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Research Series

Investment Opportunities in the Forest Bioeconomy

A Comparison of Ecosystem-Focused & Production-Oriented Projects

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Executive Summary

Climate change, global population growth, declining natural resources and the loss of biodiversity challenge us to move towards a global bioeconomy, based on the sustainable utilization of renewable natural resources in the production of energy, products and ecosystem services. Major global agreements and policy goals have started to shift our economic and financing models towards sustainability-linked approaches. For example, forests serve as major stores of carbon from industrial and bio-based products that can substitute for fossil- based materials, such as plastics, chemicals, textiles and many other materials. But how are the economics informing financing and business models that allow for catalyzing this transition? This paper provides an overview of the opportunity of the circular forestry bioeconomy, the revenue, business model and investment challenges for structuring and scaling forest projects.

It is important to make a distinction between conservation- and economic productivity-driven forest bioeconomy projects. While interrelated, the economic and financing implications differ, as the latter implies an industrial policy, requires realignment of value chains, and attracts different financing approaches. Conservation forest economics aimed at carbon sequestration and other environmental co-benefits as well as recreation has strong dependencies on tree type, harvesting cycles, the market price of carbon, government subsidies, the cost of acquisition and management, and opportunity cost considerations of alternative crops. Cost barriers, certification schemes and the risk of potential over-creditation have been early challenges in the development of projects, but new protocols and better tracking and verification are being implemented to build confidence for carbon credit buyers aiming to achieve net-zero strategies. Investment models in carbon offset forest projects are shifting from public financing to market driven financing mechanisms including through direct investment, public private partnerships (P3), green bonds, real options structures, carbon farming agreements and carbon offtake guarantees. When economic production economies can be linked to forest bioproducts, private financing mechanism such as project finance and private equity investment becomes possible, given the requirements for higher rates of return.

The Great Lakes region has the potential availability for fifty-two gigatons of high-quality carbon by 2050 with a revenue potential of at least $783B USD. Execution on this opportunity will require a more granular understanding of forest quality and ownership and depend on the structuring of financing mechanisms (and offtake agreements) based on reliable accreditation, tracking, and use cases. Long-term stable income and hedges against volatility will be a key element of the financing structures that can be implemented on heterogeneous carbon quality, rotations, and ownerships. A regulated Great Lakes Carbon Market will go a long way towards the implementation of economic incentives, financing models, and carbon accounting practices as can be deployed using decentralized ledger technologies.

Conservation-Focused Forest Projects and Production-Oriented Forests: An Overview

Forests serve a multitude of functions in the economy, from ecosystem services such as biomass production, recreational value, and carbon sequestration or water quality control to bioproducts such as timber, pulp and paper, energy and chemicals. While related in the forest bioeconomy, they represent two different management strategies with separate value propositions, revenue streams and investment models. Conservation-focused forest projects such as afforestation and reforestation contribute to negative emissions, and include zoning enforcement, stopping illegal deforestation, and development of domestic carbon markets that incentivize increased forest cover. On the other hand, the use and 'upcycling' of wood resources as a substitute for non-renewable, carbon-intensive materials is often referred to as a production-oriented forest bioeconomy (Chart 1).[1]

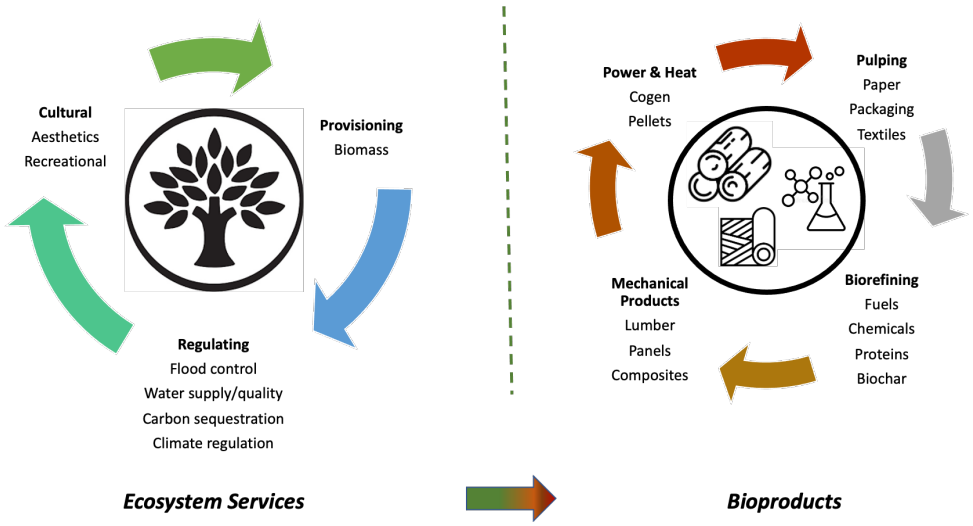

Chart 1. Relationship between conservation-focused and production-oriented forest projects.

A wide spectrum of industry policy shifts, technological innovations, and market development is needed to build and scale a functioning and efficient circular forest-based bioeconomy capable of reducing fossil fuel use through upcycling of bio-based products, and for maximizing carbon sequestration and ecosystem services.[2] The specific focus of this paper is on the economics and investment models for both types of forest projects.

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1 Gregg, J.S., Jürgens, J., Happel, M.K., Strøm-Andersen, N., Tanner, A.N., Bolwig, S. and Klitkou, A., 2020. Valorization of bio-residuals in the food and forestry sectors in support of a circular bioeconomy: A review. J. cleaner production, 267, p.122093.

2 Hetemäki, L., Kangas, J. and Peltola, H., 2022. Forest Bioeconomy and Climate Change. Springer Nature Switzerland AG. 256 p

Value Proposition of Conservation Forest Projects

It has long been recognized that nature-based climate change mitigation strategies, which leverage natural ecosystem carbon sequestration and storage processes, have the potential to substantially reduce global greenhouse gas (GHG) emissions. The Intergovernmental Panel on Climate Change (IPCC) indicated that such strategies, which include afforestation, reforestation, improved forest management, and avoided forest conversion, can play a critical role in the global abatement portfolio. Forest sector policies are starting to feature prominently in national and international commitments, and regional initiatives to mitigate GHG emissions.[3] Research suggests that these abatement activities have the potential to achieve one-quarter to one-third of the mitigation required to meet climate stabilization targets by 2030.[4]

Economic incentives play an important role in the success of reforestation and afforestation projects, especially in the beginning because it takes several years for newly planted forests to start generating revenue from marketable products, such as bioplastics, timber, and other engineered benefits, commonly referred to as bioeconomy upcycling. Whether financial incentives are sufficient to convince landowners to participate in reforestation and afforestation projects depends primarily on the costs and benefits of such projects.[5] There have been cost-benefit analyses of carbon sequestration through afforestation in several countries, such as Canada, Argentina and Ecuador, as well as Australia. However, there are only few studies analyzing the economic attractiveness of afforestation projects that take full account of the carbon sequestration value. Furthermore, the costs and benefits of afforestation projects change with stand age because trees sequester more additional carbon dioxide when they are young and produce more marketable products when they are older.

Climate policy is expected to reverse historic losses in forest cover given the affordability and broader attractiveness of land-based emissions reductions. Net-zero target announcements will accelerate over the coming five years. These policies will rely heavily on ending deforestation and shifting to forest restoration as one of the world's only massively scalable options for negative emissions. For example, the Inevitable Policy Response (IPR), which models expected policy developments in a Forecast Policy Scenario (FPS), predicts a cessation of net forest cover loss by 2030, and a total of 350 Mha of afforestation and reforestation globally by 2050[6]. Such policies involve large scale development projects that sequester carbon by expanding and restoring carbon-dense natural ecosystems including forests. Delivering these solutions at scale will involve historic

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3 Ladu, L., Imbert, E., Quitzow, R. and Morone, P., 2020. The role of the policy mix in the transition toward a circular forest bioeconomy. Forest policy and economics, 110, p.101937.

4 Nunes, L.J., Meireles, C.I., Pinto Gomes, C.J. and Almeida Ribeiro, N.M., 2020. Forest contribution to climate change mitigation: Management oriented to carbon capture and storage. Climate, 8(2), p.21.

5 Austin, K.G., Baker, J.S., Sohngen, B.L., Wade, C.M., Daigneault, A., Ohrel, S.B., Ragnauth, S. and Bean, A., 2020. The economic costs of planting, preserving, and managing the world's forests to mitigate climate change. Nature communications, 11(1), pp.1-9.

6 UNPRI (2020). https://www.unpri.org/sustainability-issues/climate-change/inevitable-policy-response.

mobilization of capital alongside a massive increase in project development capacity around the world.

Forest-related Nature-Based Solutions (NBS) could generate US$800 billion in annual revenues by 2050, worth US$1.2 trillion today in NPV terms, surpassing the current market capitalization of the oil & gas majors. Natural forest restoration, as a low-cost mitigation strategy with a more direct compensation model, is expected to be taken up first and generated most of the early benefits. Avoided deforestation could represents an additional large-scale investor opportunity but is further away from at-scale commercialization since relevant low-emissions agriculture projects require more complex compensation mechanisms. Afforestation is the process of introducing trees and tree seedlings to an area that has previously not been forested. Afforestation can be done through tree planting and seeding, naturally or artificially. Generally, afforestation is driven by conservation goals resulting in the valuation of environmental or social co-benefits.

Value Proposition for Production-Oriented Forest Projects

The global forest industry is undergoing major structural changes as global demand for traditional forest products either declines, stagnates or shifts from the North to South. The market for newsprint and printing and writing paper continues to shrink due to digital media. The most significant emerging forest-based product markets are expected to include new innovative engineered wood products in the construction sector, pulp used for textiles, chemicals, bioplastics and energy, and for a number of niche markets, including cosmetics, food additives, pharmaceuticals, etc.. With the new products, the boundaries of industries will diminish, as the chemical, textile and energy industries are investing into forest based raw materials.

Valorization of forestry byproducts is highly dependent on case study analyses and industry surveys, and has focused largely on the resource procurement, valorization, and business strategies. Waste minimization through the valorization of bio-residuals is a key component to the circular bioeconomy. The value chain for residuals from the pulp and paper industry is constrained by the materiality of the residuals, regulation (particularly for disposal), the technology involved in transformation, the firms' capabilities, the relevant actors, and the market formation. A generic overview of the emerging forestry bioeconomy value chain is provided in Chart 2, which includes technology and solutions providers, expert services and digital/new disruptive players. Starting with forestry, wood-based product manufacturing, bioenergy production and pulp and paper processing are traditional core activities, resulting in paper and hygienic products, packaging solutions, and other bio-based residuals. Advanced pulp processing for biofuels and refining of pulp for industrial and consumer chemicals represents a new(er) extension of the value chain, supplemented with new agricultural and food industry side streams.

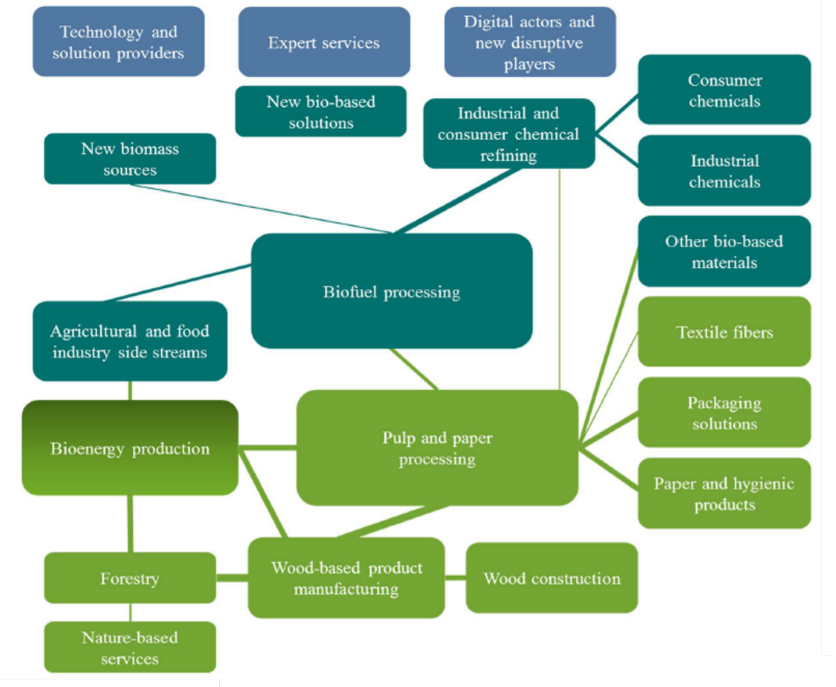

Chart 2. Value chain of extended forestry industry products (Source. Various)

To execute on this expanded value chain strategy, traditional forest companies are looking for partners with insight from a broader range of sectors beyond forestry, including research institutes, startups and established companies from other sectors.[7] In Finland, for example, the bioeconomy ecosystem for cellulose-based products consists of the traditional forest industry giants, as well as innovative startups. These tend to be engaged in either the design and development of new bioproducts and biocomposites, or new cellulose-based textiles.[8] Corporations and customer brands are actively participating in the development of cellulose-based textiles. For example, strong clothing brands can partner in the development and marketing phase of new cellulose-based fibers for a high-end clothing line.[9]

Established corporate leaders in the forestry industry ecosystem employ a wide range of criteria to select new startup or market partners, including market knowledge or material knowledge about technologies or materials currently used in the forestry industry. A key value for startup partner selection is to enable quick market entry with a new product or service, aligned with the company's lines of business. Other criteria include the need of corporates to address sustainability commitments or strategies, or new quality standards. Yet others target alignment between startups and brands to address the need for

7 Grundel, I. and Dahlström, M., 2016. A quadruple and quintuple helix approach to regional innovation systems in the transformation to a forestry-based bioeconomy. Journal of the Knowledge Economy, 7(4), pp.963-983.

8 D'Amato, D., Veijonaho, S. and Toppinen, A., 2020. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. Forest policy and economics, 110, p.101848.

9 Gregg, J.S., Jürgens, J., Happel, M.K., Strøm-Andersen, N., Tanner, A.N., Bolwig, S. and Klitkou, A., 2020. Valorization of bio-residuals in the food and forestry sectors in support of a circular bioeconomy: A review. Journal of cleaner production, 267, p.122093.

scalability where global brand owners with big sales potential require suppliers with reliable production capacities to meet future demand.[10]

The Economics of Conservation- and Production-Oriented Forest Projects

The economic model behind conservation- and production-oriented forest-based projects differs in terms of cost and revenue streams, thus impacting financing models. While this paper is not exhaustive in describing all options for new business and revenue models, it explores approaches taken to scale conservation and production practices.

Business Models of Ecosystems Service Forest Projects

According to a recent (2021) report on forest ecosystem business models by SINCERE (Spurring INnovations for forest eCosystem sERvices in Europe), funded through the European Commission's Horizon 2020 program, the following types of revenue and owner incentive models can be identified[11,12,13]

- *Reverse Auctions*[14]: The forest owners will put forward offers/bids to the contractor, representing the prices at which the landowners are willing to sell goods and services, i.e. in the case of forest protection the prices at which they would give up harvesting rights. The sources of revenue could be derived from hunting licenses, tax revenues or other sources (e.g. Denmark: buyout of production rights for biodiversity; Belgium: habitat restoration using hunting permit auctions).
- *Offtake Market Models*: Payment for a clearly defined service with a close market connection, such as carbon offsets, mushroom picking licenses or funeral forests (e.g. Italy: EcoPay contracts).
- *Compensation Models*: Compensation for the lost revenue due to changes in forest management. Funding is collected through donations from tourists and visitors (e.g. Finland: Payments for production losses for management changes).
- *Payment/Benefits with 'Administrative Pricing'*: Payment comes from those who benefit from forest ecosystem services such as city water utilities or park users who need to apply for permits (e.g. permits for recreation/sports events, water use fees or taxes).

From the perspective of the current paper, the opportunity of carbon offset markets will be

10 Näyhä, A., 2019. Transition in the Finnish forest-based sector: Company perspectives on the bioeconomy, circular economy and sustainability. Journal of Cleaner Production, 209, pp.1294-1306.

11 https://sincereforests.eu/making-the-business-of-forest-ecosystem-services-work/

12 Winkel, G., Lovrić, M., Muys, B., Katila, P., Lundhede, T., Pecurul, M., Pettenella, D., Pipart, N., Plieninger, T., Prokofieva, I. and Parra, C., 2022. Governing Europe's forests for multiple ecosystem services: Opportunities, challenges, and policy options. Forest Policy and Economics, 145, p.102849.

13 Tyrväinen, L., Mäntymaa, E., Juutinen, A., Kurttila, M., Ovaskainen, V., 2021. Private landowners' preferences for trading forest landscape and recreational values: A choice experiment application in Kuusamo, Finland. Land Use Policy, 107, p.104478. https://doi.org/10.1016/j.landusepol.2020.104478

14 Kindu, M., Mai, T.L.N., Bingham, L.R., Borges, J.G., Abildtrup, J. and Knoke, T., 2022. Auctioning approaches for ecosystem services–Evidence and applications. Science of the Total Environment, p.158534.

explored further. The creation of forest-based offsets is guided by protocols that dictate how sequestered carbon dioxide equivalent (CO2e) is converted into marketable offsets. Existing protocol designs aim to produce offsets that meet sustainability requirements, while providing financial incentives for landowner participation. Appropriate protocol design may encourage additional participants and generate a supply of offsets, but there is little consensus regarding an optimal protocol for forest-based projects.

An alternative abatement method is CO2e sequestration via afforestation, as increasing forest cover has been estimated to provide 42.6% of maximum global mitigation potential from manipulating ecosystems. At a national or regional level, the Global Timber Model (GTM) is often used to capture the potential for feedbacks between markets and land use, interactions between abatement actions, and spatial allocation in harvest patterns and mitigation activities, all of which have a strong influence on abatement costs and inform investment modes for reforestation and afforestation. Afforestation cost methods have been widely used for calculating the carbon sink cost of forest. At the project level, the economic attractiveness of shifting cropland to forest land uses for afforestation considers multiple factors[15]:

- Tree species, planting density and stand age: (i) planted as monocultures, (ii) a survival rate of at least 70%, and (iii) no large-scale cutting. Growth rate of tree species determines carbon sequestration and harvesting cycle for bio-based forest products.
- Comparison of income from forest and cropland to determine costs and benefits in a net present value framework, by considering (i) site preparation; (ii) management; (iii) harvesting and (iv) tools and machinery.
- Assessment of revenue contributions from carbon credits (as a reward for the ecosystem service provided by the landowner) as a value add in the forest management financial model
- Availability of subsidies and length of time of the afforestation project for carbon credits
- Impact of the type of investment models in afforestation project (e.g. direct

15 Hou, G., Delang, C.O., Lu, X. and Olschewski, R., 2019. Valuing carbon sequestration to finance afforestation projects in China. Forests, 10(9), p.754.

investment vs public-private partnership

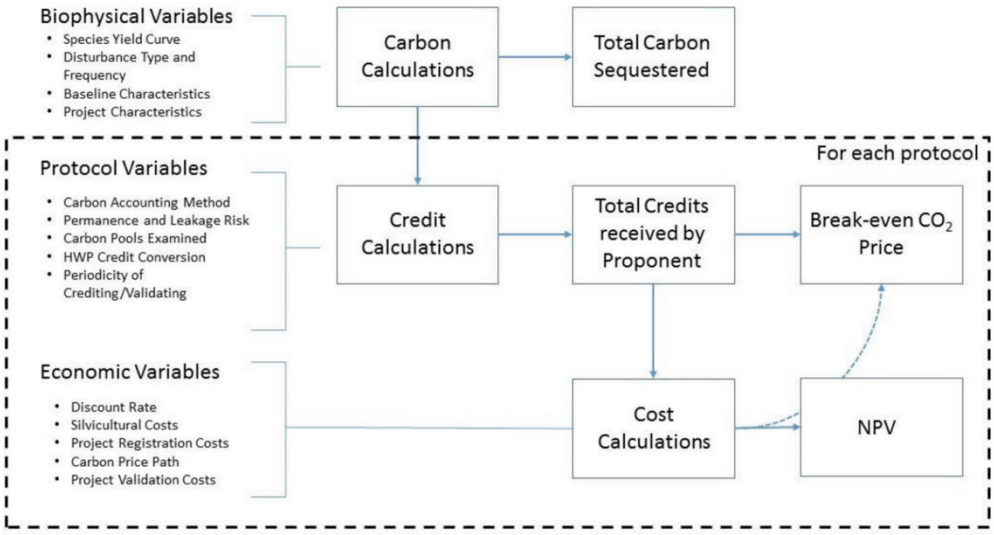

Chart 3. Framework showing the three key model stages, key variables within each stage, and the calculated outputs for afforestation considerations (from Hope et al., 2021)

Hope et al (2021) developed a financial analysis framework (Chart 3) for assessment of carbon offset protocols in Canada to explore how landowners could be incentivized to participate in forest-based offsets, and showed that current incentives are insufficient to produce carbon offsets via private landowners.[16] Hence, improvements on carbon offset verification protocols and sustainable financing models with proper incentives are central to broader adoption of forestry carbon offset projects. In addition, financial models indicate that carbon offsets alone are likely insufficient to make the economic model work, and revenue models including subsidies and auctions may be required.

Despite the general acceptance of forest management as a means of climate change mitigation through carbon sequestration, the number of registered forestry carbon offset projects of any kind is limited[17], and forest carbon offsetting programs suffer from systematic over-crediting.[18] A comprehensive analysis by Kreibich and Hermwille (2021) highlights a big discrepancy between the seemingly gigantic potential demand for carbon credits and the ability of the established certification schemes to supply credits legitimately and in a way that supports the objectives of the Paris Agreement without

16 Hope, E.S., Filewod, B., McKenney, D.W. and Lemprière, T.C., 2021. A financial analysis of four carbon offset accounting protocols for a representative afforestation project (southern Ontario, Canada). Canadian Journal of Forest Research, 51(7), pp.1015-1028.

17 VERRA. (2020). Public consultation – proposal for scaling voluntary carbon markets and avoiding double counting Post-2020. Retrieved January 20, from https://verra.org/project/vcs-program/public-consultation-proposal-for-scaling-voluntary-carbon-markets-and-avoiding-double-counting-post-2020/

18 Badgley, G., Freeman, J., Hamman, J.J., Haya, B., Trugman, A.T., Anderegg, W.R. and Cullenward, D., 2022. Systematic over crediting in California's forest carbon offsets program. Global Change Biology, 28(4), pp.1433-1445.

undermining them.[19]

Business Models for Production-Oriented Forest Projects

As highlighted in the value proposition, the opportunity for linking sustainably sourced forests and valuation of upcycled bio-based products in new value chains results in new business and revenue models.[20] Industrial policies, for example in Finland and Sweden, have taken a more holistic view of the forest bioeconomy opportunity, which includes carbon offsets, but are primarily geared towards the realignment of industries towards bio-based commodity use for low carbon economic renewal.[21] D'Amato et al. (2020) outlined the main business model archetypes, and identified the key characteristics that enable value capture and delivery for various stakeholders.

- *Maximizing material and energy efficiency.* Companies offer environmentally and/or socially more sustainable products and services, created through technological improvements (reducing inputs and outputs). Cost (e.g. less raw material needed, lower transport costs) and environmental impact reductions result in discounted pricing models relative to fossil fuel inputs.
- *Green public procurement models.* Policies function as market-makers for the realignment of industries towards bio-based commodity use for low carbon economic renewal, resulting in accelerated innovation and adoption of bio-based products.
- *Scale-up solutions.* These models focus on designing ideas and products that can be sold or exported through licensing or development of new value chain partners, and result in cost reduction and price competitiveness, as well as competitive positioning and increasing revenues.
- *Upcycling of waste for corporate product lines.* Sales of recycled products and value-added products from saw dust and pulp waste, with focus on compatibility in existing business lines. These models benefit from subsidies, lower cost of production for the offtaker and increased profit margins.

Execution on a circular forest bioeconomy requires innovations in policy measures to address the challenges of developing, and increasing adoption of new business models and market opportunities.[22] An innovation ecosystem tends to have the following characteristics: Investment in innovation and startups; Integration of forestry products in transitional industry supply chains; Upcycling of traditional forestry products in higher value products and services; Green forestry procurement strategies; and, Re-training of

19 Kreibich, N. and Hermwille, L., 2021. Caught in between: credibility and feasibility of the voluntary carbon market post-2020. Climate Policy, 21(7), pp.939-957.

20 D'Amato, D., Veijonaho, S. and Toppinen, A., 2020. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. Forest policy and economics, 110, p.101848.

21 Kröger, M. and Raitio, K., 2017. Finnish forest policy in the era of bioeconomy: A pathway to sustainability? Forest policy and Economics, 77, pp.6-15.

22 Näyhä, A., 2019. Transition in the Finnish forest-based sector: Company perspectives on the bioeconomy, circular economy and sustainability. Journal of Cleaner Production, 209, pp.1294-1306.

the forestry workforce towards broader economic integration. As an example, the Finnish National Forestry Bioeconomy program has emphasized implementation of these policy elements to shift and pilot emerging value chains, products and services.[23]

The economic metrics have resulted in a prioritization of production over ecological goals and objectives and tend to conflict with public sentiment on conservation, biodiversity and recreation, over the broader delivery of bio-based low carbon productivity. The tension has financial implications and reverberations as well, because a production-oriented forest project can leverage significant private investment against potentially attractive returns, according to the CleanTech Group's I3 Platform[24], an investor group, and Environmental Finance[25], a professional on-line news and analysis service for sustainable investment.

Investment Models for Conservation and Production-Focused Projects

The link between the ecosystem services oriented goals of climate-smart forestry and low carbon economic productivity objectives is a necessary step in the development of the forest bioeconomy[26], and opens up new investment models that would allow for scaling carbon offset projects.[27] The reason is that afforestation and reforestation projects require high upfront investments in land purchasing, planting and remediation costs, with benefits accruing over long time horizons.[28] In addition, opportunity costs to switch from crops to forests are difficult to overcome, and require careful design of incentives. Hence, long-term capital will need to be mobilized with stable returns over time and be structured to hedge risk from uncertain future carbon prices. In addition, new financing models will need to be developed and tested for small landholders. While project delivery may draw on large-scale, land-based project expertise traditionally practiced by institutional investors in agriculture and forestry, emerging and developing economies have been exploring both smaller scale direct investment and PPP models for afforestation projects.[29]

Conservation-Focused Projects

To date, financing of forestry and land-based mitigation has largely involved public concessional finance models (like REDD+; the UN framework to Reduce Emissions from Deforestation and forest Degradation) flowing from developed to developing countries.

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23 D'Amato, D., Veijonaho, S. and Toppinen, A., 2020. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. Forest policy and economics, 110, p.101848.

24 https://www.cleantech.com/

25 https://www.environmental-finance.com/

26 Gregg, J.S., Jürgens, J., Happel, M.K., Strøm-Andersen, N., Tanner, A.N., Bolwig, S. and Klitkou, A., 2020. Valorization of bio-residuals in the food and forestry sectors in support of a circular bioeconomy: A review. J. cleaner production, 267, p.122093.

27 Hetemäki, L., Kangas, J. and Peltola, H., 2022. Forest Bioeconomy and Climate Change. Springer Nature Switzerland AG. 256 p

28 UNPRI (2020). https://www.unpri.org/sustainability-issues/climate-change/inevitable-policy-response.

29 Li, X.; Hu, W.; Zhang, F.; Zhang, J.; Sheng, F.; Xu, X. Carbon Sink Cost and Influence Factors Analysis in a National Afforestation Project under Different Investment Modes. Int. J. Environ. Res. Public Health 2022, 19, 7738. https:// doi.org/10.3390/ijerph19137738

At the same time, forest finance markets are maturing, and private sector engagement is expected to expand as market-based approaches accelerate. Forest finance, historically dominated by public sector support, will thus increasingly be delivered by the private sector, using direct investment or through public private partnerships (PPP) through new ownership, co-financing and revenue sharing contracts. Recent innovations in green finance make private sector participation in the forest sector possible through the bond market. The adoption and scalability of new afforestation projects for carbon sequestration, water and tourism co-benefits will ultimately provide a more reliable long-term market structure for private actors. However, the challenges of risk and return expectations for landowners and investors remain, as do the challenges with registration and over-certification.[30] A range of financing options is being explored in the context of ecosystem services:

- *Distressed asset investment*, where deforested or degraded public and private land are purchased and restored to benefit from the carbon stock it produces, with the potential to sell the land on to other investors or to the government for conservation purposes.
- *Real option investment*[31], where investors take an option on the joint production of forest products and environmental goods, like biodiversity, hunting, groundwater production, carbon storage, and recreation to address the uncertainty of the future value of ecosystem services (e.g. Denmark)
- *Stewardship model*[32], where deforested or degraded land is leased without an ownership change, and the leaseholder receives the benefits flowing from the carbon stock associated with restorative management before returning it to the previous owner (e.g. Maine).
- *Carbon farming agreements*, where an investor supports the 'farming' of carbon through forest growth by providing financing for the initial land purchase and planting costs. In return, the investor receives payments tied to the carbon stock increases. Such a model is used to finance large land holders or cooperatives of smallholders, reducing the risk to those cooperatives while simultaneously reducing the administrative burden on investors (e.g. Pachama).
- *Sustainable farming agreements*, where an investor supports traditional crop farming practices that reduce emissions or sequester carbon (e.g. in soils) by financing farmers' land or capital cost. Investors receive payments when the carbon-reduction certificates are created and sold on the market. This too can be used to finance large farmers or cooperatives of small farmers (e.g. Agoro Carbon

30 Doelman, J.C., Stehfest, E., van Vuuren, D.P., Tabeau, A., Hof, A.F., Braakhekke, M.C., Gernaat, D.E., van den Berg, M., van Zeist, W.J., Daioglou, V. and van Meijl, H., 2020. Afforestation for climate change mitigation: Potentials, risks and tradeoffs. Global Change Biology, 26(3), pp.1576-1591.

31 Strange, N., Jacobsen, J.B. and Thorsen, B.J., 2019. Afforestation as a real option with joint production of environmental services. Forest Policy and Economics, 104, pp.146-156.

32 Zhao, J., Daigneault, A. and Weiskittel, A., 2020. Forest landowner harvest decisions in a new era of conservation stewardship and changing markets in Maine, USA. Forest Policy and Economics, 118, p.102251.

Alliance, Indigo Ag).

- *Green or Resiliency bonds*, where investors can purchase securitized forest sequestration and carbon-reduction projects. This can allow investors to take stakes in projects already developed by others, and they can be used to aggregate projects that are of insufficient scale for investors, or that are developed by a government or NGO (e.g. Forest Resiliency Bond, Family Forest Carbon Program).
- *Forest insurance provision*, a disaster insurance against carbon losses from extreme weather, disease, or forest fires, which can improve carbon credit ratings and allow for risk sharing. This financing mechanism is currently provided predominantly through public funds but presents an increasingly viable business for private insurers as the market grows.
- *Carbon off-take guarantees*, financial instruments guarantee a future price for carbon credits, reducing carbon price volatility and risk for developers. Like insurance, they allow for risk sharing, and can be underwritten by public or private financial institutions.

Production-Oriented Forest Project Investment Strategies

It is important to differentiate the financing of forest projects for timber or pulp and paper production from projects aiming at product and market innovation, given the maturity of the former and the application-specific needs of the latter. As a general observation, the traditional timber value chain is financed through investment corporations such as TIMOs and REITs, sales-driven reinvestment, and corporate strategic investment. In addition, financial instruments including asset backed- or cash flow- loans for working capital or new equipment financing are common loan products in the industry. Emerging activities in the value chain receive risk capital, corporate strategic or corporate venture investment (Chart 4).

- *Timber Investment Management Organizations (TIMO)* typically invest in and manage large tracts of timberland and may also own or lease sawmills and other wood-processing facilities. They generate returns for investors through the sale of timber, leasing of land for hunting or other recreational uses, and the eventual sale of the land itself.

- *Real Estate Investment Trusts (REIT).* Like TIMOs, timber REITs invest in and manage timberland properties for the purpose of generating returns for its investors. Timber REITs typically own and manage large tracts of timberland, and generate returns through the sale of timber, leasing of land for hunting or other recreational uses, including the eventual sale of the land itself.

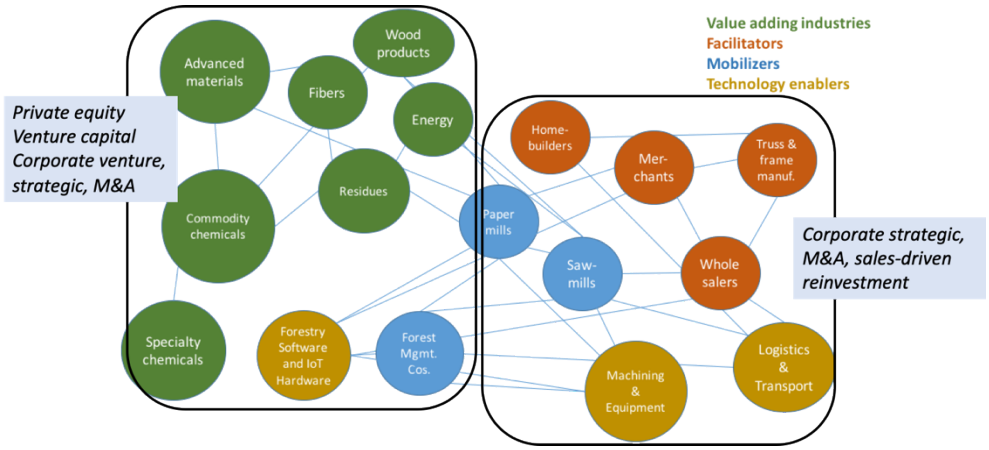

Chart 4. Financing the forestry value chain (Source: CleanTech i3 platform)

To engage private equity investors in forestry bioeconomy projects, the projects need to be bankable and generate sufficient cash flows to meet the financial obligations created during capital outlay. One of the bottlenecks for offtakers of forest-based commodities is production costs, especially when replacing (for example) plastics content in packages with bio-based materials, the new material needs to be economically competitive. Currently, higher production costs of bio-based materials are still limiting market (off-take) demand and the willingness of private equity or corporate investors to invest in large-scale production. The overwhelming placement of capital is in seed or early-stage investments, emphasizing technology de-risking and production efficiency. The question is how much an end user would be willing to pay for the added value from bio-based materials.

More recently, private equity impact funds have been on the rise, with focus on social and environmental impact along financial returns[33] in public-private partnerships (P3), where the financial risk and revenues are typically distributed between the public and private investors, but contracts can include partial or total private ownership. Generally, a project is financed by establishing a special purpose vehicle (SPV) to 'ring fence' the project revenues and debt or equity liabilities against the balance sheet of the project company. The following entities would be involved (exemplified for a forestry investment): a project sponsor (for example, a forest landowner, paper company or downstream corporate entity), a lender (government and/or commercial), a private equity investor, and an offtaker of the product (e.g. forest-based chemistries). For project finance deals, much of

33 https://www.privateequityinternational.com/kkr-to-join-growing-band-of-impact-investors/

the funding requirement is met through long-term debt, which typically varies from 70% (to as much as 90%) of total, depending on the perceived risks of the project. The cash flow from the offtake contract serves to pay operations and maintenance, to keep a reserve, to service debt and to distribute excess revenue to the private equity investors. In the case of a forestry project where the sponsor is a landowner, state tax credits may provide (part of) the capital required to sponsor a project.

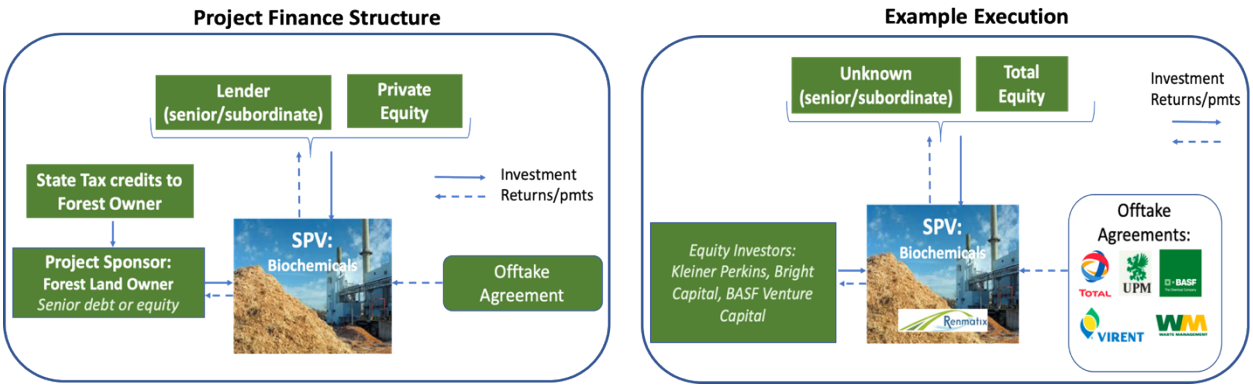

Chart 5. Project finance model concept and application for forestry biochemicals

Strategies to Enhance the Forest Value Proposition and Stimulate Enhanced Deal Flow

Despite many ecosystem services not being traded in formal markets, they provide an important contribution to economies at all geographical scales, from local to global. One of the biggest limitations to adequately account for the true value of forest ecosystem service contributions is that they are difficult to measure and quantify. In the product-oriented bioeconomy beyond timber and energy, the key challenges for development of a bio-based products are related to: (1) sharing costs and risks, as well as (2) addressing variable standards and quality requirements across industries as companies consider new offtake markets. There is a need for public support to share the risks encumbered by high pre-production development costs, to support new industry ecosystem development and company pilot demonstrations, to educate consumers about the environmental and societal benefits of bio-based materials, and to unify and clarify the variable regulations, rules and standards across industries. Potential strategies to stimulate deal flow and leverage the forest value proposition can be captured in the following:

Quantification of co-benefits

Given the increasing importance of ecosystem services and their assessments in policymaking, there is a growing need to develop methods to adequately assess the potential of different ecosystems to deliver the services that are essential for marketable services. The Common International Classification of Ecosystem Service (CICES) encompasses 83 ecosystem services, each of which require indicators that can be

measured and valued[34,35]. These indicators include carbon sequestration, water quality improvement, biodiversity, and many others. The measurements fall short of required leels of quality control. For example, over-crediting of carbon offsets, where climate-equivalence claims fall far short based on directly observable evidence have resulted in awarding large volumes of offset credits to forest projects with carbon stocks that exceed regional averages. In California, 30.0 million tCO2e worth an estimated $410 million at recent market prices has been estimated to be over-credited. Approaches to estimate the carbon storage in trees based on fusing multi-spectral aerial imagery and LiDAR data to identify tree coverage, geometric shape, and tree species -- key attributes to carbon storage quantification – have been demonstrated to improve biomass quantification.[36] Accounting mechanisms to ascertain veracity in carbon quality and quantity for crediting can potentially be executed through digital ledger technologies such as blockchain.[37,38] For example, Blockchain Triangle implemented data platforms to link carbon accounting to contract pricing for asset owners, investors, risk underwriters and other contractual parties and was recently featured at the World Economic Forum in Davos.

Business model innovation

The discussion of business models for conservation practices and bioproducts has indicated that many options are being tested and piloted to facilitate generation of revenue, driving adoption of new products and integration of ecosystem services. Interestingly, productivist archetype business models such as delivery of functionality, rather than ownership and re-purposing the business for society/the environment have not been implemented (Hansen, 2016)[39]. The former model emphasizes user-driven access to expensive products and services of forests, while the latter emphasizes cooperatives emphasizing social and environmental benefits over profits. Lastly, digital solutions to transform the forest-based bioeconomy into a platform industry have been proposed but not deployed.[40] The value proposition of this type of innovation is that digitalization has enabled real-time, end-to-end supply chain visibility, improved delivery accuracy as well as stock level optimization and alignment with demand planning. The advancement of e-commerce relationships has led to the elimination of intermediaries between the

34 Grima, N., Jutras-Perreault, M.C., Gobakken, T., Ørka, H.O. and Vacik, H., 2023. Systematic review for a set of indicators supporting the Common International Classification of Ecosystem Services. Ecological Indicators, 147, p.109978.

35 Wolfslehner, B., Linser, S., Pülzl, H., Bastrup-Birk, A., Camia, A. and Marchetti, M., 2016. Forest bioeconomy–a new scope for sustainability indicators. From science to policy, 4.

36 Klein, L.J., Zhou, W. and Albrecht, C.M., 2021. Quantification of carbon sequestration in urban forests. arXiv preprint arXiv:2106.00182.

37 Howson, P., Oakes, S., Baynham-Herd, Z. and Swords, J., 2019. Cryptocarbon: the promises and pitfalls of forest protection on a blockchain. Geoforum, 100, pp.1-9.

38 Sun, R., He, D., Yan, J. and Tao, L., 2021. Mechanism Analysis of Applying Blockchain Technology to Forestry Carbon Sink Projects Based on the Differential Game Model. Sustainability, 13(21), p.11697.

39 Hansen, E., 2016. Responding to the bioeconomy: Business model innovation in the forest sector. Environmental impacts of traditional and innovative forest-based bioproducts, pp.227-248.

40 Watanabe, C., Naveed, N. and Neittaanmäki, P., 2018. Digital solutions transform the forest-based bioeconomy into a digital platform industry-A suggestion for a disruptive business model in the digital economy. Technology in Society, 54, pp.168-188.

upstream material provision and the downstream integration of commodities in the chain, thus reducing cost and improving efficiency.

New financial Instruments

The wide range of financial instruments highlighted in this treatise are in various stages of testing, piloting and deployment, with many applicable only to niche markets (e.g. specific forest product offtake models). While some models may work in certain geographies and economies with variable public funding or policy support and others are more universally applicable (e.g. private and institutional investment, or carbon offset financing), the time may be ripe for a different approach to valuation. Current financing models are based on valuation of the physical asset that forests can deliver. In other words, the articulation of capitalism and biotechnology is built on notions of commodity production, commodification, and materiality. There is an opportunity to rethink the analytical importance of the "promissory" or "speculative" value of the bio-economy in a context of discounted future socio-political value such as climate impact [41]. Similar to how equity investors consider the future market promise of a product of service, what is the future value of reducing carbon, drought, floods, and how does that influence financing models?

The Forest Bioeconomy in the Great Lakes Basin: Opportunities for GLIIP

A recent report commissioned by the Great Lakes St. Lawrence Governors & Premiers indicated that fifty-two gigatons (1 gigaton equals 10 billion tons) of at-scale, environmentally sound, high-quality carbon storage is available in the Great Lakes region by 2050 with a revenue potential of at least $783B USD from sales of nature-based (e.g., tree planting) and engineered projects (e.g., direct air capture) into the voluntary carbon offset markets. According to the report[42], *"The region's waters, abundant forests, agricultural regions, as well as vast geologic formations, hold the potential to store billions of tons of CO2. The region can take incremental steps over the next decade and beyond to position itself as a destination for high-quality carbon offsets for companies and other organizations to meet their 2030, 2040, and 2050 carbon neutrality goals."*

The challenges associated with implementation are highlighted in the report, but this paper further illustrates both the opportunity and barriers to adoption at scale associated with carbon quality verification, over-creditation, and innovative financing mechanisms required to structure investor agreements. Depending on whether a conservation forest

41 Birch, K., 2017. Rethinking value in the bio-economy: Finance, assetization, and the management of value. Science, Technology, & Human Values, 42(3), pp.460-490.

42 https://greatlakesimpactinvestmentplatform.org/news-events/research-series/positioning-the-great-lakes-st-lawrence-region-as-a-leader-in-the-voluntary-carbon-offset-market/

policy or a productivist bio-product opportunity will be pursued, whether afforestation or reforestation projects are emphasized, and large public or private landowners are engaged, different barriers and options will emerge. The Great Lakes Impact Investment Platform (GLIIP) already features green bond issuances on its platform, and has experience with developing an outcomes-based financing projects (e.g. in partnership with Quantified Ventures), two types of financing mechanisms that will play a role in market-based financing. The emergence of new revenue streams and business models from demonstrated value propositions will drive innovation in financial instruments to scale the opportunity.

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