



## THE ROLE OF VIRTUAL LABORATORIES IN THE DEVELOPMENT OF ECOLOGICAL STARTUPS IN THE SMALL BUSINESS SECTOR

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**Abstract.** *This article explores how virtual laboratories can serve as a strategic infrastructure for ecological startups emerging in the small business sector. The paper argues that virtual laboratories should be understood not merely as educational software, but as integrated environments for experimentation, simulation, prototype validation, business-model testing and stakeholder communication. For green startups, which must simultaneously prove environmental usefulness, technical feasibility and economic viability, such environments reduce the cost of trial-and-error and accelerate movement from idea to pilot implementation. The article identifies the core value of virtual laboratories in five dimensions: competence formation, safe testing, resource optimization, digital incubation and investment readiness. It also proposes an implementation roadmap that links universities, incubators, local firms and public support institutions into one coordinated innovation ecosystem.*

**Keywords.** *virtual laboratory, ecological startup, small business, green entrepreneurship, digital incubation, simulation, sustainable innovation, entrepreneurial ecosystem.*

### **Introduction**

Across the world, ecological entrepreneurship is increasingly becoming a practical response to climate pressure, resource scarcity and growing demand for responsible production. Yet the pathway from a green idea to a viable small business remains fragile. Founders must demonstrate that their solution works technically, creates measurable environmental value and can survive market competition. This triple burden is particularly difficult for small firms because they usually lack expensive equipment, specialized experts and stable financing during the early stage.



Virtual laboratories can significantly improve this situation. They provide simulation-based learning, allow experimentation without large physical costs, and create a controlled environment in which teams can test assumptions before investing in hardware, raw materials or field pilots. In the context of ecological startups, this is especially relevant because mistakes are costly not only in financial terms but also in environmental terms: a weak prototype may waste materials, increase emissions, or generate unnecessary energy use.

The central argument of this article is that virtual laboratories should be seen as a bridge between entrepreneurship education, applied innovation and small-business incubation. Their role is not limited to teaching students how to use a tool. Rather, they shape a new model of evidence-based green entrepreneurship in which business decisions emerge from iterative testing, multi-disciplinary collaboration and transparent evaluation.

### **1. Why ecological startups need a virtual experimentation environment**

Ecological startups differ from many conventional startups because value creation is inseparable from environmental performance. A recyclable package, a water-saving device, a waste-sorting system, an environmental monitoring service or an energy-efficiency solution cannot be assessed only through customer demand or price elasticity. Its ecological effect, resource intensity and life-cycle logic matter as much as revenue potential. This means founders need an environment where several variables can be tested together instead of separately.

A virtual laboratory offers such an environment. It can combine technical simulation, environmental indicators, cost projections and market scenarios into one interface. In practice, this means that a startup team can compare alternative materials, estimate resource input, model user behavior, visualize process bottlenecks and identify which prototype deserves physical production. The result is a more disciplined innovation path, where learning is accelerated and uncertainty becomes manageable.

Another important advantage is accessibility. Small business founders often operate outside major research centers. Virtual laboratories enable remote participation, asynchronous learning and distributed mentoring. When combined with incubator guidance, they can reduce regional inequality by making advanced experimentation available even to teams that do not have daily access to expensive laboratories.

### **2. From educational platform to incubation infrastructure**

The value of virtual laboratories becomes much greater when they are embedded into the startup support system. In a narrow sense, a virtual lab is a digital learning tool. In a broader sense, it can function as incubation infrastructure: a place where ideas are challenged, teams are formed, mentors intervene, and early evidence is produced. This broader interpretation is especially suitable for small business ecosystems that cannot afford a large number of specialized physical labs.



In such a model, universities generate methodological content and provide disciplinary expertise. Incubators organize mentoring, peer review and milestone-based progression. Local firms and municipalities contribute real ecological problems, operational data and pilot opportunities. Investors and grant organizations use the outputs of the virtual laboratory - simulations, dashboards, test reports and scenario analysis - to evaluate whether a startup is mature enough for further support. In other words, the virtual laboratory becomes a transaction space where knowledge is converted into entrepreneurial credibility.

This transformation also changes the meaning of entrepreneurial education. Instead of treating education as a preliminary stage before real business begins, the virtual laboratory integrates learning into venture development itself. Students, founders and practitioners participate in the same iterative process. Green entrepreneurship is therefore learned not by memorizing abstract principles but by solving concrete problems in a digitally structured environment.


**Table 1. Startup stages and virtual laboratory functions**

Stage of eco-startup	Relevant virtual lab function	Expected managerial effect
Problem framing	Mapping environmental challenge, stakeholders and measurable outcomes	Sharper value proposition and better problem definition
Concept design	Testing alternative product or service scenarios in a simulated setting	Lower uncertainty before building a prototype
Prototype validation	Comparing materials, energy use, operational logic and user interactions	Safer design choices and lower waste
Business model formation	Linking ecological benefit with costs, demand and pricing scenarios	More realistic and sustainable revenue model
Funding and scaling	Generating evidence dashboards, reports and visual models for partners	Improved investment readiness and stronger partnerships

### 3. Strategic contributions of virtual laboratories to green small business

First, virtual laboratories support evidence-based decision-making. Instead of relying on intuition alone, startup teams can observe how design changes affect cost, environmental performance and operational feasibility. This helps founders avoid the common early-stage mistake of over-investing in an attractive but weak concept.





Second, they improve the quality of collaboration. Ecological entrepreneurship requires engineers, business planners, environmental specialists, designers and often public actors to speak a common language. The virtual laboratory acts as a shared platform where different stakeholders can see the same model, question the same assumptions and revise the same scenario. This reduces fragmentation in the innovation process.

Third, virtual laboratories strengthen the learning capacity of small businesses. Many startups fail not because they lack creativity, but because they cannot organize rapid cycles of feedback and adaptation. A well-designed virtual laboratory enables repeated experimentation without large physical losses, thereby institutionalizing learning-by-doing. For green ventures, where uncertainty is naturally high, this capacity is a major strategic asset.

Fourth, they can support inclusive entrepreneurship. Women entrepreneurs, students, regional innovators and part-time founders often face mobility and infrastructure barriers. Remote access to simulation environments, online mentorship and digital teamwork can broaden participation in green startup ecosystems and make entrepreneurial opportunity more geographically and socially distributed.

#### **4. Implementation roadmap for Uzbekistan and similar emerging ecosystems**

For Uzbekistan and comparable emerging economies, the expansion of virtual laboratories should follow a phased approach. The first phase is conceptual: defining priority areas such as waste management, water saving, eco-packaging, agricultural sustainability or environmental data services. The second phase is infrastructural: selecting affordable software, open-source platforms or modular tools that can be adapted to local educational and business needs. The third phase is organizational: connecting universities, technoparks, entrepreneurship centers and local firms through clear roles, shared datasets and mentorship networks.

The fourth phase is financial and regulatory. Small pilot grants should encourage teams to move from virtual validation to physical testing. At the same time, startup competitions and grant programs should recognize simulation-based evidence as a legitimate indicator of project maturity. This would motivate teams to conduct serious pre-pilot analysis rather than presenting only descriptive business plans.

The fifth phase is localization. Virtual laboratories become effective only when the interface, case studies and mentoring language are accessible to users. Therefore, local-language modules, examples based on domestic ecological problems and partnerships with national industry actors are essential. Without localization, the tool may remain technologically impressive but practically underused.





## 5. Risks and governance principles

Despite their advantages, virtual laboratories are not a universal substitute for real experimentation. Their outputs depend on data quality, scenario design and user competence. Poorly designed simulations may create false confidence, while teams with weak analytical skills may misread results. Therefore, virtual laboratories should be governed by three principles: methodological transparency, expert supervision and gradual transition from simulation to field validation.


Methodological transparency means that assumptions, indicators and limitations are clearly documented. Expert supervision ensures that environmental, technical and business interpretations remain realistic. Gradual transition means that virtual results must eventually be tested in limited real-world pilots before the startup scales. In this sense, the virtual laboratory is best understood as an accelerator of responsible experimentation rather than a replacement for reality.

**Conclusion:** Virtual laboratories have the potential to become one of the most effective support mechanisms for ecological startups in the small business sector. Their strategic value lies in their capacity to combine experimentation, analytics, learning and incubation within one manageable environment. For green ventures, this integration is crucial because ecological usefulness, business viability and resource efficiency must be tested together rather than in isolation.

When embedded into a wider ecosystem involving universities, incubators, local enterprises and public support institutions, virtual laboratories can reduce entry barriers, improve startup quality and increase the probability that innovative green ideas become operational firms. For Uzbekistan, the most promising path is not the blind import of expensive systems, but the creation of accessible, locally adapted virtual laboratory models linked to real environmental challenges and small-business development priorities.

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