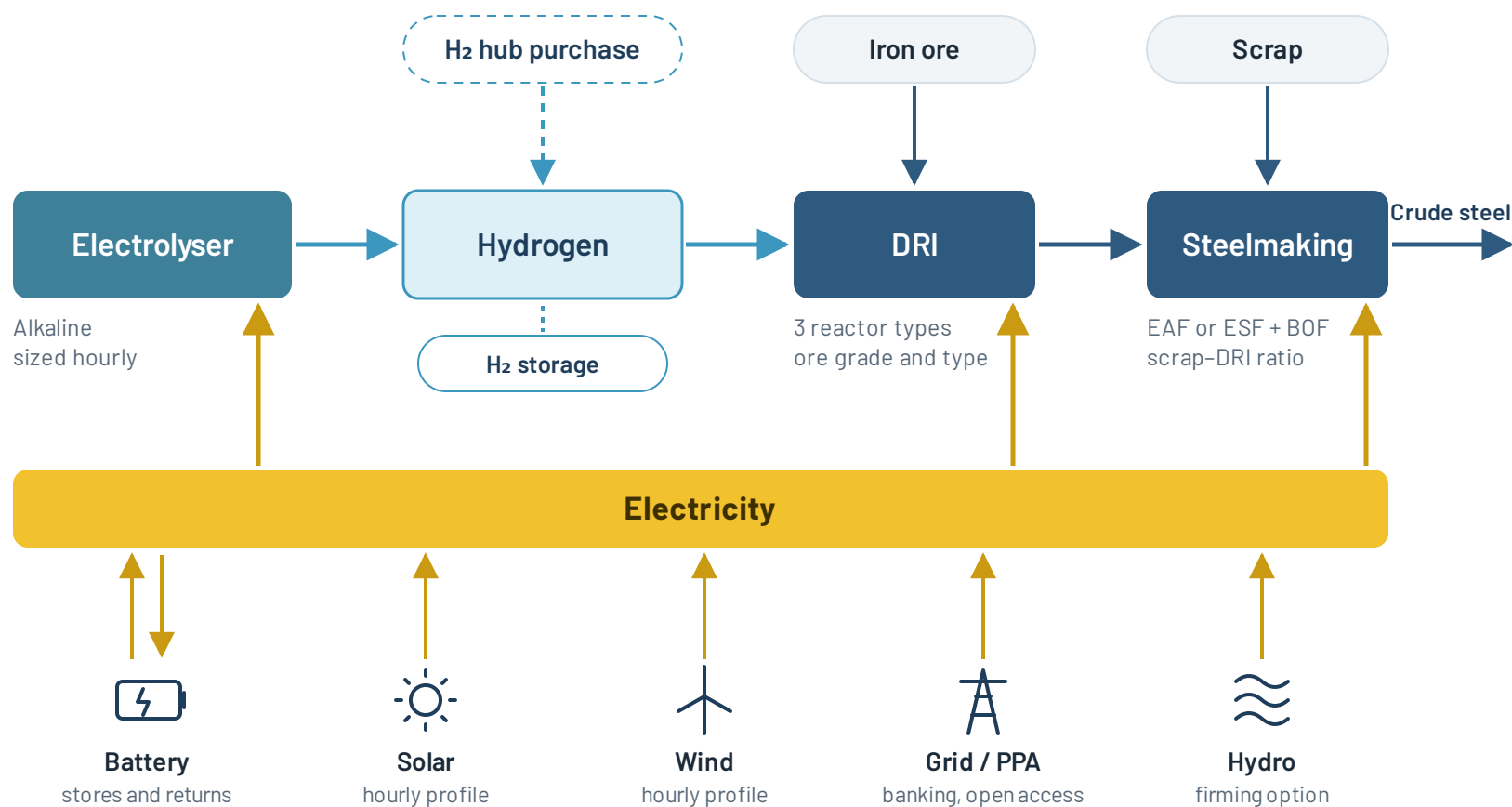


S1 combustion at the plant · S2 purchased power · S3 embedded in purchased materials

BF-BOF comparator (\$536/tcs, 2.6 tCO₂/tcs): UC Berkeley (2026).
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METRIC	LCOS, \$/tcs in 2025 USD: capital and operating cost over each asset's life, per tonne of crude steel
PLANT	9.6 Mtpa at 85% · 2030 decision · 10% WACC
CASES	3 routes × 4 fuels: 100% gas, 30% and 70% H ₂ , 100% H ₂ ■ ■ ■ ■
POWER	Group-captive solar-wind, banked with the DISCOM: ≈\$0.044/kWh
HYDROGEN	Made on site: alkaline electrolysis at \$394/kW after state subsidy, plus SIGHT in years 1–3
CARBON	\$0/tCO ₂ in the base case · CCTS and CBAM added later
COMPARATOR	Greenfield BF-BOF, Phase 1 design: \$536/tcs, 2.6 tCO ₂ /tcs

A process-based model of the whole plant, from power supply to crude steel



THE ENGINE

8,760 hours a year

- Sizes solar, wind, electrolyzers, batteries and H₂ storage at least cost
- Dispatches every hour within each reactor's turndown and ramp limits
- Meets an emission-intensity cap; draws grid when renewables fall short
- Buy-in cases (hub H₂, contracted power) take the contract price

— OUTPUTS PER CASE

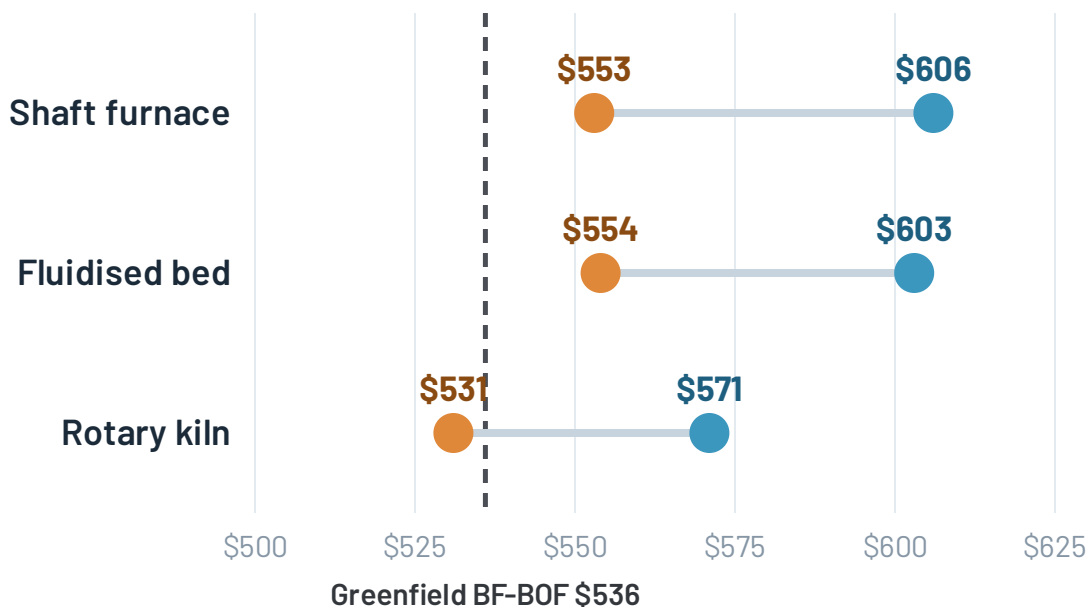
Levelised cost, \$/tcs, and **emission intensity**, tCO₂/tcs, for every route and fuel mix on the site's real ore, tariffs and policy.

— BACKUP · NATURAL GAS IN THE SAME REACTORS

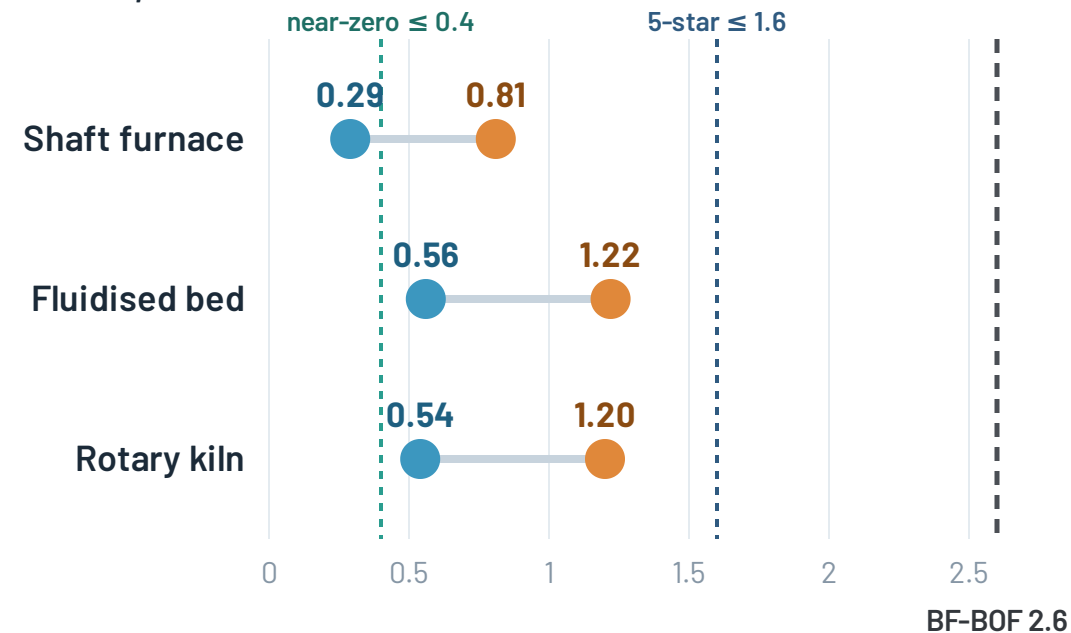
On natural gas, the same reactors match a greenfield BF-BOF on cost, but not on emissions

● 100% natural gas ● 100% green hydrogen

Cost, \$/tcs



Emissions, tCO₂/tcs



On gas: **\$40–53/tcs cheaper** than on hydrogen

Natural gas buys **cheaper** but **higher-emission** steel.

Buying hydrogen from the hub is the biggest lever in the plant's own hands, if the hub delivers

	MAKE ON SITE		BUY FROM THE HUB at \$2/kg	
Cost of steel shaft furnace, \$/tcs	\$606	→	\$578	-\$28/tcs
Project debt	\$6.1 bn	→	\$5.3 bn	-\$1.2 bn of electrolyser capital
Minimum debt cover	1.65×	→	1.93×	lenders need 1.3×
Steel price for 1.3× cover \$/tcs	\$611	→	\$590	-\$21/tcs

ROTARY KILN ON HUB HYDROGEN

\$541 /tcs

within \$5 of a greenfield BF-BOF

THE CONDITION IS DELIVERY

- Phase 2 needs about **1,200 t of hydrogen a day**, 80% of the hub's planned output.
- Needs an offtake written into the hub's build-out.

How the power structure works, and what each alternative costs

Group captive

saves \$81/tcs

Under the Electricity Rules 2005 (amended March 2026), the plant holds **≥26% of the equity** in the vehicle that owns the generation and consumes **≥51% of its output**. In return it is exempt from the cross-subsidy and additional surcharges (\$0.019/kWh, about \$660 m a year); it still pays wheeling. The 2026 amendment lets the equity sit anywhere in the corporate group. The equity (~\$0.8 bn) sits outside the plant.

As-generated power

saves \$77/tcs

The plant takes a wind-solar portfolio as it is produced and absorbs the swings with the flexibility of its electrolyzers, reactor and hydrogen storage. A firm round-the-clock contract at ₹5.06/kWh costs 66% more than solar (₹3.05) and 38% more than wind (₹3.66).

Utility banking

saves \$50/tcs

The distribution utility takes surplus power when it is injected and returns it within the month: **92% returned** (8% charge in kind), monthly settlement, no carry-forward. It acts as a free month-long battery, but is not storage. The AP Integrated Clean Energy Policy 2024 caps banking at **5% of state peak demand, ~700 MW**, shared by all open-access users. Phase 2 would bank ~1,555 MW on average; ~470 MW if it buys hub hydrogen.

Power structure	Power \$/kWh	Steel SF, \$/tcs	CO ₂ t/tcs	Min debt cover
Group captive, as-generated, banked	0.044	606	0.29	1.65×
Group captive, as-generated, no banking	0.053	656	0.73	1.23×
Group captive, firm round-the-clock	0.064	683	0.29	–
Self-build: own solar, wind, storage	0.047	653	0.49	1.25×
Third-party open access, banked	0.064	687	0.29	0.92×
Third-party open access, no banking	0.072	735	0.75	–

Self-build buys independence: it needs neither the surcharge exemption nor banking. But it needs **\$14.4 bn of debt** against \$6.1 bn, and a steel price of **\$662/tcs** for lenders' 1.3× cover, against \$611.