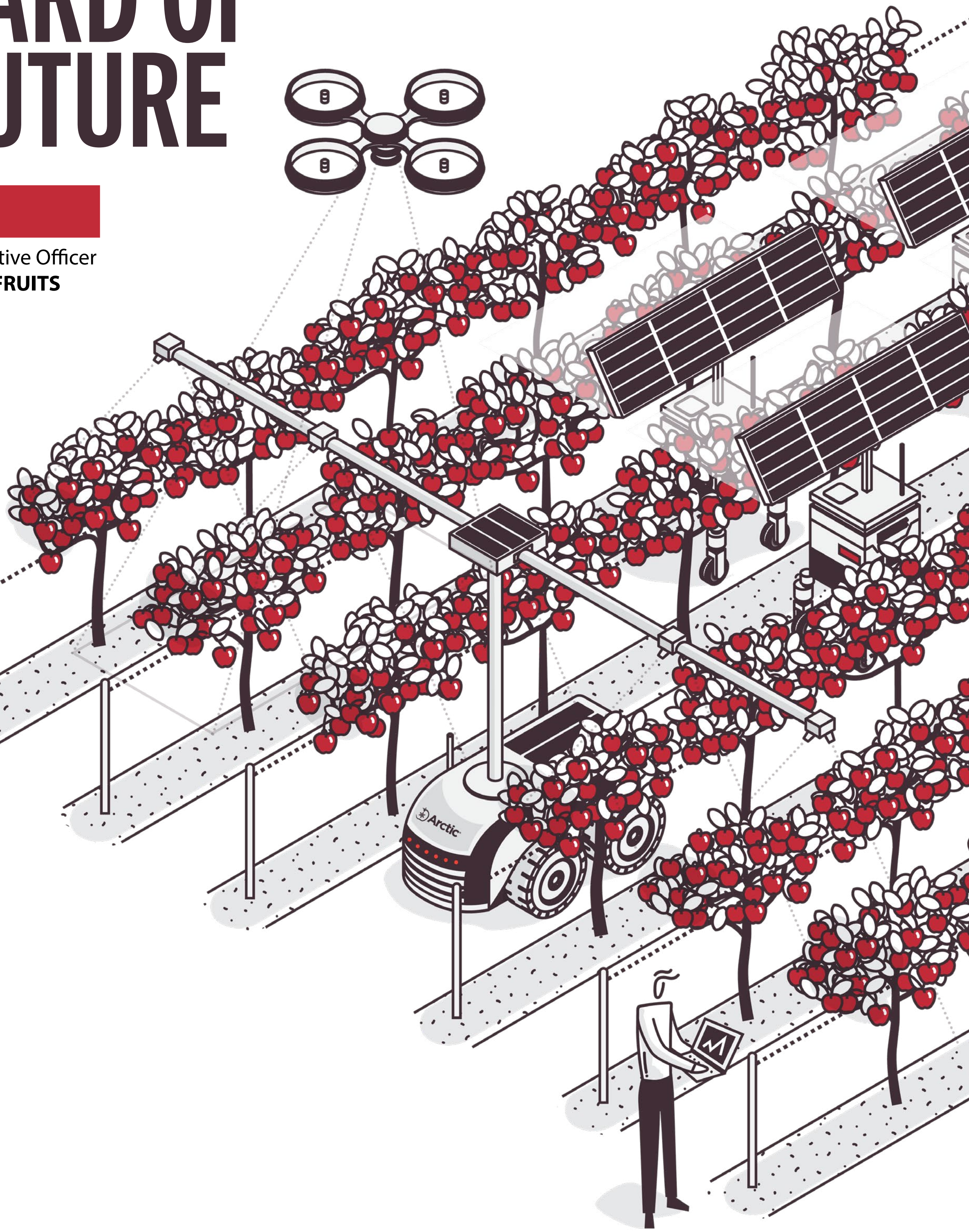
# TRAITS AND TECH: DESIGNING THE ORCHARD OF THE FUTURE


**NEAL CARTER**

Co-Founder & Chief Executive Officer
**OKANAGAN SPECIALTY FRUITS**


April 30, 2025

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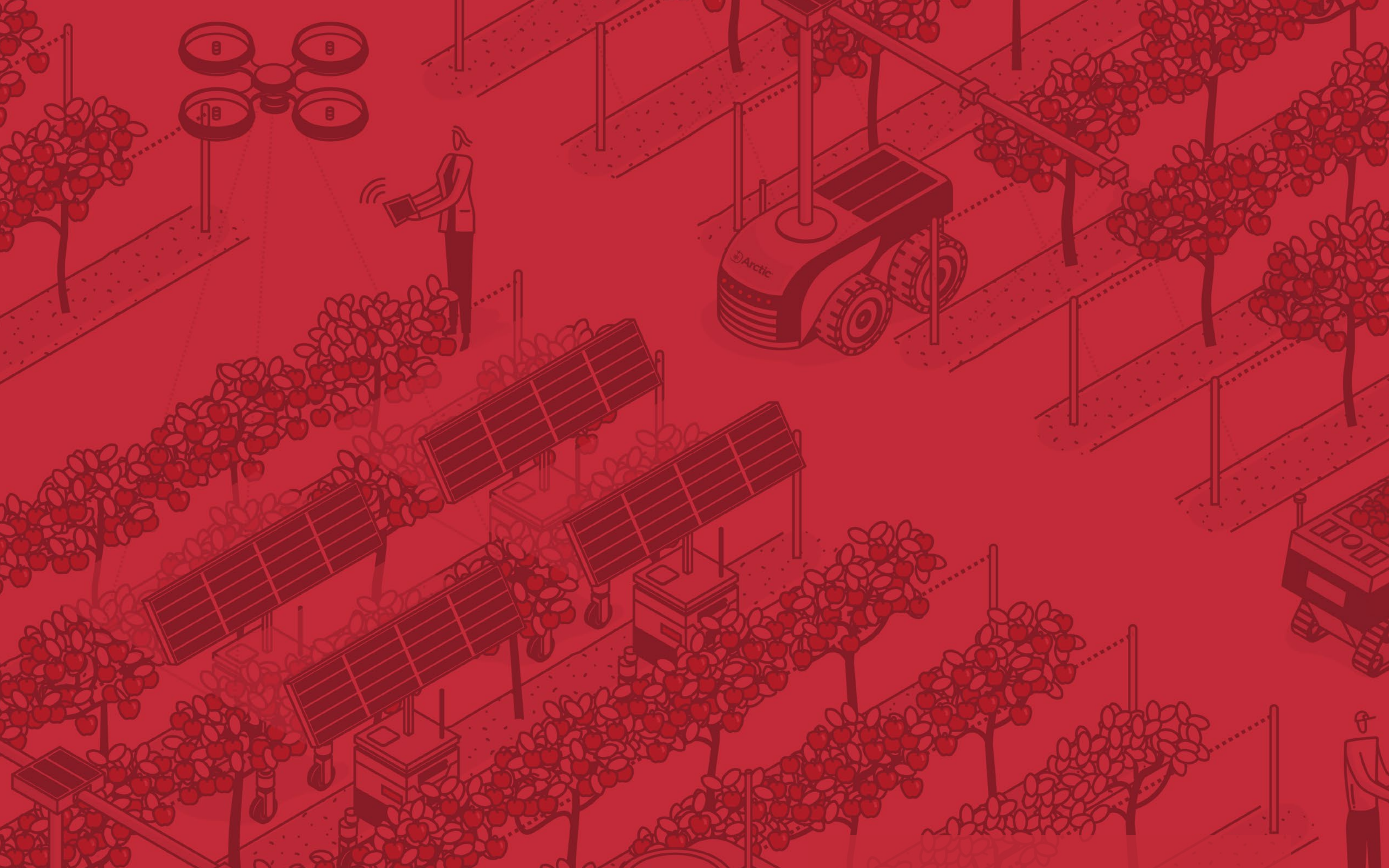

# CONTENTS




## ACKNOWLEDGEMENTS

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# EXECUTIVE SUMMARY

The United States apple industry is at a crossroads, confronting existential threats from economic volatility, labor shortages, and climate instability. As one of the nation's most iconic agricultural sectors, its decline would ripple across rural economies, jeopardizing jobs, supply chains, and America's position in global fruit markets.

Though the industry has continuously adapted over the past 40 years by adopting new horticultural approaches, such as increasing the density of tree plantings, employing various trellis structures, developing new dwarfing rootstocks, and creating exciting new market-driven varieties, it has maximized its ability to change the system through physical tools. Some of these practices are now working to exacerbate the challenges that are pushing smaller operations into the red.

Facilitating the nearly full automation of apple orchard production is the best way to staunch the flow of financial losses and ensure the continued viability of the U.S. apple industry. The orchard of the future needs to be built on new genetics and a new tree architecture that facilitates automation.

Improved genetics represent the industry's only real option to implement a market-disrupting, game-changing system that can effectively reduce the high labor demands that are economically unsustainable. Okanagan Specialty Fruits (OSF) proposes a very different approach to that challenge—one that employs the tools of genome editing to alter the characteristics of the modern apple tree and thus its architecture.

Fundamentally, OSF scientists will change apple's germplasm so that it bears flowers and fruit on new growth that develops after breaking dormancy each spring, compared to current production methods, where trees bear on second- or third-year wood. OSF will also activate genes that influence the strength of the wood, causing the trees to adopt an upright or willowy habit that can be trained onto a single horizontal cordon wire, creating a truly pedestrian orchard. This simple trellis system will be much easier and cheaper to construct.

This genetic alteration of commercial apple tree architecture will concentrate the fruit zone in one elevation, facilitating fully mechanized harvests and improved orchard maintenance through robotics and artificial intelligence, at sharply reduced costs.

**PROJECTED SAVINGS OF $8,000 TO $10,000 PER ACRE COULD BE REALIZED OVER CURRENT PRODUCTION COSTS OF $14,000 TO $16,000 PER ACRE.**

Within three years of initiating research, OSF could have trees in the greenhouse that are headed to the fields, rendering this a timely and realistic solution to the key problems now facing U.S. apple orchards. It may take 10 to 20 years to fully implement the apple farm of the future. But with hundreds of thousands of acres to be planted in the U.S. alone—and positive implications for other fruit crops and geographies—stakeholders have ample opportunity to realize a robust return on investment. It's time to get started.

# INTRODUCTION

The United States apple industry is facing profound economic and climate change challenges that threaten its short- and long-term viability. Given its prominence in the country's agricultural sector, failing to address these impacts promptly and proactively will result in adverse socio-economic consequences.

The U.S is the world's third-largest apple producer, after China and Turkey, and apples are the second-most produced fruit in the country, after grapes.[1] The U.S. apple industry is valued at about $23 billion, with $3.3 billion generated each year in farm gate revenue. As such, it is a major contributor to the economy, supporting about 150,000 jobs and generating more than $8 billion annually in wages.[2]

The U.S. apple industry produces about 11.1 billion pounds of fruit (265 million bushels) annually.[2] In the 2023/24 calendar year (July-June), the U.S exported over 42 million bushels of fresh apples—primarily to Mexico and Canada—while importing just 4 million bushels, for a net export valuation of almost $918 million.[3] However, both of these export markets are increasing production, with Mexico's crop expected to expand by about 1%, to 43 million bushels, and Canada's by 7%, to almost 21 million bushels.[2]

Though apples are grown in all 50 states, Washington is the top-producer, with an estimated crop of almost 179 bushels valued at nearly $2.2 billion. It is followed by New York (31 million bushels) and Michigan (about 29 million bushels).[2]

## TOP U.S. PRODUCERS

**1. WASHINGTON STATE**
**179 MILLION BUSHELS**
**($2 BILLION ANNUALLY)**

**2. NEW YORK**
**31 MILLION BUSHELS**

**3. MICHIGAN**
**29 MILLION BUSHELS**

**4. CALIFORNIA**
**5.48 MILLION BUSHELS**

**5. VIRGINIA**
**4.75 MILLION BUSHELS**

## TOP 5 U.S. EXPORT MARKETS


**2024**
**$756 MILLION**

1 https://worldostats.com/agriculture-food/apple-production-by-country/

2 https://usapple.org/industry-at-a-glance

3 https://usaa.memberclicks.net/assets/USApple_OutlookReport_2024.pdf

## THE U.S. APPLE INDUSTRY

VALUE:
**$23 BILLION**

ANNUAL FARM GATE REVENUE:
**$3.3 BILLION**

AVERAGE ANNUAL PRODUCTION:
**11.1 BILLION POUNDS OF FRUIT**
(265 MILLION BUSHELS)

EXPORT MARKET:
**42 MILLION BUSHELS**
OF FRESH APPLES

NET EXPORT VALUATION:
**NEARLY $918 MILLION**

2023-24 SEASON:
**288.8 MILLION BUSHELS**

2024-25 SEASON:
**259.5 MILLION BUSHELS**

NUMBER OF U.S. PRODUCERS: **≈5,000**

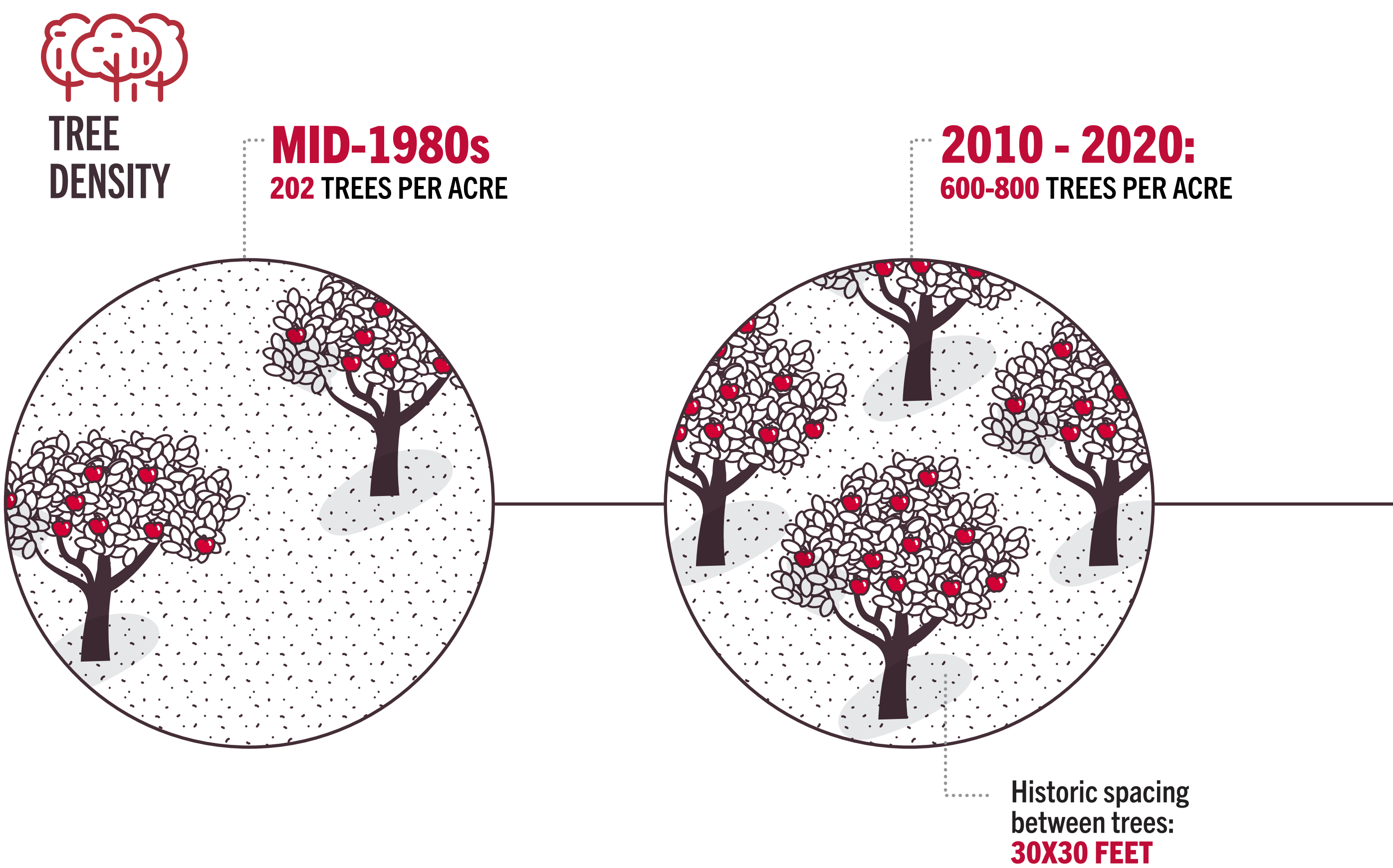
Roughly 67% of the crop is grown for fresh consumption.[2] As the number one-consumed fruit in the U.S.,[2] it also plays a significant role in helping consumers meet the dietary goals associated with good health.

With U.S. production at or near all-time highs and exports below historical levels, prices fell continuously through the 2023-24 season as labor, fuel, and fertilizer costs rose, resulting in negative returns for most operations.[2] Though these challenges are multifaceted, they are based in horticultural practices—specifically, the intensive planting systems that the industry has adopted over the past 40 years.

# APPLE TREE ARCHITECTURE: A RETROSPECTIVE

Traditionally, commercial apple orchards were planted at a density of about 100 trees per acre, spaced 20 feet by 20 feet, giving each tree 400 square feet of space. Up until the late 1970s, tree architecture was natural, open-centered, and free-standing. As the trees grew, the tops were cut off and the lower branches spread out. Farmers could spend an entire day pruning one tree. It typically took eight years to get a tree into significant production.

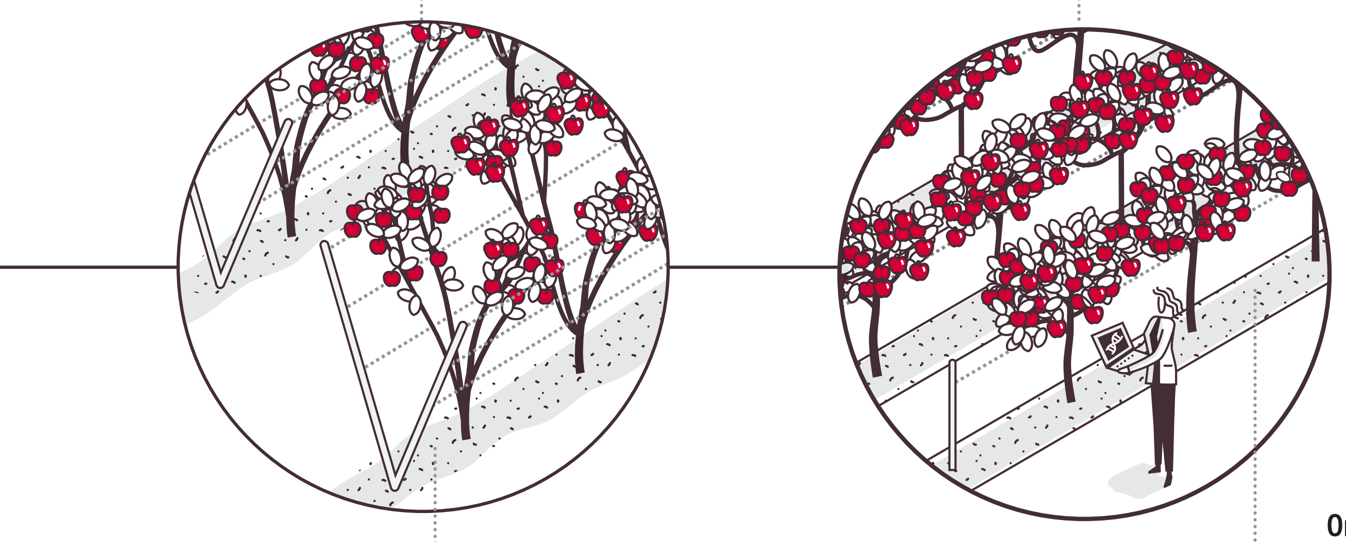
In the 1980s, farmers recognized that changes were needed, as new varieties were introduced. Orchard density was doubled, with 202 trees per acre spaced in 12-feet x 18-feet plantings. That trigged a trend of almost continuous improvement in tree architecture as dwarfing rootstocks became more popular. Europe led the movement into extremely high-density plantings of 600-800 trees per acre, planted 4 feet apart, using a spindle block model. Each tree had to be trained to a support post because there was not enough rootstock to support a free-standing structure. By 2010, the U.S. was using a super spindle block model to support trees planted at a density of 800–2,400 per acre. The spindle was replaced with a trellis, with trees planted 2-4 feet apart in 10-foot-wide rows and growing to the same height as the distance between rows. Orchards became two-dimensional—akin to a fruiting wall—to maximize light penetration and maintain a tractor alleyway. Yet, over time, even this approach failed to achieve the productivity required to keep an orchard economically viable.



In response, farmers began experimenting with a V-trellis structure, erected at 45-degrees off vertical, with a range of new rootstocks and a focus on new, high coloring, premium varieties. This approach was intended to improve productivity by permitting maximum sunlight to reach the trees. The trellises were very robust structures because the rootstock was insufficient to support the trees. But as the fruit grew too heavy for the trellis, a wind event could trigger a collapse, damaging trees that were typically brittle where the rootstock was grafted onto the scion. The tree architecture of these V-trellises got closer and closer, decreasing from 45 degrees off center to 22.5 degrees and then 12 degrees, with some growers eventually transitioning back to vertical trellises. Though vertical trellises are less expensive to construct, averaging about $2,500 per acre compared to $8,000-$10,000 per acre for V-trellises, the V-trellis model is still being used in most new plantings in Washington State.

Buoyed by higher productivity and good returns on premium grades, the North America apple industry began expanding in 2010 as growers planted new blocks of trees and experimented with new varieties. The average cost of establishing a new orchard to produce premium varieties grew to $75,000-$100,000 per acre, including the costs of buying the land, planting the trees, erecting the trellises, and manually training the trees onto each of the many wires on these V-trellises. These high costs were supported by good returns on premium varieties.

But when COVID hit in 2020, consumer buying habits changed. As they switched to purchasing bags of apples online, the premium price suddenly disappeared. The product could no longer support the elaborate, expensive, and labor-intensive tree architecture system prevalent on most farms. Since then, the situation has only gotten worse.



# CHALLENGES FACING THE U.S. APPLE INDUSTRY

## LABOR

**2024**
Labor costs represented **99%** of the returns that growers received per bin by 2024

**2024**
Labor represents more than **60%** of total production costs

**2013**
Labor costs represented **37%** of the returns that growers received per bin

**NUMBER OF SEASONAL WORKERS IN WASHINGTON APPLE INDUSTRY: 40,000 TO 50,000**

**ROBOTICS: COULD INCREASE PRODUCTIVITY BY 25-30%**

While the V-trellis system has increased production, it also increased establishment costs and labor demands. Escalating labor costs are the primary challenge to the continued viability of the U.S. apple industry. Labor costs began to rise in 2020 during the COVID-19 pandemic and have continued an upward trend. Over the past 10 years, labor costs per bin of apples have more than doubled for Washington growers using the H-2A seasonal worker visa program, compared to 30% inflation across the U.S. economy in the same period. In 2013, labor represented 37% of the returns that growers received per bin—a figure that increased to 99% by 2024, making it virtually impossible to survive, much less turn a profit.[4] Labor now represents more than 60% of total production costs—a figure that can go even higher if farmers provide worker housing. Washington, which employs an estimated 40,000 to 50,000 seasonal workers per year,[5] is currently the most expensive state in the U.S. for agricultural labor.

Another drawback to V-trellises is the challenge they create for robotic harvester systems, which have the potential to greatly reduce both labor costs and labor infrastructure requirements, such as worker housing and recruitment fees. Robots are now picking only a small percentage of the U.S. apple crop, but harvest aids such as picker platforms with conveyance systems, etc. are becoming increasingly prevalent. While robotic harvesting is not yet that common, it is anticipated it will eventually become a mainstream automation tool; however, the cost is high, and it is not clear how the orchard operators today will be able to pay for it.

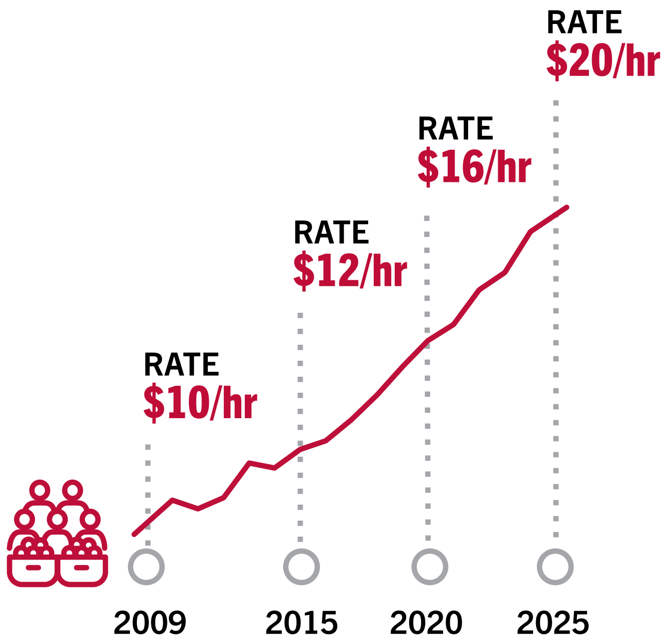
Maintaining trees that typically reach a height of 10 feet requires most farmers to purchase worker and/or picking platforms, which cost between $50,000 and $150,000. The platforms—either self-propelled or pulled by a tractor—travel between rows of trees and lift workers up to fruit level. Growers also use ladders, which are cumbersome to transport and increase the risk of falls and other accidents, as well as the associated workers' compensation claims. They are also inefficient, with workers spending up to a third of their time moving and positioning ladders.[6] Whether on platforms or ladders, pickers place apples into bags that hang over their shoulders and are emptied into bins when full.

4 https://www.goodfruit.com/a-new-look-at-labor-costs-for-apple-growers/

5 https://www.ers.usda.gov/amber-waves/2023/june/advancements-in-apple-picking-an-industry-addresses-tight-farm-labor-markets#:~:text=However%2C%20as%20the%20Nation's%20top,in%20that%20State%20each%20year

6 https://www.ers.usda.gov/amber-waves/2023/june/advancements-in-apple-picking-an-industry-addresses-tight-farm-labor-markets

## LABOR COSTS ARE INCREASING[7]




**Source:** Department of Labor, various years

Farmers have begun bending the trees over, experimenting with a tree leader system that has multiple uprights, with shorter branches and less tree volume. While it simplifies pruning, it's still very labor-intensive, with field workers needed to conduct the pruning and train the trees to the wire. The trees also tend to weaken as they bend, making them more susceptible to high winds and other damaging factors. This approach is failing to solve the problems the industry faces.

The U.S. apple industry is experiencing grave challenges in large part due to its existing plant architecture. Small operations under 50 acres are struggling the most. In Washington alone, 187 orchards closed between 2017 and 2022, with 2,335 remaining[8].

7 Gallardo, R.K., S.P. Galinato, and B. Sallato-Carmona. 2025. "2024 production Costs and Returns of WA Grown Apples". Presentation at the Apple Crop Protection Meetings of the Washington State Tree Fruit Commission. January 30.

8 https://missoulacurrent.com/washington-apple-farmers/

## PRODUCTION AND HARVESTING ISSUES

**BRUISING:**
**5-30% OF FRUIT**
Damaged during harvest

**DISEASES:**
**$100 MILLION**
Annually in crop losses

**REPLANT DISEASE:**
**$70,000-$150,000**
Per acre in lost productivity over life of planting (approx. 20 years)

## EXTREME WEATHER:

**SPRING FROSTS:**
**30-80% REDUCTION IN PRODUCTION**
(Potentially 100% crop loss)

# DESIGNING THE APPLE ORCHARD OF THE FUTURE

Facilitating the nearly full automation of apple orchard production is the best way to return to profitability and ensure the continued viability of the U.S. apple industry. Employing digital tools to create a "smart" orchard is not enough. The orchard of the future needs to be built on new genetics and a new tree architecture paradigm.

The apple industry has survived to date by introducing new tree planting systems and architecture platforms, but the industry has maximized its capabilities to change the system through physical tools like trellises, pruning, and tree spacing. Improved genetics represent the industry's only real option to implement a market-disrupting, game-changing system that can effectively reduce the high labor demands that are economically unsustainable. Okanagan Specialty Fruits (OSF) proposes a very different approach to that challenge—one that employs the tools of genome editing to alter the characteristics of the modern apple tree and thus its architecture.

Fundamentally, OSF scientists will change apple's germplasm so that it bears flowers and fruit on new growth that develops after breaking dormancy each spring, compared to current production methods, where trees bear on second- or third-year wood. OSF will also promote genes that influence the strength of the wood, causing the trees to adopt an upright or willowy habit.

Once trees are established and bearing on new wood, the industry can create structures akin to grape trellises. The scion grafted on the rootstock would be brought up to waist height and trained onto a single horizontal cordon wire, creating a truly pedestrian orchard. This simple trellis system will be much easier and cheaper to construct.

The primary tree architecture will be a perennial root and trunk system trained along the cordon wire. Each season, shoots will push out of that permanent structure to create new fruiting wood. Growth regulators and existing tools may be used to control shoot extension and growth and the related crop load this will generate. It is expected that such a planting approach will have a tree density of about 1,800 trees per acre.

Pruning would be very simple, as a hedger running horizontally would move along the rows, cutting off last year's wood, potentially multiple rows at a time.

The new growth branches would be 18 to 30 inches long—similar to a grape cane—and would drop onto the ground and decompose, eliminating the need to remove the larger branches of today's trees. Pruning would become entirely automated, eliminating the need for platforms and ladders. For most farmers, pruning costs would drop from the current yearly cost of $1,000 to $1,200 per acre to about $50 per acre annually — similar to today's mowing cost.

Apples would hang down from the new shoots growing each year to be mechanically harvested. Though each tree would not produce as much as a 10-foot-tall tree does today, production could be increased by spacing the rows more closely—4 feet apart, with a 6-foot-wide tractor lane every fifth row—in a setup akin to a row crop system. Less production also means fewer apples to thin, a process that could be done chemically to again reduce labor costs. The real advantage would be a concentration of fruit in one area., This would facilitate crop protection treatment by autonomous equipment (drone or autonomous sprayer) and mechanical harvesting using a robotic harvester, all at one level. Concentrating the fruit zone in one elevation is a huge benefit for all orchard maintenance and harvesting activities.

Maintaining an orchard with less tree volume would also facilitate targeted treatments in responding to cold events. Over-canopy sprinklers could be erected to warm up a shorter orchard, as opposed to the 50-foot-high wind machines currently used to protect an entire orchard.

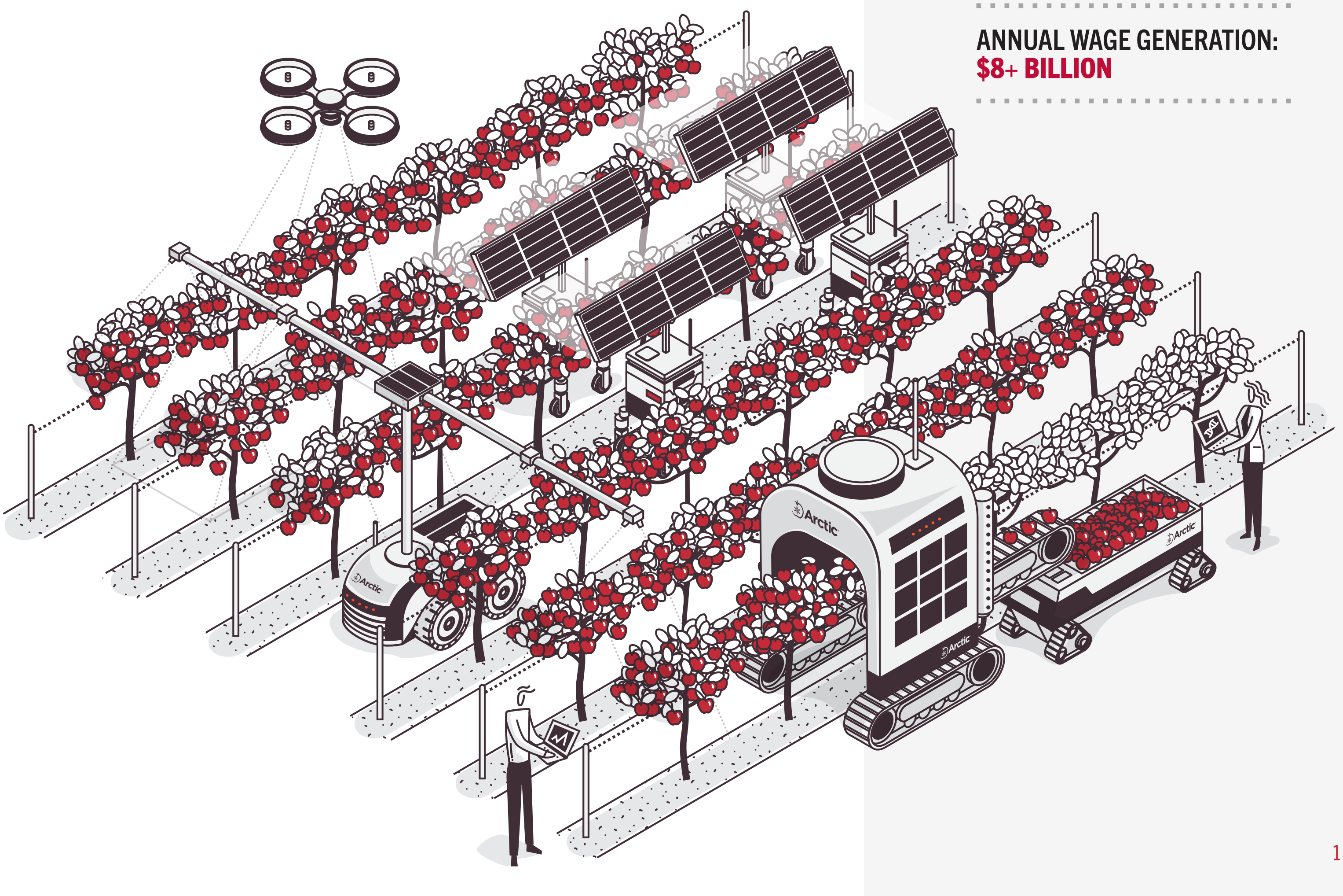
In response to pest infestations or plant diseases, crop protection products would be applied by drone or by using a boom that can cover multiple rows at once, as is the practice in row crop production.

By bringing in other genetic traits, such as PPO inhibition and disease-resistance, as well as consumer-forward traits related to taste and color, OSF would create an orchard well-suited to future environmental considerations and consumer demands while minimizing labor.

This genetically informed approach to plant architecture has the potential to generate the yields that farmers are seeking for productive operations while producing far less biomass and requiring less labor.

We estimate savings of $8,000 to $10,000 per acre could be realized over today's costs of $14,000 to $16,000 per acre.

Farmers could save $1,000 an acre by eliminating pruning alone, a feat that cannot currently be achieved without altering a tree's genetics. Though some farmers may try to achieve the architectural platform we describe without altering tree genetics, they will still incur extensive labor costs to tie, train, manipulate, and prune the plants, rendering that approach economically unfeasible.




## FARM OF THE FUTURE PROJECTED COST SAVINGS

**TOTAL PRODUCTION SAVINGS:**
**$8,000 TO $10,000 PER ACRE**

**PRUNING:**
**$1,000 PER ACRE**

**CHEMICAL USE:**
**50% ON AVERAGE**

**TRELLIS CONSTRUCTION:**
**75% ON AVERAGE**

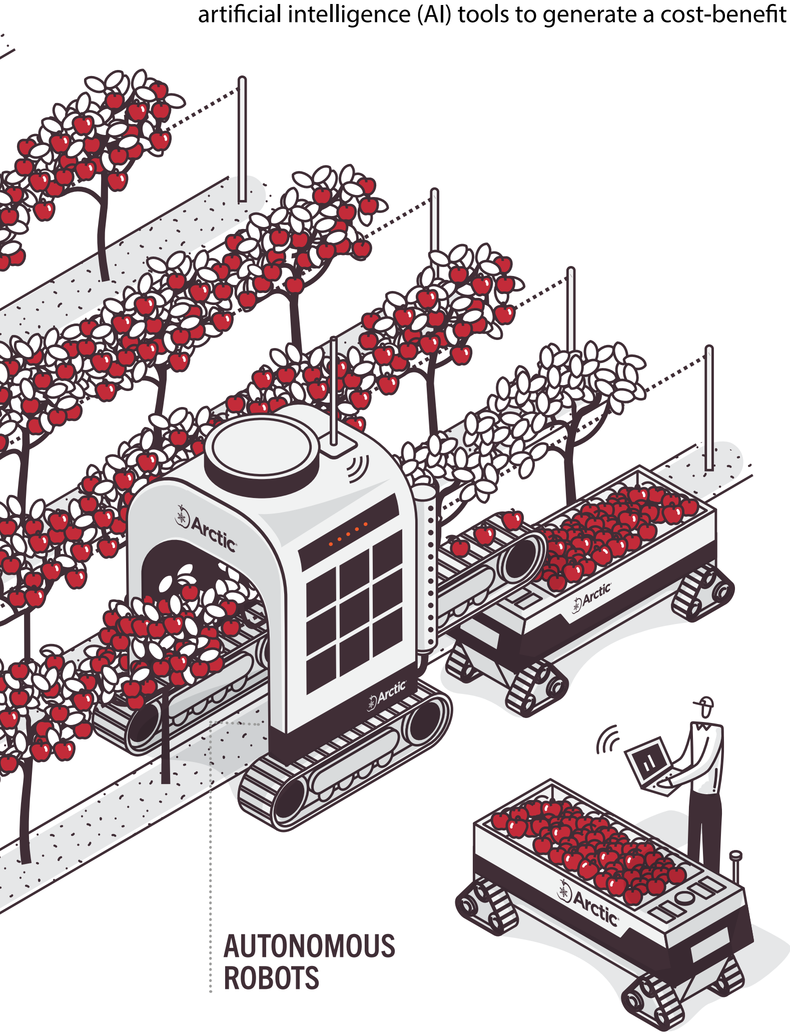
**WATER USE:**
**60%**

**EMPLOYMENT IMPACT:**
**150,000 JOBS**

**ANNUAL WAGE GENERATION:**
**$8+ BILLION**

# IN ADDITION TO GENETICS — ENGAGING ROBOTICS, AUTOMATION, AND ARTIFICIAL INTELLIGENCE

Apple farmers currently send a UTV or tractor with a vision system mounted on the front down a row of trees to calculate the number of apples, the tree volume, and other agronomic data. This information is used to plan orchard management actions in an effort to make data-driven decisions that will optimize performance and minimize costs. The apple tree architecture of the future will facilitate a much more successful data capture system that uses artificial intelligence (AI) tools to generate a cost-benefit analysis of crop load management and pest and disease control strategies. The AI tools will also identify weak sites, in terms of tree vigor, and identify useful nutrition and/or irrigation adjustments that can increase apple production. Data collection tools, including cameras, sensors, LIDAR, and drones, can assume the role of a horticultural advisor. This frees up staff who may not have the time or expertise to review and evaluate sensor data collected in the orchards, resolving a major challenge in modern orchards. The AI agent can identify top priorities, in terms of an orchard's irrigation needs, pest pressure, and other issues.



AUTONOMOUS ROBOTS

Harvesting can be facilitated through use of autonomous robots that pick the apples and transport the fruit to storage and/or processing centers. These robots can be modified to perform multiple activities, such as weed control, orchard mowing, and crop protection, at a fraction of the current cost of a tractor and operator. The apple orchard of the future could employ a range of autonomous equipment, including tractors and equipment that serve dual purposes, such as a sprayer and mechanical harvester. Some of this equipment is already being used in vineyards in France and Northern Italy.[9]

Many of these labor-reducing technologies and systems are already being developed, such as autonomous harvesting and maintenance; robotic pruners and thinners; harvesters with in-field sorting; sprayer/mower/weeder combinations; integrated microclimate management meshed weather stations with cameras to monitor pest pressure and detect airborne pathogens; sub-row irrigation and fertigation; misting frost protection with electric fans; radiant heaters; and pollination drones and thinners.

Through robotics, automation, and AI, the farm of the future would greatly reduce the need for unskilled labor while creating a demand for computer and information technology experts in the agricultural sector.

9 https://youtu.be/rrS2cJ471nc?si=Wn___MZd6US_87uc

# CREATING THE APPLE ORCHARD OF THE FUTURE

OSF currently understands and has access to all the genes required to perform the germplasm manipulations described previously. Flowering and fruiting on new wood is a genetic trait, as is disease resistance to reduce the use of crop protection products, and OSF's PPO suppression trait, which supports automation by reducing superficial browning from bruising.

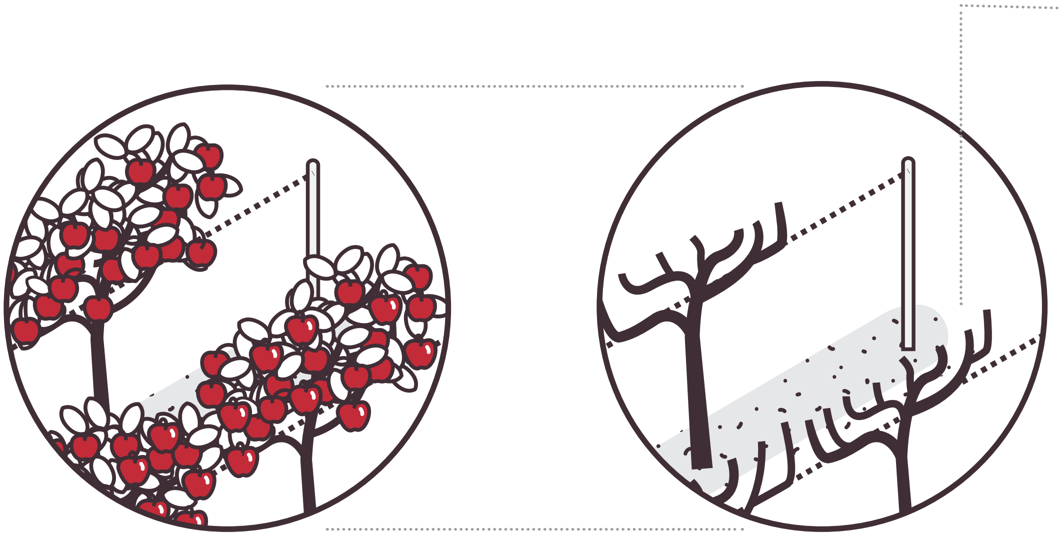
Within three years of initiating research, OSF could have trees in the greenhouse that are headed to the fields. Nuances will arise regarding which roots work best for a high quality and yielding fruiting platform. The genome-edited trees would be trained quickly to the single-wire horizontal trellis and one or two seasons of growth are sufficient for field trial assessment. Within five years of initiating research, fruit could be harvested from the system.

From there, OSF would take existing on-going research and work to integrate it into this platform. This will involve other genetic traits, such as disease resistance, self-thinning, climate resiliency, and frost-tolerance. Genetics would also be used to produce the desired amount of lignin, which determines the stiffness of the wood in a new growth branch.

Farmers are typically reluctant to cut out an existing orchard, which tends to last as long as it's making money. But few are making money now, so the time is right to explore new planting systems and methods. About 5% of an orchard needs to be renovated each year. Farmers could phase into this system by applying a graft with the new genetics onto an existing tree or planting new trees in an existing orchard. Because farmers typically do what they can afford, some would likely try to put the new genetics onto systems they already know, because that's what they've got and that's what their equipment works with. Even if they did take this approach and had a hybrid system, it would be a simpler system than the one currently in use.

OSF envisions the apple farm of the future as an entirely new system, with attributes more akin to a grape planting than an apple orchard. It's essential to develop a system that works and complements the way a tree wants to grow, rather than battling its natural tendencies. Fruit on new wood is the fundamental difference that can be achieved through OSF's genome editing.

**ATTRIBUTES MORE AKIN TO A GRAPE PLANTING THAN AN APPLE ORCHARD**

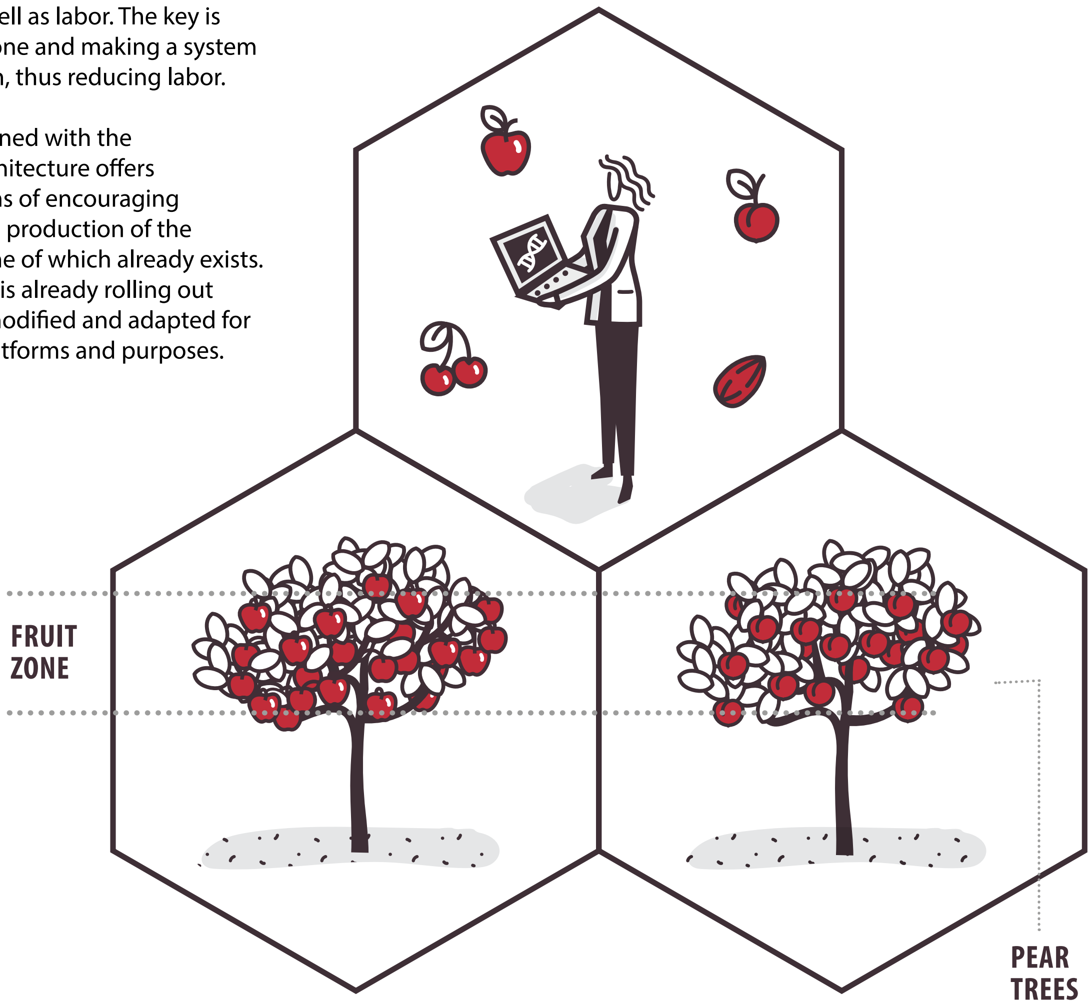


# OTHER APPLICATIONS FOR THE TECHNOLOGY

Other than OSF, no one is addressing tree architecture from the standpoint of genome editing. Some research laboratories in Germany and New Zealand are starting to work with conventional germplasm, though they are investigating peach, almond, and cherry trees that grow in a columnar shape, like what the U.S. apple industry adopted 40 years ago.

OSF anticipates that its genetics-driven approach to the apple farm of the future will be quickly copied by pear and almond growers who are attracted by significant reductions in irrigation costs and water use, as well as labor. The key is concentrating the fruit zone and making a system well suited to automation, thus reducing labor.

Getting fruit growers aligned with the OSF approach to tree architecture offers huge advantages, in terms of encouraging manufacturers to expand production of the required equipment, some of which already exists. Europe, particularly Italy, is already rolling out equipment that can be modified and adapted for different architectural platforms and purposes.



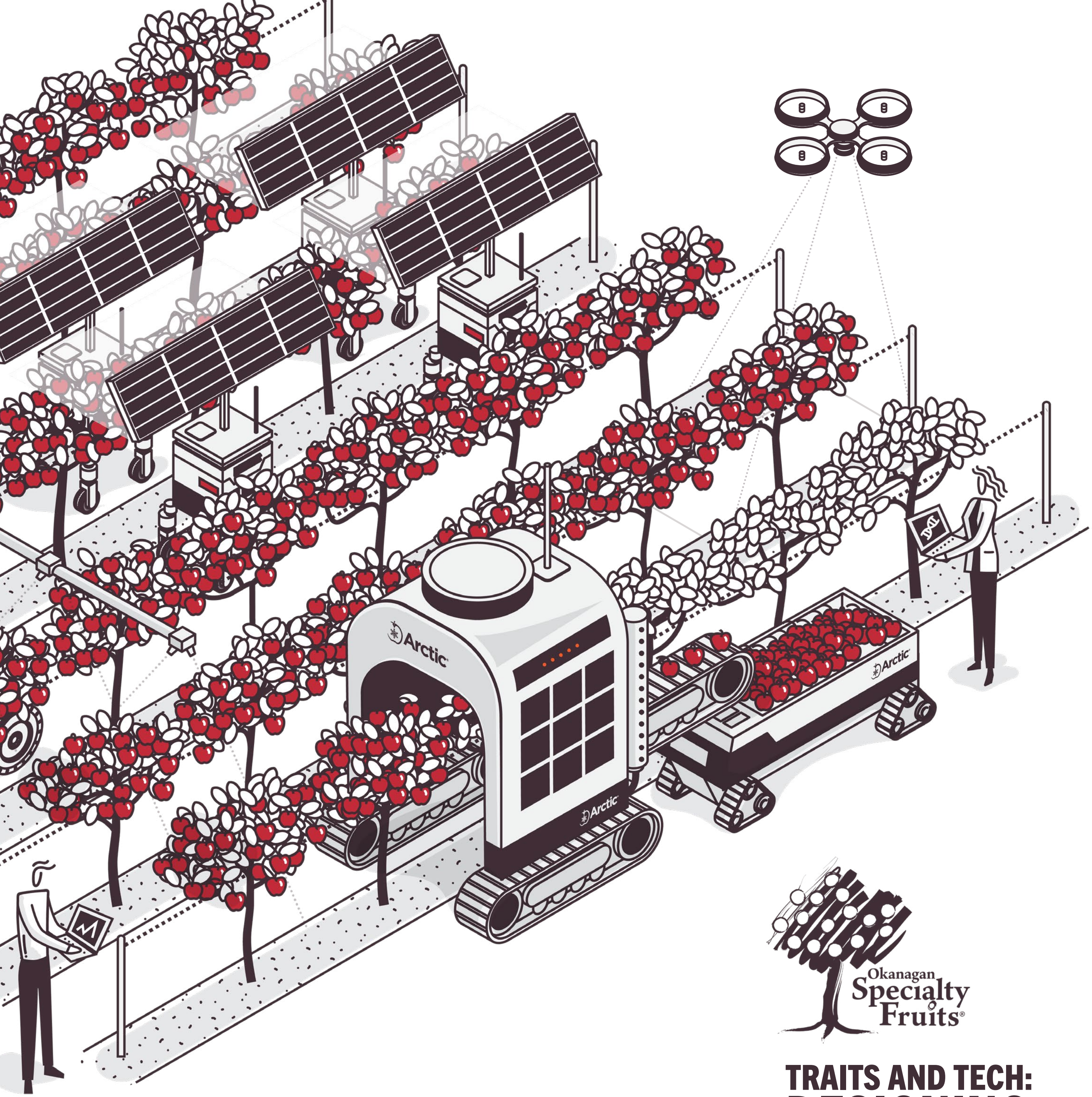
# CONCLUSION

Tree architecture is clearly a target for OSF science activities. OSF can be the science team that executes the architecture for the apple orchard of the future, most likely in collaboration with other partners. Whether OSF is the body to bring new germplasm forward alone, or in partnership, remains to be determined.

While OSF is confident in its ability to deliver the improved germplasm that will inform a new platform for tree architecture, challenges do remain. One is weed control, as weeds could easily grow taller than the fruit zone in an orchard. The other is convincing farmers, a notoriously change-adverse group, to alter their operations. Our industry tends to stick to what is known, even if it's no longer working. And modern apple orchards clearly are not working.

As apple operations continue to go broke, it may remove enough acreage to right size the industry. But that is just a temporary fix.

The current sense of economic urgency may motivate the U.S. apple industry to accept a new approach to tree architecture, especially if it can be rolled out with significant cost savings. OSF will also be addressing key industry drivers and hesitancies, including reassurances that the orchard of the future will produce the high-quality fruit that the market requires. It may take 10 to 20 years to fully implement the apple farm of the future. But with hundreds of thousands of acres to be planted in the U.S. alone, stakeholders have ample opportunity to realize a robust return on investment.

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