

Supplementary Information: A settlement currency to finance climate restoration and human prosperity

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Supplementary Note 1 | Evidence classes and the 89-module registry

The Planetary Restoration framework registers 89 modules spanning climate, carbon removal, ocean and land restoration, food, water, health, justice, education, housing, robotics, energy, transport, finance and governance (Supplementary Table 1). Each module carries one evidence class: externally executed, legacy mechanistic, literature screen, engineering scenario, policy scenario, service-capacity scenario, diagnostic only or open science gate. Supplementary Table 1 also states each module's role in this Article: executed here with FaIR by Supplementary Code 1, input to that run, quantified as a screen, described but not costed, registered only, or not used. Hector, OSCAR and paired removal-on/off attribution modules belong to related archived work and are not used in this Article. No result inherits validation across evidence classes. No global solar radiation modification enters the climate pathway; regional marine cloud brightening is evaluated only as a local reef-cooling sensitivity in the coral screen (Supplementary Note 9).

Supplementary Note 2 | FaIR restoration pathway and inverse CDR requirements

The pathway is computed with FaIR 2.2.4 and all 841 calibrated-constrained configurations of fair-calibrate 1.4.1 (main-text refs 8,9) from the archived carbon trajectory D10 (Methods). Every configuration is forced after 2026 to the ensemble-median non-CO₂ effective radiative forcing of a no-removal run; the harmonization converged to $6.7 \times 10^{-8} \text{ W m}^{-2}$ for the canonical schedule and below $2 \times 10^{-8} \text{ W m}^{-2}$ at each inverse solution. After 2183 the residual sources are held at 2.39 GtCO₂ yr⁻¹ and deliberate removal at a constant rate solved by bisection. Run with the 2183 removal rate (5.28 GtCO₂ yr⁻¹) held constant, the same code reproduces the archived FaIR run of this schedule (github.com/bcjohnjr/Planetary-Restoration-Version-62.2, commit 89a0f4a, fair_matched_timeseries_run12.csv) to 0.0 ppm and 0.0 °C at every year to 2300; that schedule reaches 303 ppm (median) in 2300, which is why a higher post-2183 rate is needed for 280 ppm.

Supplementary Table 2 | Restoration-pathway milestones, FaIR 2.2.4, 841 configurations, post-2183 removal 9.49 GtCO₂ yr⁻¹ (no global solar radiation modification).

Milestone	Median (5–95%)	Year
CO ₂ peak	435.6 ppm (431.2–438.7)	2034
CO ₂ below 400 ppm (median)		2057
CO ₂ below 350 ppm (median)		2105
CO ₂ below 300 ppm (median)		2219
CO ₂ in 2300	280.0 ppm (275.7–283.9)	2300
Warming peak	1.67 °C (1.22–2.22)	2051
Warming below 1.5 °C after peak (median)		2112
Warming below 1.0 °C after peak (median)		2230
Warming in 2300	0.75 °C (0.40–1.35)	2300

Supplementary Table 3 | Constant post-2183 CDR at which the FaIR ensemble median reaches 280 ppm (inverse solves, Supplementary Code 1).

Target year	Post-2183 CDR (GtCO ₂)	Median CO ₂ in target	5–95% (ppm)	Configurations at or
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	yr ⁻¹)	year (ppm)		below 280 ppm
2200	31.48	280.01	276.8–283.3	420 of 841
2300	9.49	280.00	275.7–283.9	420 of 841
2400	7.02	280.00	275.6–283.9	420 of 841

Bringing the target forward from 2300 to 2200 raises the required post-2183 removal from 9.49 to 31.5 GtCO₂ yr⁻¹; deferring it to 2400 lowers it to 7.02 GtCO₂ yr⁻¹. Because each solution targets the ensemble median, about half of the configurations remain above 280 ppm in the target year. The solutions are specific to FaIR's carbon cycle and to the matched non-CO₂ forcing; repetition in other carbon-cycle models is an open step. Ocean pH recovery is coupled to the CO₂ decline, but no threshold year is claimed.

Supplementary Note 3 | CDR cost, revenue required and fee elasticity

Supplementary Table 4 | Annual CDR cost and share of the reference envelope (full adoption US\$6.96 tn yr⁻¹; U.S. out US\$5.07 tn yr⁻¹).

Envelope	CDR case	GtCO ₂ yr ⁻¹	US\$ tCO ₂ ⁻¹	CDR cost (US\$ tn yr ⁻¹)	Share of envelope	Within envelope
Full adoption	280 ppm by 2400	7.02	100	0.70	10%	yes
Full adoption	280 ppm by 2400	7.02	200	1.40	20%	yes
Full adoption	280 ppm by 2400	7.02	400	2.81	40%	yes
Full adoption	280 ppm by 2300	9.49	100	0.95	14%	yes
Full adoption	280 ppm by 2300	9.49	200	1.90	27%	yes
Full adoption	280 ppm by 2300	9.49	400	3.80	55%	yes
Full adoption	Peak removal 2043-2153	15.20	100	1.52	22%	yes
Full adoption	Peak removal 2043-2153	15.20	200	3.04	44%	yes
Full adoption	Peak removal 2043-2153	15.20	400	6.08	87%	yes
Full adoption	280 ppm by 2200	31.48	100	3.15	45%	yes
Full adoption	280 ppm by 2200	31.48	200	6.30	90%	yes
Full adoption	280 ppm by 2200	31.48	400	12.59	181%	no
U.S. out, 90% RoW	280 ppm by 2400	7.02	100	0.70	14%	yes
U.S. out, 90% RoW	280 ppm by 2400	7.02	200	1.40	28%	yes
U.S. out, 90% RoW	280 ppm by 2400	7.02	400	2.81	55%	yes
U.S. out, 90% RoW	280 ppm by 2300	9.49	100	0.95	19%	yes
U.S. out, 90% RoW	280 ppm by 2300	9.49	200	1.90	37%	yes
U.S. out, 90% RoW	280 ppm by 2300	9.49	400	3.80	75%	yes
U.S. out, 90% RoW	Peak removal 2043-2153	15.20	100	1.52	30%	yes

U.S. out, 90% RoW	Peak removal 2043-2153	15.20	200	3.04	60%	yes
U.S. out, 90% RoW	Peak removal 2043-2153	15.20	400	6.08	120%	no
U.S. out, 90% RoW	280 ppm by 2200	31.48	100	3.15	62%	yes
U.S. out, 90% RoW	280 ppm by 2200	31.48	200	6.30	124%	no
U.S. out, 90% RoW	280 ppm by 2200	31.48	400	12.59	248%	no

The reference envelope is a scale anchor, not an estimate of revenue. Supplementary Table 5 therefore inverts the question: for each requirement, it gives the effective fee on global foreign-exchange turnover (US\$9.5 trillion per day $\times$ 252 trading days = US\$2,394 trillion yr^{-1} ; main-text ref. 7) that would raise it at a given adoption share, with no fee-driven loss of volume. Supplementary Table 6 adds that loss. If settled volume is $aB_0 \exp(-\eta f)$, with f in basis points, revenue cannot exceed $aB_0 \times 10^{-4}/(\eta f)$, reached at $f = 1/\eta$. A requirement is attainable only below a critical η ; at full adoption this is 2.9% per basis point for CDR (2300 target) + hunger + Gavi, 1.3% for the reference envelope and 0.7% for a tier that adds universal health care at the full allowance with the central robot-doctor multiplier. The semi-elasticities are illustrative; no settlement-fee elasticity has been measured, and foreign-exchange turnover is a transparent base, not a claim that all of it is taxable settlement.

Supplementary Table 5 | Effective fee (basis points of settled foreign-exchange turnover) needed to raise each annual requirement, with no volume response. CDR at US\$200 tCO_2^{-1} , 2300-target maintenance.

Requirement	US\$ tn yr^{-1}	25% adoption (bp)	50% adoption (bp)	75% adoption (bp)	100% adoption (bp)
CDR (2300 target) + hunger + Gavi	3.06	51.2	25.6	17.1	12.8
Reference envelope	6.96	116.3	58.2	38.8	29.1
+ universal health care, full allowance, robot doctor central	12.26	204.9	102.4	68.3	51.2

Supplementary Table 6 | Revenue ceiling when settled volume falls exponentially with the fee, and whether each requirement (US\$ tn yr^{-1}) is attainable.

η (% volume per bp)	Adoption	Revenue-maximizing fee (bp)	Maximum revenue (US\$ tn yr^{-1})	CDR + hunger + Gavi (3.06)	Reference envelope (6.96)	+ UHC, full allowance (12.26)
0.5	25%	200	4.40	yes	no	no
0.5	50%	200	8.81	yes	yes	no
0.5	75%	200	13.21	yes	yes	yes
0.5	100%	200	17.61	yes	yes	yes
1	25%	100	2.20	no	no	no
1	50%	100	4.40	yes	no	no
1	75%	100	6.61	yes	no	no
1	100%	100	8.81	yes	yes	no
2	25%	50	1.10	no	no	no
2	50%	50	2.20	no	no	no
2	75%	50	3.30	yes	no	no
2	100%	50	4.40	yes	no	no
5	25%	20	0.44	no	no	no
5	50%	20	0.88	no	no	no
5	75%	20	1.32	no	no	no
5	100%	20	1.76	no	no	no

Supplementary Note 4 | Allocation ledger

Supplementary Table 7 | Carbonite allocation ledger (US\$ trillion yr⁻¹). Health coverage is the residual after CDR, food and vaccines divided by the capacity-adjusted need at US\$2,500 per uncovered person. A negative residual means the commitments exceed the envelope.

Envelope	CDR period	US\$ tCO ₂ ⁻¹	Residual after CDR	Food share of residual	Residual after food + vaccines	Health coverage, no AI	Robot doctor central	Robot doctor high
Full adoption	Post-2183 maintenance	100	6.01	19%	4.85	42%	53%	63%
Full adoption	Post-2183 maintenance	200	5.06	23%	3.90	34%	42%	51%
Full adoption	Post-2183 maintenance	400	3.16	37%	2.00	17%	22%	26%
Full adoption	Peak removal 2043-2153	100	5.44	21%	4.28	37%	46%	56%
Full adoption	Peak removal 2043-2153	200	3.92	30%	2.76	24%	30%	36%
Full adoption	Peak removal 2043-2153	400	0.88	132%	-0.28	0%	0%	0%
U.S. out	Post-2183 maintenance	100	4.13	28%	2.96	26%	32%	39%
U.S. out	Post-2183 maintenance	200	3.18	37%	2.01	18%	22%	26%
U.S. out	Post-2183 maintenance	400	1.28	91%	0.11	1%	1%	1%
U.S. out	Peak removal 2043-2153	100	3.55	33%	2.39	21%	26%	31%
U.S. out	Peak removal 2043-2153	200	2.03	57%	0.87	8%	9%	11%
U.S. out	Peak removal 2043-2153	400	-1.01	n/a	-2.17	0%	0%	0%

Supplementary Note 5 | Hunger and diet pathways

Supplementary Table 8 | Coverage of the full-allowance hunger screen (US\$1.161 trillion yr⁻¹) by allocation share, CDR at US\$200 tCO₂⁻¹.

Share of residual to food	Full adoption, Peak removal 2043-2153	Full adoption, Post-2183 maintenance	U.S. out, Peak removal 2043-2153	U.S. out, Post-2183 maintenance
10%	0.34×	0.44×	0.18×	0.27×
20%	0.68×	0.87×	0.35×	0.55×
25%	0.84×	1.09×	0.44×	0.68×
30%	1.01×	1.31×	0.53×	0.82×

35%	1.18×	1.53×	0.61×	0.96×
40%	1.35×	1.74×	0.70×	1.09×
50%	1.69×	2.18×	0.88×	1.37×

Supplementary Table 9 | Share of the post-CDR residual needed to end hunger, by cost basis (645 million people; CDR at US\$200 tCO₂⁻¹).

Cost basis	Full adoption, Peak removal 2043-2153	Full adoption, Post-2183 maintenance	U.S. out, Peak removal 2043-2153	U.S. out, Post-2183 maintenance
US\$300 person ⁻¹ yr ⁻¹	4.9%	3.8%	9.5%	6.1%
US\$600 person ⁻¹ yr ⁻¹	9.9%	7.6%	19.0%	12.2%
US\$1,200 person ⁻¹ yr ⁻¹	19.7%	15.3%	38.0%	24.4%
US\$1,800 person ⁻¹ yr ⁻¹	29.6%	22.9%	57.1%	36.6%
Ceres2030 incremental (US\$33 bn yr ⁻¹)	0.8%	0.7%	1.6%	1.0%

A full food allowance is an upper bound on the public cost of ending hunger, because most people facing hunger already obtain part of their diet; the Ceres2030 estimate (main-text ref. 10) is additional public spending by donors and low-income countries. If financing and delivery succeed, the archived framework retains a 2031–2036 window for near-universal food security; this rollout window is a policy-deployment sensitivity, not a forecast. Food-security screens retain an optimized omnivore pathway including meat, a mixed pathway and a vegetarian-plus-dairy/eggs-plus-aquatic-foods pathway; the framework does not require eliminating meat. Food-waste recovery, regenerative agriculture, agricultural robotics and edible seaweed streams are registered as separate modules.

Supplementary Note 6 | Health care, robot doctors and vaccines

Supplementary Table 10 | Robot-doctor service-capacity scenarios. Uses: triage, documentation, decision support, remote monitoring, pharmacy/logistics, robotic assistance, translation and scheduling.

Case	Routine task volume eligible	Assumed capacity gain	Capacity multiplier	Human clinical oversight
conservative	15%	10%	1.10	Mandatory for regulated diagnosis, treatment and prescribing
central	30%	25%	1.25	Mandatory for regulated diagnosis, treatment and prescribing
high_automation	50%	50%	1.50	Mandatory for regulated diagnosis, treatment and prescribing

Supplementary Table 11 | Universal-health-care coverage by cost basis, full adoption, CDR at US\$200 tCO₂⁻¹ (residual after CDR, food and vaccines; all cases in Supplementary Data 1, E12).

Cost per uncovered person	Capacity case	CDR period	Need (US\$ tn yr ⁻¹)	Coverage
US\$250	no AI capacity gain	Post-2183 maintenance	1.15	≥100%
US\$250	robot doctor, central	Post-2183 maintenance	0.92	≥100%
US\$500	no AI capacity gain	Post-2183 maintenance	2.30	≥100%
US\$500	robot doctor, central	Post-2183 maintenance	1.84	≥100%
US\$1,000	no AI capacity gain	Post-2183 maintenance	4.60	85%
US\$1,000	robot doctor, central	Post-2183 maintenance	3.68	≥100%
US\$2,500	no AI capacity gain	Post-2183 maintenance	11.50	34%

US\$2,500	robot doctor, central	Post-2183 maintenance	9.20	42%
US\$250	no AI capacity gain	Peak removal 2043-2153	1.15	≥100%
US\$250	robot doctor, central	Peak removal 2043-2153	0.92	≥100%
US\$500	no AI capacity gain	Peak removal 2043-2153	2.30	≥100%
US\$500	robot doctor, central	Peak removal 2043-2153	1.84	≥100%
US\$1,000	no AI capacity gain	Peak removal 2043-2153	4.60	60%
US\$1,000	robot doctor, central	Peak removal 2043-2153	3.68	75%
US\$2,500	no AI capacity gain	Peak removal 2043-2153	11.50	24%
US\$2,500	robot doctor, central	Peak removal 2043-2153	9.20	30%

About 4.6 billion people were not fully covered by essential health services in 2023 (main-text ref. 5), but many receive some care, so the incremental cost per uncovered person lies below a full allowance. The residual after CDR, food and vaccines covers up to US\$848 per uncovered person per year during maintenance and US\$599 during peak removal at full adoption, and US\$438 and US\$189 without U.S. participation; robot-doctor multipliers raise these thresholds in proportion. The Stenberg et al. estimate (main-text ref. 13) covers 67 low- and middle-income countries, not the full uncovered population, and is shown as an incremental anchor rather than a like-for-like cost.

Supplementary Table 12 | Vaccine-finance screen. Pledges were reported as more than US\$9 billion; using US\$9.0 billion makes the gap an upper bound.

Item	US\$ bn (2026–2030)	US\$ bn yr ⁻¹	Share of full-adoption maintenance residual
Gavi 2026–2030 funding target	11.9	2.38	0.047%
Gavi 2026–2030 gap after June 2025 pledges (upper bound)	2.9	0.58	0.011%

In 2024, 89% of infants received a first DTP dose and 85% all three doses; 14.3 million infants received no vaccine, and first- and second-dose measles coverage was 84% and 76% (main-text ref. 6). The vaccine screen compares Gavi's 2026–2030 funding target and remaining gap with Carbonite revenue; it is not a costing of universal immunization or of global vaccine finance as a whole, and immunization also depends on health-system reach. Antibiotic access and stewardship, and an mRNA cancer-vaccine pipeline that would be financed only if candidates are validated and approved, are registered as policy-scenario modules without a costed ledger. Robotic eldercare and disability assistance is a separate service-capacity module.

Supplementary Note 7 | Robot lawyers and access to justice

Supplementary Table 13 | Robot-lawyer access-to-justice scenarios (index: 100 = present capacity). Uses: triage, legal information, research, drafting, form completion, document review, translation and mediation support.

Case	Routine legal volume eligible	Public legal-access capacity index	Human oversight
conservative	20%	110	Required for regulated advice, representation and adjudication; all substantive filings verified
central	40%	120	Required for regulated advice,

			representation and adjudication; all substantive filings verified
high_digital_access	60%	130	Required for regulated advice, representation and adjudication; all substantive filings verified

Supplementary Note 8 | Required envelope by service tier

Supplementary Table 14 | Annual revenue required for each tier with CDR at US\$200 tCO₂⁻¹ and health care at US\$2,500 per uncovered person, and the effective fee it implies at full adoption (US\$9.5 trillion per day × 252 days).

CDR period	Tier	Required (US\$ tn yr ⁻¹)	Effective fee on all FX turnover (bp)
Post-2183 maintenance	CDR + hunger + vaccines	3.06	12.8
Post-2183 maintenance	+ universal health care (no AI capacity gain)	14.56	60.8
Post-2183 maintenance	+ universal health care (robot doctor, conservative)	13.52	56.5
Post-2183 maintenance	+ universal health care (robot doctor, central)	12.26	51.2
Post-2183 maintenance	+ universal health care (robot doctor, high)	10.73	44.8
Peak removal 2043-2153	CDR + hunger + vaccines	4.20	17.6
Peak removal 2043-2153	+ universal health care (no AI capacity gain)	15.70	65.6
Peak removal 2043-2153	+ universal health care (robot doctor, conservative)	14.66	61.2
Peak removal 2043-2153	+ universal health care (robot doctor, central)	13.40	56.0
Peak removal 2043-2153	+ universal health care (robot doctor, high)	11.87	49.6

Supplementary Note 9 | Coral recovery screen

Supplementary Table 15 | Coral recovery windows under the FaIR restoration pathway (1.0× local cooling response; 0.7× and 1.3× cases are in Supplementary Data 1). Only the 40 W m⁻² case is anchored to a published simulation; 20 and 60 W m⁻² assume linear scaling.

Local reef cooling (W m ⁻²)	Peak SST cooling (°C)	Thermal gate (°C)	CO ₂ gate (ppm)	Window opens	Hard-coral recovery	Thermal exceedance years 2035–2100
0	0.00	1.2	400	2181	2191–2196	66
0	0.00	1.2	350	2181	2191–2196	66
0	0.00	1.2	320	2181	2191–2196	66
0	0.00	1.2	300	2219	2229–2234	66
0	0.00	1.0	400	2237	2247–2252	66
0	0.00	1.0	350	2237	2247–2252	66
0	0.00	1.0	320	2237	2247–2252	66
0	0.00	1.0	300	2237	2247–2252	66
20	0.25	1.2	400	2122	2132–2137	66

20	0.25	1.2	350	2122	2132–2137	66
20	0.25	1.2	320	2144	2154–2159	66
20	0.25	1.2	300	2219	2229–2234	66
20	0.25	1.0	400	2168	2178–2183	66
20	0.25	1.0	350	2168	2178–2183	66
20	0.25	1.0	320	2168	2178–2183	66
20	0.25	1.0	300	2219	2229–2234	66
40	0.50	1.2	400	2057	2067–2072	0
40	0.50	1.2	350	2105	2115–2120	0
40	0.50	1.2	320	2144	2154–2159	0
40	0.50	1.2	300	2219	2229–2234	0
40	0.50	1.0	400	2112	2122–2127	66
40	0.50	1.0	350	2112	2122–2127	66
40	0.50	1.0	320	2144	2154–2159	66
40	0.50	1.0	300	2219	2229–2234	66
60	0.75	1.2	400	2057	2067–2072	0
60	0.75	1.2	350	2105	2115–2120	0
60	0.75	1.2	320	2144	2154–2159	0
60	0.75	1.2	300	2219	2229–2234	0
60	0.75	1.0	400	2057	2067–2072	0
60	0.75	1.0	350	2105	2115–2120	0
60	0.75	1.0	320	2144	2154–2159	0
60	0.75	1.0	300	2219	2229–2234	0

Local reef cooling represents seasonal regional marine cloud brightening over a reef-scale domain (main-text ref. 15). Marine cloud brightening is a radiative climate intervention; here it is a local one, evaluated as a reef-scale sensitivity and kept separate from the global restoration pathway, which contains no solar radiation modification. The cited simulation supports the $40 \text{ W m}^{-2} \rightarrow$ about $0.5 \text{ }^{\circ}\text{C}$ seasonal point; the 20 and 60 W m^{-2} values assume linear scaling, which it does not establish. Broader structural recovery is assumed to take up to 30 years after the window opens. The regional daily sea-surface-temperature and Degree-Heating-Week postprocessor is available in the framework but has not been run with coupled-ocean input, so all coral results are screening-level.

Supplementary Note 10 | Wild fisheries

Supplementary Table 16 | Literature-bounded fisheries screen.

Metric	Value	Unit	Status
baseline_sustainable_assessed_stocks_2023	62.4	percent	observed external reference
typical_managed_stock_rebuilding	10	years after effective reform	literature median screen; not every stock
visible_recovery_range	5-15	years	management/ecosystem planning sensitivity
broad_resilient_stock_recovery	20-40	years	planning sensitivity; not a global forecast
modelled_healthy_fraction_by_2050	98	percent	external global reform study scenario

The ten-year median rebuilding time and the 98%-healthy-by-2050 value are published global management-reform results (main-text ref. 16), not outputs of this framework. Aquaculture and seaweed production are tracked separately from wild-stock recovery.

Supplementary Note 11 | Participation stress

Supplementary Table 17 | U.S. accession and refusal cases. The ppm penalty is a screening conversion pending a rerun with positive-emissions forcing.

Case	Excess emissions to 2183 (GtCO ₂)	Years of peak removal (15.2 GtCO ₂ yr ⁻¹)	Screening CO ₂ penalty in 2183 (ppm)
join_2036	23.1	1.52	1.1
join_2046	58.95	3.88	2.81
join_2056	92.48	6.08	4.41
low_emissions_refusal	203.05	13.36	9.69
central_refusal	308.33	20.29	14.72
high_fossil_refusal	468.65	30.83	22.37
flat_policy_stress	606.58	39.91	28.95

On the revenue side, the U.S.-out envelope removes the 19% of global foreign-exchange turnover booked by U.S. sales desks (BIS Triennial Survey, April 2025; main-text ref. 23) and applies 90% participation elsewhere: $E \times 0.81 \times 0.90 = \text{US\$}5.07 \text{ trillion yr}^{-1}$, 27% below the reference envelope. The 19% share is a location-of-trading proxy on a net-gross basis, not a measure of U.S. payment or settlement flows; a payments-based share would change the U.S.-out envelope in proportion.

Supplementary Note 12 | Tree-backed stablecoin architecture

Carbonite is a settlement stablecoin whose backing is a geotagged reserve of planted trees rather than fiat-currency reserves (main-text Fig. 6). The registry modules that implement it are Carbonite_stablecoin, geotagged_tree_reserve, tree_harvest_durable_storage, country_equalizer, MRV_audit_chain, no_carbon_credit_finance and US_nonparticipation_stress (Supplementary Table 1). A coin can be registered on the blockchain only after its miner pays a registration fee that funds planting on land contributed by land stakers, who operate validating nodes in return. Mining is restricted to electricity that a consensus of administrators has verified as clean or otherwise wasted, and miners' hardware is throttled to the verified supply. The species, location and planting date of every tree are written to the blockchain under quantum-resistant encryption, and drone and field surveys update growth and losses so that backing values are recalculated and published continuously.

Two rules hold the backing of each coin stable. Coin-level equalization reassigns trees among all registered coins, to the nearest whole tree, so that every coin carries the same intrinsic value regardless of the species, age or location of the trees first planted for it. A stability pool of unassigned trees (20% of each planting in the reference design) is drawn on when timber prices fall and replenished when they rise. Supplementary Table 18 gives the resulting change in backing per coin; Supplementary Table 19 gives the growth of backing per coin for combinations of reserve-value growth and issuance dilution. Both tables are design arithmetic from Supplementary Code 1, not market-price projections.

Supplementary Table 18 | Change in backing per coin after a timber-price fall, by stability-pool share.

Stability-pool share	10% fall	20% fall	30% fall	40% fall	50% fall
0%	-10.0%	-20.0%	-30.0%	-40.0%	-50.0%
10%	0.0%	-11.1%	-22.2%	-33.3%	-44.4%
20% (reference)	0.0%	0.0%	-12.5%	-25.0%	-37.5%
30%	0.0%	0.0%	0.0%	-14.3%	-28.6%

Supplementary Table 19 | Annual growth of backing per coin, $(1 + g)/(1 + \delta) - 1$, and the backing after ten years of an initial US\$1,000.

Reserve-value growth g (yr^{-1})	Issuance dilution δ (yr^{-1})	Backing growth per coin (yr^{-1})	Backing after 10 yr (US\$)
3%	1.0%	1.98%	1,217
3%	1.5%	1.48%	1,158
3%	2.0%	0.98%	1,102
4%	1.0%	2.97%	1,340
4%	1.5%	2.46%	1,275
4%	2.0%	1.96%	1,214
5%	1.0%	3.96%	1,475
5%	1.5%	3.45%	1,404
5%	2.0%	2.94%	1,336

Harvest is the only authorized route by which reserve carbon leaves the forest. A holder burns (permanently retires) coins and receives, by quantum-resistant smart contract, timber rights to the corresponding trees, conditional on a covenant that the wood will not be intentionally burned or disposed of in a manner that returns its carbon to the atmosphere; trees used as Christmas trees, for example, must afterwards be put to a carbon-storing use. Each log and piece of sawn timber is stamped or engraved with a QR code (or bar code) and registered on the blockchain as carbon-sequestration wood, giving a chain of custody from stump to end use. Sawdust and offcuts are dried and stored underground, in trenches or in pits, a lower-energy store than compressing gaseous CO_2 . Land stakers may harvest fruit, nuts and sap from standing trees but may not fell them without coin burn. Carbon in the reserve and in carbon-sequestration wood is not credited against the deliberate removal costed in the ledger, and any carbon-credit income accrues to coin backing, not to the restoration fund.

The country equalizer addresses participants whose trees grow more slowly (for example boreal or semi-arid regions) or whose species yield lower-value timber. Because land is graded by expected growth and timber value, such participants would otherwise gain less backing per staked hectare. Participant i , with verified staked area A_i and value increment per hectare $v_i = G_i P_i$ (verified growth in $\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$ times timber value in US\$ m^{-3}), receives $Q_i = \theta A_i \max(0, \bar{v} - v_i)$, where $\bar{v}$ is the area-weighted mean over all participants and $\theta \in [0, 1]$ is the equalization share set by treaty. Only land meeting minimum suitability standards counts towards A_i , and drone and field verification applies before any transfer. The equalizer is a registered policy-scenario module and is not costed in the main ledger. If the United States does not participate, all of these mechanisms operate among participating states, and trees are planted only on land staked in those states (main-text Participation section and Supplementary Note 11).

Supplementary Note 13 | Other human-prosperity and restoration modules

Universal education and vocational training, AI tutoring with educator oversight, housing buildout, construction automation, clean-water desalination, wastewater treatment and reuse, drought and shock resilience, workforce transition, population planning and an Africa-focused vulnerability priority are registered as policy, engineering or service-capacity scenarios. Ocean plastic cleanup, eutrophication relief, blue-carbon restoration, robotic ocean cleanup and robotic, satellite and drone monitoring, reporting and verification support the ecological modules. The finance architecture also registers protected fee-free basic food and health payments, a country equalizer for differing domestic restoration potential and a geotagged tree reserve (both described in Supplementary Note 12), a restoration charity funded by settlement fees, bank and project-finance transition, liquidity stress and treaty sanctions. None of these modules is costed in the main ledger.

Supplementary Note 14 | Supplementary Data 1 and Supplementary Code 1

Supplementary Data 1 contains the inputs (D01 89-module registry with each module's role in this Article; D04 and D05 robot-doctor and robot-lawyer scenarios; D10 annual carbon trajectory 2026–2183; D18 fisheries; D25

legal access; D30 participation cases), the FaIR outputs (F00 summary and inverse solutions; F01 canonical-schedule run; F02 restoration pathway with 5–95% ranges) and every derived table (E00–E12). Supplementary Code 1 contains `run_fair_restoration_inverse.py`, which produces the FaIR outputs from D10 and the FaIR v2.2.4 calibration files (about 70 minutes on two cores), and `restoration_finance_screen.py`, which regenerates every derived table and Figs 1–6 in seconds. The environment is pinned (Python 3.13.16; fair 2.2.4, numpy 2.5.3, pandas 3.0.5, xarray 2026.9.0, scipy 1.18.1, matplotlib 3.11.2), and two consecutive runs produce byte-identical tables and figures.

Supplementary Table 1 | Complete 89-module registry

Each module's evidence class and its role in this Article.

Module ID	Domain	Module	Evidence class	Role in this Article
climate_gross_emissions	Climate	Gross anthropogenic CO2 emissions pathway	LEGACY_MECHANISTIC	input to FaIR run (D10)
climate_cdr_schedule	Climate	Canonical CDR schedule and post-2183 controls	EXTERNALLY_EXECUTED	executed here (FaIR, Supplementary Code 1)
fair_paired_attribution	Climate	FaIR paired removal-on/off attribution	EXTERNALLY_EXECUTED	not used in this Article
hector_paired_attribution	Climate	Hector paired programme-feedback comparator	EXTERNALLY_EXECUTED	not used in this Article
inverse_fair_targets	Climate	Inverse FaIR 2200/2300/2400 target solves	EXTERNALLY_EXECUTED	executed here (FaIR, Supplementary Code 1)
stored_carbon_reversal	Climate	Programme-contingent stored-carbon reversal	EXTERNALLY_EXECUTED	input to FaIR run (D10)
dynamic_permafrost	Climate	Temperature-responsive permafrost feedback	EXTERNALLY_EXECUTED	input to FaIR run (D10)
nonco2_forcing	Climate	Non-CO2 forcing sensitivity/background	DIAGNOSTIC_ONLY	registered only
temperature_response	Climate	Temperature response / target-year diagnostics	EXTERNALLY_EXECUTED	executed here (FaIR, Supplementary Code 1)
sea_level	Cryosphere/Ocean	Sea-level persistence screen	LITERATURE_SCREEN	registered only
ice_melt	Cryosphere/Ocean	Glacier/ice-sheet lag represented through sea-level context	LITERATURE_SCREEN	registered only
ocean_ph	Ocean	Surface-ocean pH / acidification screen	DIAGNOSTIC_ONLY	registered only
coral_reefs	Ocean/Biodiversity	Coral survival, cover and ecological recovery clocks	LITERATURE_SCREEN	quantified screen in this Article
fisheries	Ocean/Food	Wild fish-stock rebuilding screen	LITERATURE_SCREEN	quantified screen in this Article
seaweed_live_carbon	Ocean/CDR	Standing live seaweed farm carbon stock	ENGINEERING_SCENARIO	registered only
seaweed_fuel_reserve_carbon	Ocean/Energy	Strategic seaweed-derived fuel reserve carbon stock	ENGINEERING_SCENARIO	registered only
seaweed_food	Ocean/Food	Edible seaweed and protein/mineral stream	ENGINEERING_SCENARIO	registered only
seaweed_fish_habitat	Ocean/Biodiversity	Managed fish habitat/co-culture services	ENGINEERING_SCENARIO	registered only
seaweed_grid_harvesting	Ocean/Engineering	Grid Harvesting energy-reduction concept	ENGINEERING_SCENARIO	registered only
seaweed_aviation_fuel	Energy/Aviation	Seaweed liquid fuels for	ENGINEERING_SCENARIO	registered only

		aviation	RIO	
seaweed_heavy_equipment_fuel	Energy/Industry	Seaweed liquid fuels for heavy equipment	ENGINEERING_SCENARIO	registered only
seaweed_marine_fuel	Energy/Shipping	Seaweed liquid fuels for marine use	ENGINEERING_SCENARIO	registered only
seaweed_CSP_HTL	Energy/Industry	Concentrated-solar + HTL integration	ENGINEERING_SCENARIO	registered only
ocean_plastic_cleanup	Ocean/Pollution	Ocean plastic interception/removal/reuse	POLICY_SCENARIO	registered only
eutrophication	Water/Ocean	Nutrient capture and eutrophication relief	LEGACY_MECHANISTIC	registered only
blue_carbon	Ocean/Biodiversity	Mangrove/marsh/seagrass restoration	LITERATURE_SCREEN	registered only
DACCS	CDR	Direct air capture with storage	ENGINEERING_SCENARIO	registered only
enhanced_weathering	CDR/Land	Enhanced rock weathering	ENGINEERING_SCENARIO	registered only
OAE_AWL	CDR/Ocean	Ocean alkalinity enhancement / accelerated weathering of limestone	ENGINEERING_SCENARIO	registered only
mineral_carbonation	CDR/Materials	Mineral carbonation	ENGINEERING_SCENARIO	registered only
biochar	CDR/Land	Biochar carbon storage	ENGINEERING_SCENARIO	registered only
BiCRS	CDR	Biomass carbon removal and storage	ENGINEERING_SCENARIO	registered only
saline_aquifer_storage	CDR/Geology	Deep saline aquifer storage	ENGINEERING_SCENARIO	registered only
CCU	CDR/Industry	Carbon utilization accounting	ENGINEERING_SCENARIO	registered only
forest_restoration	Land/CDR	Tree planting, growth and ecological restoration	LEGACY_MECHANISTIC	registered only
tree_harvest_durable_storage	Land/CDR	Strategic harvest/use/burial/durable wood	POLICY_SCENARIO	described, not costed
wildfire_permanence	Land/Risk	Wildfire/drought permanence risk	POLICY_SCENARIO	registered only
soil_emissions_carbon	Land	Soil emissions/carbon response	LEGACY_MECHANISTIC	registered only
regenerative_agriculture	Land/Food	Soil/agronomic restoration pathway	POLICY_SCENARIO	registered only
food_diet_omnivore	Food	Optimized omnivore pathway including meat	LITERATURE_SCREEN	described, not costed
food_diet_mixed	Food	Mixed/EAT-Lancet-like pathway	LITERATURE_SCREEN	described, not costed
food_diet_vegetarian_aquatic	Food	Vegetarian + dairy/eggs + aquatic foods	LITERATURE_SCREEN	described, not costed
hunger_elimination	Food/Human	Dietary energy/protein access floor	POLICY_SCENARIO	quantified screen in this Article
food_waste	Food/Waste	Food-waste recovery	LEGACY_MECHANISTIC	registered only
wastewater_methane	Water/Energy	Wastewater methane capture and energy	LEGACY_MECHANISTIC	registered only
desalination	Water	Clean-water desalination	ENGINEERING_SCENARIO	registered only
water_reuse	Water	Wastewater	ENGINEERING_SCENARIO	registered only

		treatment/reuse	RIO	
universal_healthcare	Human/Health	Universal basic health-care resource envelope	POLICY_SCENARIO	quantified screen in this Article
vaccines_antibiotics	Human/Health	Vaccination, antibiotics and stewardship access	POLICY_SCENARIO	quantified screen in this Article
mrna_cancer_vaccine_pipeline	Human/Health	mRNA cancer-vaccine R&D/access if validated/approved	POLICY_SCENARIO	registered only
robot_doctors	AI/Health	AI-assisted and robotic healthcare	SERVICE_CAPACITY_SCENARIO	quantified screen in this Article
robot_lawyers	AI/Justice	AI-assisted legal access	SERVICE_CAPACITY_SCENARIO	quantified screen in this Article
legal_access	Human/Justice	Affordable legal information/representation access	POLICY_SCENARIO	quantified screen in this Article
education	Human/Education	Universal education and vocational training	POLICY_SCENARIO	registered only
robot_tutors	AI/Education	AI tutoring with educator oversight	SERVICE_CAPACITY_SCENARIO	registered only
housing	Human/Housing	Housing resource/buildout screen	POLICY_SCENARIO	registered only
robot_construction	AI/Infrastructure	Construction automation	ENGINEERING_SCENARIO	registered only
robot_agriculture	AI/Food	Agricultural robotics	ENGINEERING_SCENARIO	registered only
robot_environmental_mrv	AI/MRV	Robotic/satellite/drone MRV	ENGINEERING_SCENARIO	registered only
robot_ocean_cleanup	AI/Ocean	Robotic ocean restoration/cleanup	ENGINEERING_SCENARIO	registered only
robot_eldercare	AI/Health	Robotic eldercare/disability assistance	SERVICE_CAPACITY_SCENARIO	registered only
energy_grid	Energy	Electricity, grid adequacy and storage	LEGACY_MECHANISTIC	registered only
tidal_energy	Energy	Tidal-energy screen	ENGINEERING_SCENARIO	registered only
shipping_decarbonization	Transport	Shipping efficiency/wind/battery/H2/e-fuel/biofuel portfolio	ENGINEERING_SCENARIO	registered only
aviation_decarbonization	Transport	Aviation electrification where feasible + low-carbon liquid fuel	ENGINEERING_SCENARIO	registered only
industrial_materials	Materials	Steel/cement/aluminium/circularity	LEGACY_MECHANISTIC	registered only
data_center_heat_reuse	Energy/AI	Distributed AI data-center waste-heat reuse	ENGINEERING_SCENARIO	registered only
Los_Jardines_Cella	Implementation	Eight-town distributed restoration/AI demonstration archetype	ENGINEERING_SCENARIO	registered only
Carbonite_stablecoin	Finance	Carbonite price-stable settlement cryptocurrency	POLICY_SCENARIO	quantified screen in this Article
Proof_of_Rent	Finance/Compute	Proof of Rent processor-rental mechanism	POLICY_SCENARIO	registered only
geotagged_tree_reserve	Finance/Forestry	Geotagged tree/timber natural-capital reserve	POLICY_SCENARIO	quantified screen in this Article
restoration_charity	Finance/Human	Global restoration charity funded by settlement fees	POLICY_SCENARIO	registered only

transaction_fee_finance	Finance	Settlement/cross-border fee funding	POLICY_SCENARIO	quantified screen in this Article
country_equalizer	Finance/Governance	Equalizer for differing domestic restoration potential	POLICY_SCENARIO	described, not costed
bank_transition	Finance	Bank/data-center/project-finance transition	POLICY_SCENARIO	registered only
liquidity_stress	Finance	Monetary liquidity/reserve stress	LEGACY_MECHANISTIC	registered only
sanctions_governance	Governance	Treaty sanctions/governance modes	POLICY_SCENARIO	described, not costed
US_nonparticipation_stress	Governance/Finance	US non-participation adoption stress case	POLICY_SCENARIO	quantified screen in this Article
protected_food_health_payments	Finance/Human	Basic food/health payments protected fee-free	POLICY_SCENARIO	registered only
workforce_transition	Human/Economy	Financial/industrial workforce transition	POLICY_SCENARIO	registered only
disaster_resilience	Human/Risk	Drought/shock resilience	POLICY_SCENARIO	registered only
Africa_vulnerability_priority	Regional	Africa-focused vulnerability/resource-access reporting	LITERATURE_SCREEN	registered only
population_scenarios	Human/Demography	Population planning and carrying-capacity screens	LITERATURE_SCREEN	registered only
MRV_audit_chain	Governance/MRV	Measurement, reporting, verification and chain of custody	POLICY_SCENARIO	described, not costed
no_carbon_credit_finance	Finance	Financing architecture independent of carbon credits	POLICY_SCENARIO	described, not costed
matched_forcing_cross_model	Climate	FaIR/Hector matched-future-non-CO2 forcing paired attribution	EXTERNALLY_EXECUTED	FaIR part executed here; Hector part not used
carbon_reservoir_decomposition	Climate/Carbon Cycle	Land/ocean/permafrost reservoir decomposition of declining atmospheric CDR response	OPEN_SCIENCE_GATE	not used in this Article
oscar_matched_forcing	Climate	OSCAR matched-future-non-CO2 forcing independent validation	OPEN_SCIENCE_GATE	not used in this Article
cdr_schedule_generality	Climate/CDR	Alternative timing/rate schedules to test generality of long-horizon CDR response divergence	OPEN_SCIENCE_GATE	not used in this Article