# **Project Chimera: The Ultimate Comprehensive Development Plan**

## **Part 7: Player Progression, Economy, and Advanced Feature Roadmap (Post-MVP)**

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Document Focus: Elaboration of Part 7 - Player Progression, Economy, and Advanced Feature Roadmap (Post-MVP)

This part of the development plan outlines the systems and strategies that drive long-term player engagement, growth, and the gradual unfolding of Project Chimera's most advanced features. It details how players will evolve from novice cultivators managing a small residential setup into master geneticists and CEOs of sprawling, high-tech cultivation empires. This includes the design of deep progression systems (Skill Tree and Research), the evolution of the game's economy from a simple NPC-driven model to a dynamic player-influenced marketplace, and a clear roadmap for introducing sophisticated late-game mechanics. The successful implementation of these systems is key to providing a compelling and enduring gameplay experience that extends far beyond the initial Minimum Viable Product (MVP).

### **7.A. Player Progression: Detailed Skill Tree Design, Research System**

Player progression in Project Chimera is the primary mechanism for unlocking new capabilities, equipment, knowledge, and gameplay systems. It is designed to provide a structured learning curve, tangible rewards for effort and achievement, and pathways for players to specialize in different aspects of cultivation, genetics, engineering, and business management. The two core pillars of this progression are a detailed, thematic Skill Tree and a robust, resource-intensive Research System. (Doc1, Sec VII.A).

* **MVP Recap (as per Part 4, Sec 4.3.9):**
  + **Skill Tree:** Simplified, visually represented as "The Tree" (cannabis plant). Limited nodes focused on MVP-relevant categories (Cultivation, Environment, Science/Observation, basic Genetics, rudimentary Business).
  + **Node Unlocks:** Primarily introduce concepts and enable the *use* of basic mechanics, tools, or equipment.
  + **Skill Point Acquisition:** From completing NPC contracts and successful harvests.
  + **Research System:** Conceptually introduced, perhaps with "Research Points" as a currency, but no significant mechanical implementation in MVP.
* **Full Vision: Deep, Interconnected Skill Trees & Strategic Research System:**  
  7.A.1. The Skill Tree: "The Tree of Knowledge" - Full Design & Philosophy  
  The Skill Tree evolves into a vast, interconnected web representing the player's accumulated knowledge and expertise across all facets of Project Chimera.
  + **Thematic Visualization (Enhanced):**
    - The cannabis plant metaphor ("The Tree") is retained and enhanced. As players unlock nodes, the visual representation of the plant in the Skill Tree UI grows more complex, vibrant, and mature.
    - **Main "Leaves" (Branches) - Expanded Categories:**
      1. **Genetics & Breeding:** (Deepest branch) Covers everything from basic inheritance understanding to advanced breeding techniques, genetic modification (late-game), strain stabilization, and pheno-hunting mastery.
      2. **Cultivation Practices:** Encompasses soil/hydroponic techniques, advanced plant training methods (LST, HST, ScrOG), organic/living soil practices, harvesting/trimming/curing mastery.
      3. **Environmental Engineering:** Focuses on understanding and controlling microclimates, advanced HVAC design, lighting science, CO2 management, and utility network optimization.
      4. **Facility Construction & Design:** Unlocks new structural components, advanced construction techniques (multi-story, specialized room types), layout optimization principles, and utility routing efficiency.
      5. **Post-Harvest Technologies:** Covers advanced drying/curing methods, extraction sciences (solventless, solvent-based), edibles/topicals manufacturing, and quality control/lab analysis techniques.
      6. **Botanical Science & Research Methodology:** Unlocks advanced diagnostic tools, understanding of plant physiology, GxE interaction principles, experimental design for research projects, and data analysis skills.
      7. **Business & Operations Management:** Focuses on market analysis, contract negotiation, financial management, facility efficiency, logistics, and potentially staff management (if added).
    - **"Nodes" (Skills/Unlocks):** Each Leaf unfurls into numerous interconnected nodes. Each node represents:
      * **Conceptual Understanding:** Unlocking a node often first provides the player with the *knowledge* or *theory* behind a technique or system (e.g., via an ADA explanation or an update to the in-game guide).
      * **Mechanical Enablement:** Allows the player to *perform* a new action, *use* a new tool, *build* a new piece of equipment, or *access* a new UI/system.
      * **Recipe/Blueprint Unlock:** Grants access to new nutrient recipes, construction blueprints, or processing formulas.
      * **Access to Higher Tiers:** Unlocks higher tiers of existing equipment or more advanced versions of consumables.
  + **Philosophy: "Unlocking Concept & Capability, Mastery Through Application & Upgrades" (Reiteration of Doc1, Sec VII.A):**
    - Unlocking a Skill Tree node is the *first step*. It grants access or understanding.
    - True mastery, efficiency, or the full potential of that unlocked capability often requires:
      * **Purchasing/Crafting Equipment:** Unlocking "Advanced Drip Irrigation" in the Skill Tree allows you to *research and then buy/build* the actual drip system components.
      * **Further Research:** Some Skill Tree nodes might be prerequisites for initiating specific Research Projects (see 7.A.2) that provide deeper benefits or specialized variants.
      * **Practice & Experience:** Some skills might have an implicit "experience" component where repeated successful use improves efficiency slightly (e.g., faster manual trimming with practice, higher success rate for cloning). This is a subtle effect.
      * **Resource Investment:** Applying the new knowledge or using the new equipment costs in-game resources.
  + **Skill Point Acquisition (Expanded):**
    - **Primary:** Completing NPC contracts (rewards scale with contract difficulty/complexity).
    - **Secondary:** Successful harvests (value tied to quantity *and* quality – incentivizing good cultivation).
    - **Tertiary (Post-MVP):**
      * Achieving specific Milestones or Achievements (e.g., "Breed a strain with >25% THC," "Design a facility with 95% energy efficiency").
      * Completing Research Projects might yield a small number of bonus Skill Points.
      * Discovering new genetic traits or successfully stabilizing a new IBL.
      * Winning "Cannabis Cup" style events (if implemented).
  + **Interconnectivity & Prerequisites:**
    - Nodes within a Leaf often have linear or branching prerequisites.
    - Significant cross-Leaf prerequisites will exist, encouraging holistic development. E.g., unlocking "Advanced Solventless Extraction" (Post-Harvest Tech) might require specific nodes from "Botanical Science" (understanding trichome chemistry) and "Environmental Engineering" (for precise temperature control of presses).
    - Some very high-tier skills might require mastery (all nodes unlocked) in multiple prerequisite Leaves.
  + **Balancing & Pacing:**
    - The Skill Point cost of nodes will increase significantly for more advanced skills, ensuring a paced progression.
    - The tree will be designed so players can specialize to some extent, but a degree of broad knowledge is necessary for overall success, especially in the mid-game. Hyper-specialization too early might lead to bottlenecks.
  + **Respec Option (Limited/Costly):**
    - A very late-game, expensive option to "respec" a limited number of Skill Points might be considered, allowing players to shift focus if their strategic goals change dramatically. This should not be easily abusable.
  + **C# Implementation (Skill Tree - Full Vision):**
    - SkillNodeSO.cs: Becomes highly detailed:
      * nodeID, displayName, detailedDescription, icon.
      * leafCategory (enum).
      * skillPointCost.
      * prerequisiteNodeIDs (List).
      * unlocks (List<UnlockEffect>): A polymorphic list where UnlockEffect is a base class. Derived classes could be:
        + UnlockEquipmentSOEffect (makes specific EquipmentDataSOs available in shop/build menu).
        + UnlockRecipeSOEffect (for nutrients, edibles, etc.).
        + EnableMechanicEffect (sets a boolean flag that enables a gameplay system or player action).
        + GrantKnowledgeEffect (triggers an ADA message or guide update).
        + UnlockResearchProjectEffect (makes a ResearchProjectSO available).
      * uiPosition (Vector2 for visual layout on the tree).
    - SkillTreeManager.cs: Manages the entire tree structure (likely loaded from a collection of all SkillNodeSOs), player's unlocked nodes, skill point balance. Handles unlock logic and event broadcasting (OnSkillUnlockedEvent).
    - Sophisticated UI C# backend for rendering the interactive tree, showing connections, prerequisites, unlock status, and handling player input for unlocking nodes. This might involve custom UI Toolkit controls for the tree visualization.
  + **AI Tooling (Skill Tree - Full Vision):**
    - Cursor AI: Generating the extensive SkillNodeSO boilerplate, C# logic for SkillTreeManager (unlock validation, prerequisite checks), and backend for the complex Skill Tree UI.
    - AI for Text Generation: Assisting with writing the detailed descriptions for hundreds of skill nodes.
    - AI for Image Generation: Creating unique icons for each skill node and for the "Leaf" categories.

The full Skill Tree becomes a central pillar of player progression, guiding their learning journey and providing a deep sense of accomplishment as they master the multifaceted arts and sciences of Project Chimera.7.A.2. The Research System: Pushing the Boundaries of Knowledge (Full Detail)While the Skill Tree represents broad learning and capability unlocking, the Research System allows for focused, resource-intensive investigation into specific technologies, genetic modifications, processing optimizations, or advanced scientific principles. It's the engine for true innovation within the game.

* + **Concept & Purpose:**
    - Research projects are distinct, often lengthy endeavors that players initiate and fund.
    - They typically unlock highly specialized or cutting-edge benefits, often building upon foundations laid by the Skill Tree.
    - Research introduces an element of strategic resource allocation (currency, time, special research resources, prerequisite knowledge).
  + **Research Project Structure (ResearchProjectSO):**
    - projectID, displayName, detailedDescription (outlining the research goals and potential benefits).
    - researchCategory (enum, aligning with Skill Tree Leaves or more specific sub-fields like "Advanced Cannabinoid Chemistry," "Mycorrhizal Symbiosis Optimization," "Cryogenic Extraction Techniques").
    - prerequisites:
      * Required SkillNodeSO(s) from the Skill Tree.
      * Previously completed ResearchProjectSO(s).
      * Access to specific lab equipment (e.g., "Requires Electron Microscope" for certain genetic research).
      * Availability of specific PlantStrainSOs or genetic material for study.
    - costs:
      * currencyCost (significant).
      * researchPointsCost ("Research Points" are a special currency earned from specific activities like analyzing unique plant samples, publishing (simulated) research papers, or achieving scientific breakthroughs – distinct from Skill Points).
      * timeToComplete (in-game days/weeks).
      * requiredConsumables (List<InventoryItemSO> and quantities – e.g., rare chemical reagents, specialized labware, data storage units).
    - unlocks (List<UnlockEffect>): Similar to Skill Tree, but often more potent or unique:
      * New, high-tier EquipmentDataSO (e.g., the AI Research Lab itself, Supercritical CO2 Extractor).
      * Advanced GeneticModificationTechnique (e.g., enabling CRISPR-like targeted gene editing - very late game).
      * Significant efficiency buffs to existing processes (e.g., "+15% extraction yield for Rosin Presses").
      * New PhenotypicTraitSOs or AlleleDefinitionSOs (representing newly discovered or understood genetic factors).
      * Access to new NPC contacts or markets.
      * Unique EnvironmentalRecipeSOs for extreme optimization.
    - successChance (float, 0.0-1.0 - optional): Some very cutting-edge research might have a chance of failure or partial success, consuming resources without yielding the full benefits. Player's "Botanical Science" skill level or relevant lab equipment quality could influence this.
    - breakthroughPotential (float): Chance of a "critical success" yielding unexpected bonus discoveries or a more potent version of the primary unlock.
  + **Research Mechanics & Player Experience:**
    1. Player identifies available Research Projects in a "Research Lab UI" (unlocked via Skill Tree).
    2. Player ensures they meet all prerequisites.
    3. Player commits the required resources (currency, research points, consumables) to start a project.
    4. The project has a timer. During this time, the assigned lab equipment (if any) might be "busy."
    5. Player might need to perform supporting actions for some research (e.g., "Grow 10 plants of Strain X under specific stress conditions and log data"). This adds interactive elements to research.
    6. Upon completion (and success, if chance-based), the unlocks are granted. ADA might announce significant breakthroughs.
    7. Failed research (if implemented) results in loss of resources but might provide some "partial data" that reduces the cost/time of a subsequent attempt.
  + **"Research Points" Acquisition:**
    - Successfully analyzing plant samples in the In-House QC Lab (especially for unique cannabinoids/terpenes).
    - Achieving "Discovery" events in the Trait Library.
    - Completing specific NPC contracts that require R&D or sample provision.
    - Late-game: "Publishing" (simulated) research findings based on in-game discoveries, granting Research Points and reputation.
  + **Research Lab UI:**
    - Displays available, in-progress, and completed research projects.
    - Shows prerequisites, costs, time remaining, success chance.
    - Allows players to allocate resources and initiate projects.
    - May include a "Data Archive" where results of completed research (e.g., new knowledge, unlocked recipes) are stored.
  + **C# Implementation (Research System - Full Vision):**
    - ResearchProjectSO.cs: As detailed above.
    - ResearchManager.cs:
      * Manages the list of all ResearchProjectSOs.
      * Tracks player's completed research and currently active projects.
      * Handles resource deduction and timer management for active research.
      * Calculates success/failure/breakthrough outcomes.
      * Applies UnlockEffects upon project completion via an event (OnResearchCompletedEvent).
    - PlayerResearchData.cs: Stores player's research progress (completed projects, active projects and their timers, accumulated Research Points).
    - UI C# backend for the Research Lab interface, dynamically displaying project information and handling interactions.
  + **AI Tooling (Research System - Full Vision):**
    - Cursor AI: Boilerplate for ResearchProjectSO, C# logic for ResearchManager (state tracking, outcome calculation, unlock application).
    - AI for Text Generation: Drafting detailed descriptions, scientific justifications (flavor text), and potential outcome scenarios for numerous research projects.
    - AI for Image Generation: Icons for research projects, categories, and potentially illustrative images for research reports or discoveries.

The Research System provides the pathway for players to make genuine breakthroughs, unlock the most advanced technologies, and push the boundaries of what's possible in cannabis science and cultivation within Project Chimera. It complements the broader learning of the Skill Tree with focused, high-investment, high-reward investigations.

### 7.B. Economic Systems: From Humble Beginnings to Cannabis Conglomerate

The economic systems in Project Chimera are designed to provide players with motivation, goals, and a tangible measure of their success in the complex world of cannabis cultivation, breeding, and product development. The economy evolves significantly from the MVP's simple NPC-driven contracts to a sophisticated, dynamic, and potentially player-influenced marketplace in the full vision, offering deep strategic challenges and opportunities.

* **MVP Recap (as per Part 4, Sec 4.3.8):**
  + **NPC-Driven Contract Economy:** Primary income source. Contracts specify strain, quantity, simplified quality, deadline (optional/generous), and reward.
  + **Limited Direct Sales:** Option to sell surplus to a generic NPC buyer at base prices.
  + **Basic Operational Costs:** Consumables (seeds, media, nutrients, treatments) and abstracted utility bills.
  + **Guidance Mechanism:** Early contracts guide players to grow foundational strains and learn basic quality achievement.
  + **Exclusions:** No player-driven market, no dynamic supply/demand pricing, no complex financial tools or NPC economic behaviors.
* **Full Vision: Dynamic, Multi-layered Economic Simulation & Strategic Market Play:**  
  7.B.1. NPC Contract Economy (Enhanced & Evolved)  
  Even with the introduction of a player-driven marketplace, the NPC contract system remains relevant, especially in the early to mid-game, and evolves to offer more diverse and challenging opportunities.
  + **Increased Contract Variety & Complexity:**
    - **Diverse Requesters:** Contracts come from a wider range of NPC entities:
      * **Local Dispensaries/Retailers:** Standard orders for various strains and product types (flower, basic extracts).
      * **Pharmaceutical Companies/Research Institutions:** Contracts for specific cannabinoid profiles (e.g., high CBD/low THC, specific minor cannabinoids like CBG or THCV), high purity extracts, or strains with unique genetic markers for research. Often pay premiums for quality and consistency.
      * **Artisan Product Makers (Edibles, Topicals):** Contracts for bulk flower or specific extracts to be used as ingredients in their (NPC-made) products.
      * **Industrial Hemp Processors:** Contracts for large quantities of hemp biomass (low THC, high fiber/CBD strains) if hemp cultivation is introduced as a distinct gameplay path.
      * **Private Collectors/Connoisseurs:** Rare, high-value contracts for exceptionally unique, high-quality, or award-winning player-bred strains.
    - **More Specific Requirements:**
      * **Detailed Quality Metrics:** Contracts specify target ranges for THC/CBD percentages, key terpene profiles (e.g., "Limonene-dominant Sativa"), absence of contaminants (pesticides, heavy metals – verified by lab tests), specific trim quality, or even cultivation method (e.g., "Certified Organic," "Living Soil Grown").
      * **Product Form:** Flower (various grades), Kief, Hash, Rosin, BHO/PHO extracts, Distillate, Edibles (specific types/dosages), Topicals.
      * **Packaging & Labeling:** Some contracts might require specific packaging or labeling standards.
    - **Multi-Stage Contracts:** Longer-term contracts involving R&D, such as "Develop a new strain with X and Y characteristics within Z generations and supply 1kg of stable F5 seeds."
  + **Dynamic Contract Generation:**
    - The ContractManager.cs uses a more sophisticated procedural generation system, influenced by:
      * **Player Reputation:** Higher reputation with specific NPCs or factions unlocks more lucrative or unique contracts. Fulfilling contracts well improves reputation; failures damage it.
      * **Game World State/Events:** Simulated news events (e.g., "New study highlights benefits of CBG" -> increased contracts for CBG-rich strains. "Music festival next month" -> increased demand for pre-rolls/vapes).
      * **Player Progression & Capabilities:** Contracts offered are generally aligned with the player's current technological level and production capacity (though some "reach" contracts might appear).
      * **Market Saturation (Simple Link):** If the player (or simulated NPC market) is flooding the market with a specific product, NPC contract prices for that product might temporarily dip.
  + **Negotiation (Simplified):** For some high-value or unique NPC contracts, a simple negotiation mechanic might be introduced: player can try to negotiate slightly better price, longer deadline, or reduced penalty, with success based on their "Business" skill or reputation with that NPC. Failure might lead to the NPC withdrawing the offer.
  + **C# Implementation (Enhanced NPC Contracts):**
    - NPCProfileSO.cs becomes more detailed, defining an NPC's specific demands, quality preferences, price elasticity, and reputation track with the player.
    - ContractTemplateSO.cs supports more complex objective types (e.g., "ResearchAndDevelopTrait," "SupplySpecificExtract").
    - ReputationManager.cs: Tracks player reputation with various NPC entities/factions.
    - NegotiationModule.cs: Handles the simple contract negotiation mini-loop.

The enhanced NPC contract system provides a steady stream of structured goals and income, coexisting with and complementing the more volatile player-driven market.7.B.2. Future Player-Driven Marketplace (Full Detail - Post-MVP Expansion)This is a major post-MVP feature that transforms the game's economy into a dynamic, player-influenced ecosystem. (Doc1, Sec VII.B; Doc2, Sec IV.E).

* + **Core Concept:** Players can list their cultivated cannabis products (flower, seeds, clones, extracts) and potentially crafted equipment or advanced consumables for sale to other (simulated or, in a hypothetical online version, real) players or to a global NPC "pseudo-market." They can also browse listings and purchase items from this market.
  + **Supply & Demand Dynamics (Simulated for Single-Player):**
    - **Player Supply:** The quantity and quality of items listed by the player directly impacts supply for those specific items.
    - **NPC Demand (Dynamic & Procedural):** The "demand" side is driven by a sophisticated simulation of NPC consumer preferences, industrial needs, and research requirements. This demand is not static:
      * **Regional Preferences:** Different simulated regions or NPC demographics might have preferences for Sativa vs. Indica, specific terpene profiles, or product types (e.g., "Region A prefers edibles," "Region B has high demand for CBD oils").
      * **Trend Cycles:** Certain strains or product attributes (e.g., "Haze strains," "High Myrcene content," "Solventless Rosin") can become trendy, boosting demand and prices temporarily. Trends fade over time or are replaced by new ones. ADA might provide "Market Trend Reports."
      * **Game World Events:** As with NPC contracts, global events influence demand.
      * **Elasticity:** Demand for essential items (e.g., basic nutrients) might be less price-elastic than demand for luxury/connoisseur strains.
    - **Price Calculation Engine:**
      * The MarketplaceManager.cs uses algorithms to determine current market prices based on:
        + **Base Value (MarketProductSO.basePrice):** An intrinsic value for the item.
        + **Current Supply:** Total quantity of that specific item (or close substitutes) listed on the market by the player and simulated NPC sellers. Higher supply = downward pressure on price.
        + **Current Demand:** Aggregated demand from simulated NPC buyers. Higher demand = upward pressure on price.
        + **Quality Modifiers:** Higher quality products (potency, purity, terpene richness, trim grade, CoA verification) command significant price premiums. A detailed QualityScoreCalculator.cs determines this.
        + **Strain Reputation/Rarity:** Player-bred strains that win (simulated) "Cannabis Cups," are genetically unique, or are consistently high quality can develop a "StrainReputation" that boosts their market value. Rare landraces or difficult-to-breed genetics also fetch higher prices.
        + **Player Reputation:** The player's overall business reputation can slightly influence the prices they can achieve.
    - **NPC Sellers (Market Makers):** To ensure availability of essential goods (basic seeds, nutrients, common equipment) and to provide price anchors, a set of NPC "market maker" sellers will always have some stock, though their prices might fluctuate with broader market conditions.
  + **Marketplace UI & Functionality:**
    - **Browse & Search:** Players can browse listings by category (flower, seeds, extracts, equipment), filter by traits (THC/CBD range, terpene profile, strain lineage), sort by price, quality, rarity.
    - **List Items for Sale:** Player selects items from their inventory, sets quantity, and can either:
      * **Set Asking Price:** For unique/high-value items. Other (NPC) buyers might make offers, or the item might sit unsold if priced too high.
      * **Sell at Current Market Rate:** For more common goods, sell immediately at the prevailing dynamically calculated price.
    - **Order Management Dashboard:** Track active listings, sales history, incoming offers, pending purchases.
    - **Market Data Analysis Tools (Unlocked via Business Skill Tree/Research):**
      * Historical price charts for specific products/strains.
      * Trading volume information.
      * Demand trend indicators.
      * Competitor analysis (if rival NPC companies are simulated selling on the market).
    - **Marketplace Wallet:** A separate currency balance for marketplace transactions.
  + **Transaction Types:**
    - **Direct Purchase:** Buy listed items at their current price.
    - **Sell Orders:** List items for sale.
    - **Buy Orders (Advanced):** Player places an order to buy a specific item/strain at a specific price if/when it becomes available.
    - **Auctions (Very Advanced/Optional):** For extremely rare genetics or award-winning products, an auction system could be implemented.
  + **C# Implementation (Player-Driven Marketplace):**
    - MarketplaceManager.cs: The core engine. Manages listings, buy/sell orders, price calculations, demand simulation.
    - MarketListing.cs: Data object for an item listed on the market (item ID, seller ID, quantity, price, quality data, timestamp).
    - DemandSimulator.cs: Procedurally generates and updates NPC demand profiles and trends.
    - PriceEngine.cs: Implements the supply/demand/quality pricing algorithms.
    - StrainReputationTracker.cs: Tracks the market "fame" of specific strains.
    - Extensive UI C# backend for all marketplace screens, data visualization for charts.
    - If a pseudo-online component is ever considered (e.g., "global" prices influenced by an aggregate of all players' single-player market activities, updated periodically from a central server – VERY complex), this would require backend server infrastructure. For single-player, it's all simulated locally.
  + **AI Tooling (Player-Driven Marketplace):**
    - Cursor AI: Logic for MarketplaceManager, DemandSimulator, PriceEngine. C# for the complex marketplace UI.
    - AI for Text Generation: Generating dynamic "Market News" snippets or trend descriptions for ADA's reports.

The player-driven marketplace transforms the economy into a living system where players can become price-setters for their unique creations, requiring keen market awareness, product differentiation, and strategic production planning.7.B.3. Player/Company Reputation System (Full Detail)The player's reputation as a cultivator, breeder, and business operator significantly influences their interactions and opportunities within the game world.

* + **Reputation Metrics (Tracked by ReputationManager.cs):**
    - **Overall Business Reputation:** A general score reflecting reliability, professionalism, and success.
    - **Faction/NPC-Specific Reputation:** Individual reputation scores with key NPC entities (e.g., "Pharmaceutical Corp X," "Local Dispensary Guild," "Connoisseur Collector Y").
    - **Strain-Specific Reputation (Optional):** If a player consistently produces exceptional batches of a particular named strain they bred, that strain itself can gain a positive reputation in the market.
    - **Quality Reputation:** Based on the consistent quality of products sold (verified by lab tests, contract feedback).
    - **Ethical Reputation (If ethical choice mechanics are added):** E.g., choices regarding organic vs. synthetic, labor practices (if staff are added), environmental impact.
  + **Factors Influencing Reputation:**
    - **Positive Impacts:**
      * Successfully completing contracts, especially high-value or complex ones.
      * Exceeding quality expectations on contracts.
      * Consistently selling high-quality products on the marketplace.
      * Winning (simulated) "Cannabis Cups" or industry awards for bred strains.
      * Fulfilling special requests from key NPCs.
      * Investing in community projects or ethical practices (if such mechanics exist).
      * Positive outcomes from narrative events/quests.
    - **Negative Impacts:**
      * Failing or cancelling contracts.
      * Delivering sub-standard or contaminated products (caught by NPC QC or lab tests).
      * Products being "recalled" due to poor dosage consistency (edibles) or safety issues.
      * Being caught using banned pesticides (if a regulatory system exists).
      * Negative outcomes from narrative events/quests.
      * Price gouging excessively on essential items (if a "fairness" mechanic is part of NPC perception).
  + **Effects of Reputation:**
    - **Contract Availability & Terms:** High reputation unlocks access to more lucrative, exclusive, or unique contracts from specific NPCs/factions. May allow for better negotiated terms. Low reputation can lead to fewer or worse contract offers.
    - **Marketplace Prices:** Slight positive or negative modifiers on prices achievable for player's products. Highly reputable sellers might command a premium.
    - **Access to Unique NPCs/Vendors:** Some specialist NPCs (rare genetics suppliers, advanced equipment vendors, research collaborators) may only deal with players of high standing.
    - **Narrative Opportunities:** Reputation levels can trigger unique narrative events, quests, or dialogues with ADA and other NPCs.
    - **Access to Advanced Features/Areas:** Certain late-game facility upgrades or research areas might require a minimum reputation level.
  + **UI Feedback:**
    - A "Reputation" screen in the player's main UI, showing overall scores and standing with key factions/NPCs.
    - Feedback messages from NPCs (e.g., "Thanks for the excellent quality on that last order, your reputation with us has increased!").
    - News articles or market reports might subtly reference the player's company/brand if their reputation becomes very high or low.
  + **C# Implementation:**
    - ReputationManager.cs: Stores all reputation scores. Provides methods to AddReputation(NPC\_ID, amount) or GetReputation(NPC\_ID).
    - ReputationModifierSO.cs: Defines events/actions that affect reputation and by how much (e.g., "ContractSuccess\_HighQuality\_Bonus = +10 Rep\_PharmaCorpX").
    - Game systems (ContractManager, MarketplaceManager, QualityControlManager) call ReputationManager to update scores based on player actions and outcomes.
  + **AI Tooling:**
    - Cursor AI: Logic for ReputationManager, data structures for tracking reputation with multiple entities.

The reputation system adds long-term consequences to player actions, encouraging consistent quality and ethical behavior (if modeled), and making the game world feel more reactive to the player's journey.7.B.4. Robust Resource & Currency Sinks (Full Detail)To maintain a balanced and challenging economy, especially with a player-driven marketplace and potentially large income streams in the late game, robust and varied resource and currency sinks are essential. These prevent runaway inflation and keep players striving for new goals. (Doc2, Sec IV.E).

* + **Operational Costs (Scaling with Facility Size & Complexity):**
    - **Utilities (Detailed):**
      * **Power:** Calculated based on the actual power consumption (EquipmentDataSO.powerConsumption) of every active piece of equipment. Different power sources (PowerGeneratorSO) have different generation capacities and running costs (fuel, maintenance).
      * **Water:** Consumption based on plant needs, hydroponic system types, and any water treatment/recycling systems. Cost of water from a municipal source or costs for well maintenance/pumping.
      * **Climate Control:** Energy cost of running HVAC systems (heaters, ACs, dehumidifiers/humidifiers, fans) scales with the size of conditioned spaces, insulation quality of rooms, and the difference between internal target temps and external ambient temps (if simulated for Warehouse/Greenhouse).
    - **Consumables:** Ongoing costs for:
      * Growing Media (soil, coco, rockwool).
      * Nutrients, pH adjusters, supplements (cost increases with more plants and advanced feeding schedules).
      * Pest/Disease Treatments & Biological Controls.
      * Lab Consumables (solvents, reference standards, test kits, sterile media for tissue culture).
      * Packaging Materials for finished products.
    - **Maintenance & Repair:**
      * Equipment degrades over time (especially complex machinery like extractors, PLCs, generators) and requires periodic maintenance using MaintenanceKitSO (consumable) or by paying an NPC service fee.
      * Random equipment malfunctions require repair costs (parts + labor/time).
      * Utility network components (pumps, breakers) can also fail.
  + **Capital Investments (Progression & Expansion):**
    - **Facility Construction & Upgrades:** Cost of building new rooms, expanding the Warehouse, installing advanced structural components (better insulation, reinforced floors).
    - **New Equipment Purchases:** Acquiring higher-tier cultivation gear, specialized processing machinery (extractors, edible lines), advanced lab equipment, automation controllers. Many late-game items will be very expensive.
    - **Research & Development:** Significant currency and Research Point costs for unlocking advanced skills and research projects.
    - **Genetic Acquisitions:** Purchasing rare seeds/clones from specialist NPCs or funding genetic expeditions.
  + **Marketplace Sinks:**
    - **Listing Fees:** A small percentage or flat fee for listing items on the player-driven marketplace.
    - **Transaction Tax:** A percentage-based tax on all successful sales in the marketplace.
    - These fees help regulate market activity and provide a continuous currency sink.
  + **"Luxury" & Endgame Sinks:**
    - **Cosmetic Upgrades (If Implemented Ethically):** Purely aesthetic upgrades for the facility, office, or equipment that are very expensive but offer no gameplay advantage.
    - **Philanthropy / "Legacy Projects" (Very Late Game):** Options to invest vast sums of currency into large-scale, non-profit endeavors within the game world (e.g., "Fund a Public Botanical Research Institute," "Establish a Genetic Diversity Seed Vault") for prestige, unique narrative outcomes, or legacy achievements rather than direct ROI.
    - **Acquiring Extremely Rare / Unique Items:** One-of-a-kind art pieces for the office, ultra-rare (but still balanced) equipment prototypes from eccentric inventors.
  + **Failure & Recovery Costs:**
    - Fines for regulatory non-compliance (e.g., improper labeling, safety violations in labs).
    - Costs associated with cleaning up after major pest/disease outbreaks or facility accidents.
    - Replacing lost crops or damaged equipment.
  + **C# Implementation:**
    - EconomyManager.cs will handle all currency transactions and track detailed expenses.
    - OperationalCostCalculator.cs: Periodically calculates and deducts utility and other ongoing costs.
    - Each piece of equipment (PlaceableEquipmentInstance.cs) will have maintenance states and associated costs.
    - MarketplaceManager.cs implements listing fees and transaction taxes.
  + **AI Tooling:**
    - Cursor AI: Logic for OperationalCostCalculator, maintenance cost tracking, marketplace fee calculations.

A well-balanced system of currency sinks is vital for the long-term health of the game economy, ensuring that money remains valuable and players always have meaningful goals to spend their earnings on, preventing an "infinite money, nothing to buy" endgame state.

### 7.C. Advanced Automation Systems: Sensors, Controllers, Workflow Automation (Post-MVP Roadmap)

The introduction of advanced automation systems is a pivotal stage in Project Chimera's post-MVP evolution, embodying the "Earned Automation" philosophy (Doc1, Sec VII.C). These systems transform the player from a hands-on micro-manager into a strategic overseer and designer of complex, self-regulating cultivation and facility operations. Their phased rollout is critical for maintaining a balanced learning curve and ensuring players appreciate their power and utility. The detailed mechanics of these systems (tiered sensors, PLCs, environmental recipe execution, PID controllers, workflow automation like robotic potters/harvesters) are described in Part 5 (specifically 5.3.4 and elements of 5.1.4). This section focuses on their strategic introduction and integration into the long-term player journey.

* **Strategic Importance & Player Impact:**
  + **Scaling Operations:** Advanced automation is the *only* viable way for players to manage the significantly larger and more complex facilities (e.g., fully built-out Warehouse, future Greenhouses) envisioned for the mid-to-late game. Manual management of hundreds or thousands of plants with precise environmental needs becomes impossible.
  + **Precision & Optimization:** Automated systems, when correctly configured, can maintain environmental parameters and execute routines with a level of precision and consistency that surpasses manual capabilities, leading to potentially higher quality, yields, and efficiency.
  + **Freeing Player Focus:** By automating repetitive tasks (environmental adjustments, watering/feeding schedules, basic data logging), these systems free the player to concentrate on higher-level strategic activities: advanced genetic breeding projects, market analysis and trading, research and development, facility expansion planning, and tackling more complex NPC contracts or narrative objectives.
  + **New Gameplay Layer:** Designing, programming (via visual rule-builders for PLCs), and optimizing automation networks becomes a new, engaging gameplay puzzle in itself, appealing to players who enjoy systems engineering and logical problem-solving.
  + **Economic Implications:** While requiring significant upfront investment in research, equipment, and potentially specialized consumables (e.g., advanced sensors, controller components), successful automation leads to reduced (simulated) labor costs (if staff were ever a feature, or abstracted as "operational overhead"), improved resource efficiency, and higher, more consistent product quality, ultimately boosting profitability.
* Phased Rollout & Integration Strategy (Conceptual Expansion Path):  
  The introduction of advanced automation will be gradual, tied to progression in the Environmental Engineering, Botanical Science & Research Methodology, and potentially Facility Construction & Design Skill Tree branches, as well as specific, high-cost Research Projects.
  1. **Post-MVP Expansion Pack 1: "Integrated Environments & Smart Sensing" (Conceptual Title)**
     + **Focus:** Introduction of intermediate networked sensors and basic Programmable Logic Controllers (PLCs).
     + **Prerequisites:**
       - Mastery of MVP manual environmental control.
       - Mid-tier Skill Tree unlocks in "Environmental Engineering" (e.g., "Networked Sensor Technology," "Basic PLC Programming") and "Botanical Science" (e.g., "Advanced Environmental Parameter Analysis").
       - Completion of Research Projects like "Development of Networked Multi-Sensors" or "Introduction to Logic-Based Control Systems."
     + **New Systems Introduced:**
       - **Intermediate Networked Sensors:** Temperature, humidity, CO2, basic soil moisture, basic inline water EC/pH sensors that transmit data to a new central "Environmental Monitoring Dashboard UI." This UI allows for real-time graphing and historical data review for multiple zones/sensors.
       - **Basic PLCs:** Allow players to create simple IF-THEN rules linking one or two sensor inputs to one or two equipment actuators (e.g., "IF Room\_A\_Temp\_Sensor > 27°C THEN Room\_A\_AC.TurnOn()"). The PLC UI will be a simple rule-builder.
       - **Automated Nutrient Solution pH/EC Monitoring (Reservoir Level):** Inline sensors in reservoirs connected to the new dashboard, providing alerts but not yet full automated dosing.
     + **Player Experience Shift:** Players begin to move from constant manual checking to centralized monitoring. They start designing simple feedback loops. The "Burden of Consistency" lessens for basic parameters, but new challenges arise in designing effective PLC rules and interpreting more data.
  2. **Post-MVP Expansion Pack 2: "Precision Cultivation & Advanced Process Control" (Conceptual Title)**
     + **Focus:** Introduction of advanced precision sensors, sophisticated PLCs with more complex logic capabilities (AND/OR, timers, sequences), environmental recipe execution, and initial automated nutrient/pH/EC dosing.
     + **Prerequisites:**
       - Proficiency with basic PLCs and networked sensing.
       - High-tier Skill Tree unlocks (e.g., "Advanced PLC Logic Design," "Environmental Recipe Programming," "Automated Nutrient Chemistry").
       - Completion of Research Projects like "High-Accuracy Sensor Arrays," "Predictive PID Control Algorithms (Simplified)," "Automated Dosing System Schematics."
     + **New Systems Introduced:**
       - **Advanced Precision Sensors:** Leaf surface temperature, PAR/quantum sensors, advanced soil/substrate probes, air particle/spore traps.
       - **Advanced PLCs / Central Facility Computer:**
         * Support for more complex rule sets, multiple conditions (AND/OR), timed sequences, and potentially simplified PID control loops for critical parameters.
         * Ability to store and execute pre-defined "Environmental Recipes" (EnvironmentalRecipeSO) that dictate target parameters for different strains/growth stages throughout the day/night cycle.
       - **Automated Nutrient & pH/EC Dosing Systems:** Dosing pumps connected to reservoirs, controlled by PLCs/Central Computer based on inline sensor readings and target recipes, automatically adjusting nutrient strength and pH.
       - **Basic Scheduled Events:** PLCs can trigger actions based on time of day or elapsed time (e.g., "Run exhaust fans for 10 minutes every hour").
     + **Player Experience Shift:** Players transition to designing comprehensive environmental strategies and automation routines. Focus shifts to optimizing recipes, fine-tuning PLC logic, and managing larger, more precisely controlled facilities. The game becomes more about proactive system design than reactive manual adjustments.
  3. **Post-MVP Expansion Pack 3: "Fully Automated Operations & Industrial Scale" (Conceptual Title - Very Late Game)**
     + **Focus:** Introduction of advanced workflow automation (robotics) and systems for managing truly massive-scale operations.
     + **Prerequisites:**
       - Mastery of precision environmental and nutrient automation.
       - Peak-tier Skill Tree unlocks (e.g., "Robotic Systems Integration," "Large-Scale Logistics Management," "AI-Assisted Operational Optimization").
       - Extremely expensive and lengthy Research Projects like "Automated Harvester Design," "Robotic Potting Systems," "AI-Driven Facility Management Suite."
     + **New Systems Introduced:**
       - **Workflow Automation Equipment (Doc1, Sec VII.C):**
         * Automated Potting/Transplanting Machines.
         * Robotic Harvesting and Trimming Systems (with quality/efficiency trade-offs).
         * Automated Plant Movement Systems (conveyors, robotic platforms).
       - **Advanced Logistics Management UI:** Tools for planning and optimizing the flow of plants and materials in very large, multi-facility operations (if players can own multiple sites).
       - **AI-Assisted Facility Optimization (Conceptual):** The Central Facility Computer might offer AI-driven suggestions for improving energy efficiency, resource allocation, or automation schedules based on historical performance data (a very advanced form of ADA's advisory role).
     + **Player Experience Shift:** Players become true industrial-scale cannabis tycoons, designing and overseeing vast, largely autonomous operations. The challenge shifts to macro-level strategic planning, market domination, and pushing the boundaries of efficiency and technological advancement.
* **Challenges & Considerations for Rollout:**
  + **Balancing Complexity & Accessibility:** Each new layer of automation must be introduced with clear tutorials and a UI that allows players to understand and manage the increasing complexity. The visual rule-builder for PLCs needs to be intuitive.
  + **Performance:** Simulating many automated systems, sensors, and their interactions in large facilities will be computationally intensive. Optimization will be paramount (see Part 4, Sec 4.2).
  + **Cost & ROI:** Advanced automation equipment will be very expensive. Players need to see a clear return on investment through increased efficiency, scale, or quality to justify the cost.
  + **Debugging Player-Created Logic:** If players design complex PLC rules, providing them with tools or feedback to debug why their automation isn't working as expected will be important (e.g., a log of PLC rule evaluations, visual state indicators on controllers).
  + **Power Creep:** Automation should feel powerful but not trivialize the core challenges of cultivation. There should always be new levels of optimization or new problems (e.g., managing the maintenance of complex machinery) to engage the player.

The roadmap for advanced automation systems is designed to mirror a real-world technological progression, providing a long and rewarding journey for players who wish to master every aspect of high-tech, large-scale cannabis cultivation and facility management.

### 7.D. Advanced Genetics & Breeding: AI Research Lab, Complex Inheritance Models (Post-MVP Roadmap)

The pursuit of "ultimate cannabis genetics" is a central theme of Project Chimera. While the MVP introduces F1 crosses and simple visual trait inheritance, the post-MVP roadmap unlocks the true depth of the genetics system, transforming breeding into a sophisticated scientific endeavor. The detailed mechanics of advanced genetics (polygenic traits, complex inheritance, advanced breeding techniques like BX/IBL/S1/Feminization, mutation, tissue culture, genetic marker analysis, AI Research Lab) are described in Part 5 (Section 5.2). This section focuses on their strategic rollout as late-game content.

* **Strategic Importance & Player Impact:**
  + **Pinnacle of Genetic Mastery:** These systems represent the endgame for players focused on the genetics pillar, allowing for the creation of truly unique, elite, and perfectly stabilized strains with highly specific target profiles.
  + **Deep Intellectual Challenge:** Understanding and applying concepts like polygenic inheritance, epistasis, and multi-generational breeding strategies provides immense intellectual depth and replayability.
  + **High-Value Products:** Strains developed through these advanced techniques (e.g., perfectly stable IBLs with rare terpene profiles, feminized seeds of elite cultivars) will command the highest prices on the player-driven marketplace or fulfill the most lucrative and demanding NPC contracts.
  + **Competitive Edge (If Rival NPCs/Leaderboards Exist):** Mastery of advanced genetics could provide a competitive edge in simulated "Cannabis Cup" events or on leaderboards tracking genetic innovation.
  + **Long-Term Engagement:** The sheer combinatorial possibilities and the time investment required for advanced breeding projects provide many hundreds of hours of potential gameplay for dedicated players.
* Phased Rollout & Integration Strategy (Conceptual Expansion Path - Very Late Game):  
  Advanced genetics features are typically unlocked very late in the player's progression, requiring significant investment in the Genetics & Breeding and Botanical Science & Research Methodology Skill Tree branches, completion of numerous prerequisite Research Projects, and often, the construction of specialized lab facilities (e.g., the AI Research Lab module, Tissue Culture Lab).
  1. **Post-MVP Expansion Pack 2 or 3: "Advanced Breeding Techniques & Polygenic Understanding" (Conceptual Title)**
     + **Focus:** Introduction of core advanced breeding methods and the full simulation of polygenic trait inheritance for cannabinoids, terpenes, and yield.
     + **Prerequisites:**
       - Mastery of MVP F1 breeding and basic GxE principles.
       - High-tier Skill Tree unlocks (e.g., "Multi-Generational Pedigree Tracking," "Principles of Quantitative Genetics," "Advanced Pollination Control," "Sterile Lab Techniques").
       - Completion of Research Projects like "Understanding Polygenic Inheritance," "Backcrossing Efficacy Studies," "Inbred Line Stabilization Protocols."
     + **New Systems Introduced (as detailed in 5.2):**
       - **Full Polygenic Trait Inheritance:** The game now fully simulates how multiple genes additively (and potentially interactively) determine complex traits like THC/CBD levels, terpene concentrations, yield, etc. The UI for displaying genetic potential becomes more detailed.
       - **Backcrossing (BX):** Mechanics and UI support for performing and tracking backcross generations.
       - **Inbred Line (IBL) Creation & Sibling Breeding:** Tools for managing sib-crosses over many generations (F2-F7+).
       - **Selfing (S1) & Feminization Techniques:** Introduction of "Pollen Reversal Sprays" (consumable) and mechanics for creating S1 and feminized seeds.
       - **Mutation System (Basic):** Spontaneous mutations begin to occur at a low rate, introducing new allelic variations.
       - **Advanced Pheno-Hunting Tools:** Enhanced UI for comparing stats across large populations of sibling plants, tagging "keeper phenos."
     + **Player Experience Shift:** Breeding becomes a much more strategic, long-term endeavor. Players must plan multiple generations ahead, manage larger populations for selection, and grapple with the complexities of polygenic inheritance and inbreeding depression. The rewards are strains with significantly improved and more consistent traits.
  2. **Post-MVP Expansion Pack 3 or 4: "Genetic Engineering & Scientific Breakthroughs" (Conceptual Title - Endgame Content)**
     + **Focus:** Introduction of the most advanced genetic tools and concepts, including the AI Research Lab, tissue culture, genetic marker analysis, and potentially epistasis/pleiotropy modeling.
     + **Prerequisites:**
       - Mastery of advanced breeding techniques.
       - Peak-tier Skill Tree unlocks (e.g., "Computational Genetics," "Advanced Cell Biology," "Genetic Marker Technology," "AI-Assisted Breeding Design").
       - Extremely expensive and lengthy Research Projects like "AI Research Lab Construction & Calibration," "CRISPR Gene Editing Protocols (Simplified Simulation)," "High-Throughput Genetic Sequencing."
       - Construction of specialized lab facilities (AI Research Lab, Tissue Culture Lab).
     + **New Systems Introduced (as detailed in 5.2):**
       - **The AI Research Lab:** Fully functional predictive breeding tool, potentially using Sentis-powered ML models for enhanced accuracy.
       - **Tissue Culture & Micropropagation:** For rapid cloning and genetic preservation.
       - **Genetic Marker Analysis:** Lab service for probabilistic early seedling selection.
       - **Complex Inheritance Models (Activated):** Full simulation of epistasis (gene-to-gene interactions) and pleiotropy (one gene affecting multiple traits), making breeding even more nuanced.
       - **Targeted Mutation Induction (Very Advanced Research):** Potential for research into methods to slightly increase or target mutations (e.g., simulated chemical mutagens, radiation - with risks).
       - **CRISPR-like Gene Editing (Highly Abstracted, Very Late Game - Optional):** If included, this would be an extremely high-cost, high-risk, endgame system allowing for direct, targeted modification of specific alleles in a plant's genome. Success would not be guaranteed and could have unintended side effects, adding an ethical/risk management layer. (Doc1, Sec VII.D).
     + **Player Experience Shift:** Players operate at the cutting edge of (simulated) cannabis science. They use sophisticated tools to design and engineer elite genetics with unprecedented precision. The game becomes a deep scientific puzzle, with the potential for creating "super strains" that dominate the market or win all competitions.
* **Challenges & Considerations for Rollout:**
  + **Complexity Onboarding:** Each new advanced genetic system needs to be introduced with clear explanations, tutorials (perhaps via ADA or specialized research reports), and intuitive UI. The science can be daunting if not presented well.
  + **Balancing Difficulty & Reward:** Advanced breeding should be challenging and time-consuming but also highly rewarding. The benefits of mastering these techniques (e.g., significantly improved strain quality, unique traits, high market value) must be substantial.
  + **Information Overload:** The amount of genetic data can become overwhelming. The UI for the Genetics Lab, AI Research Lab, and Trait Library must be exceptionally well-designed for filtering, sorting, and clear presentation of complex information.
  + **Performance:** Managing the genetic data for potentially thousands of unique player-bred strains in their library, and running complex predictive simulations in the AI Research Lab, will require optimized data structures and algorithms.
  + **"Solving" Genetics:** While the AI Research Lab provides predictions, the system should be designed such that there's always an element of chance, GxE influence, and the need for player observation/selection. It should not be possible to "perfectly solve" breeding to the point where it becomes a deterministic math problem with no surprises. Mutations and subtle GxE effects help maintain this.

The roadmap for advanced genetics and breeding ensures that Project Chimera offers an unparalleled journey of genetic discovery and mastery, providing hundreds of hours of deep, strategic gameplay for dedicated players and fulfilling the core promise of pursuing "ultimate cannabis genetics."

### 7.E. Advanced Post-Harvest & Processing Mechanics (Post-MVP Roadmap)

Beyond drying, curing, and basic trimming, the ability to transform cultivated cannabis into a diverse array of value-added products (concentrates, edibles, topicals) is a major post-MVP expansion path. This introduces new layers of chemical engineering, product development, quality control, and economic opportunity. The detailed mechanics of these systems (extraction methods, edibles/topicals manufacturing, QC lab testing, specialized equipment) are described in Part 5 (Section 5.8). This section focuses on their strategic rollout.

* **Strategic Importance & Player Impact:**
  + **Economic Diversification & Value Addition:** Allows players to move up the value chain, transforming raw flower (which might have fluctuating market prices) into higher-margin processed goods. Different products will appeal to different NPC contract types or market segments in the player-driven economy.
  + **New Skill Sets & Gameplay Loops:** Introduces new gameplay focused on chemical processing, recipe formulation, precision measurement, quality control, and safety management. This appeals to players who enjoy crafting, production chains, and scientific experimentation beyond just cultivation.
  + **Product Differentiation:** Enables the creation of a wide range of branded products, from high-potency extracts to precisely dosed edibles, allowing players to carve out unique market niches.
  + **Resource Sink & Progression Vector:** Requires significant investment in specialized lab equipment, research into processing techniques, and potentially new facility zones, providing strong mid-to-late game currency and resource sinks.
  + **Risk Management:** Solvent-based extraction introduces safety hazards (fires, explosions if mismanaged), adding a new risk/reward element. Edibles production has risks associated with dosage consistency and product recalls.
* Phased Rollout & Integration Strategy (Conceptual Expansion Path):  
  The introduction of advanced post-harvest processing will be tied to progression in the Post-Harvest Technologies and Botanical Science & Research Methodology Skill Tree branches, extensive Research Projects, and the construction of dedicated, specialized lab/processing facility modules.
  1. **Post-MVP Expansion Pack 1 or 2: "Artisan Concentrates & Solventless Mastery" (Conceptual Title)**
     + **Focus:** Introduction of foundational solventless extraction techniques (dry sift, ice water hash, rosin pressing) and more detailed trimming/kief collection.
     + **Prerequisites:**
       - Mastery of advanced drying/curing and basic trimming from the core game.
       - Mid-to-high tier Skill Tree unlocks (e.g., "Trichome Separation Principles," "Advanced Kief Collection," "Ice Water Extraction Methodology," "Rosin Press Operation & Safety").
       - Completion of Research Projects like "Micron Screen Optimization for Dry Sift," "Optimal Temperatures for Rosin Pressing Different Materials."
       - Investment in initial solventless extraction equipment (Kief Tumblers, Bubble Bag Kits, basic Rosin Presses).
     + **New Systems Introduced (as detailed in 5.8):**
       - **Detailed Trimming Mechanics:** Wet vs. Dry trim choice, manual trimming minigame or skill-based system, kief collection via trim bins. Different trim quality tiers affecting flower value.
       - **Dry Sift / Kief Tumbling:** Equipment and process for producing various grades of kief.
       - **Ice Water Extraction (Bubble Hash):** Equipment, consumables (ice), and process for making bubble hash of different qualities.
       - **Rosin Pressing:** Basic to intermediate rosin presses. Mechanics for pressing flower, kief, or hash. Player controls temperature, pressure, duration. Yield and quality depend on starting material and technique.
       - **Basic In-House QC:** Perhaps a simple "Microscope Station" for visually inspecting trichome quality in kief/hash or rosin clarity.
     + **Player Experience Shift:** Players can now create their first generation of concentrates, significantly increasing product value and opening new market opportunities. They learn the hands-on art of solventless extraction.
  2. **Post-MVP Expansion Pack 2 or 3: "Advanced Extraction Science & Laboratory Operations" (Conceptual Title)**
     + **Focus:** Introduction of solvent-based extraction methods (BHO, PHO, Ethanol, CO2), post-extraction refinement (distillation, basic crystallization), and more rigorous lab testing/QC.
     + **Prerequisites:**
       - Proficiency with solventless extraction.
       - High-tier Skill Tree unlocks (e.g., "Closed-Loop Hydrocarbon Extraction Principles," "Ethanol Extraction & Winterization," "Vacuum Purging Techniques," "Short Path Distillation," "Basic Cannabinoid Isolation").
       - Completion of very expensive and lengthy Research Projects like "BHO Extractor Design & Safety Protocols," "CO2 Extraction Parameter Optimization," "THC/CBD Distillate Production."
       - Construction of a dedicated, properly ventilated "Extraction Lab" zone with safety equipment (explosion-proof fans, gas detectors).
     + **New Systems Introduced (as detailed in 5.8):**
       - **Solvent-Based Extraction Equipment & Processes:** Closed-Loop BHO/PHO systems, Ethanol extraction setups, Supercritical CO2 extractors (very late game). Abstracted simulation focusing on parameter control, solvent recovery, and purging.
       - **Safety Management Systems:** Real consequences for solvent leaks or improper purging (fires, explosions, facility damage).
       - **Winterization/Dewaxing:** Processes to improve extract purity.
       - **Distillation:** Equipment and process for creating high-potency THC/CBD distillate.
       - **Basic Crystallization:** Initial methods for producing THCA/CBDA crystals or CBD isolate.
       - **In-House QC Lab (Expanded):** Equipment for testing cannabinoid potency (HPLC simulator), terpene profiles (GC-MS simulator), and residual solvents.
     + **Player Experience Shift:** Gameplay incorporates elements of chemical engineering and industrial safety. Players can produce highly potent and pure extracts, but must manage significant risks and costs. Lab testing becomes crucial for verifying product quality and safety.
  3. **Post-MVP Expansion Pack 3 or 4: "Infused Product Manufacturing & Gourmet Creations" (Conceptual Title)**
     + **Focus:** Introduction of edibles and topicals manufacturing, recipe development, dosage control, packaging, and labeling.
     + **Prerequisites:**
       - Access to stable sources of decarboxylated flower or extracts (from previous expansions).
       - High-tier Skill Tree unlocks (e.g., "Cannabinoid Infusion Science," "Edible Formulation & Dosage Control," "Cosmetic Chemistry Basics," "Food Safety Protocols," "Product Packaging & Labeling Regulations").
       - Completion of Research Projects like "Optimal Decarboxylation Curves," "Emulsification Techniques for Edibles," "Shelf Stability of Infused Products."
       - Construction of a "Clean Room" or "Food-Grade Processing Kitchen" zone.
     + **New Systems Introduced (as detailed in 5.8):**
       - **Decarboxylation & Infusion Equipment/Processes.**
       - **Edibles Manufacturing Lines:** Equipment for making gummies, chocolates, baked goods, tinctures (mixers, depositors, ovens, bottling lines).
       - **Topicals Manufacturing Lines:** Equipment for creams, balms, salves (cosmetic mixers, homogenizers, filling machines).
       - **Recipe System:** Players unlock, develop, or purchase recipes (EdibleRecipeSO, TopicalRecipeSO).
       - **Dosage Consistency & QC:** Critical gameplay loop involving careful measurement, batch testing (in-house lab or NPC service), and consequences for inaccurate dosing.
       - **Packaging & Labeling Systems:** Equipment and UI for designing compliant packaging and labels (displaying potency, ingredients, batch numbers, warnings).
     + **Player Experience Shift:** Players become manufacturers of finished consumer goods. New challenges in recipe development, precise process control, quality assurance, and (simulated) regulatory compliance. Opens up entirely new markets.
* **Challenges & Considerations for Rollout:**
  + **Complexity Creep:** Each new processing type adds significant new equipment, resources, UI, and simulation logic. Rollout must be carefully paced to avoid overwhelming players or developers.
  + **Balancing Product Value & Effort:** The effort and cost required to produce advanced products must be justified by their market value and utility in fulfilling high-tier contracts.
  + **UI for Complex Processes:** Designing intuitive UIs for managing multi-stage extraction processes, formulating edible recipes, or controlling distillation parameters will be challenging.
  + **Safety Mechanics:** For solvent extraction, safety systems must be clear, and consequences for failure significant but not unfairly punitive (e.g., financial setbacks and repair time rather than "game over" unless truly catastrophic negligence).
  + **Interdependencies:** These systems rely heavily on outputs from the cultivation and genetics systems (quality of starting material is paramount) and feed into the advanced economy and QC systems.

The roadmap for advanced post-harvest and processing mechanics allows Project Chimera to evolve into a comprehensive "seed-to-shelf" simulation, offering players diverse pathways to economic success and creative product development, far beyond simply growing and selling flower. This provides immense long-term depth and replayability.