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Cellulose Nanomaterials: State of the Industry The Road to Commercialization

PRESENTED BY

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Acknowledgments

Much of the information in this presentation is derived from and/or updated from the following:

- *Nanocellulose: Technology, Applications and Markets,* by Jack Miller, published in 2014 by RISI
- TAPPI Webinar *Cellulose Nanomaterials: An End-user Perspective,* October, 2016
- Nanocellulose end user survey, Jan. – Mar, 2017, Market-Intell

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www.risiinfo.com/product/nanocellulose-technology-applications-markets/

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- Jeff Youngblood, Associate Professor, School of Materials Engineering, Purdue University

Agenda

- State of the industry
  - Commercial development highlights
  - Commercial applications
- The Road to Commercialization
  - Challenges
  - End user perspectives
  - Value proposition

Types of “nano” cellulose

- Cellulose nanofibrils (CNF) vs. Cellulose nanocrystals (CNC): vastly different
- Microfibrillated cellulose: MFC
- Cellulose filaments (CF)
- Different forms of CNC, CNF, MFC
- And… MCC, CMC, etc.

Types of “nano” cellulose

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- And… MCC, CMC, etc.

Which is best for each application?

At what loading?

Commercial Development Highlights

Several hundred companies have tested cellulose nanomaterial, possibly more than 1,000.

Yet, few commercial applications reported to date.

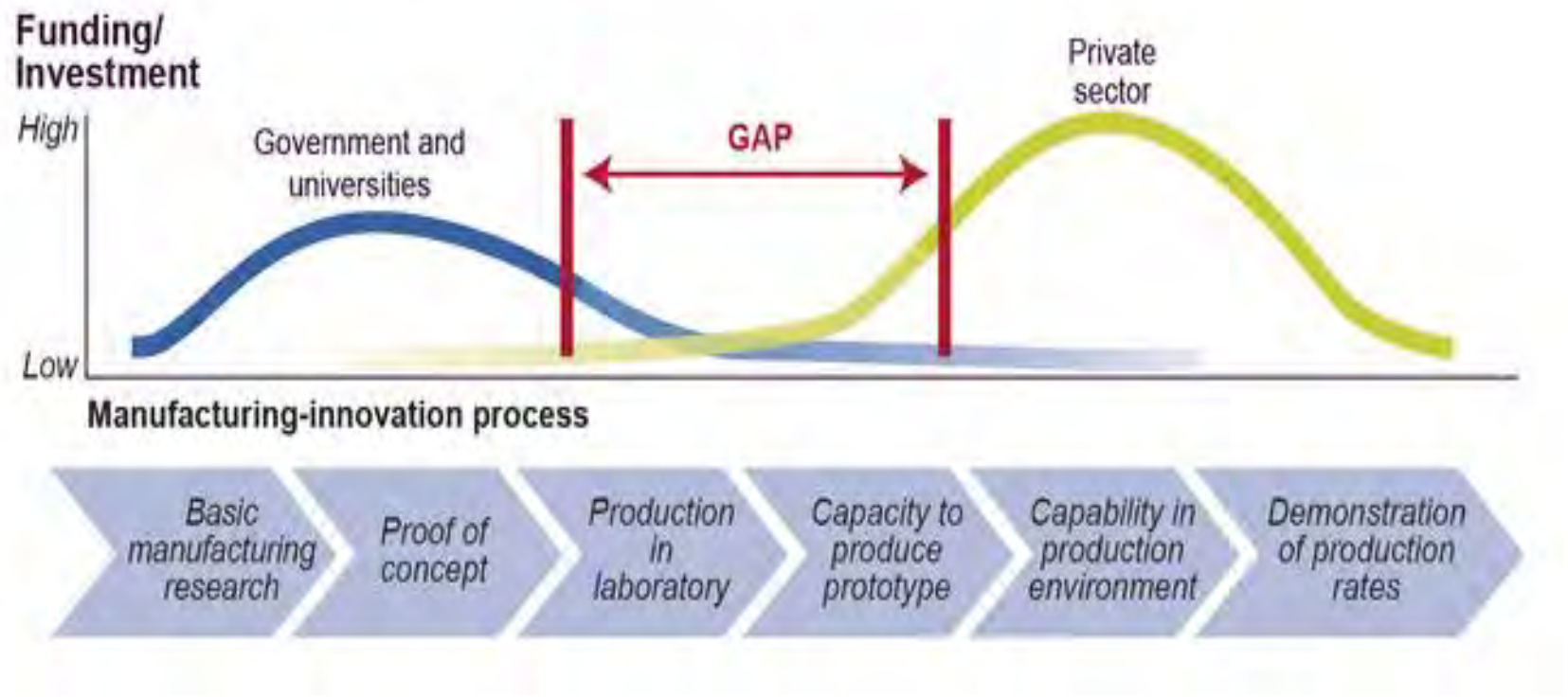
Commercial Development Highlights

- CelluForce: CNC 1 tpd, January, 2012. Development in oil and gas with Schlumberger. Strategic partnership with Fibria.
- American Process: 100 tpy demonstration plant April 2015. Joint development with Birla Carbon and MYBiomass.
- Paperlogic: 2 tonne/day CNF plant started up 2015, Turners Falls MA.
- FiberLean Technologies, Omya/Imerys j/v; 8,000 tpy MFC = 40,000 tpy FiberLean MFC® mineral/MFC composite.
- Borregaard, Norway. Exilva: First “commercial scale” MFC. 1,000 tpy Q3 2016. Commercial development, including consortium with Unilever and several research groups.
- Daicel: “leader in commercial MFC since 1990” with 1,000 tpy 10% to 35% paste.
- Oji agreement with Nikko Chemicals for joint development of CNF for cosmetic applications.
- Kruger: Running CF at 5 tpd since March.

Commercial Applications

- Nippon Paper Crecia Co., Ltd., " first commercial products made of functional cellulose nanofibers": TEMPO CNF in deodorant sheets for "Hada Care Acty" adult diapers.
- Stora Enso. 100 million Elopak packages in Eastern Europe pilot market with New Natura Concept board grades containing MFC.
- Innovatech: DeLeon cosmetics and nanocellulose sheet.
- Mitsubishi Pencil Co and DKS ballpoint pen ink with Rheocrysta.
- CNF/MFC produced and used on site by pulp and paper mills – volumes unknown/confidential.
- Consortium of 100 companies: Nippon Paper Industries; Oji Holdings Corp.; Toyota Auto Body Co.; Mitsubishi Motors Corp.; Mitsui Chemicals Inc.

The road to commercialization



Source: GAO

Technical challenges

- Drying and dispersion
- Aggregation and dispersion
- Hydrophilicity and compatibility
- Process improvement
- Cost

Business challenges

- Proof of concept
- Need solid value proposition
- Competitive materials
- Low oil prices
- Funding challenges: the Valley of Death
- Scale up in production
- It is not a “drop in”: implications for customer process
- Applications development
- Who develops the applications? Who does the R&D? Who owns the IP?
- Which material is best for a given application?
- What loading is optimal?
- Consistent quality from batch to batch
- Scale up of applications
- Safety and regulatory issues

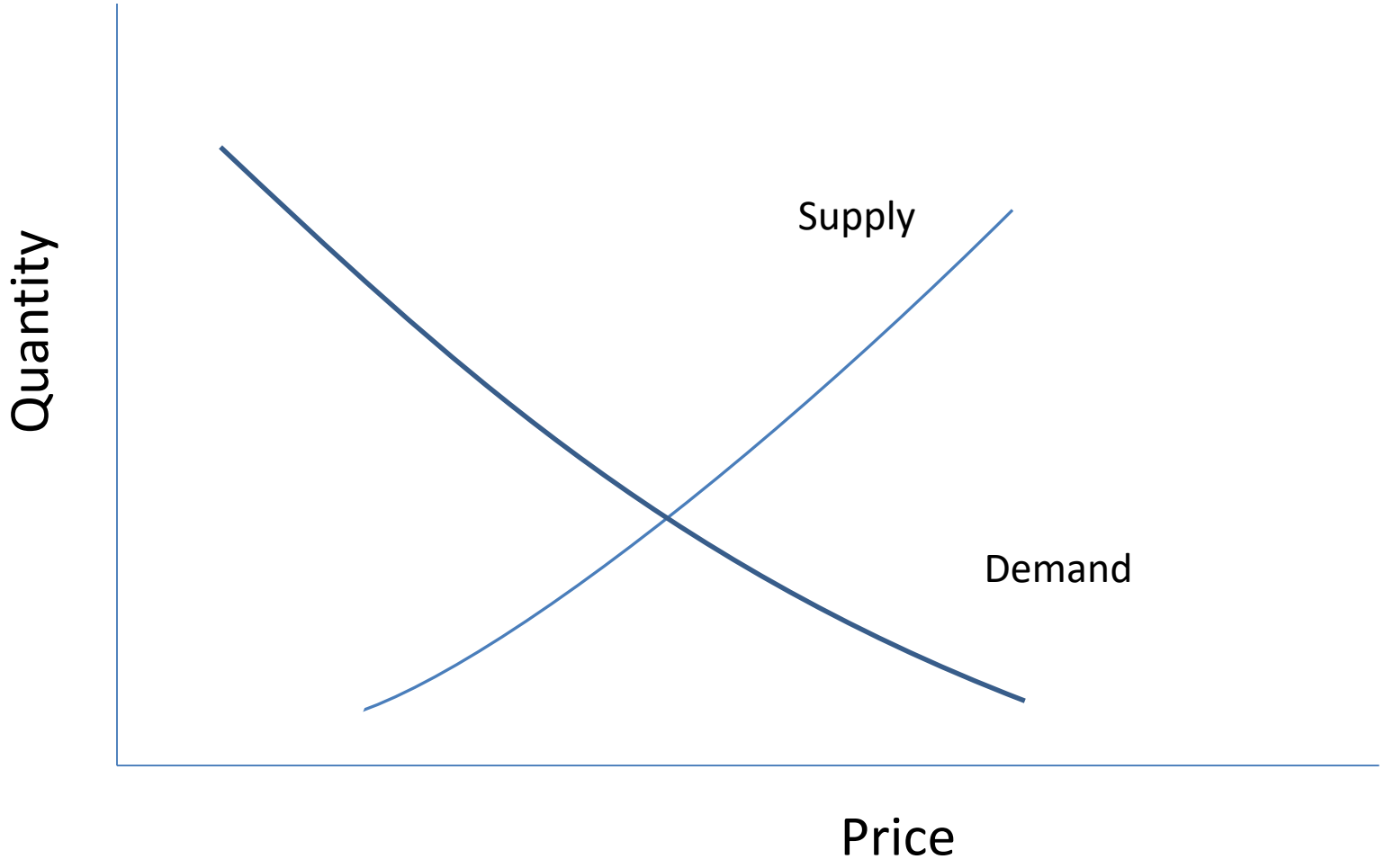
End user perspectives

- End users will need to invest in R&D to develop the applications
- CNC: 16% investing in serious R&D; CNF: 24% investing in serious R&D
- 36% will not do serious work until commercial quantities are available
- 64% will not do serious work until they see data demonstrating the value proposition
- Other issues: multiple sources of supply, consistent quality, uncertainty re future prices

Value proposition

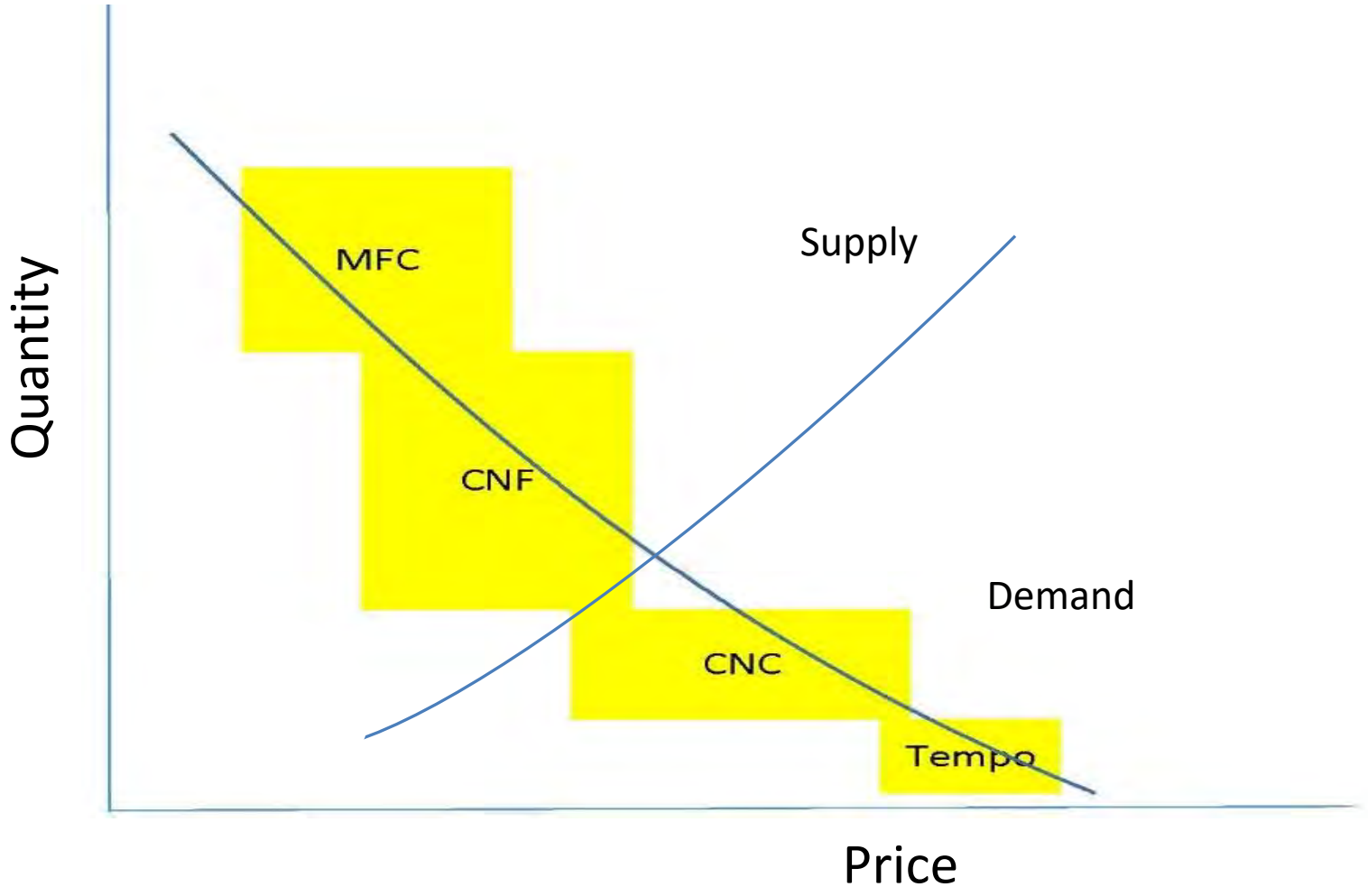
- Weight reduction
- Rheology
- Improved performance/ substitution
- Process improvement
- Need data!

Supply and Demand



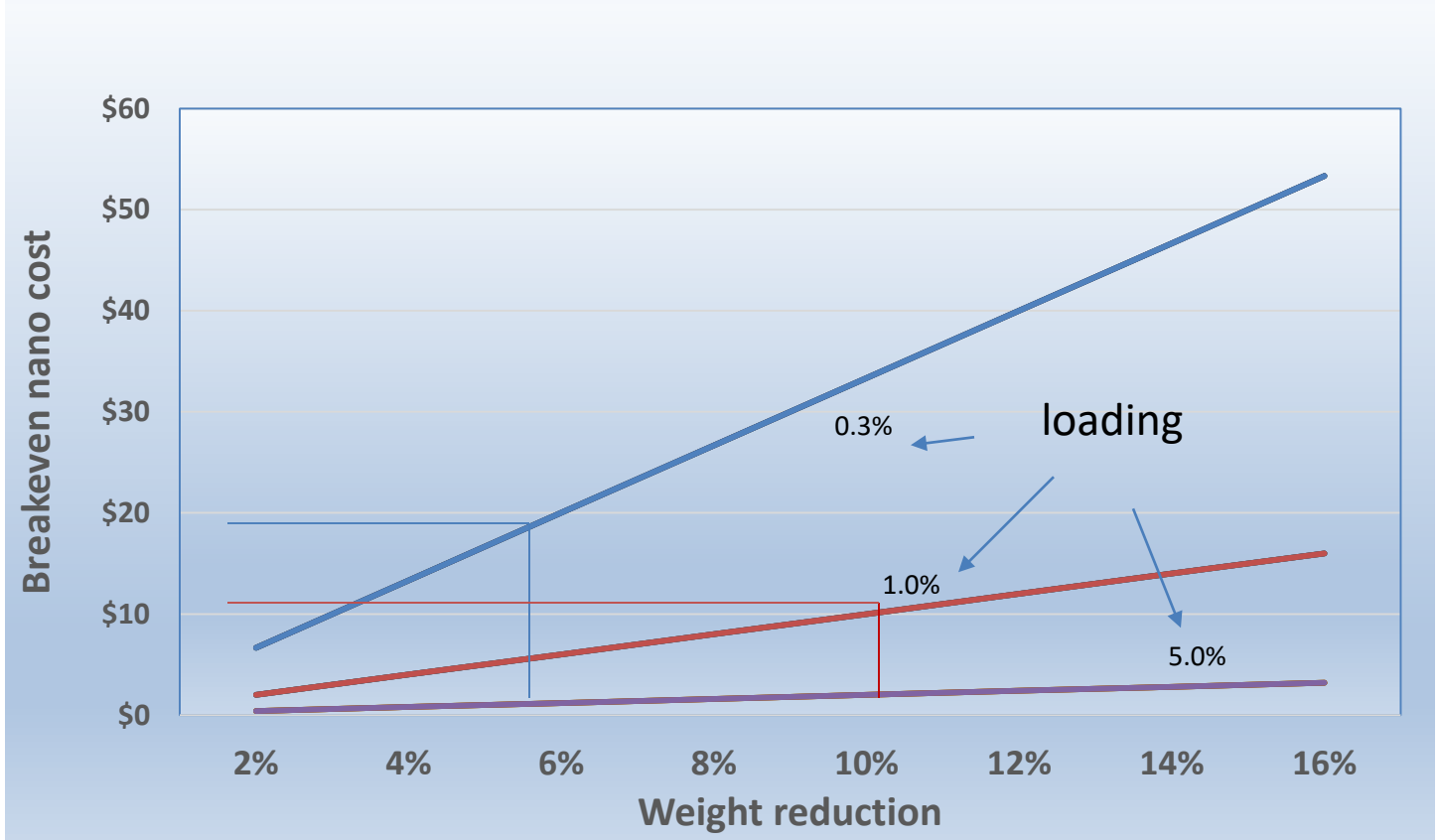
Source: TAPPI Webinar, Market-Intell LLC, Oct 2016

Supply and Demand



Source: TAPPI Webinar, Market-Intell LLC, Oct 2016

Breakeven nano cost vs. weight reduction and loading



Source: TAPPI Webinar, Market-Intell LLC, Oct 2016

Business models

- Sell pre-commercial quantities to fund scale up
- Samples with collaboration or JDA
- Joint venture
- Consortium
- Licensing arrangements
- Who owns the downstream IP?

Applications and potential volume

(thousand tons)

	Market size	Potential loading	Nano Cellulose potential
Paper and paperboard	400,000	5.0%	20,000
Paints and coatings	40,000	2.0%	800
Composites	9,000	2.0%	180
Films and barriers	9,670	2.0%	193
Excipients	4,600	2.0%	92
Natural textiles	34,500	2.0%	690
Manufactured textiles	56,300	2.0%	1,126
Cement	15,000	0.5%	75
Oil and gas	17,500	1.0%	175
Nonwovens	7,000	2.0%	140
Adhesives	500	2.0%	10
TOTAL			23,500

Source: *Nanocellulose: Technology, Applications and Markets*, RISI 2014

Forecasts

	Tonnes (000)	Year
Vireo Advisors, high	56,481	potential
USDA	34,000	~2045
RISI, potential*	23,500	potential
Vireo Advisors, low	18,283	potential
RISI, forecast*	450	2025
Arbora Nano	145	NA
CelluForce*	15	2017
Future Markets	0.8	2017

$ 8 billion by 2030: Japanese government

*Source: *Nanocellulose: Technology, Applications, and Markets,* RISI 2014

TAPPI NANO DIVISION

See you in Montreal!

Thank you!

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Which of these characteristics matter for each application?

Powder, paste, gel, slurry, aqueous dispersion

Dispersibility

Compatibilization

Nano, micro, macro?

Aspect ratio

Crystallinity

Chemistry

Degree of fibrillation

Electric charge

Purity

Is it cellulose?

End user questions

- What will be the price at commercial scale?
- When will producers be at commercial scale?
- Will there be multiple sources of supply?
- What is the status of compliance with health and safety regulations?
- What patents have been published recently?
- How to disperse CNC in aqueous/alkaline medium?
- Is it possible to increase hygroscopicity of cellulosic fibers by using cellulose nanomaterials?
- How to ensure the stability of nanomaterial dispersion in aqueous dispersion (any characterization technique?)
- Which applications will be commercialized first?

Cellulose Nanocrystals (CNC) Capacity 2017

(kg per day)

CelluForce	1,000
American Process	500
Melodea	100
Alberta Innovates	20
US Forest Products Lab	10
Blue Goose Biorefineries	10
FPInnovations	2

Source: RISI, *Nanocellulose: Technology Applications, and Markets,* Market-Intell LLC

Cellulose Nanofibrils (CNF) Capacity 2017

Paperlogic, USA	2,000
University of Maine, USA	1,000
American Process, USA	500
Nippon Paper, Japan	150
Oji Paper, Japan	150
Innventia, Sweden	100
Empa	15
UPM, Finland	Pre-commercial
Dai-ichi Kyogo, Japan	Pilot
FPInnovations, Canada	Pilot
Seiko PMC	Pilot
SAPPI, Netherlands	Pilot
U of Kyoto, RISH	Pilot
VTT, Finland	Pilot
Daicel, Japan	Lab
Luleå University of Technology, Sweden	Lab
US Forest Products Laboratory, USA	Lab

Source: RISI, *Nanocellulose: Technology Applications, and Markets*,
Market-Intell LLC, VTT, Nippon Paper,

Microfibrillated Cellulose (MFC) Capacity 2017

(kg/day dry basis)

FiberLean Technologies *	20,000	*
FiberLean Technologies, UK	5,000	
Borregaard, Norway	3,000	
Daicel, Japan	500	
CTP/FCBA, France	100	
Stora Enso, Finland	Pilot market	**
UPM, Finland	Pre-commercial	
FPInnovations, Canada	Pilot	
Norske Skog, Norway	Pilot	
Luleå University of Technology, Sweden	Lab	
US Forest Products Laboratory, USA	Lab	
* Started up 2016; location is confidential		
** With Elopak		

Source: RISI, *Nanocellulose: Technology Applications, and Markets*, Market-Intell LLC, ISO/TC, VTT

Cellulose Filaments
(kg/day dry basis)

Kruger, Canada	15,000
Performance Biofilaments	lab

Source: RISI, *Nanocellulose: Technology Applications, and Markets;*
Kruger, Market-Intell LLC