RESEARCH BLOCK I • TECHNICAL CONCEPT REPORT

# CYC X1 Pro Integration and Dual-Stage Energy Architecture

High-power, low-profile e-mobility integration study for a hardtail platform operating in wet urban and mixed-surface conditions.

**Design objective.** Package a 5 kW peak mid-drive, dual-source 72 V energy system, weather protection, and discreet instrumentation within the silhouette of a conventional mountain bike while preserving serviceability and controllability.

> **Concept boundary:** the high-power configuration is a closed-course engineering prototype. Structural, battery, thermal, braking, tire, and control validation must be completed before release. Public-road use also requires confirmation of all applicable vehicle-classification, equipment, licensing, insurance, speed, and power rules.

## DESIGN BASIS

| | |
|---|---|
| **5.0 kW**<br>PEAK PROPULSION TARGET | **72 V / 84 V**<br>NOMINAL / FULL-CHARGE BUS |
| **2.52-2.88 kWh**<br>NOMINAL ENERGY ENVELOPE | **73 mm BSA**<br>THREADED DRIVE INTERFACE |

Visual, analytical, and engineering-consistency revision • May 2026

# Executive summary

## 1.1 Operational requirement

Commercial e-bikes commonly prioritize either regulatory-compliant low power or openly visible conversion hardware. This study explores a third architecture: a high-power prototype whose batteries, wiring, controls, and instrumentation remain within the visual envelope of a conventional hardtail. The low-profile objective is intended to reduce visual clutter, improve weather protection, and deter opportunistic theft; it is not a substitute for legal classification or required equipment.

The concept combines a CYC X1 Pro Gen 4 mid-drive, a 72 V dual-source battery system, and a hardtail chassis with a large frame triangle. The report sets targets of 5,000 W peak output, up to 75 km/h, and as much as 140 km of mixed-use range. These values are design targets rather than test results and depend on gearing, total mass, electrical losses, thermal limits, terrain, weather, rider position, and operating mode.

## 1.2 Operating environment

The operating environment is the Richmond and Vancouver metropolitan region, where repeated rain, coastal corrosion, fine river silt, gravel, and long mixed-surface routes create demanding sealing and maintenance requirements. The platform therefore needs low acoustic noise, protected electrical interfaces, reliable traction, and serviceable packaging.

Components that tolerate occasional splash may still be inadequate for repeated wet-weather exposure and abrasive contamination. Proposed countermeasures include sealed connectors, drip loops, strain relief, corrosion-resistant finishes, protected bearings, and disciplined drivetrain cleaning. Cool ambient air increases thermal margin, but it does not replace instrumented motor and controller temperature limits.

**Table 1.** Design targets, derived values, and verification status

All quantitative values originate in the supplied report or are calculated directly from those values; they are not test results or manufacturer certification.

| Requirement | Basis | Target / derived value | Release implication |
|---|---|---|---|
| **Peak propulsion** | Report target | 5.0 kW peak | Bench and closed-course validation; not a continuous rating |
| **Battery bus** | 20-series Li-ion concept | 72 V nominal / 84 V full charge | Verify every component, connector, fuse, and instrument rating |
| **Combined capacity** | 15 Ah + 20-25 Ah packs | 35-40 Ah | Independent BMS, fuse, disconnect, and charge path for each pack |
| **Nominal energy** | Voltage × capacity | 2.52-2.88 kWh | Before reserve margin, sag, conversion loss, and temperature effects |
| **Crank torque** | Report target | 250 N·m | Bottom bracket, chainline, drivetrain, wheel, and frame release tests |
| **Maximum speed** | Report target | Up to 75 km/h | Closed-course only until frame, fork, tire, wheel, and brake validation |
| **Mixed-use range** | Report target | Up to 140 km | Requires approximately 18-21 Wh/km; see Figure 6 |
| **Operating environment** | Richmond / Vancouver | Repeated rain, silt, gravel, coastal exposure | Ingress, corrosion, contamination, vibration, and thermal testing |

**Interpretation rule:** the report distinguishes stated targets, transparent calculations, and required verification. No target should be presented as demonstrated performance until the final integrated vehicle passes the release matrix.

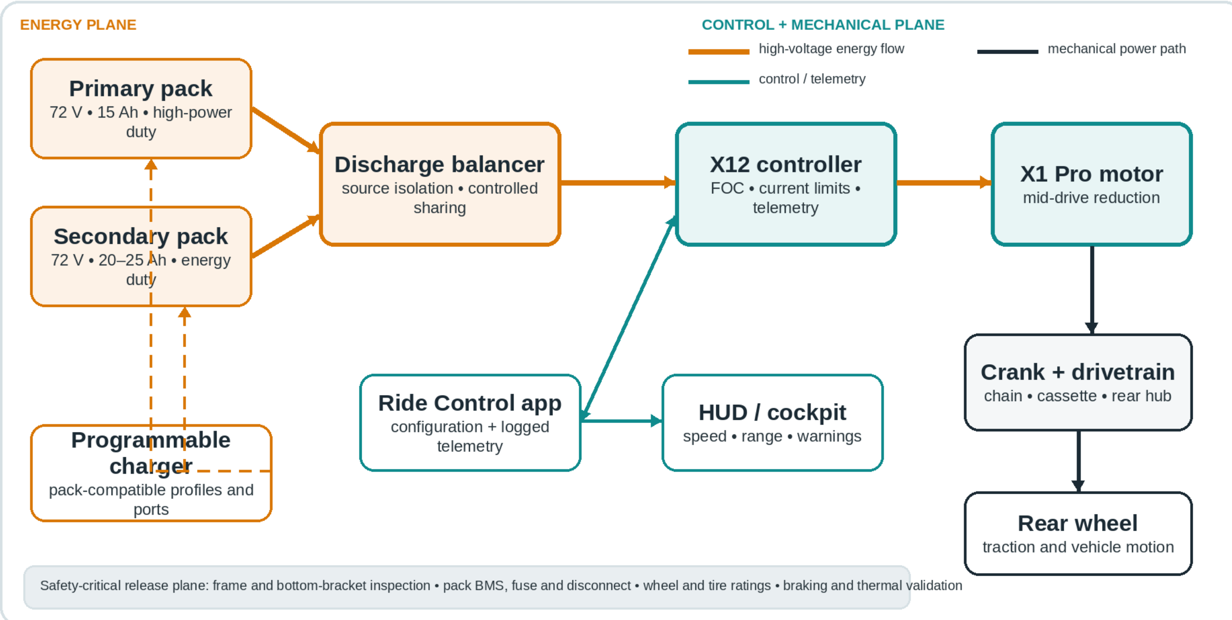


***Figure 1.*** *Integrated energy, control, and mechanical architecture.*
The diagram is a functional architecture, not a wiring schematic. Pack protection, connector ratings, and exact interfaces must be engineered from verified component documentation.

# 2.0 Airframe: Cannondale Habit HT 2

## 2.1 Chassis selection

The Cannondale Habit HT 2 provides a useful combination of structural simplicity, internal frame-triangle volume, and relatively slack geometry. A full-suspension platform can improve comfort and traction, but its shock, linkages, and pivots consume the space needed for a protected battery installation and add service points within the high-torque load path.

The hardtail layout creates a direct structural path between the bottom bracket and rear axle and preserves the main triangle for the secondary energy module. This packaging advantage is the primary reason for selection; it does not imply that the frame is certified for the report’s motorcycle-like power or speed targets.

**Table 2.** Chassis architecture trade-off

| Criterion | Hardtail platform | Full-suspension platform | Design implication |
|---|---|---|---|
| **Frame-triangle volume** | Large, uninterrupted volume | Reduced by shock and linkage | Hardtail better supports protected internal battery packaging |
| **Torque load path** | Direct bottom bracket to rear axle | Passes through pivots and bearings | Hardtail reduces the number of high-load joints |
| **Service points** | Fewer bearings and seals | Additional pivots, hardware, and seals | Hardtail simplifies inspection and wet-weather maintenance |
| **Ride compliance** | Fork, tire, and frame compliance only | Front and rear suspension | Full suspension remains superior for rough terrain comfort |
| **High-speed suitability** | Not certified by selection alone | Not certified by selection alone | Either platform requires complete closed-course stability testing |

| Criterion | Hardtail platform | Full-suspension platform | Design implication |
|---|---|---|---|
| **Integration result** | Selected for packaging and structural simplicity | Rejected for this specific energy architecture | Selection is an integration decision, not a speed certification |

## 2.2 Geometric stability at speed

Cross-country mountain bikes are optimized for agility at moderate speed. The Habit HT's 64-degree head angle generally provides more trail and lower steering sensitivity than steeper cross-country geometry, which can improve straight-line stability. High-speed behavior still depends on fork stiffness, wheel and tire condition, rider position, load distribution, and frame compliance.

On long straight sections, additional trail can reduce steering sensitivity and provide a stronger self-centering tendency. Closed-course testing remains essential because tire runout, wheel imbalance, bearing play, flexible bicycle components, or an unfavorable mass distribution can still produce oscillation.

## 2.3 Bottom-bracket interface and motor integration

The structural heart of the installation is the bottom-bracket interface. The source report specifies a BSA 73 mm threaded shell, which provides a positive mechanical interface for the CYC mounting hardware. The proposed stack-up uses threaded cups and an asymmetric spacer arrangement; all torque values and hardware combinations must be confirmed against the exact frame and motor installation instructions.

Chainline alignment between the front chainring and rear cassette is critical at the stated torque level. The source schematic uses a non-drive-side spacer stack and no added drive-side spacer to center the crank assembly while preserving chainstay clearance. Final release requires physical measurement of crank centering, chainring clearance, chainline, and cable routing.

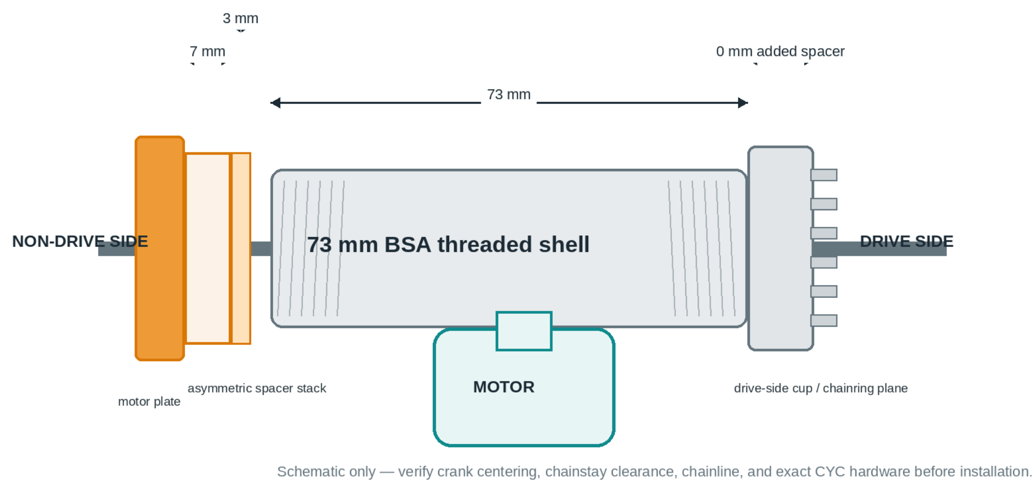


***Figure 2.*** *Redrawn 73 mm BSA bottom-bracket spacing concept.*
The existing source figure has been replaced with a consistent high-resolution schematic. Dimensions are design inputs and require physical fit verification.

**Table 3.** Bottom-bracket stack-up and release checks

Values reproduce the supplied spacing concept. Exact motor hardware, crank offset, and torque must be verified against the final frame and manufacturer instructions.

| Interface item | Design value | Function | Release check |
|---|---|---|---|
| **Shell standard** | BSA threaded, 73 mm | Primary mechanical interface | Confirm thread condition, shell width, and face parallelism |
| **Non-drive spacer stack** | 7 mm + 3 mm | Crank centering and motor-plate position | Measure left/right crank clearance and spindle engagement |
| **Drive-side added spacer** | 0 mm in source schematic | Preserves chainring inboard position | Verify chainstay clearance and chainline across cassette |

| Interface item | Design value | Function | Release check |
|---|---|---|---|
| **Threaded-cup torque** | 50 N·m report value | Locks mounting plates to frame faces | Use exact CYC/frame specification and calibrated tooling |
| **Torque-reaction interface** | 3 mm EPDM contact layer | Spreads contact and reduces fretting | Inspect frame surface and motor movement after every test stage |
| **Final acceptance** | Physical measurement | Reconciles all tolerance stack-ups | No interference, cable pinch, loose hardware, or abnormal bearing preload |

### 2.4 Structural reinforcement and fatigue

The frame is being asked to carry loads well above normal human-power duty. The proposed 3 mm EPDM contact layer between the motor housing and downtube can spread impact and reduce fretting at the torque-reaction point, but it is not a substitute for structural assessment. Welds, the bottom-bracket shell, downtube contact area, motor plates, and fasteners require scheduled inspection for cracking, movement, or permanent deformation.

> **Structural release gate:** the EPDM torque-reaction layer is a contact-management feature, not reinforcement. Any crack, growing witness mark, loose cup, shifted motor plate, or permanent frame deformation stops testing until the cause is resolved.

## 3.0 Propulsion: CYC X1 Pro Gen 4

### 3.1 Powerplant architecture

The CYC X1 Pro Gen 4 uses a high-speed inrunner motor with reduction gearing rather than placing a large low-speed motor in the wheel. This architecture keeps unsprung mass out of the wheel and allows the motor to operate in an efficient speed range while multiplying torque at the crank.

The source report assigns a 250 N·m crank-torque target and a 0-50 km/h target of less than four seconds. Those outcomes have not been verified in this document. They place the bottom bracket, chain, cassette, freehub, wheel, tire, and frame in a high-load regime that requires controlled testing and conservative current ramping.

### 3.2 X12 controller and field-oriented control

The X12 controller uses field-oriented control rather than coarse trapezoidal commutation. Rotor-position-aware current control can reduce electrical noise, improve low-speed torque control, and support smoother throttle response when the phase, sensor, and current parameters are configured correctly.

At cruising speed, the remaining acoustic signature is expected to come mainly from the reduction drive, chain, and tires rather than controller commutation. The report assumes a 72 V nominal battery with an 84 V full-charge condition. Controller voltage, battery-current, phase-current, and thermal limits must remain within verified manufacturer ratings.

### 3.3 Tuning parameters and throttle mapping

The Ride Control application provides access to current limits, throttle response, field weakening, and related control parameters. A repeatable configuration record is required so test results can be tied to a specific firmware and calibration state.

Field weakening can extend motor speed beyond the natural back-EMF limit, but it also increases current demand, heat generation, and efficiency loss. It should therefore be treated as an instrumented test mode with explicit motor and controller temperature limits, not as an unrestricted default setting.

Current-control throttle mapping makes rider input proportional to requested torque rather than target speed. This can feel more direct and provides better low-speed modulation, but wet conditions require a progressive current ramp, traction testing, and a clear fail-safe response for throttle or sensor faults.

**Table 4.** Controller functions, benefits, and required safeguards

| Function | Intended benefit | Primary risk | Required control |
|---|---|---|---|
| **Field-oriented control** | Smooth torque and lower electrical noise | Incorrect phase/sensor setup or unstable tuning | Baseline commissioning at low current; verify current, noise, and temperature |
| **Current-mode throttle** | Direct torque modulation | Wheel slip or abrupt chain loading | Progressive ramp, deadband check, wet-traction testing, and fail-safe input handling |
| **Field weakening** | Extends motor speed above natural back-EMF limit | Higher heat, current, and efficiency loss | Instrumented closed-course mode with hard temperature/current limits |
| **Software profiles** | Repeatable street/test calibration states | Uncontrolled or undocumented settings | Version-controlled configuration and locked release profile |
| **Thermal/current protection** | Protects controller, motor, and packs | Sensor failure or incorrect thresholds | Independent plausibility checks and conservative derating behavior |

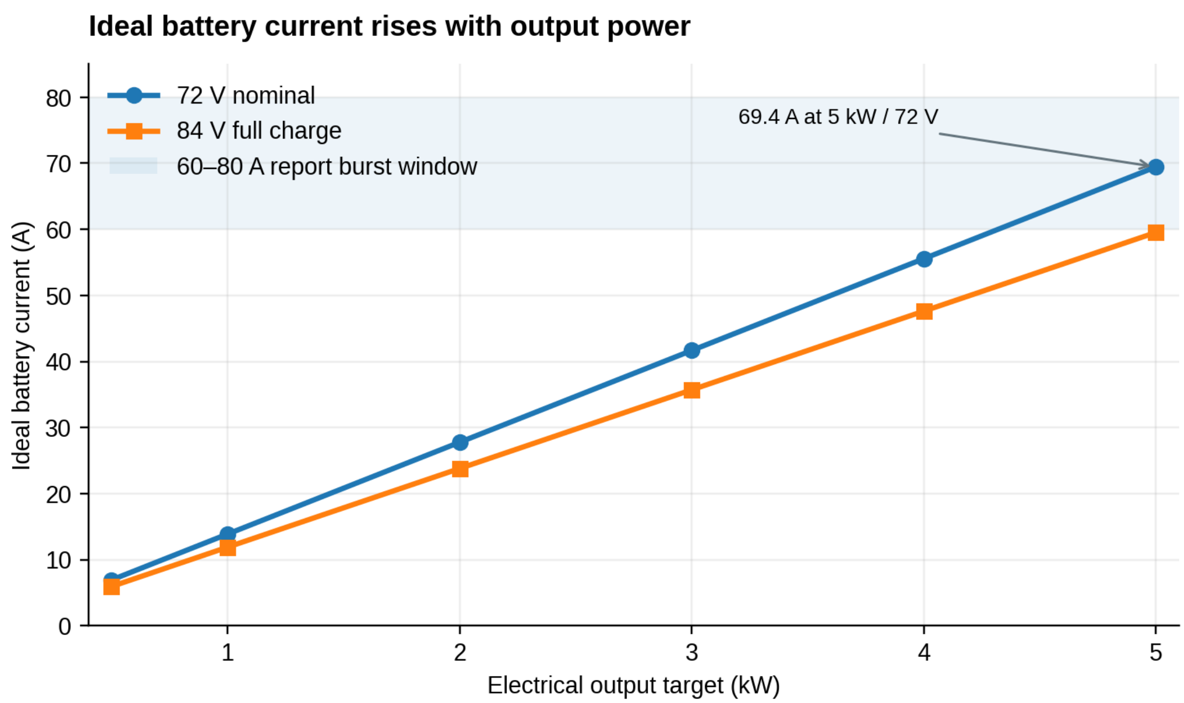


*Figure 3. Ideal pack current for the stated output range.*

Electrical calculation only. Actual current will be higher after losses and may rise further as pack voltage sags under load.

**Table 5.** Ideal battery current by output level

Current = power ÷ voltage. Values exclude drivetrain and controller losses, voltage sag, auxiliary loads, and current ripple; actual battery current will be higher.

| Electrical output | At 72 V nominal | At 84 V full charge | Operating note |
|---|---|---|---|
| **1.0 kW** | 13.9 A | 11.9 A | Part-load region |
| **2.0 kW** | 27.8 A | 23.8 A | Part-load region |
| **3.0 kW** | 41.7 A | 35.7 A | Part-load region |
| **4.0 kW** | 55.6 A | 47.6 A | Peak-load region |
| **5.0 kW** | 69.4 A | 59.5 A | Peak-load region |

# 4.0 Energy systems: dual-stage matrix

High acceleration and long range impose different cell-selection priorities. High-power cells minimize voltage sag under burst current, while high-energy cells maximize stored energy. The proposed architecture assigns those duties to separate packs and combines them through an active discharge balancer rather than direct parallel wiring.

## 4.1 Primary power unit: current delivery

The primary pack is specified as a 72 V, 15 Ah, 20S3P assembly using Molicel INR-21700-P50B cells. Its nominal energy is approximately 1.08 kWh. The source report assigns it the high-current role for the stated 60-80 A burst window, with packaging on the downtube in a protected enclosure.

## 4.2 Secondary power unit: capacity module

The secondary pack is a custom 72 V triangle assembly rated at approximately 20-25 Ah, or 1.44-1.80 kWh nominal. It is assigned the energy and cruise-load role and fills the hardtail frame triangle. Each pack requires its own compatible BMS, fuse, service disconnect, temperature monitoring, and protected charge interface.

**Table 6.** Dual-source battery allocation and nominal energy

| Source | Configuration | Nominal energy | Assigned duty | Packaging / protection |
|---|---|---|---|---|
| **Primary pack** | 72 V • 15 Ah • 20S3P | 1.08 kWh | Acceleration and high-current transients | High-power cells; protected downtube enclosure |
| **Secondary pack** | 72 V • 20-25 Ah | 1.44-1.80 kWh | Cruise load and range extension | High-energy cells; restrained triangle enclosure |
| **Combined through balancer** | 72 V • 35-40 Ah | 2.52-2.88 kWh | Shared discharge after voltage convergence | No direct parallel connection; independent protection remains active |

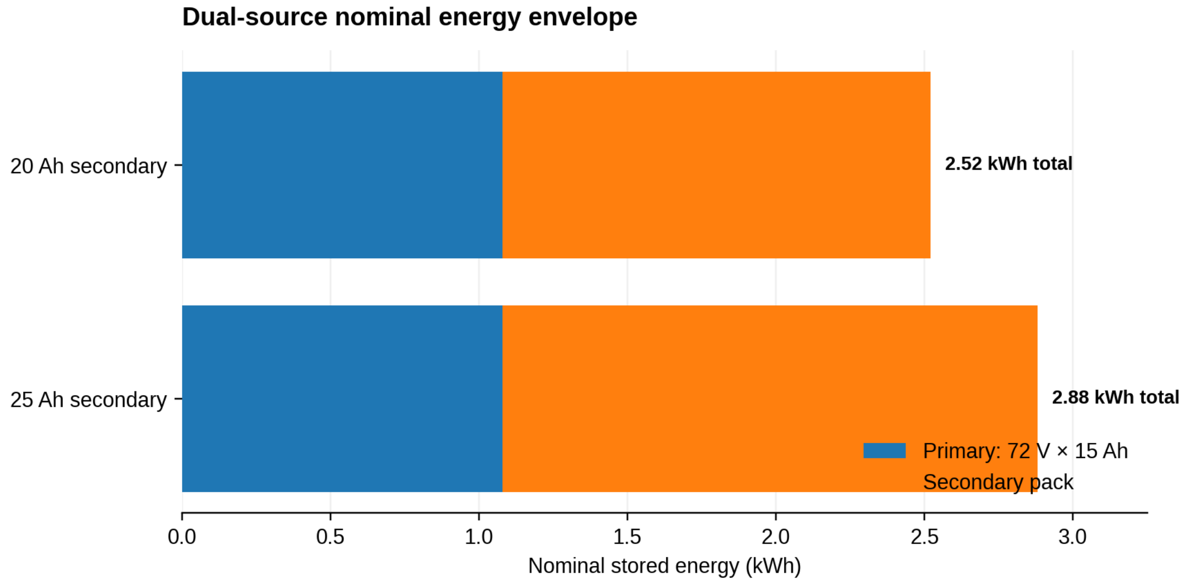


***Figure 4.*** *Nominal stored energy for the 20 Ah and 25 Ah secondary-pack options.*
Energy = nominal voltage × rated capacity. Usable energy is lower after reserve margin, voltage sag, temperature effects, and conversion losses.

## 4.3 Active power management: discharge balancer

Directly paralleling packs with different state of charge, internal resistance, cell chemistry, or BMS behavior can produce uncontrolled equalization current. The two sources therefore require electrical isolation and controlled load sharing.

The proposed dual-battery discharge balancer accepts independent pack inputs and presents a single output to the controller. The higher-voltage pack initially carries the load; both sources contribute after their terminal voltages converge. The combined design capacity is 35-40 Ah, corresponding to 2.52-2.88 kWh nominal before reserve margin and conversion losses.

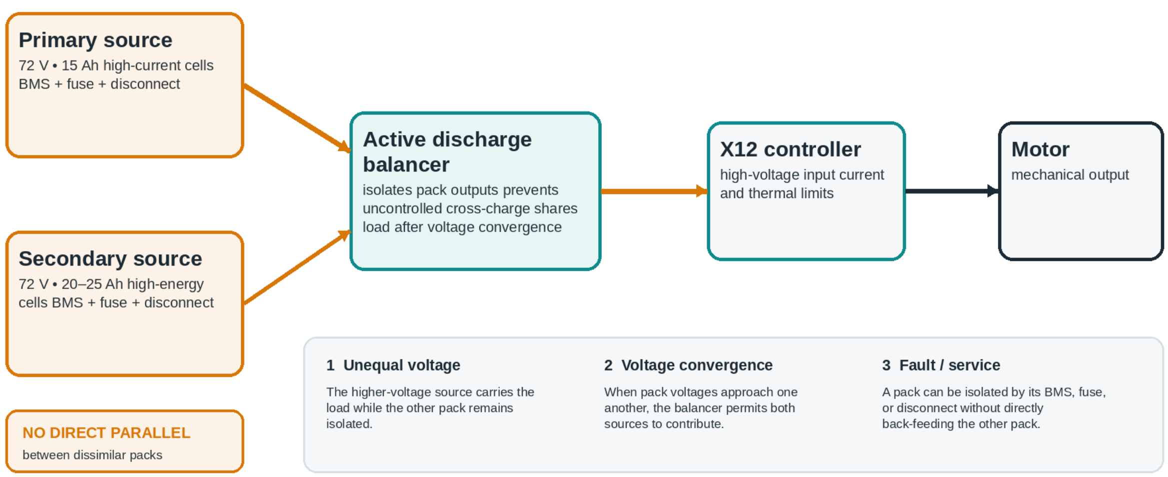


***Figure 5.*** *Redrawn dual-source discharge architecture with independent protection and isolation.*
This replaces the original energy-matrix graphic and adds BMS, fuse, disconnect, and fault-isolation requirements for consistency and safety.

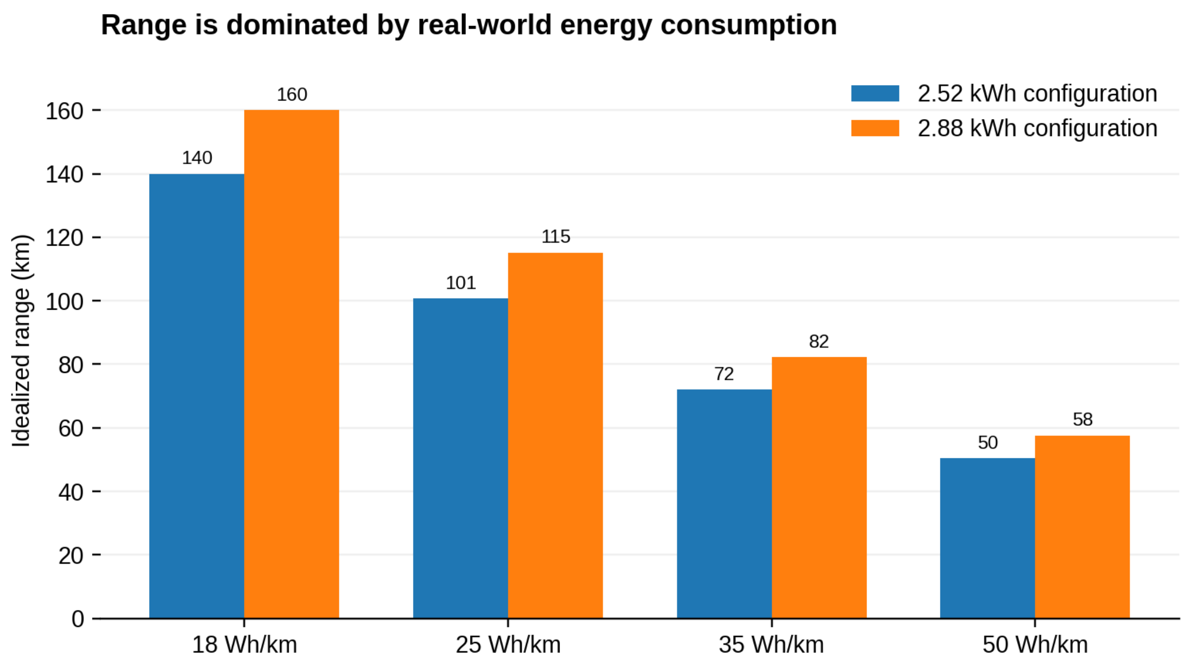


***Figure 6.*** *Idealized range sensitivity to real-world energy consumption.*
The 140 km target requires approximately 18 Wh/km with the 2.52 kWh configuration or about 21 Wh/km with the 2.88 kWh configuration. Reserve and losses reduce practical range.

### 4.4 Charging infrastructure

The Grin Cycle Satiator is proposed as a programmable, weather-resistant charging platform. Each battery must use a charge profile, connector, and current limit compatible with its exact cell configuration and BMS. An 80 percent everyday charge target can reduce time spent at maximum cell voltage, while periodic full-charge balancing may still be required by the pack design.

> **Charging release gate:** do not assume that one profile safely serves both packs. Cell chemistry, series count, BMS behavior, balance strategy, charge connector, and maximum current must be confirmed for each pack.

## 5.0 Drivetrain: managing high crank torque

The drivetrain is a primary durability constraint because the stated motor torque is well above typical rider input. Shock loading can elongate chains, deform cassette teeth, damage freehub mechanisms, and loosen interfaces. Current ramping, shift discipline, inspection intervals, and replaceable wear components are therefore part of the system design.

### 5.1 Box Prime 9 and KMC e9 Turbo

A robust 9-speed drivetrain is selected in place of a narrower 12-speed system. The Box Two Prime 9 cassette provides an 11-50T range with thicker components and fewer shifts, which can improve durability under high mid-drive load when chainline and shift timing are correct.

The KMC e9 Turbo is selected as an e-bike-oriented chain with corrosion-resistant surface treatment. Regardless of chain specification, wear must be measured frequently because power shifts under load, poor chainline, and abrasive contamination can shorten service life rapidly.

## 5.2 Lubrication and contamination control

Wet lubricants can retain fine silt and form an abrasive paste. Hot-wax lubrication can reduce dirt adhesion and make cleaning easier, but it does not eliminate maintenance. The chain, cassette, jockey wheels, chainring, and freehub should be inspected after wet or silty operation.

# 6.0 Braking and traction

The stated 75 km/h target places braking demand far beyond normal commuting conditions. The stock brake system should not be assumed adequate. Rotor diameter, caliper stiffness, pad compound, fluid condition, lever feel, tire grip, wheel strength, and repeated-stop thermal capacity must be validated together.

## 6.1 Hope Tech 4 V4 and thermal management

The proposed Hope Tech 4 V4 system uses a four-piston downhill-oriented caliper and a rigid monoblock body. The primary benefit is controllable lever force and heat capacity. Good modulation can help the rider stay near the tire’s traction limit, but it is not an anti-lock braking system and does not prevent wheel lock.

Kinetic energy increases with the square of speed: a stop from 75 km/h involves nine times the kinetic energy of a stop from 25 km/h at the same total mass. The proposed 220 mm front and 203 mm rear rotors therefore require instrumented temperature testing, repeated-stop testing, bed-in verification, and conservative replacement limits for pads, rotors, and fluid.

## 6.2 Tires: Schwalbe Super Moto-X

The proposed Schwalbe Super Moto-X tires use a large 29 × 2.4 inch contact patch and substantial air volume for wet pavement and mixed surfaces. Final selection must confirm rim compatibility, load capacity, pressure range, casing condition, and any applicable speed limitation. Tire pressure and wear should be treated as safety-critical pre-ride checks.

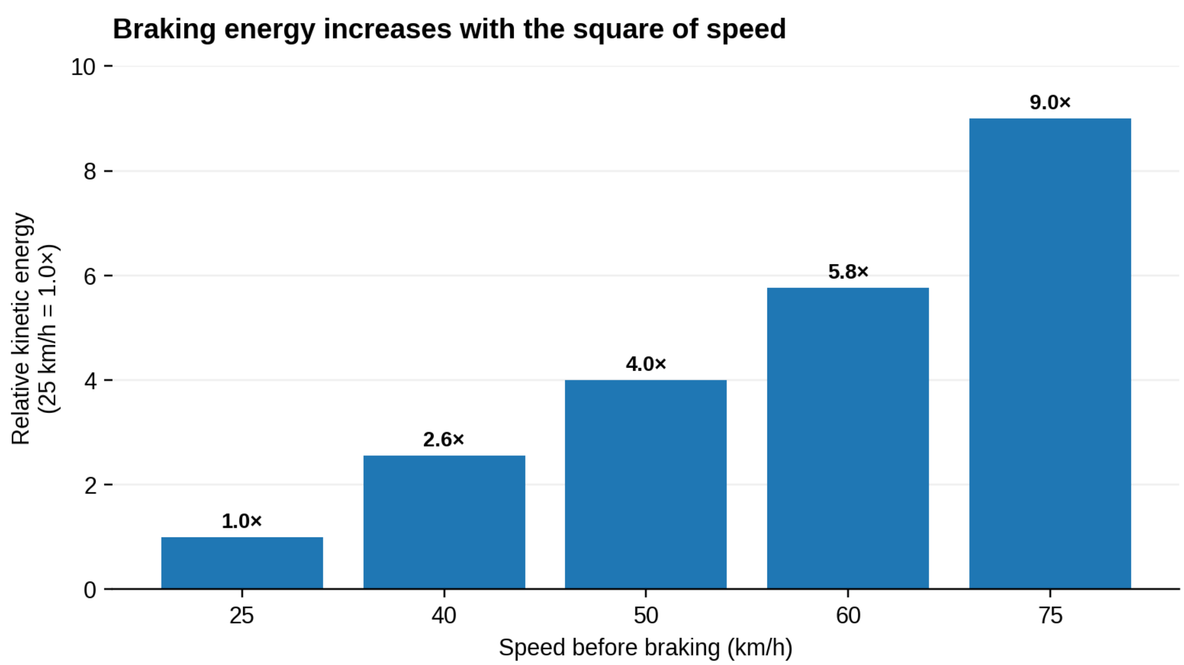


***Figure 7.*** *Relative braking energy at the stated speed envelope.*
The ratio is independent of mass, while absolute energy scales directly with total vehicle-and-rider mass. This chart does not predict stopping distance or rotor temperature.

**Table 7.** Drivetrain, wheel, braking, and traction hardening matrix

| Subsystem | Dominant failure mode | Selected response | Inspection / release gate |
|---|---|---|---|

| Subsystem | Dominant failure mode | Selected response | Inspection / release gate |
|---|---|---|---|
| **Bottom bracket / frame** | Torque reaction, fretting, fatigue | Threaded interface, rigid plates, EPDM contact layer | Torque audit; crack and movement inspection after staged load tests |
| **Chain / cassette** | Shock load, elongation, tooth damage | Heavy-duty 9-speed system and controlled shifting | Chain-wear measurement, chainline check, no power shifts under load |
| **Freehub / rear wheel** | Drive-pawl overload, spoke loosening, rim fatigue | Robust hub/wheel build and conservative current ramp | Pawl inspection, spoke-tension log, rim and axle inspection |
| **Lubrication** | Silt retention and abrasive paste | Hot-wax protocol with cleaning access | Post-wet inspection and scheduled rewax |
| **Brake system** | Thermal fade and limited modulation | Four-piston calipers and large rotors | Bed-in, repeated-stop test, temperature monitoring, pad/rotor/fluid limits |
| **Tires** | Wet grip, heat, casing or pressure failure | Large-volume road/mixed-surface tire | Rim fit, pressure, load, casing, wear, and speed-capability review |

# 7.0 Avionics and low-profile integration

Low visual clutter supports theft deterrence, weather protection, and a conventional cockpit layout. It must not conceal equipment that is legally required or safety information the rider needs immediately.

## 7.1 Minimal cockpit

The proposed cockpit removes the large conversion display and routes controller telemetry through a phone and Engo 2 smart glasses. The interface should prioritize speed, battery state, temperature warnings, and faults without obstructing the rider’s view. A visible or audible fallback warning is required if the phone, Bluetooth link, or HUD fails.

## 7.2 Packaging and enclosure strategy

The primary pack is packaged in a rigid downtube enclosure and the secondary pack, balancer, and tracker are placed in a custom waterproof frame bag. Low-profile packaging must still provide cable strain relief, drainage, ventilation where required, access to fuses and disconnects, secure battery restraint, and a service path that does not require damaging the frame.

**Table 8.** Low-profile packaging and cockpit integration

| Element | Integration strategy | Serviceability / safety requirement |
|---|---|---|
| **Primary battery** | Rigid downtube enclosure with conventional-bike proportions | Positive restraint, drainage, BMS access, fuse and disconnect access |
| **Secondary battery** | Custom waterproof triangle bag | No cell compression or chafe; serviceable retention and thermal path |
| **Balancer / wiring** | Inside protected frame volume | Strain relief, abrasion protection, connector locking, inspection access |
| **Cockpit display** | Phone and HUD replace large conversion LCD | Critical warnings remain visible/audible if wireless link fails |
| **Controls** | Minimal external switchgear | Throttle and brake cut-off behavior are obvious, testable, and fail-safe |
| **Required road equipment** | Not concealed by low-profile packaging | Lighting, reflectors, identification, and other required equipment remain compliant |

# 8.0 Environmental hardening, safety, and verification

The platform must be released as an integrated electromechanical vehicle rather than as a collection of individually capable parts. Water protection, battery fault containment, current delivery, structural response, thermal behavior, wheel integrity, braking, and control fail-safe performance interact and therefore require system-level tests in the final packaging.

**Table 9.** Environmental hardening plan for wet coastal operation

| Hazard | Design response | Validation method |
|---|---|---|
| **Water ingress** | Sealed connectors, drip loops, cable glands, protected seams, controlled drainage | Spray exposure followed by insulation, connector, and function checks |
| **Fine silt and gravel** | Shields, cleaning access, protected bearings, waxed drivetrain | Post-route inspection for contamination, grinding, and seal damage |
| **Coastal corrosion** | Corrosion-resistant finishes, compatible hardware, dielectric protection where appropriate | Salt-film inspection and fastener/connector condition log |
| **Vibration and impact** | Locking fasteners, strain relief, supported cable runs, restrained batteries | Progressive rough-surface test and re-torque audit |
| **Thermal accumulation** | Temperature sensing, current derating, airflow paths, no trapped insulating layers | Sustained-load test inside final closed packaging |
| **Battery fault** | Independent BMS, fuse, service disconnect, protected charge interface | Fault isolation and emergency-disconnect test; no cross-charge path |

**Table 10.** Recommended integration verification matrix

| Verification area | Method | Pass criterion |
|---|---|---|
| **Mechanical fit** | Assemble final motor, packs, bag, wiring, and controls | No interference, cable pinch, movement, or service-access conflict |
| **Structural** | Progressive static and dynamic load stages with inspections | No cracks, permanent deformation, loose interfaces, or increasing motor movement |
| **Electrical protection** | Verify BMS, fuse, disconnect, polarity, isolation, and connector temperature | Each pack isolates safely; no uncontrolled equalization or hot connection |
| **Power integrity** | Log pack voltage/current during launch and sustained load | No BMS trip, connector overheating, excessive sag, or controller reset |
| **Thermal** | Instrument motor, controller, batteries, connectors, and brakes | All temperatures remain within verified component limits with stable derating |
| **Braking** | Repeated stops and wet-surface modulation tests | Consistent lever feel and stopping performance without fade or wheel instability |
| **Controls and fail-safe** | Throttle, brake cut-off, sensor-fault, wireless-loss, and power-cycle tests | Predictable safe state with clear rider warning |
| **Environmental** | Rain/silt exposure in final packaging followed by inspection | No ingress-related fault, corrosion, chafe, or trapped contamination |

**Public-operation gate:** retain a compliant low-power configuration where required and reserve high-power calibration for controlled test environments. Do not use low-profile packaging to hide mandatory equipment, identification, or operating status.

# 9.0 Conclusion

The proposed vehicle is a systems-integration exercise centered on a hardtail frame, high-output mid-drive, dual-source energy architecture, and protected cockpit. The hardtail provides packaging volume and a simpler torque path; the CYC propulsion system supplies the target performance; the two-pack architecture separates burst-current and energy-density duties; and the drivetrain, brakes, wheels, tires, and frame become safety-critical parts of one load path.

The source report sets ambitious targets of 5 kW peak output, up to 75 km/h, and up to 140 km of mixed-use range. This revision treats them as targets rather than achieved results. Release depends on measured structural integrity, battery isolation and current delivery, temperature control, braking repeatability, wet traction, wheel durability, and predictable fail-safe behavior. Low-profile packaging is valuable only when it also improves protection, serviceability, and rider awareness.

# 10.0 Procurement and design-freeze checklist

**Table 11.** Updated procurement and design-freeze checklist

Product names and configurations are retained from the supplied report. Availability, exact specifications, compatibility, and legal suitability must be revalidated before purchase.

| Subsystem | Proposed item | Key configuration | Verification before purchase |
|---|---|---|---|
| **Frame** | Cannondale Habit HT 2 | Size L or XL | Confirm exact model-year geometry, BSA shell, wheel/fork specification, condition, and warranty implications |
| **Motor** | CYC X1 Pro Gen 4 | BSA 73 mm • 40T chainring | Confirm installation kit, voltage/current limits, chainline, firmware, and sensor package |
| **Primary battery** | Molicel P50B-based pack | 72 V • 15 Ah • 20S3P | Qualified pack builder, BMS, fuse, disconnect, temperature sensing, enclosure fit |
| **Secondary battery** | Custom triangle pack | 72 V • 20-25 Ah | Cell choice, BMS, structural restraint, waterproofing, thermal path, charge connector |
| **Power combining** | Grin dual-battery discharge balancer | High-voltage / current-compatible model | Voltage and current ratings, connector choice, pack compatibility, fault behavior |
| **Charger** | Grin Cycle Satiator | Pack-specific programmable profiles | Connector, voltage, current, balancing strategy, and charge-location safety |
| **Drivetrain** | Box Two Prime 9 + KMC e9 Turbo | 11-50T • 9-speed | Chainline, rear-hub compatibility, replacement-parts availability, wear-gauge plan |
| **Brakes** | Hope Tech 4 V4 | 220 mm front • 203 mm rear | Fork/frame rotor limits, adapters, hose routing, pad compound, fluid and rotor compatibility |
| **Tires** | Schwalbe Super Moto-X | 29 × 2.4 in | Rim width, frame/fork clearance, load, pressure, casing, and speed suitability |
| **Avionics** | Engo 2 / ActiveLook + phone | Wireless telemetry HUD | Controller data compatibility, warning fallback, charging, rain operation, field of view |
| **Packaging** | Custom frame bag + downtube shell | Waterproof, restrained, serviceable | Battery restraint, chafe protection, drainage, disconnect access, heat management |
| **Safety hardware** | Fuses, disconnects, temperature sensors, protective sleeving | Per-pack and system-level protection | Select after measured current, fault-energy, connector, and enclosure review |