

H120-He60

Entwicklungskosten, Costed WBS & Prototype-BOM

60-Personen Regional-Luftschiff | v0.1 | 20. September 2026

Planungsbaseline Gesamtprogramm bis zur zertifizierten, industrialisierungsfähigen H120-He60-Basis: EUR 319.92 Mio. inklusive 20 % Managementreserve. Davon sind EUR 266.6 Mio. als konkrete Arbeits-, Hardware-, Test- und Organisationspakete identifiziert.

Wichtig Dies ist eine belastbare Kostenarchitektur auf Vorentwurfsniveau, keine behauptete finale Einkaufsstückliste. Einzelteilnummern und exakte Schraubenzähler entstehen erst nach CDR/EBOM-Freeze. Kleinteile werden deshalb über konkrete Fastener-/Consumable-Familien, Mengensätze und Einheitspreise budgetiert.

Autor: Chris Oesterreich

Projekt: Starrluftschiff - wissenschaftliche Entwicklung

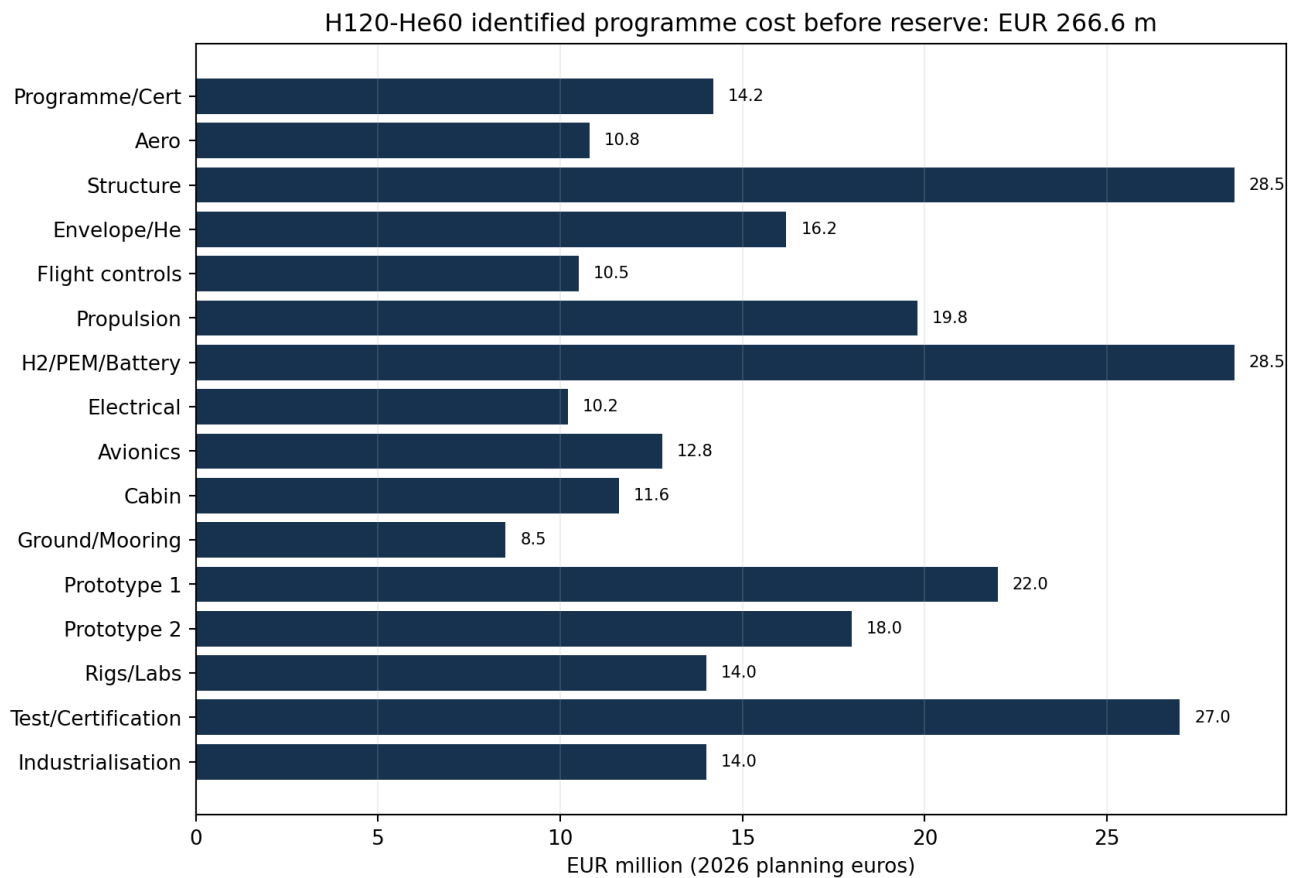
1. Executive Summary

Der H120-He60 wird als ca. 120 m langes, ca. 25 m breites Starrluftschiff fuer 60 Passagiere betrachtet. Helium liefert den statischen Auftrieb; elektrische Propulsion wird primaer ueber ein PEM-Brennstoffzellensystem mit Wasserstoff und einen Pufferakku versorgt. Die aktuelle Konzeptmasse von rund 27,8 t, ca. 100 km/h Reisegeschwindigkeit und etwa 350 km planbarer Reichweite sind Projektannahmen und noch keine zertifizierten Leistungsdaten.

Der Bottom-up-Ansatz dieses Berichts ergibt EUR 266.6 Mio. identifizierte Entwicklungskosten. Eine 20%-Managementreserve von EUR 53.32 Mio. fuehrt zu einer P50-Planungsbaseline von EUR 319.92 Mio. bis zur Typzulassung und Produktionsreife. Der Betrag umfasst zwei Full-Scale-Fluggeraete, Testanlagen, Flight-Test, Compliance-Arbeit und Industrialisierung; er ist nicht mit dem spaeteren Verkaufspreis eines einzelnen Luftschiffs gleichzusetzen.

Kennzahl	Baseline	Interpretation
Identifizierte Entwicklungs-/Test-/Hardware-Pakete	266,60 m	WBS A-P
Managementreserve (20 %)	53,32 m	Nicht vorab verplanen
P50 Gesamtprogramm	319,92 m	Zielbaseline
Prototype No. 1 - Vollbuild	22,00 m	Im Entwicklungsprogramm enthalten
Prototype No. 2 - Conforming/Certification	18,00 m	Im Entwicklungsprogramm enthalten
Mature recurring factory-cost estimate	23,61 m	Noch ohne NRE-Amortisation / Marge
Bisheriger Ziel-Serienpreis	ca. EUR 50 m	Bankcase-Annahme, nicht Kosten

Nicht vermischen EUR 319,92 Mio. = Entwicklungsprogramm. Rund EUR 23.61 Mio. = heutiger parametrischer recurring factory cost pro spaeterem Serienfahrzeug. Der ca. EUR 50-Mio.-Zielpreis muss zusaetzlich NRE-Rueckfluss, Finanzierung, Gewaehrleistung, Vertrieb und Marge tragen.



2. Costing Rules and Design Maturity

Waehrungsbasis: Euro, Planungsjahr 2026, netto vor Umsatzsteuer. Engineering-Pakete sind als voll belastete Programmaufwaende kalkuliert, also inklusive Arbeitgeberkosten, Infrastruktur, Software, Management-Overhead und Lieferantenmarge. Externe Benchmarkpreise fuer Batterien, Brennstoffzellen, H2-Speicher und Helium werden nicht 1:1 als Luftfahrt-Einkaufspreise angesetzt; sie dienen als Untergrenze/Sanity Check. Low-volume, qualifizierte Luftfahrthardware wird deutlich hoeher budgetiert [S5-S8].

Zulassungsbasis: Fuer grosse Gas-Luftschiffe existiert bei EASA die Special Condition SC GAS. EASA beschreibt, dass fuer grosse Luftschiffe keine allgemeine veroeffentlichte CS in derselben Weise wie fuer konventionelle Flugzeuge vorliegt; die Special Condition bildet daher einen zentralen Teil der Zertifizierungsbasis [S1]. Die historische/draft CS 30T adressiert Transport Airships und sieht Tests, Berechnungen und ggf. zusaetzliche Special Conditions fuer neue Designmerkmale vor [S2].

Genauigkeit: Die Werte sind eine P50-Planungsbaseline mit einer separaten 20%-Managementreserve. Einzelne WBS-Zeilen koennen spaeter stark verschoben werden, ohne dass das Gesamtbudget proportional steigt oder faellt. Besonders hohe Unsicherheit besteht bei H2-Speicherung, Full-Scale-Strukturtests, Authority-bedingten Designaenderungen, Hangar/Testinfrastruktur und der realen Lieferanten-Risk-Share-Struktur.

3. Aircraft Costing Baseline

Parameter	Working value	Status / note
Length	ca. 120 m	Project baseline
Max diameter	ca. 25 m	Project baseline
Passenger seats	60	Regional/panoramic cabin
Lifting gas	Helium	No H2 as lifting gas
Approx. ellipsoidal reference volume	39.270 m3	Simple geometry sanity check, not final gas-cell volume
Target concept mass	ca. 27.8 t	To be revalidated with detailed mass statement
Cruise speed	ca. 100 km/h	Project baseline
Planned range	ca. 350 km	Project baseline
Primary energy	PEM fuel cell + H2	He60 propulsion baseline
Buffer battery	High-power aviation pack	Sizing still open
Crew assumption	2 flight crew + service as required	Certification/operation assumption

Helium cost sanity check A simple 120 m x 25 m ellipsoid is about 39,270 m3. USGS reports an estimated 2024 Grade-A helium base price of about USD 14/m3 before surcharges [S5]. The report therefore budgets roughly EUR 0.8 Mio. for an initial delivered fill/service-loss allowance rather than multiplying the US base price directly. Final fill cost depends on actual cell volume, purity, logistics, recovery and contract terms.

4. Development Programme Cost Summary

WBS	Cost block	EUR million	Share
A	Programme, Systems Engineering & Certification Basis	14,20 m	5,3 %
B	Aerodynamics, Performance & Flight Mechanics	10,80 m	4,1 %
C	Rigid Structure, Loads & Structural Test	28,50 m	10,7 %
D	Envelope, Gas Containment, Helium & Outer Skin	16,20 m	6,1 %
E	Flight Controls & Actuation	10,50 m	3,9 %
F	Propulsion: Motors, Inverters, Propellers & Pods	19,80 m	7,4 %
G	Hydrogen, PEM Fuel Cells & Buffer Battery	28,50 m	10,7 %
H	Electrical Power Distribution, Wiring & Lightning	10,20 m	3,8 %

WBS	Cost block	EUR million	Share
I	Avionics, Navigation, Communications & Software Integration	12,80 m	4,8 %
J	Passenger Cabin, Safety & Environmental Control	11,60 m	4,4 %
K	Landing, Ground Handling, Mooring & Turnaround	8,50 m	3,2 %
L	Prototype Aircraft No. 1 - Full Vehicle Build	22,00 m	8,3 %
M	Prototype Aircraft No. 2 - Conforming / Certification Vehicle	18,00 m	6,8 %
N	Test Rigs, Labs & Development Infrastructure	14,00 m	5,3 %
O	Ground Test, Flight Test & Type Certification Campaign	27,00 m	10,1 %
P	Industrialisation, Production Readiness & Continued Airworthiness	14,00 m	5,3 %
R	Management reserve (20 %)	53,32 m	16,7 %
TOTAL	Programme baseline	319,92 m	100,0 %

5. Cash Need by Development Gate

Die folgende Gate-Struktur zeigt, wann wirtschaftlich welcher Betrag verfuegbar sein muss. Sie ist keine Finanzierungszusage: Supplier Risk Sharing, Foerderung und Kundenanzahlungen koennen den externen Cash-Bedarf reduzieren, aber nicht die realen Programmkosten.

Gate	Purpose	Gate spend	Cumulative	Main use
G0	Concept lock + certification strategy	7,50 m	7,50 m	Certification basis, system architecture, first safety/loads models
G1	Feasibility / PDR	24,50 m	32,00 m	Aerodynamics, sizing, supplier RFQs, material/joint coupons, early rigs
G2	Technology maturation / CDR	55,00 m	87,00 m	Full subsystems, structural sections, H2/PEM rig, detailed design, tooling start
G3	Prototype 1 + ground test	71,00 m	158,00 m	Full prototype build, integration labs, structural/gas/propulsion testing
G4	Prototype 2 + flight-envelope expansion	58,00 m	216,00 m	Conforming vehicle, first flight, handling, performance, failure tests
G5	Certification closure +	50,60 m	266,60 m	Compliance closure,

Gate	Purpose	Gate spend	Cumulative	Main use
	production readiness			authority findings, POA/ICA, rate-capable tooling
R	Management reserve (20%)	53,32 m	319,92 m	Released only against closed risk / approved change

6. Detailed Costed Work Breakdown Structure

Jede folgende Zeile ist ein eigener Kostencontainer. In einem echten ERP/PLM-System werden diese WBS-Pakete später in Purchase Orders, Arbeitspläne und serialisierte EBOM-Positionen zerlegt. Die Summe aller Tabellen A-P ist exakt EUR 266.6 Mio.

6.1 WBS A - Programme, Systems Engineering & Certification Basis

ID	Cost item	What the money buys	Type	EUR m
A.01	Programme office / PMO	Core PMO, schedule, cost, risk, suppliers	NRE	2,40 m
A.02	Systems engineering	Architecture, interfaces, trade studies	NRE	2,20 m
A.03	Requirements / configuration / data management	Requirements DB, baselines, change control	NRE	1,10 m
A.04	Certification basis & authority engagement	EASA SC GAS basis, CRIs, compliance planning	CERT	1,40 m
A.05	Design Organisation capability / DOA readiness	Processes, manuals, independent checking	ORG	2,00 m
A.06	Safety engineering	FHA, PSSA, SSA, common cause, zonal safety	CERT	2,10 m
A.07	Software / airborne electronic hardware assurance planning	DO-178C / DO-254 plans and supplier assurance	CERT	1,20 m
A.08	Quality management system	Design quality, audits, nonconformance process	ORG	0,80 m
A.09	Standards, legal, IP & technical records	Standards access, IP work, controlled records	ORG	1,00 m
	Subtotal WBS A			14,20 m

6.2 WBS B - Aerodynamics, Performance & Flight Mechanics

ID	Cost item	What the money buys	Type	EUR m
B.01	Aerodynamic concept refinement	Hull/tail/propulsor integration loops	NRE	0,90 m
B.02	Performance sizing model	Mass, buoyancy, drag, power, range, reserves	NRE	0,80 m
B.03	Low-fidelity CFD campaign	Design-space sweeps	NRE	1,00 m
B.04	High-fidelity CFD campaign	Viscous/transient cases, crosswind, prop interaction	NRE	1,50 m
B.05	Wind-tunnel models & test campaign	Models, tunnel time, instrumentation, analysis	TEST	2,30 m

ID	Cost item	What the money buys	Type	EUR m
B.06	Stability & control derivatives	6-DoF derivative set and validation	NRE	1,10 m
B.07	Handling-quality simulation	Pilot-in-the-loop / desktop simulator	TEST	0,80 m
B.08	Crosswind, weather & mooring aerodynamics	Gust and ground interaction cases	NRE	0,70 m
B.09	Acoustic / propulsor interaction work	Community and cabin noise pre-assessment	NRE	0,70 m
B.10	Model validation & uncertainty allowance	Correlation and model uncertainty closure	TEST	1,00 m
	Subtotal WBS B			10,80 m

6.3 WBS C - Rigid Structure, Loads & Structural Test

ID	Cost item	What the money buys	Type	EUR m
C.01	Global loads model	Flight, gust, mooring, ground and emergency cases	NRE	2,00 m
C.02	Global FEM / structural sizing	Frames, longitudinals, keel, tail interfaces	NRE	2,70 m
C.03	Material down-selection	Al/CF/GFRP/hybrid trade and allowables plan	NRE	0,80 m
C.04	Material coupon programme	Tension/compression/shear/fatigue/environment	TEST	1,30 m
C.05	Joint and fastener test programme	Bolted/bonded/insert joints, knockdowns	TEST	1,80 m
C.06	Ring/frame subscale prototypes	Representative rings and node details	HW	2,20 m
C.07	Longitudinal member development	Stringers, longerons, buckling tests	NRE	1,60 m
C.08	Keel & cabin-floor load path	Passenger loads, equipment, landing loads	NRE	1,80 m
C.09	Empennage attachment development	Tail-fin and control-surface interfaces	NRE	1,30 m
C.10	Propulsion-pylon attachments	Local reinforcement and fail-safe paths	NRE	1,00 m
C.11	Damage tolerance & fatigue	Inspection intervals and residual strength	CERT	1,60 m
C.12	Corrosion / lightning structural protection	Bonding, coatings, conductive paths	NRE	1,00 m
C.13	Full-scale representative section test	Large structural article + load rig	TEST	3,20 m
C.14	Major structure tooling & assembly jigs	Frames, alignment, drilling/bonding fixtures	TOOL	4,00 m
C.15	Structural substantiation reports	Compliance reports and stress dossiers	CERT	1,20 m
C.16	Structural test fixtures / load introduction hardware	Dedicated reaction frames, adapters, instrumentation	TEST	1,00 m
	Subtotal WBS C			28,50 m

6.4 WBS D - Envelope, Gas Containment, Helium & Outer Skin

ID	Cost item	What the money buys	Type	EUR m
D.01	Gas-cell membrane material development	Barrier film / laminate qualification	NRE	1,50 m
D.02	Permeability, ageing & fire test programme	Helium loss, UV, humidity, flammability	TEST	1,20 m
D.03	Gas-cell geometric / load design	Cell geometry, restraints, service access	NRE	1,40 m
D.04	Seams, bonds and penetrations	Joint process development and validation	NRE	1,00 m
D.05	Gas valves and distribution manifold	Isolation, fill, vent and service architecture	NRE	1,00 m
D.06	Overpressure / emergency relief	Sizing, prototypes and functional tests	TEST	0,70 m
D.07	Helium fill / recovery ground system	Recovery compressor, storage, hoses, interfaces	HW	1,10 m
D.08	Thermal / solar buoyancy model	Day-night and altitude temperature model	NRE	0,80 m
D.09	Outer aerodynamic cover development	Fabric/laminate, attachments, access panels	NRE	2,00 m
D.10	Rain, icing, UV & lightning environmental work	Environmental protection validation	TEST	0,80 m
D.11	Leak detection & gas monitoring	Sensors, localisation and maintenance method	NRE	0,60 m
D.12	Ballast / trim system development	Water/solid ballast, transfer and control	NRE	1,00 m
D.13	Full-scale gas-cell prototype	Representative full-size cell + service testing	HW	2,00 m
D.14	Gas-cell / skin tooling and handling equipment	Cutting, welding/bonding, lifting fixtures	TOOL	1,10 m
	Subtotal WBS D			16,20 m

6.5 WBS E - Flight Controls & Actuation

ID	Cost item	What the money buys	Type	EUR m
E.01	Flight-control architecture	Redundancy, modes, failure cases	NRE	1,40 m
E.02	Actuation architecture	Electric actuators, power and local control	NRE	1,00 m
E.03	Actuator prototypes & qualification units	Primary-surface actuator hardware	HW	1,30 m
E.04	Control surfaces / hinges / bearings	Surface structural and mechanical development	NRE	1,00 m
E.05	Air-data / attitude sensor integration	Sensor suite and voting logic	NRE	0,60 m
E.06	Redundancy / reversion analysis	Jammed surface, runaway, power-loss cases	CERT	0,70 m
E.07	Hardware-in-the-loop flight-control rig	Computers, I/O, actuator emulation	TEST	1,60 m
E.08	Flight-control software	Control laws, modes,	NRE	1,50 m

ID	Cost item	What the money buys	Type	EUR m
	development	monitoring		
E.09	Verification & compliance evidence	Requirements-based V&V, reports	CERT	1,40 m
	Subtotal WBS E			10,50 m

6.6 WBS F - Propulsion: Motors, Inverters, Propellers & Pods

ID	Cost item	What the money buys	Type	EUR m
F.01	Propulsion sizing / redundancy trades	Installed power and OEI cases	NRE	1,00 m
F.02	Electric motor development / supplier NRE	Low-volume aviation-qualified motor shipset	NRE	2,50 m
F.03	Inverter development / qualification	HV power electronics, redundancy	NRE	1,50 m
F.04	Propeller aerodynamic design	Diameter, RPM, efficiency, noise	NRE	1,80 m
F.05	Propeller prototype sets	Ground and flight-test articles	HW	1,60 m
F.06	Bearings / shafts / couplings	Direct-drive mechanical train qualification	HW	0,60 m
F.07	Nacelle / pylon development	Structure, cooling, access, aerodynamics	NRE	1,40 m
F.08	Vectoring / thrust-direction mechanism	Actuation, bearings, locks, sensing	NRE	1,20 m
F.09	Motor/inverter thermal management	Liquid/air cooling hardware development	NRE	0,80 m
F.10	Local propulsion control electronics	Motor control, isolation, monitoring	NRE	0,70 m
F.11	EMI/EMC propulsion mitigation	Filters, shielding, bonding	TEST	0,60 m
F.12	Full-power endurance rig	Motor-inverter-prop endurance test stand	TEST	2,50 m
F.13	Foreign-object / rain / erosion tests	Propeller and pod environmental tests	TEST	0,50 m
F.14	Prototype spares / development replacements	Rotors, bearings, controllers, props	HW	0,80 m
F.15	Propulsion certification documentation	Compliance and qualification reports	CERT	0,80 m
F.16	Integrated propulsion system testing	Multi-pod control, transients, failure cases	TEST	1,50 m
	Subtotal WBS F			19,80 m

6.7 WBS G - Hydrogen, PEM Fuel Cells & Buffer Battery

ID	Cost item	What the money buys	Type	EUR m
G.01	Energy-system architecture	Power split, dispatch, reserve and failure cases	NRE	1,20 m
G.02	PEM fuel-cell supplier NRE	Aviation integration, controls, qualification	NRE	4,00 m

ID	Cost item	What the money buys	Type	EUR m
G.03	Fuel-cell prototype system units	Development / qualification stacks and modules	HW	2,50 m
G.04	Fuel-cell balance of plant	Air, humidification, pumps, valves, sensors	NRE	1,50 m
G.05	Fuel-cell thermal management	Radiators, loops, pumps, controls	NRE	1,50 m
G.06	Hydrogen tank system design / supplier NRE	Low-volume aerospace storage integration	NRE	2,00 m
G.07	Hydrogen prototype tank sets	Qualification and flight-test tank hardware	HW	2,20 m
G.08	H2 regulators / valves / manifolds	Redundant isolation and pressure control	HW	0,80 m
G.09	H2 detection / ventilation / venting	Sensors, ducts, hazard-zoning provisions	NRE	0,70 m
G.10	Refuelling interface & ground coupling	Nozzle, bonding, procedures, interlocks	NRE	0,50 m
G.11	Buffer-battery architecture	Power/energy sizing and containment	NRE	0,80 m
G.12	Prototype battery packs	Flight-test packs including thermal enclosure	HW	1,20 m
G.13	Battery management system	BMS HW/SW and independent protection	NRE	0,50 m
G.14	DC/DC and HV-bus interface	Converters, contactors, precharge	NRE	0,80 m
G.15	Battery fire / propagation test programme	Cell-to-pack abuse and containment tests	TEST	1,20 m
G.16	Hydrogen leak / fire / burst test programme	Representative system safety tests	TEST	1,80 m
G.17	Energy-management software	Fuel cell/battery dispatch and health monitoring	NRE	1,00 m
G.18	Integrated endurance / mission-cycle rig	Full mission power-system cycles	TEST	2,00 m
G.19	Qualification & compliance documentation	System safety and compliance evidence	CERT	2,30 m
	Subtotal WBS G			28,50 m

6.8 WBS H - Electrical Power Distribution, Wiring & Lightning

ID	Cost item	What the money buys	Type	EUR m
H.01	HV/LV electrical architecture	Bus topology, segregation, load analysis	NRE	0,70 m
H.02	HVDC switchgear / contactors	Prototype and qualification hardware	HW	1,00 m
H.03	Power distribution units	HV and LV distribution units	HW	0,80 m
H.04	Wiring / harness engineering	Routing, sizing, separation, EWIS rules	NRE	0,80 m
H.05	Prototype harness sets	Ship-level prototype wiring	HW	0,70 m
H.06	Low-voltage converters and buses	28V/48V services and redundancy	HW	0,50 m

ID	Cost item	What the money buys	Type	EUR m
H.07	Grounding / bonding network	Bond straps, return paths, verification	NRE	0,60 m
H.08	Lightning / HIRF protection	Shielding, diverters, tests	TEST	1,00 m
H.09	Emergency electrical power	Independent emergency source and loads	HW	0,60 m
H.10	Essential battery / UPS systems	Avionics and safety load ride-through	HW	0,50 m
H.11	EMC/EMI system test campaign	Conducted/radiated susceptibility/emissions	TEST	1,30 m
H.12	Environmental qualification	Temperature, vibration, humidity	TEST	1,00 m
H.13	Electrical compliance documentation	EWIS, load analysis, qualification records	CERT	0,70 m
	Subtotal WBS H			10,20 m

6.9 WBS I - Avionics, Navigation, Communications & Software Integration

ID	Cost item	What the money buys	Type	EUR m
I.01	Avionics architecture	Functions, partitioning, redundancy	NRE	0,70 m
I.02	Flight-deck / HMI design	Crew stations, controls, human factors	NRE	1,20 m
I.03	Computers & displays	Prototype/qualification units	HW	1,50 m
I.04	GNSS / inertial navigation	Receivers, AHRS/INS, antennas	HW	0,80 m
I.05	Air data / altitude sensing	Probes, static system, sensors	HW	0,50 m
I.06	VHF communications	Radios, audio panels, antennas	HW	0,50 m
I.07	Transponder / ADS-B	Mode S / surveillance installation	HW	0,30 m
I.08	Weather sensing / radar	Weather awareness system	HW	0,40 m
I.09	Traffic / terrain awareness	TCAS/traffic and terrain functions	HW	0,60 m
I.10	Flight-data / health monitoring	Recorder, data concentrators, HUMS	HW	0,30 m
I.11	Autopilot integration	Modes, guidance, flight-controls interface	NRE	1,00 m
I.12	Integrated software / databus work	I/O, networks, displays, maintenance	NRE	1,40 m
I.13	DO-160 qualification	Environmental/EMC qualification campaign	TEST	1,40 m
I.14	DO-178C / DO-254 assurance support	Lifecycle evidence and independent V&V	CERT	1,50 m
I.15	Cybersecurity / security assessment	Threat analysis and mitigations	CERT	0,70 m
	Subtotal WBS I			12,80 m

6.10 WBS J - Passenger Cabin, Safety & Environmental Control

ID	Cost item	What the money buys	Type	EUR m
J.01	Cabin layout / ergonomics	60-passenger layout, aisles, crew stations	NRE	0,60 m
J.02	Seat development / substantiation	Lightweight seats, belts, dynamic loads	NRE	0,80 m
J.03	Windows / transparency system	Panoramic windows, frames, impact tests	NRE	0,70 m
J.04	Floor, liners and monuments	Lightweight interior panels and attachments	NRE	0,70 m
J.05	HVAC / ventilation	Cabin comfort and smoke-control interfaces	NRE	1,20 m
J.06	Cabin lighting / passenger power	Normal/emergency lighting and outlets	HW	0,50 m
J.07	Compact galley / service module	Minimal regional service equipment	HW	0,30 m
J.08	Lavatory module	Compact certified lavatory provision	HW	0,40 m
J.09	Emergency exits / escape path	Doors, mechanisms, markings, lighting	NRE	0,80 m
J.10	Fire / smoke detection and extinguishing	Cabin/equipment fire protection	NRE	1,20 m
J.11	Full-scale evacuation demonstration	Mock-up, participants, instrumentation	TEST	1,20 m
J.12	Portable oxygen / first-aid provision	Emergency equipment integration	HW	0,30 m
J.13	PA / interphone	Crew/passenger audio system	HW	0,30 m
J.14	Cabin safety equipment	Life vests/rafts where route demands, extinguishers	HW	0,30 m
J.15	Material flammability qualification	Panels, fabrics, foams, wiring	TEST	1,00 m
J.16	Cabin compliance documentation	Occupant safety, interiors, equipment	CERT	0,60 m
J.17	PRM accessibility & serviceability	Boarding, wheelchair and service design	NRE	0,70 m
	Subtotal WBS J			11,60 m

6.11 WBS K - Landing, Ground Handling, Mooring & Turnaround

ID	Cost item	What the money buys	Type	EUR m
K.01	Landing gear / ground support concept	Loads, configuration and safety	NRE	1,20 m
K.02	Ground manoeuvring system	Steering/tug interfaces and procedures	NRE	0,80 m
K.03	Mooring-mast aircraft interface	Nose fitting, loads, sensors, release	NRE	1,00 m
K.04	Mobile mooring-mast prototype	Ground demonstrator mast and controls	HW	1,40 m
K.05	Ground power / H2 service	Carts, hoses, bonding,	HW	0,70 m

ID	Cost item	What the money buys	Type	EUR m
	equipment	interlocks		
K.06	Tow fittings / ground vehicles interfaces	Adapters and tow equipment	HW	0,40 m
K.07	Wind operating-envelope analysis	Ground gust, mooring and turnaround limits	NRE	0,60 m
K.08	Emergency recovery equipment	Deflation/vent/restrain contingencies	HW	0,50 m
K.09	Ground-crew procedures / training	Turnaround and abnormal operations	ORG	0,50 m
K.10	Hangar / dock interface definition	Dimensions, doors, work platforms	NRE	0,60 m
K.11	Ground-system validation tests	Mooring, towing, turnarounds, wind cases	TEST	0,80 m
	Subtotal WBS K			8,50 m

6.12 WBS L - Prototype Aircraft No. 1 - Full Vehicle Build

ID	Cost item	What the money buys	Type	EUR m
L.01	Primary structure material & fabricated parts	Frames, longerons, keel, fittings	HW	4,00 m
L.02	Gas cells & outer skin shipset	Full vehicle containment/cover shipset	HW	2,00 m
L.03	Propulsion shipset	Motors, inverters, props, pods	HW	2,20 m
L.04	PEM/H2 energy shipset	Fuel cell, H2 storage, BoP	HW	2,60 m
L.05	Buffer battery shipset	Prototype pack and enclosure	HW	0,40 m
L.06	Avionics shipset	Flight deck, nav/com, computers	HW	0,90 m
L.07	Flight-control shipset	Actuators, computers, sensors	HW	0,70 m
L.08	Electrical distribution & harnesses	HV/LV distribution and EWIS	HW	0,60 m
L.09	Cabin / interior shipset	Seats, floor, liners, safety systems	HW	0,80 m
L.10	Landing / mooring aircraft hardware	Gear, fittings, ground interfaces	HW	0,40 m
L.11	Initial helium fill & service losses	Approx. 39,000 m3-class lifting-gas volume	HW	0,80 m
L.12	Prototype assembly labour	Major assembly, systems installation, finishing	MFG	3,70 m
L.13	QA, NDT & conformity inspection	Inspection, metrology, records	MFG	1,00 m
L.14	Fasteners, connectors, sealants & consumables	Detailed allowance - see Appendix B	HW	0,90 m
L.15	Spares / rework / first-build scrap	Prototype contingency inside build	HW	1,00 m
	Subtotal WBS L			22,00 m

6.13 WBS M - Prototype Aircraft No. 2 - Conforming / Certification Vehicle

ID	Cost item	What the money buys	Type	EUR m
M.01	Primary structure material & fabricated parts	Learning applied vs. prototype 1	HW	3,60 m
M.02	Gas cells & outer skin shipset	Conforming shipset	HW	1,80 m
M.03	Propulsion shipset	Conforming motors/inverters/props/pods	HW	2,00 m
M.04	PEM/H2 energy shipset	Conforming fuel-cell and storage shipset	HW	2,30 m
M.05	Buffer battery shipset	Conforming pack	HW	0,35 m
M.06	Avionics shipset	Conforming avionics	HW	0,80 m
M.07	Flight-control shipset	Conforming actuators/computers	HW	0,60 m
M.08	Electrical distribution & harnesses	Conforming EWIS	HW	0,50 m
M.09	Cabin / interior shipset	Conforming passenger cabin	HW	0,70 m
M.10	Landing / mooring aircraft hardware	Conforming aircraft hardware	HW	0,35 m
M.11	Helium fill & service losses	Certification vehicle fill	HW	0,80 m
M.12	Assembly labour	Improved learning vs. prototype 1	MFG	2,05 m
M.13	QA, NDT & conformity inspection	Authority conformity and records	MFG	0,80 m
M.14	Fasteners, connectors, sealants & consumables	Conforming build allowance	HW	0,75 m
M.15	Rework / spares	Certification-vehicle allowance	HW	0,60 m
	Subtotal WBS M			18,00 m

6.14 WBS N - Test Rigs, Labs & Development Infrastructure

ID	Cost item	What the money buys	Type	EUR m
N.01	Systems integration laboratory	Avionics, networks, systems bench	TEST	2,00 m
N.02	Iron-bird / actuation rig	Flight controls and system integration	TEST	2,50 m
N.03	HV power laboratory	Power electronics, load banks, protection	TEST	1,00 m
N.04	H2 / fuel-cell integration rig	Ventilated powertrain laboratory	TEST	1,50 m
N.05	Structural load rigs	Frames, sections, attachments	TEST	1,50 m
N.06	Environmental chamber / lab access	Temperature, humidity, vibration	TEST	0,80 m
N.07	Telemetry ground station	Real-time flight/ground monitoring	TEST	0,70 m

ID	Cost item	What the money buys	Type	EUR m
N.08	Flight-test instrumentation shipset	Sensors, DAS, wiring, calibration	TEST	1,10 m
N.09	Metrology / tooling equipment	Laser trackers, jigs, calibrated tools	TOOL	0,80 m
N.10	Test-site / hangar modifications	Safety zones, H2 ventilation, access	TOOL	1,30 m
N.11	Safety / rescue equipment	Fire, gas, PPE, emergency response	TEST	0,80 m
	Subtotal WBS N			14,00 m

6.15 WBS O - Ground Test, Flight Test & Type Certification Campaign

ID	Cost item	What the money buys	Type	EUR m
O.01	Ground vibration / modal survey	Structural dynamics correlation	TEST	1,00 m
O.02	Static structural proof tests	Critical load cases and proof factors	TEST	1,50 m
O.03	Restrained / tethered powered tests	Propulsion and control before free flight	TEST	1,00 m
O.04	Ground handling / mooring trials	Taxi/tow/mast/turnaround cases	TEST	0,70 m
O.05	Envelope / gas-system validation	Leak, vent, fill, thermal cycles	TEST	0,80 m
O.06	First-flight campaign	Incremental initial envelope opening	TEST	1,50 m
O.07	Handling / stability flight tests	Control effectiveness and failure cases	TEST	2,00 m
O.08	Performance / range tests	Speed, drag, power, endurance, reserves	TEST	1,50 m
O.09	Crosswind / gust / weather tests	Operational envelope expansion	TEST	1,20 m
O.10	Propulsion / energy endurance campaign	Mission cycles and degradation	TEST	1,50 m
O.11	Emergency / failure demonstrations	OEI, sensor, actuator, bus and power failures	TEST	2,20 m
O.12	Hydrogen safety demonstrations	Leak detection, isolation, venting	TEST	1,20 m
O.13	Passenger evacuation / cabin safety tests	Full-scale compliance demonstrations	TEST	0,80 m
O.14	Reliability growth programme	Fault elimination and dispatch maturity	TEST	1,80 m
O.15	Flight-test data reduction	Instrumentation, models, compliance data	CERT	1,50 m
O.16	Test crew / flight operations	Pilots, engineers, ground crew, insurance	ORG	2,00 m
O.17	Authority fees / witnessing / support	EASA fees and external authority support allowance	CERT	1,50 m
O.18	Compliance reports / certification dossiers	Final reports and findings closure	CERT	2,00 m
O.19	Certification-driven design	Late mandatory design	NRE	1,30 m

ID	Cost item	What the money buys	Type	EUR m
	changes	changes		
	Subtotal WBS O			27,00 m

6.16 WBS P - Industrialisation, Production Readiness & Continued Airworthiness

ID	Cost item	What the money buys	Type	EUR m
P.01	Production-process planning	Make/buy, stations, takt, special processes	MFG	1,50 m
P.02	Supplier qualification	Audits, FAI, source inspection	MFG	1,50 m
P.03	Production tooling / fixtures	Rate-capable assembly and process tooling	TOOL	3,00 m
P.04	Work instructions / build records	Controlled manufacturing documentation	MFG	1,00 m
P.05	POA readiness / production approval support	Production quality and authority readiness	ORG	1,20 m
P.06	Production QA / NDT capability	Processes, personnel, calibration	MFG	1,00 m
P.07	Supply-chain setup	Contracts, logistics, long-lead management	ORG	1,00 m
P.08	Rate-build / factory simulation	Capacity and flow modelling	MFG	0,60 m
P.09	Production workforce training	Technicians, inspectors, special processes	ORG	0,50 m
P.10	Initial spares / repair definition	Spares list and repair schemes	ORG	0,80 m
P.11	Maintenance manuals / ICA	Instructions for Continued Airworthiness	CERT	0,90 m
P.12	Final assembly line enabling work	Utilities, platforms, logistics cells	TOOL	0,50 m
P.13	ERP/MES / serial traceability setup	Configuration and serialized parts traceability	ORG	0,50 m
	Subtotal WBS P			14,00 m

7. Recurring Vehicle Cost - Costed EBOM Level 1

Die folgende Tabelle ist kein Verkaufspreis, sondern ein parametrischer recurring factory cost fuer ein spaeteres Serienfahrzeug bei niedriger bis mittlerer Stueckzahl. Sie ist bewusst konsistent mit dem bisherigen ca. EUR 50-Mio.-Serienpreis-Bankcase: Der Verkaufspreis muss NRE-Amortisation, Finanzierung, Gewaehrleistung, Vertrieb, Programmrisiko und Marge tragen.

Assembly / cost family	Included scope	EUR m
Primary rigid structure	Frames, longerons, keel, joints, fittings, local reinforcements	4,20 m
Gas containment & outer skin	Gas cells, barriers, cover, valves, service hardware	2,20 m
Propulsion shipset	Motors, inverters, propellers, pods,	2,35 m

Assembly / cost family	Included scope	EUR m
	vectoring	
PEM/H2 energy system	Fuel-cell modules, BOP, storage, valves, cooling	2,75 m
Buffer battery	Approx. mission-buffer pack, enclosure and BMS	0,45 m
Electrical distribution & EWIS	HV/LV switchgear, harnesses, bonding	0,65 m
Avionics / flight deck	Displays, computers, nav/com, surveillance	0,95 m
Flight controls / actuation	Actuators, control computers, sensors	0,75 m
Passenger cabin	60 seats, interior, HVAC, safety equipment, lavatory	1,10 m
Landing / mooring aircraft hardware	Gear, nose mooring fitting, tow interfaces	0,50 m
Initial helium fill	~39,000 m3 class volume incl. delivered-price allowance	0,80 m
Fasteners / connectors / sealants / consumables	Appendix B granular allowance	0,91 m
Final assembly direct labour	Assembly, installation, finishing, test	3,20 m
QA / NDT / conformity	Inspection and records	0,80 m
Factory overhead / warranty / initial spares	Recurring overhead and service reserve	2,00 m
TOTAL recurring factory cost	Current parametric baseline	23,61 m

8. Appendix A - Fastener, Connector & Consumable Allowance

Dieser Block beantwortet die "jede Schraube"-Frage so weit, wie es vor einem eingefrorenen Detaildesign serioses moeglich ist. Mengen sind EBOM-Platzhalter auf Basis der Groessenordnung eines 120-m-Starrluftschiffs. Bei CDR werden sie durch echte Part Numbers, Material/Finish, Lieferant, Einzelmasse, Torque/Installation und Serial/Lot Traceability ersetzt.

Family	Qty assumption	Unit	Cost	Use / note
Structural lockbolts / Hi-Lok type	42,000	EUR 4.50	EUR 189.000	Primary structure; final type/finish TBD
Aerospace bolts, high-strength steel/titanium	12,000	EUR 8.00	EUR 96.000	Pylons, gear, equipment, high-load joints
Self-locking aerospace nuts	14,000	EUR 2.50	EUR 35.000	Matched to bolted joints
Washers / shims / spacers	20,000	EUR 0.60	EUR 12.000	Corrosion isolation and load distribution
Solid rivets	80,000	EUR 0.25	EUR 20.000	Secondary/light-gauge structure allowance
Blind structural rivets	10,000	EUR 1.00	EUR 10.000	Access-limited and secondary joints
Composite threaded/bonded inserts	7,500	EUR 6.00	EUR 45.000	Panels, fairings, interiors, access panels
P-clamps / cushioned	6,000	EUR 3.00	EUR 18.000	EWIS, tubes and hoses

Family	Qty assumption	Unit	Cost	Use / note
clamps				
Safety wire / cotter pins / retainers	10,000	EUR 0.15	EUR 1.500	Mechanical locking consumables
Aerospace cable ties	15,000	EUR 0.40	EUR 6.000	EWIS secondary retention
Bonding straps	1,000	EUR 15.00	EUR 15.000	Lightning/EMC bonding network
Helicoils / threaded repair inserts	3,500	EUR 2.00	EUR 7.000	Thread reinforcement / repair allowance
O-rings / static seals	5,000	EUR 2.00	EUR 10.000	Fluids, gas and equipment interfaces
Hose / tube fittings	1,800	EUR 25.00	EUR 45.000	Cooling, H2 BOP, service systems
HV connectors / service disconnects	200	EUR 180.00	EUR 36.000	High-voltage power paths
LV / signal connectors	1,200	EUR 40.00	EUR 48.000	Avionics, sensors, cabin systems
Cable lugs / terminals / backshell small parts	8,000	EUR 1.50	EUR 12.000	EWIS termination allowance
Grommets / edge protection	4,000	EUR 1.50	EUR 6.000	Wire/tube pass-through protection
Two-part cartridge adhesives	350	EUR 45.00	EUR 15.750	Secondary bonding / local assembly
Structural adhesive bulk	1,200 kg	EUR 35/kg	EUR 42.000	Bonded structural / semi-structural joints
Sealants / fuel- and weather-resistant compounds	500 L	EUR 25/L	EUR 12.500	Weather sealing and systems installation
Tapes / films / protective materials	Lot	EUR 20,000	EUR 20.000	Masking, abrasion, temporary protection
Composite process consumables	Lot	EUR 80,000	EUR 80.000	Vacuum bagging, peel ply, release media
Lubricants / assembly fluids	Lot	EUR 20,000	EUR 20.000	Assembly and servicing
Labels / placards / serialized tags	Lot	EUR 15,000	EUR 15.000	Compliance, maintenance, traceability
Coatings / primers / touch-up / conductive paint	Lot	EUR 90,000	EUR 90.000	Corrosion, UV and conductive protection
TOTAL current allowance			EUR 906.750	Rounded in vehicle build budget to ~EUR 0.9 m

9. Appendix B - What Development Money Is Actually Paying For

Cost nature	What it covers
Engineering labour	Architecture, loads, CFD/FEA, detailed design, drawings, software, safety, compliance. This is the largest invisible cost; a new aircraft is not primarily a materials bill.
Prototype hardware	Two full-scale airships plus qualification articles, spare units, destructive test items and first-build scrap.

Cost nature	What it covers
Tooling	Large jigs, alignment fixtures, gas-cell fabrication tooling, composite/metal tools, lifting fixtures, calibrated metrology.
Test infrastructure	Iron bird, HV rig, H2/PEM lab, structural rigs, telemetry, instrumentation and safety infrastructure.
Certification evidence	Plans, analyses, witnessed tests, reports, conformity, configuration control, finding closure and authority charges.
Industrialisation	Production processes, FAI, supplier qualification, traceability, POA readiness, maintenance/ICA, training and rate tooling.
Reserve	Not a "miscellaneous" pot. It covers uncertainty that is real but cannot be assigned to a known PO today: redesign, failed tests, supplier failure, schedule slips and authority findings.

10. Appendix C - H120-Be60 Battery Variant Delta

Die Be60-Variante nutzt dieselbe 60-Personen-Plattform, ersetzt jedoch das H2/PEM-System durch etwa 1,30 MWh Batterie fuer kurze Routen. BloombergNEF meldete 2025 einen globalen durchschnittlichen Li-Ion-Packpreis von USD 108/kWh; Europa lag deutlich hoeher [S6]. Dieser Wert ist fuer ein zertifiziertes Low-volume-Aviation-Pack keine belastbare Einkaufsofferte. Fuer Entwicklung und Qualifikation ist deshalb ein Mehrfaches des Automotive-Benchmarks einzuplanen.

Delta item	Planning range	Comment
Common H120 airframe / avionics / cabin / flight-control development	Re-used from He60 baseline	No second full programme
1.30 MWh aviation battery pack engineering & qualification	EUR 8-12 m	Cells/modules, enclosure, BMS, cooling, abuse tests
HV distribution / chargers / ground interface delta	EUR 3-5 m	Higher continuous battery currents and charging
Thermal-runaway / fire / containment certification delta	EUR 3-5 m	Large-pack safety evidence
Prototype battery shipsets and spares	EUR 2-4 m	Low-volume certified hardware
Flight-test / range / degradation delta	EUR 2-4 m	Battery-specific envelope and ageing
Indicative Be60 derivative development delta	EUR 18-30 m	If developed after a stable common H120 platform

11. Appendix D - Supplier Risk Sharing and External Cash Need

Supplier risk sharing reduces the cash Chris/the programme must fund up front; it does not make the engineering free. The economic cost stays in the programme baseline and the supplier receives later workshare, repayment, margin or another negotiated consideration.

Supplier area	Potential economic contribution	Mechanism
Primary structure / large fabricated frames	EUR 18-28 m	Supplier NRE deferral, prototype material at cost, series workshare
Gas-cell / envelope materials	EUR 7-12 m	Material development and prototype lots

Supplier area	Potential economic contribution	Mechanism
Propulsion motors / inverters / propellers	EUR 10-16 m	Supplier NRE and qualification units
PEM fuel cell / H2 storage	EUR 15-25 m	Largest strategic-partner opportunity
Avionics / flight controls	EUR 6-10 m	Integration NRE and qualification credits
Cabin / interiors / seats	EUR 3-6 m	Supplier-designed shipsets and certification support
Ground / mooring equipment	EUR 3-5 m	Prototype mast and service equipment
Plausible total industrial risk-share target	EUR 62-102 m	Target band, not committed funding

Cash view At a EUR 319.92 m programme baseline, an illustrative EUR 80 m supplier risk-share would reduce direct cash funding to about EUR 239.9 m before grants, customer deposits or debt. That is a financing view only; it does not reduce the true development value consumed by the programme.

12. Appendix E - Uncertainty and Sensitivity

Scenario	Programme cost	Meaning
P10 / aggressive partner-led case	EUR 240-270 m	Strong reuse of qualified supplier systems, limited redesign, major in-kind NRE support
P50 / current planning baseline	EUR 319.9 m	This report
P80 / difficult certification case	EUR 390-430 m	Major design iterations, extra test article, supplier failures, longer flight-test programme
Catastrophic programme reset	> EUR 450 m	Architecture or certification basis must materially change after CDR

The largest cost levers are (1) certification-basis stability, (2) structural mass closure without redesign, (3) H2/PEM supplier maturity, (4) number of full-scale articles, (5) authority-requested demonstrations, (6) need for dedicated hangar/test facilities, and (7) supplier NRE terms. Therefore the current EUR 319.92 m should be managed as a gate-based budget, not released as a single unrestricted programme pot.

13. Sources and External Benchmarks

External sources are used for regulatory framework and market sanity checks only. The H120 cost model itself is an engineering planning model built from the project architecture; no source below claims that a 60-passenger rigid airship will cost exactly the values in this report.

[S1] EASA - Final Special Condition SC GAS, Gas Airships, Issue 01 (2022).

<https://www.easa.europa.eu/en/document-library/product-certification-consultations/final-special-condition-sc-gas-gas-airships>

[S2] EASA - CS 30T, Transport Airships draft airworthiness code.

<https://www.easa.europa.eu/en/downloads/139573/en>

[S3] EASA - Type Certificate process / airship applicability and DOA framework.

<https://www.easa.europa.eu/en/faq/67026>

[S4] EASA - Fees for certification of products; Regulation (EU) 2025/2347 references.

<https://www.easa.europa.eu/en/the-agency/faqs/b-fees-certification-products>

[S5] USGS Mineral Commodity Summaries 2025 - Helium: 2024 estimated Grade-A base price about USD 14/m3 before surcharges. <https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-helium.pdf>

[S6] BloombergNEF 2025 Battery Price Survey - average Li-ion pack price USD 108/kWh; Europe above global average. <https://about.bnef.com/insights/clean-transport/lithium-ion-battery-pack-prices-fall-to-108-per-kilowatt-hour-despite-rising-metal-prices-bloombergnef/>

[S7] U.S. DOE Program Record 26002 - 275-kW PEM fuel-cell system cost: about USD 282/kW at current industrial baseline under 1,000 systems/year; automotive/heavy-duty benchmark, not aviation-qualified cost. <https://www.energy.gov/documents/record-26002-heavy-duty-fuel-cell-system-cost-2024>

[S8] U.S. DOE Program Record 24006 - 700-bar Type IV H2 storage cost/performance benchmark; high-volume automotive reference, not aviation-qualified low-volume procurement. <https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/24006-onboard-storage-cost-performance-status.pdf?Status=Master>

[S9] Destatis / Eurostat - 2025 labour-cost comparison in EU business economy; used only as a sanity check, while this report uses fully burdened aerospace programme rates rather than payroll wages. https://www.destatis.de/Europa/EN/Topic/Population-Labour-Social-Issues/Labour-market/EU_LabourCostPerHourWorked.html

14. Next Cost-Model Freeze Steps

#	Freeze item	Effect
1	Freeze propulsion installed power and motor count	Converts propulsion supplier allowances into actual shipset RFQ quantities.
2	Freeze H2 storage pressure / usable kg H2 and buffer-battery kWh	Largest open energy-system BOM driver.
3	Freeze structural architecture and material split	Allows mass-normalised material take-off and true fastener count.
4	Create Level-3 EBOM in PLM format	Part number, revision, material, quantity, unit mass, unit cost, supplier, lead time, certification status.
5	Issue supplier RFIs/RFQs only after approval	Turns parametric allowances into quotations without creating contractual commitments.
6	Update v0.2 from real quotes and test plans	Replace uncertainty by evidence; keep all deltas traceable.

Current financial answer Plan today with approximately EUR 320 Mio. economic development value to reach a certified and production-ready H120-He60. Do not attempt to raise the full amount on day one: release capital by gates, while converting as much of the supplier NRE as commercially sensible into risk-sharing/workshare.