Nanocellulose: Market perspectives

Nanocellulose, or cellulose nanomaterial (CN), has generated a lot of excitement: it is bio-based with raw materials that are abundant and inexpensive, extremely strong and lightweight, non-toxic, and lower cost than other nanomaterials. Why, then, hasn't the industry grown further faster?

The reality is that new advanced materials take a long time to emerge. Plastics, for example, were around for more than 50 years before they became widely accepted. Among newer advanced materials, carbon fiber was invented around 1960, and did not surpass 10,000 tons for nearly 40 years, and nanocellulose is on a similar track (**Fig. 1**) [1]. Much progress has been made with CN, but challenges remain, both technical and commercial.

Jack Miller, Biobased Markets

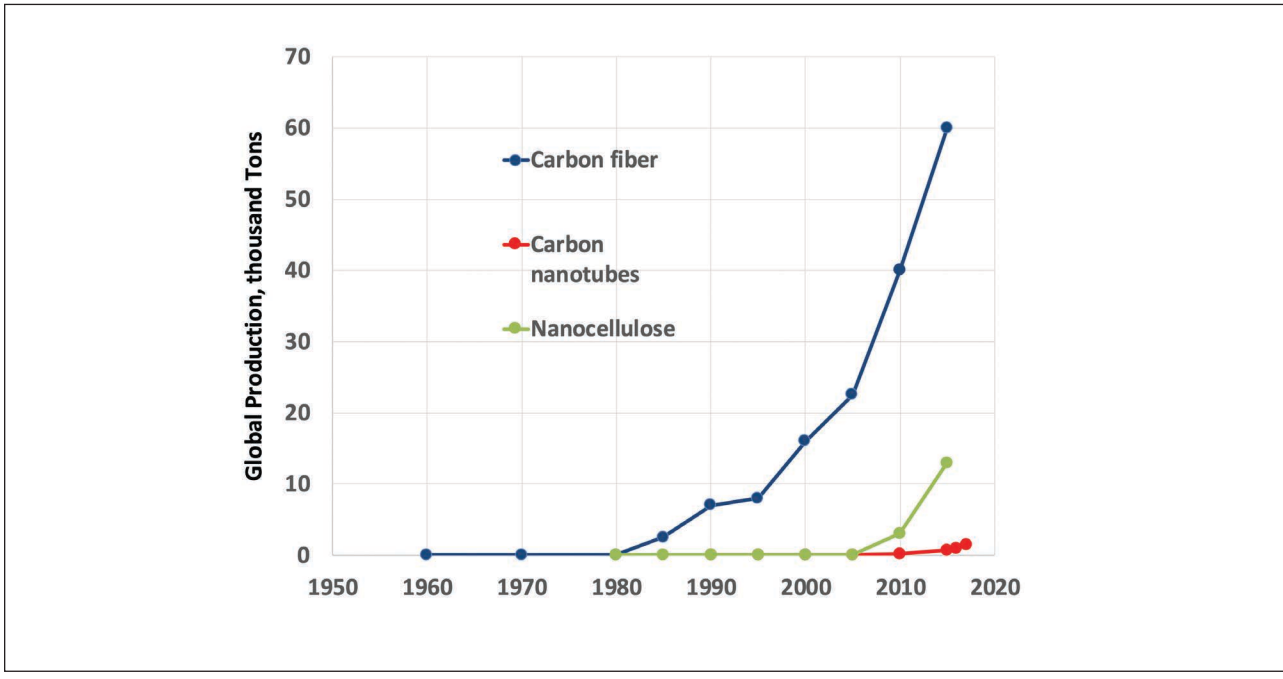
tells the story of nanocellulose market development in a nutshell. There are four key messages about the Investment Gap chart:

1. The chart is not drawn to scale, and the investment required from the private sector for full commercialization is much larger than the chart depicts.
2. The funding for this investment must ultimately come from customers and must result from a sound value proposition.
3. The industry is effectively moving across the Gap, and even more encouraging, none of the new nanocellulose ventures have died in the Valley of Death.
4. However, major funding from customers has still been slow to develop, and companies have more often gained funding from equity partners.

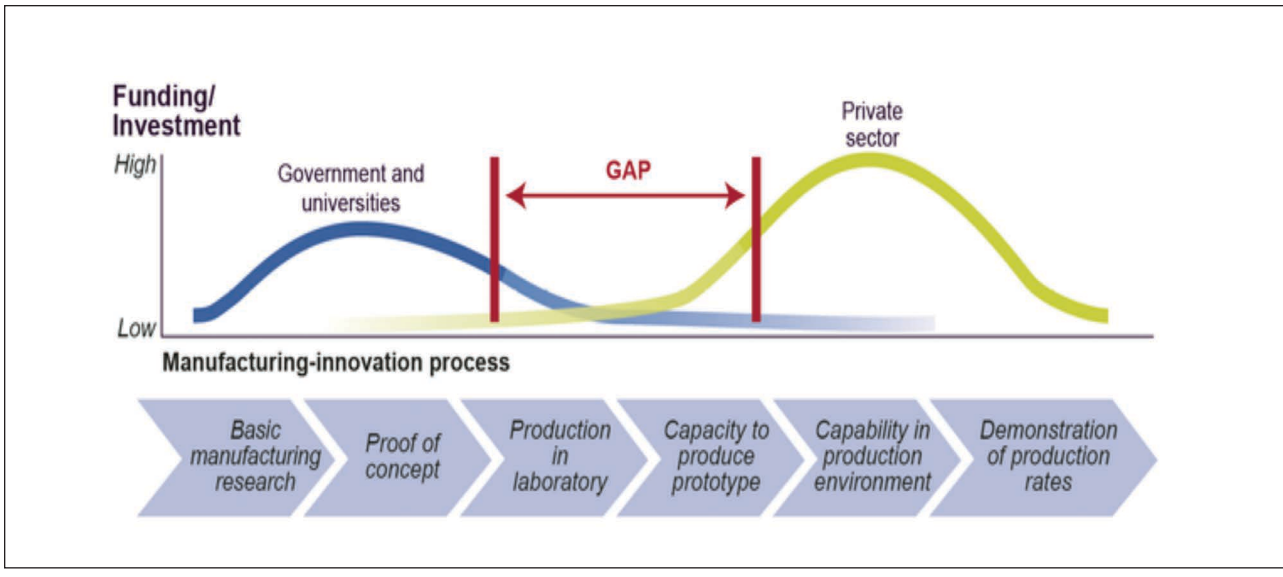
THE INVESTMENT GAP

By now, many of us have seen the familiar chart in **Fig. 2**, which portrays the Investment Gap, also called the Valley of Death, because this is where startups often die. This chart

Let's examine these messages point by point. In 2012, the U.S. Department of Agriculture Forest Products Laboratory unveiled a new $1.7 million cellulose nanocrystal (CNC) pilot plant with capacity of 50 kg per week. Earlier in 2012, Cellu-



1. Emergence of advanced materials [1].



2. The Investment Gap (source: U.S. GAO).

Force had started the first "commercial" installation for nanocellulose, a one metric ton per day CNC plant at Windsor, QC, Canada. The initial investment by founding partners FPInnovations and Domtar was $41 million, which included capital as well as operating expenses for the first several years. Note that even with this investment, Windsor is not a commercial plant in the sense that it does not have the economies of scale that a 100 tpd, or even a 50 tpd, plant would enjoy. For a 50 tpd CNC plant, a study by de Assis et al. [2] estimated capital investment at up to $180 million, depending on whether the plant was co-located at a mill site or a greenfield site, and whether or not sulfuric acid is recovered. Clearly, this is a big leap from the pilot or demonstration scale investment, but this scale will be needed to get costs to a level where economics are sound for a wide range of applications.

Beyond the issue of cost and the classic technical challenges of compatibilization and drying/redispersion, there are commercial challenges that have inhibited customer support. Foremost among these challenges is the need to develop the value proposition through the entire supply chain. Supply chains can be multilayer, and producers often do not have the necessary expertise in downstream processes and economics. For example, for a producer who wants to develop CNC as an additive in automotive paints, there may be one or more intermediates in paints and chemicals between the producer and the auto manufacturer, and the value proposition must work for all.

Who does the R&D? Who develops the application? Who owns the intellectual property? Who proves the value proposition? Can the producers do this or do they ask their customers to do it?

A number of commercial applications have been reported, including oil and gas drilling fluids, adult diapers, coatings, composites, rubber latex, cosmetics, gel inks for pens, and gels for running shoes. However, none of these have yet grown to the stage where they generate sufficient revenue to provide funding for a commercial scale investment, and so the industry largely remains in the Investment Gap.

The good news is that the industry is steadily moving across the Gap and finding funding where needed. Except for one or two paper mills that closed due to conditions in the paper industry, no companies that entered into the field of nanocellulose production have dropped out. However, the challenge of business development remains, as most funding has come from equity partners rather than customer purchases:

- CelluForce: Equity investment from Schlumberger and Fibria (now Suzano) in addition to initial funding from Domtar and FPInnovations.
- American Process: Acquisition by GranBio.
- FiberLean: Launched as a joint venture by Omya and Imerys.
- Melodea: Equity investment from Klabin and Holmen.

MARKET OUTLOOK

For mills producing microfibrillated cellulose (MFC) and using it in their own paper and paperboard, the classic technical challenges of compatibilization and drying/redispersion are moot. The material is produced and used on site and need not be dried before it is added on the paper machine. Cost is also greatly reduced: not only is drying unnecessary, but shipping is also eliminated, as is the need for an infrastructure to market the MFC. The challenge of developing the value proposition is also virtually eliminated as the mill is its own customer, and if the mill is forward integrated, the downstream customer, i.e., the converter, is also captive. Indeed, a 2019 Biobased Markets study on nanocellulose in packaging [3] estimated that in 2018 more than 75% of all nanocellulose was produced by mills and used on site in their own products. Much of this is unreported, but we do know of work by Stora

	2018	2020	2025	Compound Annual Growth Rate 2018-2025
Total	39600	80000	251000	30%
Mills Captive	30000	45000	125000	23%

I. Cellulose nanomaterials forecast to 2025 (metric tons) [3].

Enso, Norske Skog, BillerudKorsnäs, and International Paper, plus several FiberLean installations. However, for other applications, developing the value proposition remains a challenge. End users and producers alike have suggested that collaboration is required, and indeed, a number of consortia have emerged globally, but challenges still remain regarding who does what R&D and who owns what intellectual property.

Markets are growing at as much as 30%, albeit from a low level. In the 2019 market study, Biobased Markets estimated that in 2018 volume of nanocellulose was around 40000 metric tons and is projected to grow at 30% per year (**Table I**). While the majority of this is paper and paperboard mills producing nanocellulose, i.e., microfibrillated cellulose (MFC), and using it in their own products (mills captive), other applications are beginning to grow faster and close the gap.

The greatest capacity is FiberLean's MFC mineral composite, which includes 8800 metric tons of MFC in commercial installations at three paper and board mills globally, plus a demonstration plant in the U.K. (**Table II**). Next is Kruger with 6,000 metric tons of cellulose filaments, a form of cellulose nanofibrils (CNF), some of which is used in the company's own paper and paperboard and some of which is sold for other applications. The largest seller of nanocellulose may well be Borregaard with 1,100 metric tons, but this is still at demonstration scale.

Given these realities, what does the industry need to do to meet or beat the forecast shown in Table I? Actually, customers have given us some of the answers, and we may also find some answers in looking at developments in Europe and Asia. In TAPPI's 2018 book, *Nanocellulose Challenges and Opportunities: End User Perspectives*, three key findings were reported: get the cost down, develop the value proposition through the supply chain, and collaborate [4].

Getting the cost down is dependent on getting volumes up and achieving economies of scale, and to do this we need to develop the value propositions and collaborate. And the industry is doing just that. Leading producers have reported collaborations, joint development agreements, and even supply agreements. In Europe and Asia, dozens of consortia have been established, some of which include several layers in the supply chain, from producer to end user plus intermediate processors. In Japan, the Nanocellulose Forum is a consortium of 220 companies including Nippon Paper Industries, Oji Holdings Corp., Toyota Auto Body Co., Mitsubishi Motors Corp., Mitsui Chemicals Inc., and others. In Europe, the Bio-Based Industries Joint Undertaking (BBI JU) is a public-private partnership between the EU and the Bio-based Industries Consortium with investment of €3.7 billion from 2014-2020, including €975 million from Horizon 2020 and €2.7 billion of private investment. BBI JU has sup-

Producer	Material	Capacity
FiberLean Technologies, UK	MFC	8,800
Kruger, Canada	CF	6,000
Borregaard, Norway	MFC	1,100
Nippon Paper, Japan	CNF	560
CelluForce, Canada	CNC	300
Norske Skog, Norway	MFC	260
University of Maine, USA	CNF	260
Daicel, Japan	MFC	200
RISE, transportable container factory	MFC	200
American Process (now GranBio), USA	CNC	130
American Process (now GranBio), USA	CNF	130
CelluComp, UK	CNF	100
Chuetsu Pulp and Paper, Japan	CNF	100
International Paper	MFC	*
Stora Enso	MFC	*

* International Paper and Stora Enso are also reported to be producing MFC, largely for use in their own paper and paperboard. The 2017 Stora Enso Annual Report says "Stora Enso invested €9 million in new MFC production at Imatra, Ingerois and Fors mills. The new capacity corresponds to 500000 tonnes of board made with MFC after a ramp-up period of 3–5 years."

II. Nanocellulose producers at demonstration scale or larger (metric tons/year; dry basis) [3].

ported more than 80 major projects such as Sherpack, which was created in 2017 to reinvent paper-based flexible packaging by developing "a renewable, biodegradable and recyclable flexible paper-based packaging material, that can be easily converted by heat-sealing and folding, with improved stiffness and grip, in order to replace materials such as plastics or aluminum foil currently used on the market by an advanced biomaterial" [5].

In the U.S., the Alliance for Pulp and Paper Technology Innovation (APPTI) is also exploring opportunities for pre-competitive joint research in areas such compatibilization for composites and drying/dewatering and redispersion. It has been suggested that processors and end users be involved as well. This sort of joint effort will give a boost to development, not only in advancing the technology, but also in helping producers gain deeper insight into customer needs. **TJ**

LITERATURE CITED

1. Nelson, K., *APPTI Critical Challenges Workshop*, 6 May 2019.
2. de Assis, C.A., Houtman, C., Phillips, R., et al., "Conversion economics of forest biomaterials: Risk and financial analysis of CNC manufacturing," *Biofuels, Bioprod. Biorefin.* 11(4): 682(2017).
3. Miller, J., "Biobased Markets,"in *Nanocellulose: Packaging Applications and Markets*, Fastmarkets RISI, Bedford, MA, USA, January 2019.
4. Miller, J., *Nanocellulose Challenges and Opportunities: End User Perspectives*, TAPPI Press, Peachtree Corners, GA, USA, 2018.
5. Sherpack, "Sherpack: a project to reinvent flexible paper-based packaging," press release, Sherpack, June 2017. Available [Online] http://www.sherpack.eu/docs/filesProject/7/F6CF09DE-A3D7-224D-E34DB1DFB5914D60.pdf <28May2019>.

Miller is founder and principal consultant, Biobased Markets. He is also an associate consultant with RISI and a member of the advisory board of Sweetwater Energy, a biorefinery company. Miller served as business development consultant for nanocellulose with CelluForce from 2011-2013, and was consulting manager, Global Nanocellulose Sales, American Process, in 2014 and 2015. Miller is the author of several publications, including Nanocellulose: Packaging Applications and Markets, *RISI, 2019;* Nanocellulose Challenges and Opportunities: End User Perspectives, *TAPPI, 2018; and* Nanocellulose Producers, Products, and Applications: A Guide for End Users, *TAPPI, 2017.*

TAPPI ACADEMY

INTRODUCTION TO

KRAFT PULPING & BLEACHING COURSE

Offered 10-Years!

AUGUST 13-14, 2019

TAPPI Headquarters,
Peachtree Corners, GA • USA

The most comprehensive two-day course available covering introductory to intermediate-level topics in the industry!

WHAT WILL YOU TAKE AWAY FROM THIS TRAINING?

FOR THOSE NEW TO THE INDUSTRY

- A rapid, in-depth and enhanced completion of your training
- The ability to demonstrate and also gain additional knowledge easily when interacting with experienced peers at the mill
- A strong foundation of knowledge to take on more advanced projects, including troubleshooting both process and pulp quality problems

FOR EXPERIENCED ATTENDEES

- Technical information to fill any gaps in knowledge and experience (we all have some!)
- The ability to better train newer employees

HELP CREATE THE CURRICULUM!

DR. MICHAEL J. KOCUREK offers a pre-course survey to determine your objectives. Learn from an instructor who has taught these topics for more than 48 years to students, industry professionals and mill operators at 200+ mills.

NEW THIS YEAR!
A digest of industry innovations and developments extracted from TAPPI PEERS proceedings, publications and top news resources.

Register by Friday, July 12 to save on rates!

TAPPI.ORG/IKPBC