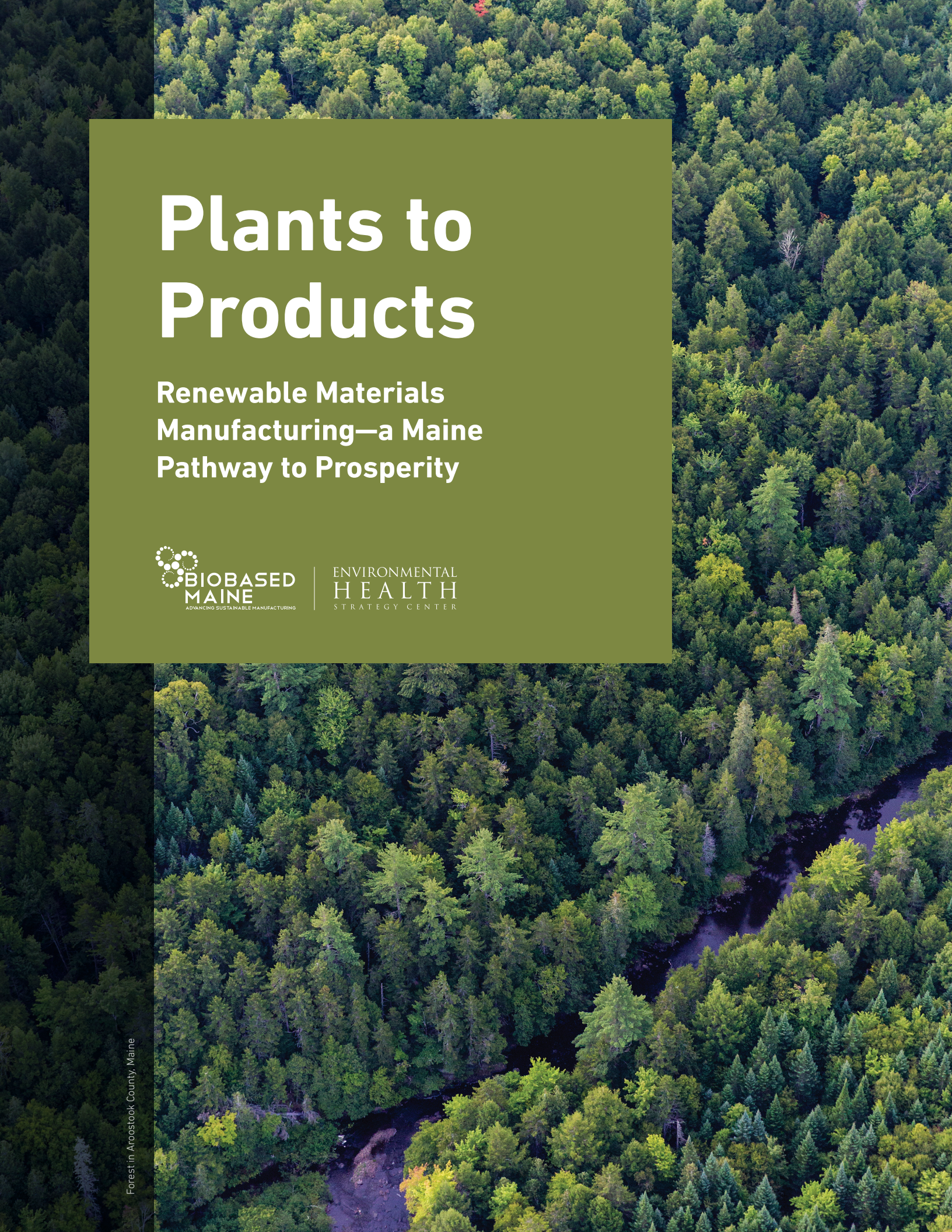
Plants to Products

Renewable Materials Manufacturing—a Maine Pathway to Prosperity

BIOBASED MAINE
ADVANCING SUSTAINABLE MANUFACTURING

ENVIRONMENTAL HEALTH STRATEGY CENTER



Forest in Aroostook County, Maine

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BIOBASED MAINE
ADVANCING SUSTAINABLE MANUFACTURING

Biobased Maine is a trade association that promotes the sustainable use of renewable biomass from forest, farm, and sea to manufacture renewable chemicals, biobased materials, and advanced biofuels in the state of Maine.

See page 20 for a full list of collaborating partners

ENVIRONMENTAL HEALTH STRATEGY CENTER

The **Environmental Health Strategy Center** works to create a world where all people are healthy and thriving, with equal access to safe food and drinking water, and products that are toxic-free and climate-friendly.

Published November 2020

Executive Summary

Maine's path to climate leadership and a strong rural economy lies through biobased manufacturing — that is, making everyday products and chemicals from renewable resources, from our forest, farms, or sea, instead of from oil and gas.

Rapidly rising global demand drives this opportunity. In response to the climate crisis, major corporations are making commitments to replace petroleum-based products with biobased products in an effort to reduce their carbon footprint.

> If we act strategically now, Maine has a unique opportunity to create high-paying green jobs and revitalize rural communities.

Indeed, the economic and climate benefits that biobased manufacturing offers are tremendous. According to a plausible development scenario based on actual companies and proven technologies, we have calculated the following benefits:

Over the next ten years, production of renewable chemicals and biofuels in Maine could create and retain more than 4,000 jobs and attract nearly $4 billion in capital investment.

In the next thirty years, biobased manufacturing in Maine could reduce greenhouse gas emissions by 44 million tons. That's the same as taking nearly 300,000 cars off the road permanently.

State policymakers took a significant step in 2020 toward establishing this industry in Maine, passing the nation's most competitive tax incentive for the production of renewable chemicals. But much more is needed.

Our analysis identified these top strategies for establishing this new industry in Maine:

- Economic development advocates must continue to assist with matchmaking between distressed regions with idle industrial sites available and emerging biotechnology companies.
- Key stakeholders must market and promote Maine's unique assets to biotechnology companies at national and international industry conferences, establishing Maine as the place to locate a biobased manufacturing company.
- Elevate the climate benefits of Maine's renewable resources to increase attention and investment in Maine assets.
- Policymakers must enact and provide financial incentives, including capital funding for research, development, and commercialization, to reduce financial barriers restricting investment.
- Pair biofuels production with more profitable technologies that generate higher-value specialty chemicals or bioplastics.

With the state's vast forest resource; established system for harvesting, transporting, and processing renewable raw material; and highly skilled workforce, Maine is well-positioned to take advantage of this unparalleled opportunity — but stakeholders must act now.

Maine's rural communities need action, as too many are suffering economic distress. Declining industries have led to job loss, the hollowing-out of downtowns, and an exodus of young people and families from once-thriving communities.

Much of the recent decline has been in the forest products sector, which now has more low-cost raw material available to support new biobased manufacturing.

With an established and robust biobased industry, Maine's rural communities will recover, bolstered by the creation of high-paying green manufacturing jobs, and Maine will be a global leader in the fight to slow climate change.

What are Biobased Products?

For more than one hundred years, the mining of petroleum and natural gas has provided the raw materials for the global industrial economy. This nonrenewable resource is used to make chemicals, fuels, plastics, rubber, and consumer products. But with the creation of new biobased technologies, that scenario is rapidly changing, creating a tremendous business opportunity for Maine.

Products you use every day—nearly anything from cosmetics and clothing to cleaning products and carpets—contain ingredients known as petrochemicals that were originally made from oil or gas.

Our materials economy doesn't have to be this way. Instead of making everyday products from climate-damaging oil and gas, we can make them from renewable resources widely available in Maine. These include the byproducts of our forests, farms, and sea that otherwise go to low-value uses or are "wasted."

The resulting "biobased" products (or bioproducts) include renewable chemicals to replace petrochemicals and plastics in consumer products and building materials, and advanced biofuels to displace fossil fuels.

Why Biobased?

FOR MAINE'S ECONOMY

New biobased manufacturing would create high-paying jobs that revitalize the state's rural communities. With abundant natural resources, Maine is well-positioned to grab a share of the growing bioeconomy. And the forest products industry, worth $8.5 billion annually to the state's economy, is actively seeking opportunities to diversify.[1] This approach aligns with Maine's recent ten-year Economic Development Strategy, which includes a focus on achieving a higher value-add for raw materials.[2]

FOR OUR GLOBAL CLIMATE

Biobased products enjoy a much smaller carbon footprint across their lifecyle. New biobased manufacturing in Maine could reduce greenhouse gas emissions by more than 44 million tons through 2050 and drastically reduce the use of nonrenewable fossil resources.

Renewable Raw Materials Drive Prosperity and Sustainability

Manufacturing products from Maine's renewable resources will bring prosperity to our state.

In the last 20 years, thousands of jobs have been lost as a result of reductions in pulp and paper manufacturing. While the forest products sector remains vibrant, growth in new biobased manufacturing could revitalize rural communities and diversify the industry for greater resilience.

The Biotechnology Innovation Organization estimates that jobs in the U.S. biobased sector will grow from approximately 40,000 in 2011 (3-4 percent of chemical sales) to 237,000 jobs by 2025 (20 percent of chemical sales).[3] We project this emerging industry in Maine will create 800 direct manufacturing jobs and 3,000 indirect jobs through 2030.

Switching to renewable feedstocks — the raw materials used for processing or manufacturing — is also a crucial strategy to halt and reverse climate change.

We can make everyday products from renewable plant resources widely available in Maine, such as the leftovers from harvesting and milling of sawlogs, farm crop waste, and even algae. These biobased products or "bioproducts" have a significantly smaller carbon footprint than their petroleum-based counterparts.

Technically, upwards of 90 percent of plastics could be made from plants instead of petroleum. If bioplastics captured just 46 percent of this market, greenhouse gas emissions would be slashed by 3.8 billion tons (of CO_2 equivalents) over thirty years. That's like taking 25 million cars off the road.[4]

For the sake of Maine's economy and the climate, it is critical that we make use of forest residuals, agricultural waste, and algae to manufacture biobased products.

Everyday Products, Made from Plants

Anything you can make from oil or gas, you can make from plants.

From the clothes you wear, to the computer you use, to ingredients in your shampoo — petroleum and natural gas are the building blocks used to make all kinds of consumer and industrial products that we rely on, every day.

But anything you can make from oil or natural gas, you can make from plants.

Just imagine a world where everyday products are biobased, instead of petroleum-based. Working on your laptop could mean relying on bioplastics made from sustainably harvested wood chips. Renewable chemicals sourced from plants could be in your shampoo and hand lotion. The clothes you wear could even be woven from fabric derived from sustainable resources, like wood or algae.

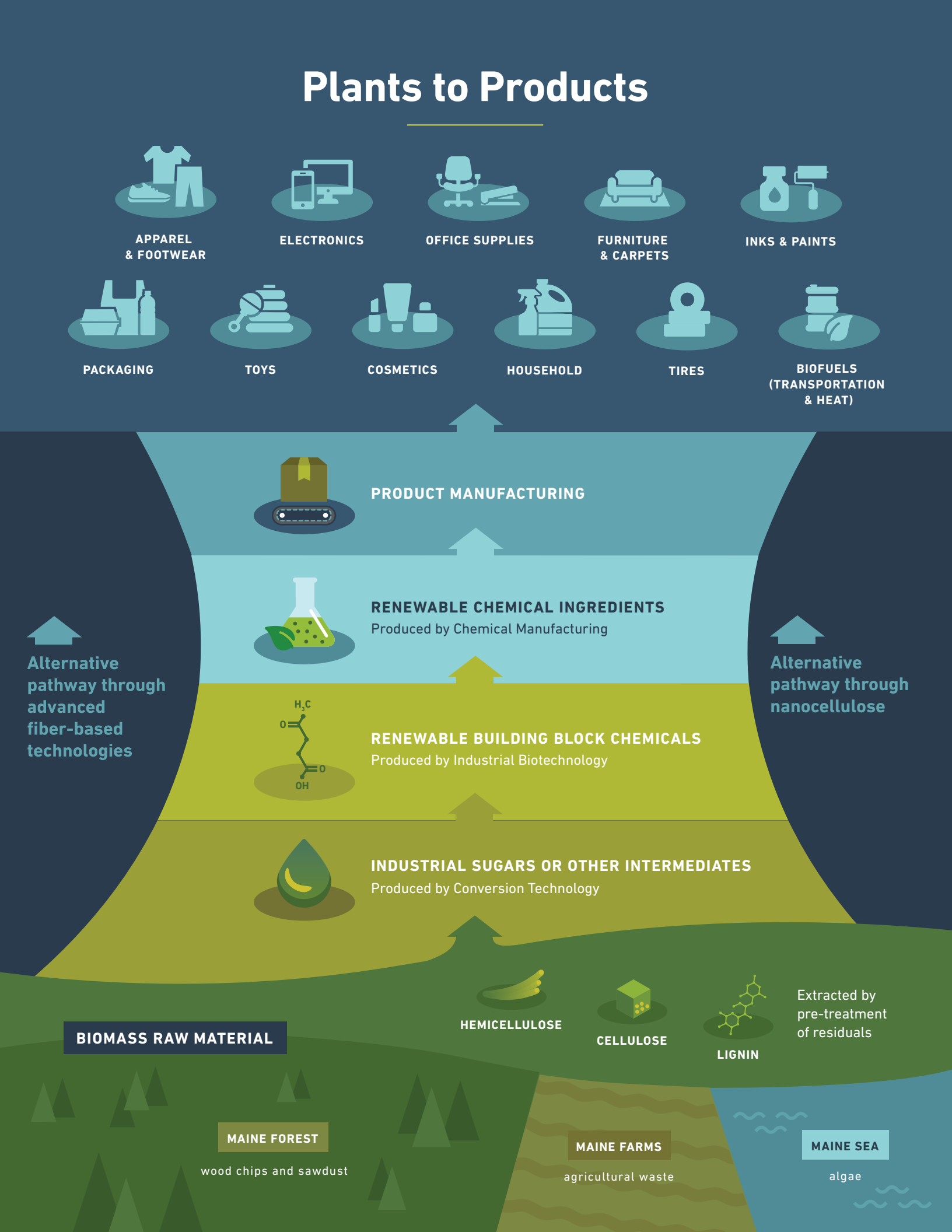
In Maine, woody biomass from forest residuals are the most abundant and promising raw material for biobased manufacturing right now.

In 2017, approximately 13 percent of all petroleum products, including natural gas liquids, were used to produce chemicals for consumer, commercial and industrial products.[5] By replacing those petro-chemicals with renewable chemicals sourced from sustainably harvested forests, Maine can drastically reduce greenhouse gas emissions and create and retain high-paying green manufacturing jobs.

Upwards of 90%

of plastic could be made from plants instead of petroleum.

Plants to Products



Rising Global Demand Creates Economic Opportunity for Maine

In response to the growing climate crisis, nearly 1,000 companies have committed to action to reduce greenhouse gas emissions.[6] For example, Coca-Cola set a goal to reduce the carbon footprint of "the drink in your hand" by 25% by 2020.[7]

Commitments like these put pressure on manufacturers to replace petroleum and natural gas with renewable raw materials in their products and packaging, which means a growing market for biobased manufacturing.

In fact, the bioplastics market alone is projected to grow from $10.5 billion in 2020 to $27.9 billion by 2025.[8]

Renewable feedstocks also tend to have less price volatility. Manufacturers' inability to accurately forecast the price of oil and gas frustrates budgetary and supply chain planning.

Moreover, while the price of oil has dropped in recent months, it will inevitably increase. The higher the price of oil and gas, the more competitive are renewable alternatives.

With all of these factors driving demand, Maine now has an unparalleled opportunity to grab its share of this rapidly growing global industry.

For example, a pilot plant in Old Town has already demonstrated small-scale production of high-quality sugars and renewable chemicals that meet exacting industry standards. If the state attracts investment to scale up production, Maine is uniquely poised to secure a share in the growing global "bioeconomy"—and create high-paying green jobs for our rural communities.

Nearly 300% growth in five years

The bioplastics market alone is projected to grow from $10.5 billion in 2020 to $27.9 billion by 2025.

Major Brands are Driving Demand for Biobased Products

To meet the growing demand for climate-friendly products, big brands are increasingly sourcing biobased content in their supply chain. These plant-based plastics, chemicals, and other renewable content can be made from biomass sourced right here in Maine. These are just a few of many big brands offering renewable consumer products.

APPAREL AND FOOTWEAR

The sole of Reebok's Cotton & Corn shoe contains 1,3-propanediol, a renewable chemical made from corn by DuPont Tate & Lyle BioProducts.[9]

CHILDREN'S PRODUCTS

Lego and Mattel have both committed to using more sustainable materials for their toys, like biobased polyethylene made from sugarcane by Braskem.[10] [11]

HOUSEHOLD PRODUCTS

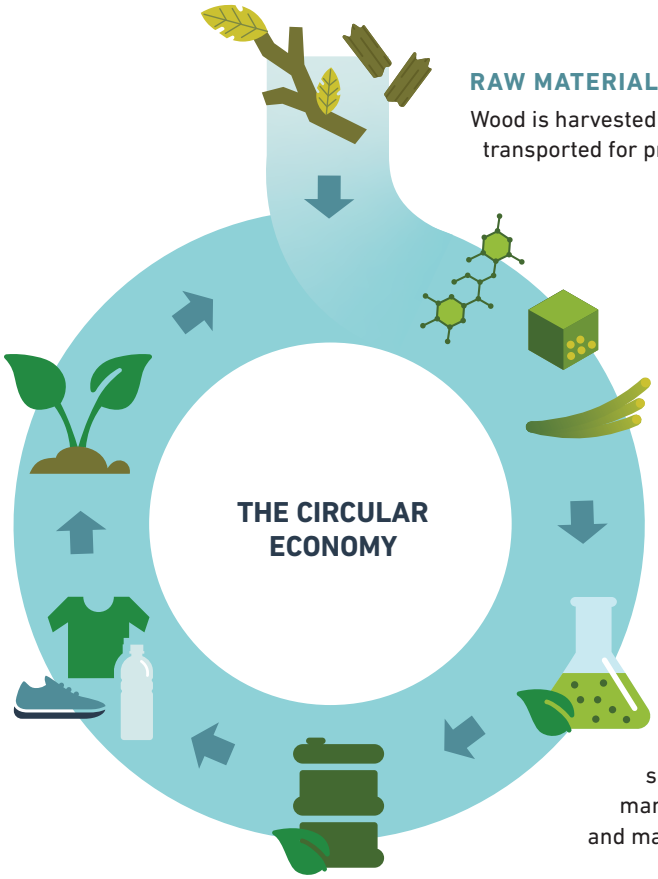
Cleaning products from Method, a brand owned by SC Johnson, contain two renewable chemical ingredients derived from ethyl levulinate made from corn stalks.[12]

FOOD SERVICE

Cups from EcoProducts are made from a compostable bioplastic, polylactic acid (PLA), produced by NatureWorks from corn.[13]

Transitioning to a Circular Economy

Re-engineering our materials economy to eliminate waste and pollution, keep products and materials in use, and regenerate natural resources—that's the circular economy. Here's what the circular economy looks like, with low-value wood as the raw material, including tops and branches of trees, and sawdust and wood chips from sawmills.



RAW MATERIALS

Wood is harvested and transported for processing.

PROCESSING

Wood is broken down into its three components: hemicellulose, cellulose, and lignin.

RENEWABLE CHEMICALS

Components of wood can be made into renewable chemicals, such as levulinic acid or furfural, or industrial sugars used as building blocks to manufacture products, chemicals, and materials.

ADVANCED MATERIALS

Bioplastics, nanocellulose, complex renewable chemicals, and advanced biofuels can all be manufactured.

BIOBASED PRODUCTS

A wide variety of consumer and commercial products can be made from biobased materials and chemicals.

CLOSING THE LOOP

Biobased products can be recycled for reuse or made to compost in the natural environment at the end of their useful life.

THE LINEAR ECONOMY

TAKE

mining of non-renewable oil and gas

MAKE

chemicals, fuels, plastics, products

WASTE

landfill, incineration, toxic carbon pollution

Woody Biomass:

The Future for Materials Production

Corn and sugarcane, both first-generation feedstocks, currently dominate the biobased manufacturing industry because the process to convert these crops to sugars is relatively easy. So-called second-generation feedstocks, like woody biomass and agricultural waste, are harder to convert to sugars, so they are just now reaching commercial scale. Using these second-generation feedstocks is preferable, because they have a lower carbon footprint and do not displace or raise the cost of food or animal feed. Moreover, there's simply not enough corn to replace all fossil carbon use—we need woody biomass and other abundant natural resources to make up the difference.

While corn enjoys temporary cost advantages, woody biomass is a superior raw material for practical, social, and environmental reasons.

See biobasedmaine.org/plants-to-products for more information on first- and second-generation feedstocks.

CASE STUDY

Sekab

ÖRNSKÖLDSVIK, SWEDEN

Sekab, a Swedish biotechnology company, boasts a suite of technologies—its Cellulose Technology Application platform (CelluAPP)—that convert softwood biomass to high-quality cellulosic sugars, hemicellulosic sugars, and lignin for use in a variety of applications, ranging from cosmetics and pharmaceuticals, to biofuels and specialty chemicals. At their new demo plant in Örnsköldsvik, Sekab will demonstrate their technology using pulp and paper industry residuals as a raw material.

www.sekab.com/en

*GMO = Genetically Modified Organism; more than 90% of corn is genetically engineered.

COMPARISON OF BIOPRODUCT RAW MATERIAL FEEDSTOCKS: WOOD VS. CORN

Consideration	Advantage	Description
Available Biomass	Wood	There's not enough corn to fully replace oil and gas. Woody biomass is needed.
Certified Sustainable Harvest	Wood	High percentage of certified forests ensures sustainable management.
Climate Benefits	Wood	Offers three times greater greenhouse gas reductions.[14]
Non-Food Crop	Wood	No impact on the availability and cost of food and feed.
Non-GMO*	Wood	Opens European market, without genetic engineering.
Chemical Inputs	Wood	Far less pesticides and fertilizers are required.
Water Use	Wood	Rainfall and snowmelt replaces intensive irrigation.
Land Use	Wood	No annual land disturbance and more mixed uses.
Infrastructure	-	Mature infrastructure supports efficient harvesting, transport, and processing.
Current Technology	Corn	Conversion of corn starch has been commercialized with government support.
Current Costs	Corn	Feedstock and processing costs are lower, for now.
Current Subsidies	Corn	More federal financial support provided for corn, both now and historically.

Maine's Greatest Asset:

Abundant and Sustainable Forest Resources

Maine is the most forested state in the U.S., with over 17.5 million acres of forest land. Maine is unique with over 90 percent privately owned forest land,[15] which makes it easier to secure a long-term wood supply.

Furthermore, Maine's forest industry produces ample residuals. Although there's a strong continued role for wood heat, it is inefficient to chip and burn residuals to produce electricity. After applying biomass retention standards to protect the forest land, ample residuals are available to support biobased manufacturing.

In 2018, Maine landowners harvested 12.1 million green tons of wood[16] — sawlogs, pulpwood, and biomass. However, due to projected sawmill growth and the downturn in pulp and biomass energy production, Maine forests have a growing quantity of sawmill chips and residuals, forest residuals, and low-grade pulpwood that currently lack robust markets.

For a detailed analysis, see the 2017 Innovative Natural Resource Solutions report "Wood Feedstock Supply for Biobased Materials in Maine."
biobasedmaine.org/plants-to-products

POTENTIAL RAW MATERIAL SUPPLY FROM MAINE FORESTS FOR PRODUCTION OF BIOBASED MATERIALS[17]

(based on USDA data from 2012 through 2016)

Woody Biomass Type	Amount (million green tons, annual)	Description
Forest residuals	**1.9**	Tops and branches from the harvest of sawlogs and pulpwood
Sawmill chips	**0.8**	Clean wood chips without bark; amount projected to grow
Sawmill residuals	**0.8**	Sawdust and bark (lower quality); amount projected to grow
Net growth, unused	**6.1**	Includes low-grade pulpwood (mostly softwood) without markets
Salvage, spruce budworm	**0.7**	Future projections, averaged over 40-years
Commercial thinnings	**Unknown**	Young thinned out trees, presumed to be too costly to recover
TOTAL	**More than 10.3 million green tons potentially available each year**	

Maine's Many Assets Support Biobased Manufacturing

Researchers at the University of Maine's Forest Bioproducts Research Institute have developed innovative CNF building materials. Photo Credit: University of Maine

- **Highly experienced workforce.** Many Maine workers have decades of experience in the pulp and paper industry, with representation from the United Steelworkers, and with knowledge and skills transferable to biobased manufacturing. The state's professional development system is also graduating a highly skilled workforce required for a number of growing occupations in the advanced manufacturing sector, according to a recent analysis. *Please see biobasedmaine.org/plants-to-products for the detailed workforce report produced by the Maine Center for Business and Economic Research in 2015.*
- **Mature system for harvesting, moving, and processing.** Thanks to Maine's robust forest products industry, the state has the infrastructure and a professional workforce of loggers and truckers who responsibly harvest and deliver raw material from the forest to mills every day.
- **Idle industrial properties throughout the state. Suitable for new manufacturing at low cost with existing infrastructure**, many offering combined heat and power, wastewater treatment, and current permits. *Please contact the Maine Department of Economic and Community Development's Office of Business Development for information on industrial sites available for co-location: https://www.maine.gov/decd/business-development*
- **World-class research and development.** The University of Maine utilizes world-class R&D facilities devoted to the development and commercialization of innovative solutions throughout the forest supply chain. From the Forest Bioproducts Research Institute's Technology Research Center, converting woody biomass to biofuels and bioproducts, a Nanocellulose Pilot Plant manufacturing cellulose nanofibrils at one ton per day, to other advanced manufacturing and building products facilities, UMaine serves as a one-stop shop for commercializing advanced forest products. UMaine researchers have also innovated cutting-edge technologies such as CNF (cellulose nanofibril) building materials.

Emerging Technologies Can Convert Woody Biomass to Bioproducts

New technological approaches to derive raw materials from forest residuals and agricultural waste are on the cusp of commercial success. Historically, these materials have been more challenging to break down and convert to biobased products than starchy food crops like corn. Many companies have now demonstrated technologies that effectively convert woody biomass into value-added bioproducts.

These are some of the strategies they are taking and the markets being targeted. Some of these technologies rely on microorganisms such as yeast and bacteria that are trained to produce highly targeted renewable building block chemicals.

Renewable raw materials have already replaced fossil carbon in nearly five percent of chemicals, plastics, and fuels. Technologies available today could achieve a 90 percent conversion rate.

Quick Plug BioStrate® Felt, made with PLA bioplastic, for microgreen, salad green, and wheatgrass production.

NATURE'S BUILDING BLOCKS

Industrial Sugars

Two components of woody biomass, cellulose and hemicellulose, can be separated and broken down into sugars such as glucose and xylose. Using microorganisms like yeast, these industrial sugars are converted to a diverse range of renewable chemicals, providing the building blocks for manufacturing everyday products.

Several companies, including **Sweetwater Energy**, **Renmatix** and **Avantium**, have demonstrated effective technologies for converting woody biomass to industrial sugars.

MORE SUSTAINABLE INGREDIENTS

Renewable Chemicals

Some technology companies skip the sugars and convert woody biomass directly into renewable chemicals such as furfural and levulinic acid. Many high-value ingredients can be derived from these platform chemicals for use in cleaners, adhesives, plastics, medicines and much more.

For example, **Biofine Developments Northeast** is working to produce a heating oil substitute in Maine, while **Origin Materials** in Sarnia, Ontario aims to help make the first 100% biobased plastic bottle.

A RENEWABLE FUTURE FOR PLASTICS

Biobased Plastics

Combating plastic pollution requires fewer single-use disposables, more renewable raw materials, and greener chemistry. Bioplastics made from industrial sugars or other renewable sources have a low carbon footprint, and many are recyclable, compostable, and can even degrade in a marine environment.

Several new bioplastics are already on the market, including PLA from **NatureWorks**, PHA produced by **Danimer Scientific**, and bio-polyethylene made by **Braskem**.

FUELING THE TRANSITION

Advanced Biofuels

Even as more vehicles become electrified and renewable energy soars, low-carbon fuels can aid the transition to a climate-friendly economy. Companies that convert woody biomass to liquid fuels are targeting industrial and marine diesel, aviation, and home heating markets.

Companies such as **Licella** and **Velocys** are deploying technologies to transform woody biomass into bio-crude oil that can be converted into biodiesel and jet fuel.

Overcoming These Challenges will Attract Biobased Investment in Maine

The northern forest has higher biomass costs compared to first-generation feedstocks and some wood.

Compared with first-generation corn, sugarcane, sugar beet, and some second-generation feedstocks, Maine wood is relatively expensive. This is due to several factors, including: Maine's shorter growing season and slow-growth trees compared to high crop turnover and relatively fast tree growth in warmer climates, and rough forest terrain that makes logging difficult compared to easy-access and quick-harvest tree plantations. Locating processing facilities close to where the wood fiber is harvested will reduce transportation costs.

Technology remains on the cusp of commercialization.

Technologies to convert woody biomass residuals to renewable building block chemicals must compete with the low price of corn to prove their economic viability. That means for these technologies to reach commercial scale, they require support on a state and federal level in the form of subsidies, R&D investment, and other fiscal incentives. While Maine has adopted a new renewable chemical and biofuel tax credit (see page 19) the state will need to significantly increase R&D funding and subsidize woody biomass conversion technologies if it wants to compete with heavily subsidized corn ethanol and oil.

Long-term supply contracts for woody biomass have not been the norm.

Successful investment in biobased manufacturing typically requires a long-term supply of raw material at a predictable price. However, forest landowners have typically supplied wood through short-term contracts or on the spot market to the pulp and paper industry, sawmills, and other users. Given the reduced demand for residual chips and biomass, landowners may be more open to longer-term supply agreements. Developing a pricing mechanism that is fair to both parties is key.

Much of Maine's forest harvest residuals do not qualify for a major federal biofuel incentive.

Only a limited portion of woody biomass from Maine's naturally regenerating and sustainably harvested forests qualifies as an acceptable feedstock under the national Renewable Fuel Standard (RFS) administered by the U.S. Environmental Protection Agency. This discrepancy makes it very difficult for Maine to attract investment from commercial scale biofuel companies, who require large volumes of biomass. Meanwhile, federal economic incentives continue to advantage plantation-grown trees and corn as raw material for biofuels.

Strategies to Effectively Leverage Maine's Assets

Assemble the biobased value chain: Concentrated matchmaking efforts are necessary to attract investment.

Engaging feedstock providers, matching the needs of technologies with available sites in Maine, and attracting downstream partners are all critical activities to build the biobased value chain and boost growth in Maine's bioeconomy.

Expand state and federal financial incentives.

Financial incentives like R&D bond funding, for example, can help technology companies overcome the challenges of scale up. Maine spends $79 million of federal R&D funding each year; that's compared to an annual $252 million of federal R&D funds spent in Iowa.[18] There are a few successful examples of bond funding in Maine, including by the Maine Technology Institute, to help finance start-up and biotechnology innovation, but additional financial incentives are needed to support growth of the bioeconomy.

Couple biofuels production with high-margin renewable chemicals.

When paired with technologies that generate higher-value specialty chemicals or bioplastics, biofuels are more likely to be profitable in Maine. It makes economic sense to make the highest-value products from Maine's forest resource.

Market Maine's assets globally.

The biobased technology industry will not discover opportunities in Maine unless we promote and market all of Maine's assets thoughtfully and strategically. This includes attending national and international biobased industry conferences, securing speaking engagements, marketing our new renewable chemical and biofuel tax credit broadly (see page 18), and nurturing relationships with companies and investors that grow over time. Maine should build on its recent agreement with Finland to enhance collaboration in forest sector bioeconomy development.

Elevate the climate benefits of bioproduct manufacturing.

Through a comparative life cycle assessment, net reductions in greenhouse gas emissions can be demonstrated for the production and use of virtually all bioproducts made from renewable biomass when compared to their fossil-based counterparts. Greater recognition of the climate benefits of sustainable materials made from Maine's renewable resources will encourage more companies to incorporate such strategies into their carbon footprint reduction plans. In turn, this will accelerate demand for biobased products.

The Economic Benefits

of Biobased Manufacturing in Maine

Significant Investment, Good Jobs, Revitalized Communities

During the next ten years, production of renewable chemicals and biofuels in Maine could create and retain more than 4,000 jobs and attract nearly $4 billion in capital investment. That's according to a forecast prepared by Biobased Maine at the request of the Maine Department of Economic and Community Development.[19]

PROJECTED ECONOMIC BENEFITS FROM BIOBASED MANUFACTURING IN MAINE THROUGH 2030

Measures of Success	Benefits	Notes
New Manufacturing	12 facilities	Based on company plans and feasible technologies
Renewable Chemicals	1.6 billion pounds	Made primarily from forest and sawmill residuals
Advanced Biofuels	660 million gallons	Made primarily from forest and sawmill residuals
Capital Investment	$3.7 billion	Co-location at industrial sites reduces capital costs
Revenues Generated	$7.4 billion	Forecast based on market prices
Jobs Created – Direct*	800	These are new high-paying manufacturing jobs
Jobs Created – Indirect	3,000	Suppliers (loggers, truckers) and other induced jobs
Jobs Retained	500	Bolt-on technology at pulp mills diversifies products

*does *not* include additional construction jobs created to build manufacturing facilities

This plausible scenario builds on known technologies, existing companies, and the availability of abundant woody biomass in Maine. Continued strategic focus could enable Maine to effectively compete with other states and countries to attract such investment.

Through financial incentives to de-risk new biobased investments, and commitments to lower carbon footprints to slow climate change, Maine's economy and the climate will benefit for decades to come.

For detailed description of data sources and assumptions that support the scenarios outlined on pp. 16 and 17, please see biobasedmaine.org/plants-to-products.

The Climate Benefits
of Biobased Manufacturing in Maine

Reduced Greenhouse Gas Emissions and Fossil Resource Use

Major corporations have responded to the climate crisis by adopting sustainability goals to shrink the carbon footprint of their products and packaging. This drives global demand for ingredients and materials made from renewable sources of carbon, like woody biomass, rather than from the fossil carbon in oil and gas.

By 2050, biobased manufacturing in Maine could reduce the use of fossil fuels by more than 20 million tons and slash greenhouse gas emissions by 44 million tons, in total, over the next 30 years. That's the same as taking nearly 300,000 gas-guzzling cars off the road permanently![19]

POTENTIAL CLIMATE BENEFITS OF BIOBASED MANUFACTURING IN MAINE THROUGH 2050

Bioproducts Manufacturing Scenario			REDUCTIONS IN:	
Number of Facilities	**Renewable Chemicals**	**Advanced Biofuels**	**Fossil Resource Use** (millions of tons)	**Greenhouse Gas Emissions** (millions of tons, CO_2-equivalents)
6	Levulinic acid & derivatives, Furfural, Formic acid	Ethyl levulinate (heating oil)	**14.9**	**35.0**
1	Biobased cleaners, Biobased degreasers, Tiki torch oil	Biodiesel, Bioheating oil	**0.39**	**0.81**
1	Cellulosic sugars	Bioethanol	**0.98**	**2.45**
1	Acetaldehyde, Ethyl acetate, Acetic acid	Bioethanol, ED95 (biodiesel)	**0.57**	**1.22**
1	Cellulosic sugars, Lignin	-	**1.38**	**0.46**
1	Lactic acid to Polylactic acid (PLA)	-	**1.21**	**0.40**
1	Furfural & derivatives	TDO oil (biodiesel)	**1.49**	**4.01**
TOTAL for 12 manufacturing facilities in 30 years:			**20.9**	**44.4**

This plausible development scenario informed the economic benefit forecast on the previous page. Net greenhouse gas reductions are based on credible life cycle assessments of biofuels compared to fossil fuels, with reasonable assumptions on renewable chemicals.

Success: Maine's Leadership Helps Level the Playing Field

In March 2020, Governor Janet Mills signed into law the nation's most competitive production tax credit to support investment in biobased manufacturing in Maine.

Maine's new law advances the manufacturing of biobased chemicals and materials in Maine with a tax credit of 8¢ per pound of renewable chemicals produced — higher than similar tax incentives offered by Iowa and Minnesota. Maine's incentive also reinstates a tax credit of 5¢ per gallon of biofuels produced.

The tax credit marks a milestone in attracting investment that is forecast to create and retain more than 4,000 jobs and attract nearly $4 billion in capital investment over the next ten years.[19]

Financing large scale industrial manufacturing facilities is not easy. Reducing risk is key for lenders and investors. The tax credit will go a long way towards mitigating a significant amount of capital risk and in turn establish Maine as the state to locate biobased business and a leader in climate change mitigation.

— MIKE CASSATA
CHIEF DEVELOPMENT OFFICER,
BIOFINE TECHNOLOGY, LLC

CASE STUDY

Biofine Developments Northeast (BDNE)

BANGOR, MAINE

BDNE is at the forefront of Maine's emerging bioeconomy. The company seeks to use cellulosic waste to make 100% renewable, CO_2-negative heating fuel and chemicals using underutilized and idle manufacturing infrastructure in rural Maine.

BDNE is the exclusive licensee of patented technology from Biofine Technology, LLC that converts woody biomass residuals into ethyl levulinate (EL), a renewable heating oil substitute. Their technology also produces a side stream of renewable chemicals: levulinic acid, formic acid, and furfural. BDNE projects their first commercial plant to be operational in 2023, creating 183 jobs.

An Action Agenda to Attract Biobased Investment in Maine

Maine's abundant biomass, including sustainably sourced forest residuals, provides ideal raw material for the production of biobased products. For Maine to capture a market share in the emerging global bioeconomy, produce climate-friendly products, and create good green jobs that revitalize our rural communities, we recommend that key stakeholders take the following actions.

STATE POLICYMAKERS:

1. **R&D Bonds.** Authorize significant annual bond funding for research, development, and commercialization of advanced technologies, including biobased manufacturing.
2. **Site Development.** Expand funding for the Rural Manufacturing and Industrial Site Redevelopment Program at the Maine Rural Development Authority to assist in repurposing industrial property for co-location of biobased manufacturing plants.
3. **Procurement.** Enact policy to give preference to the state purchase of biobased products, including those manufactured within the state.
4. **Workforce.** Identify biotechnology workforce development needs and implement appropriate professional development and workforce training systems.
5. **Low Carbon Fuel.** Consider recommendations by the Maine Climate Council's Energy Working Group to institute a Renewable Fuel Standard for all heating fuels in order to drive investment in low carbon and renewable alternative fuels.

FEDERAL POLICYMAKERS:

6. **Renewable Fuels.** Include sawmill residuals from naturally regenerating forests in the federal Renewable Fuels Standard (RFS).
7. **Production Tax Credit.** Pass a federal renewable chemical production tax credit to create a level playing field that encourages more companies to replace petroleum with renewable resources in everyday products.
8. **Energy Financing.** Enact the Financing Our Energy Future Act (S.1841/H.R.3249, 116th Congress) to release private capital by allowing energy generation and renewable fuel companies to form master limited partnerships (MLPs) to enable cost-effective financing of capital-intensive projects.

THE PRIVATE SECTOR:

9. **Long-Term Contracts.** Forest landowners and sawmills should seek out opportunities for long-term supply contracts that suit their individual needs and contribute to the growing industry. The more successful these emerging technologies are in Maine, the more resilient and profitable the entire industry.
10. **Diversify Products.** Maine pulp and paper manufacturers should consider emerging biotechnology co-location and bolt-on opportunities to diversify products and increase business sustainability.

ALL STAKEHOLDERS:

11. **Market Maine's Assets.** Maine should continue to market our assets to the global biotechnology industry, for which the portfolio of available technologies is continuously changing, to establish Maine as the opportune place for biotechnology investment.
12. **Ready Local Sites.** Local economic development advocates should share details of their local assets and site characteristics in the state of Maine database of available co-location sites to allow matchmaking of assets with biotechnology company needs.
13. **Elevate Climate Benefits.** Maine's Climate Council should promote the climate benefits of biobased materials to support the development of Maine's bioproduct manufacturing industry for both the economic and climate benefits.

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Endnotes

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19. Sources, reports, assumptions, and additional references can be found at biobasedmaine.org/plants-to-products

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