Path forward - MFC Technology development at Valmet

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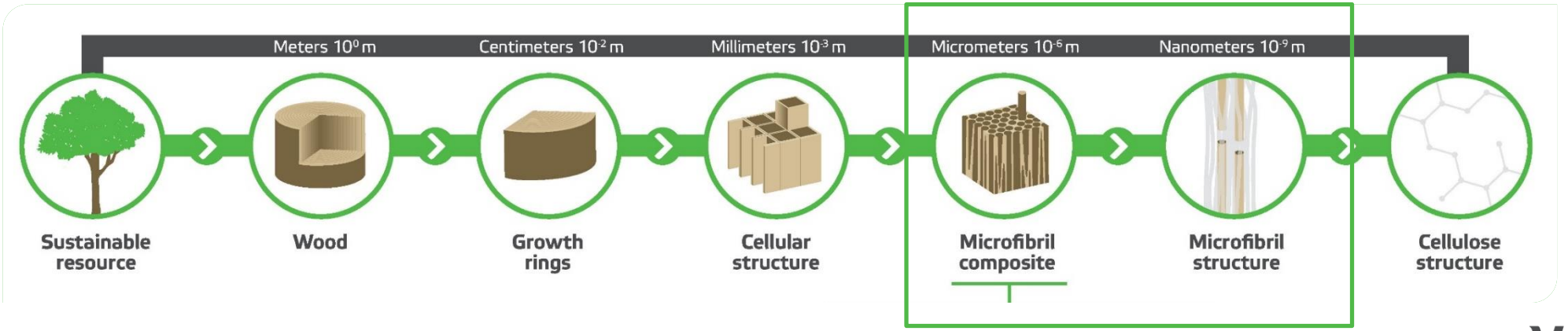
What is MFC and how do we define it?

- MFC is fiber that has been highly refined using mechanical refining energy
- The level of refining is expressed as a given % Fines
  - A fine can be defined as being less than 0.2mm in length
- We typically produce pulps that are 65% - 95% total fines
- Fines level can be measured by several instruments including the Valmet FS5 Fiber Analyzer



ISO definition

TECHNICAL SPECIFICATION

ISO/TS 20477

Second edition
2023-05

Nanotechnologies — Vocabulary for cellulose nanomaterial

Nanotechnologies — Vocabulaire pour les nanomatériaux à base de cellulose

B.2 Cellulose microfibril

Cellulose microfibrils (CMF) are a form of wood or plant fibre with smaller fractions of the fibre partially separated and, with some of these smaller fractions or branches, forming a web-like network structure. Starting with wood pulp, CMF can be produced by mechanical shearing (fibrillation or refiner plates) or the combination of enzymatic hydrolysis and mechanical shearing. Generally, diameters of CMF are smaller than 10 µm whereas the fibre diameter of pulp is usually around 30 µm.

CMF is also known as microfibrillar or microfibrillated cellulose (MFC).

Examples of MFC end uses

Versatile end uses in which properties and specific features of MFC are utilized

Paper & board, Non-woven

- Strength, light-weighting
- Replacement of chemicals in corrugated board

Films, textiles

- Gas barrier
- Modified barrier films
- Spinnova: textile fibres

Adheshives & Coatings

- Rheology & strength additive

Pharma & medical

- Pharmaceuticals
- Wound care
- Medical labs

Composites

- Fiber composites
- Strength additive in polymer mixtures

Cosmetics

- Multifunctional additive, e.g. dry-out time, viscosity & stability adjustment

Agricultural chemicals

- E.g. wetting agents
- Dry-out time additive

Construction

- Strength additive
- Rheology & performance additive

Home Care

- Performance additive
- Dry out time, dispersing, viscosity additive
- Surfactant

Electronics

- R&D phase
- Flexible electronics, replacement of fossil gels in Li-Ion batteries

Source: Google pictures, Stora Enso, Borregaard, UPM

Valmet’s MFC pathway

Valmet’s MFC Pathway

- **Concept and application development**
  - Continuous & specialty production processes
  - Equipment development for production and application
  - Characterization of fibers, fines, and fibrils
- **Competences**
  - From lab and pilot to commercial production – continuously investing in facilities
  - Multiple application technologies for a wide range of paper grades
- **Collaboration with universities**
  - University of Maine is our Alliance Partner
    - Sample and large scale distribution of MFC to over 600 entities in 50 countries
- **Collaboration with number of customers**
  - Customer trials on site and pilot facilities
  - Joint R&D projects

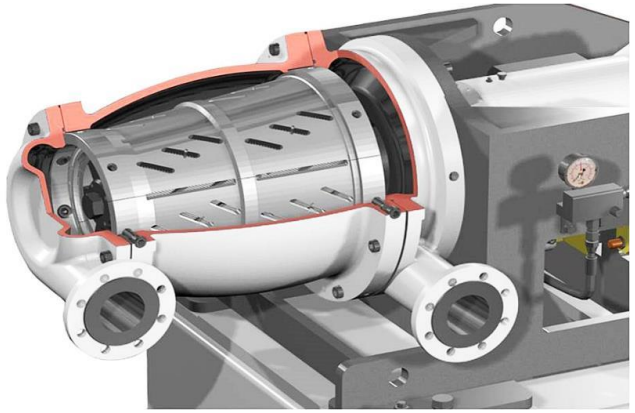
Micro-fibrillated Cellulose (MFC)

How do we produce MFC?

- Refiner based process – multiple platforms available.
  - Valmet Conical Refiner
  - Valmet Double Disk Refiner
  - Valmet Pro Refiner
- Largest existing installed base in the world.
- Production skid available for rent.
  - Refiner-based unit (DD® 6000 technology)
- Multiple commercial facilities are currently in production.

Valmet

Valmet Conical refiner Pro
The industry standard in producing MFC

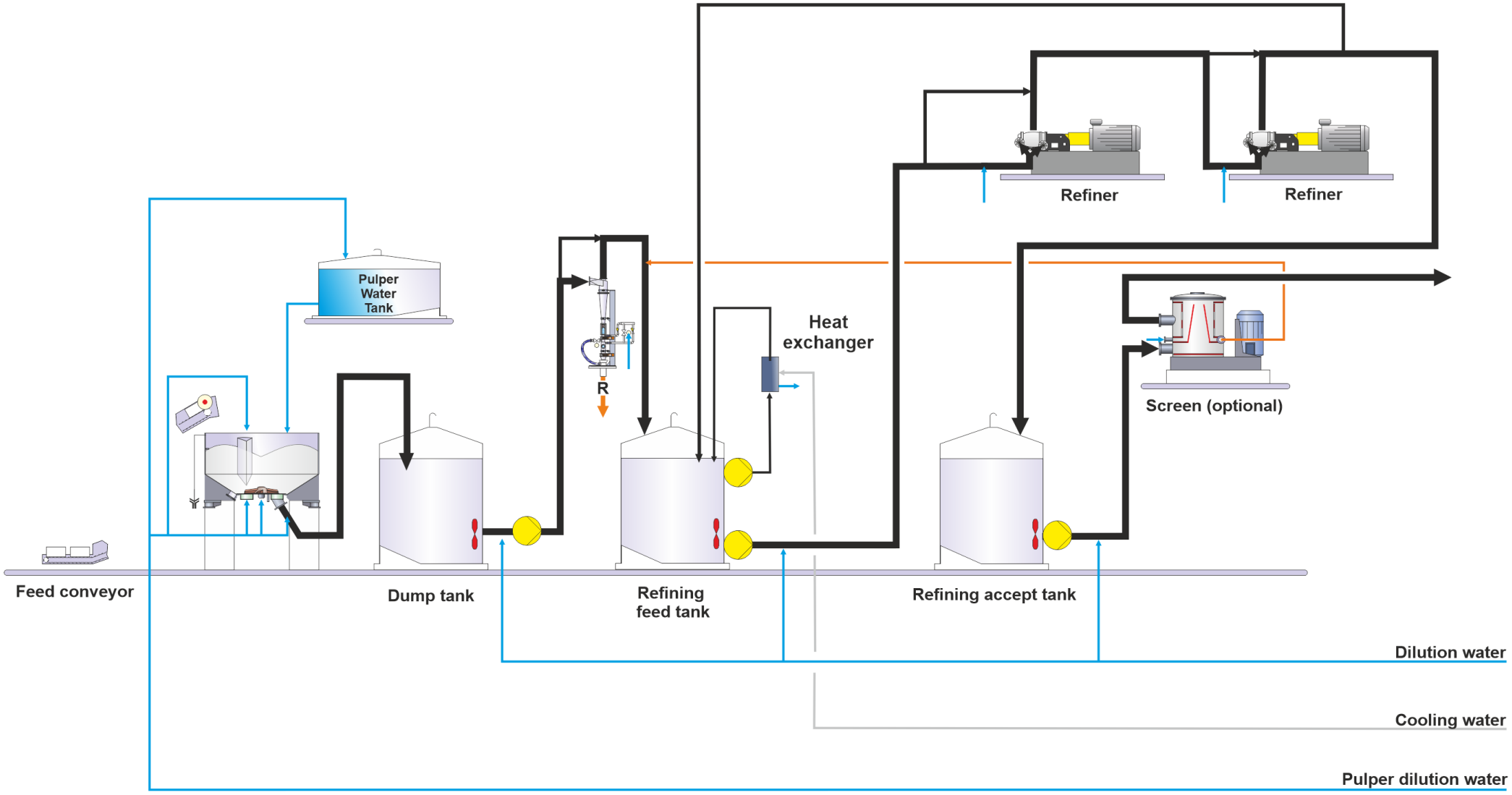


- Proven technology for MFC production
- Proactive two-ended feeding
  - Ensures equal fiber distribution to refining area
- Specific MFC fillings available

- Fillings gap control
  - Fillings gap determines the type and amount of fines and thereby the quality of produced MFC
    - Accurate filling gap control is utmost important
  - Servo motor enables fast and accurate fillings gap control down to 1 µm level
  - TPC (Touch Point Control) system allows explicit fillings gap determination and online filling gap calibration during production

Source: Valmet internal

Valmet MFC Line



Source: Valmet internal

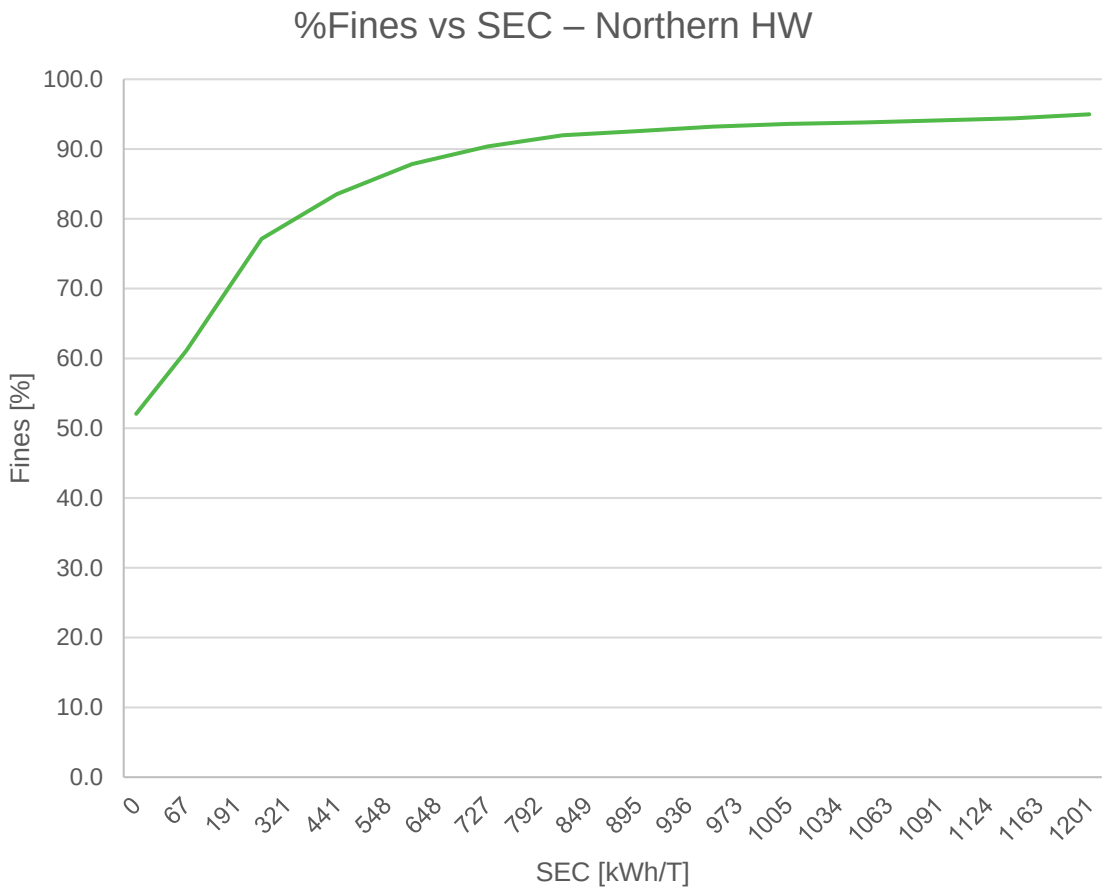
Valmet Fiber Technology Center

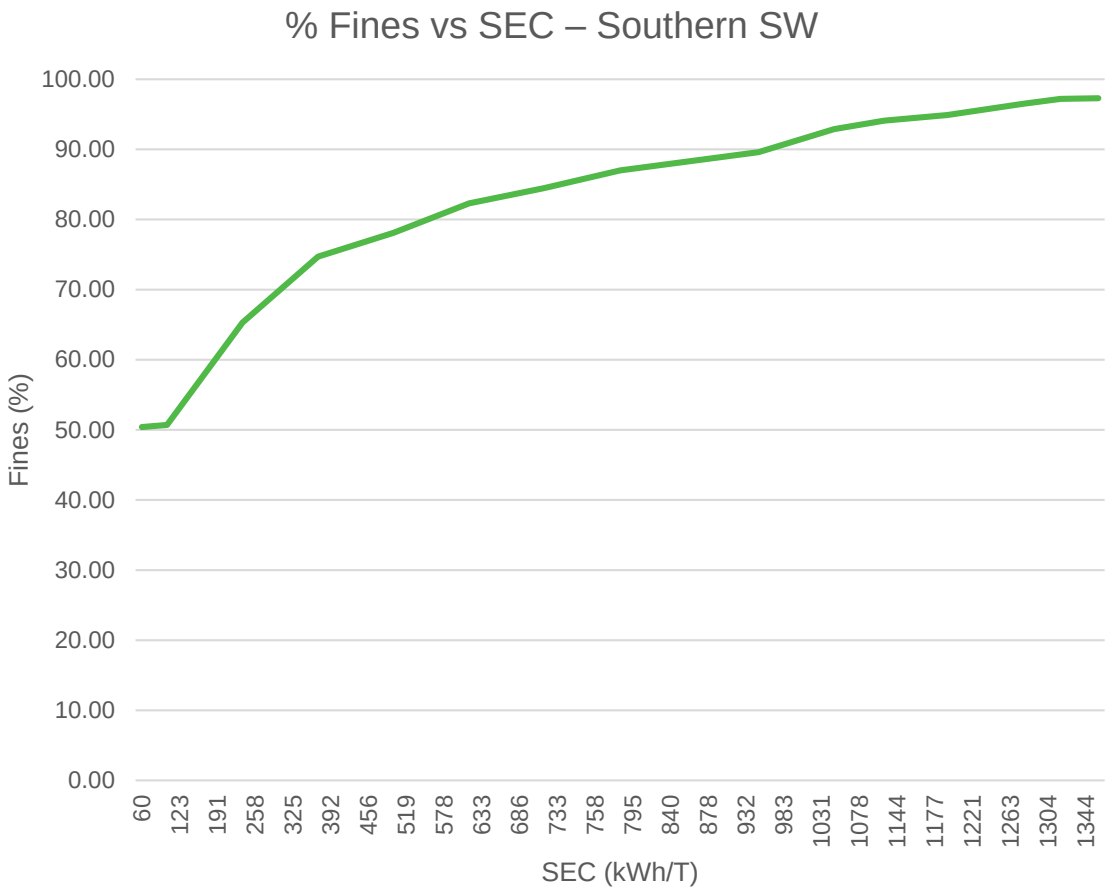
Refining trial and result example

- Pulp used was market bleached softwood pulp
- Consistency range 4.0 – 4.5 %
- Batch Process - up to 40 rounds or passes of pulp turnover
- Power used, fiber morphology and fines content, handsheet results
- Fiber analysis made by FS5

MFC Production Technology - Valmet's FS5 Analyzer

Total fines measurement by Valmet's FS5 Analyzer





Source: Valmet internal

Valmet Technologies – MFC Application

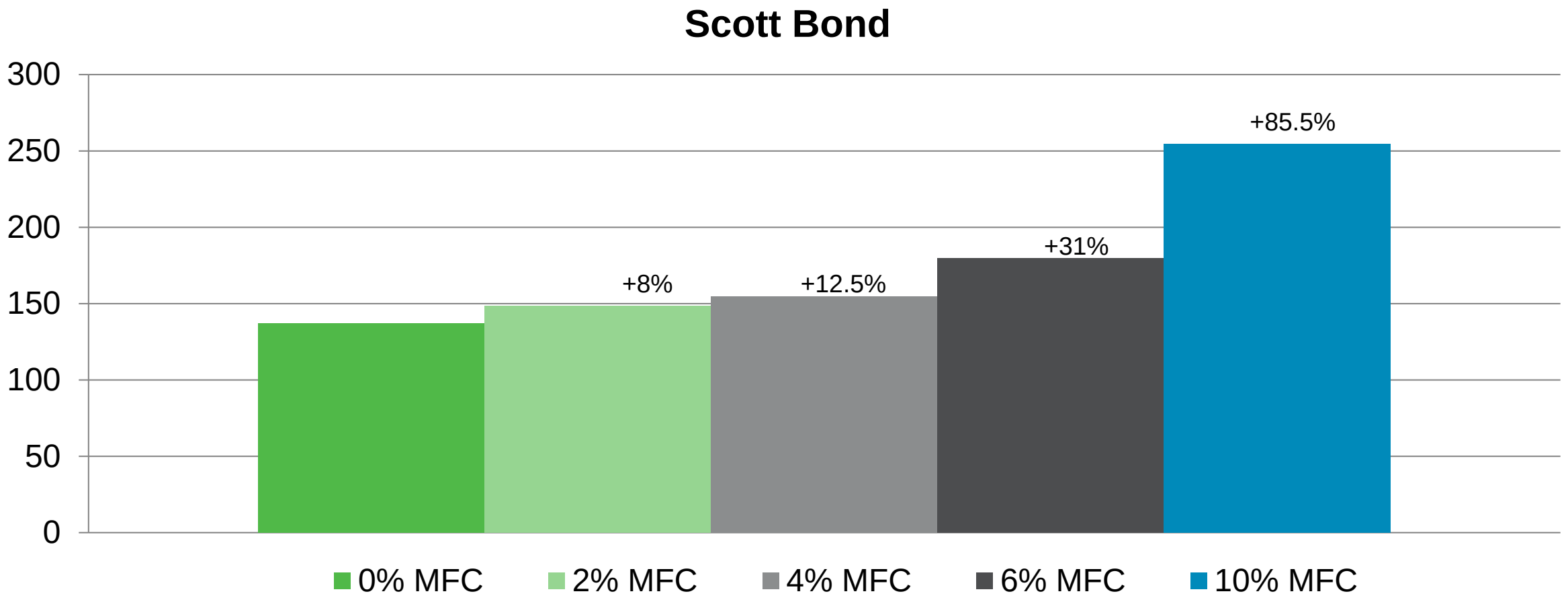
MFC Application

- Headbox technology eg. Aqua layering
- Internal Application
- Valmet Wet End Applicator
- Sizing and coating technology for surface applications

Source: Valmet internal

MFC Paper Results

Example of Internal Application - Specialty Electrical Paper 62 g/m^2



Source: Valmet internal

Valmet FS5 - Valmet Fiber Image Analyzer

The Valmet FS5 is the 5th generation automated fiber image analyzer from Valmet

- Highly automated and easy to use for fast, accurate and reliable measurements
  - Automated sample conditioning saves labor time
  - Tens of thousands of fibers per analysis brings reliability and repeatability to your results
  - Integrated and compact analyzer unit and user interface
  - All measurements done at the same time
  - Customizable run modes
- Sophisticated applications support detailed analysis of special particles and fibers
- Identical algorithms provides exact comparable results between laboratory and on-line analyzers
- Testing can be done anywhere you need it – Either in the laboratory, in the control room or at the process

ISO and TAPPI standard compliant

Available measurements include:

- Fiber dimensions
- Fines particles
- Coarseness
- Blend ratio
- Fibrillation
- Fiber deformations
- Vessel cells
- Minishives
- Fiber entanglements
- And more...

FS5 Unit available at Valmet Nashua / Bedford, NH

Latest Valmet MFC Lines references

Year Started	Customer/Location	Design Production TPD	Actual Production TPD	Grade Type	Wood species
2023	Confidential / Turkey	40	TBD	Board	OCC
2023	Confidential / Germany	30	TBD	Tissue	HW
2023	Confidential / Brazil	63	TBD	Mix	HW
2023	Confidential / Slovakia	30	TBD	Tissue	HW
2022	Confidential / Finland	30	TBD	Tissue	HW
2021	Confidential / Sweden	48	TBD	Board	HW
2021	Confidential / Italy	8	TBD	Specialty	HW
2021	Confidential / Finland	4	TBD	Non-Paper	HW
2021	Confidential / Sweden	57	TBD	Board	Broke
2021	University of Maine / USA	1-2	TBD	Refining Research	All

Year Started	Customer/Location	Design Production TPD	Actual Production TPD	Grade Type	Wood species
2020	Valmet / Finland	1	1	Refining Research	All
2019	Confidential / Brazil	1	1.5	MFC Pilot Various	SW
2018	Confidential / Finland	40	TBD	Board	SW
2018	Confidential / Australia	1.5	2	MFC Pilot Liner	OCC
2017	Confidential / Brazil	2	2	MFC Pilot Pulp	HW
2015	Confidential / USA	1	1	Specialty Paper	HW
2015	Confidential / Netherlands	0.2	0.2	MFC Pilot Various	All
2015	Confidential / Finland	40	TBD	Board	SW
2014	Confidential / Sweden	28	TBD	Board	Broke
2013	Confidential / Finland	28	TBD	Board	SW

Valmet as a partner in joint R&D projects

Beyond Circularity

Transforming waste and emissions into valuable resources for sustainable growth

Valmet' R&D and innovation program, Beyond Circularity, is one of the Veturi initiatives co-funded by Business Finland

The Beyond Circularity program

- improves Valmet's readiness to support the green transition in Valmet's customer industries
- supports the implementation of Valmet's Climate program, which sets ambitious targets in the areas of carbon neutral production and energy efficiency of Valmet's current offering.

Beyond Circularity

Transforming waste and emissions into valuable resources for sustainable growth

Funding

Valmet

Valmet invest EUR 40 million into the program with an additional EUR 20 million by Business Finland.

Ecosystem

EUR 50 million (Ecosystem participants' own funding) + EUR 50 million (Business Finland funding) reserved for Ecosystem projects.

Ecosystem

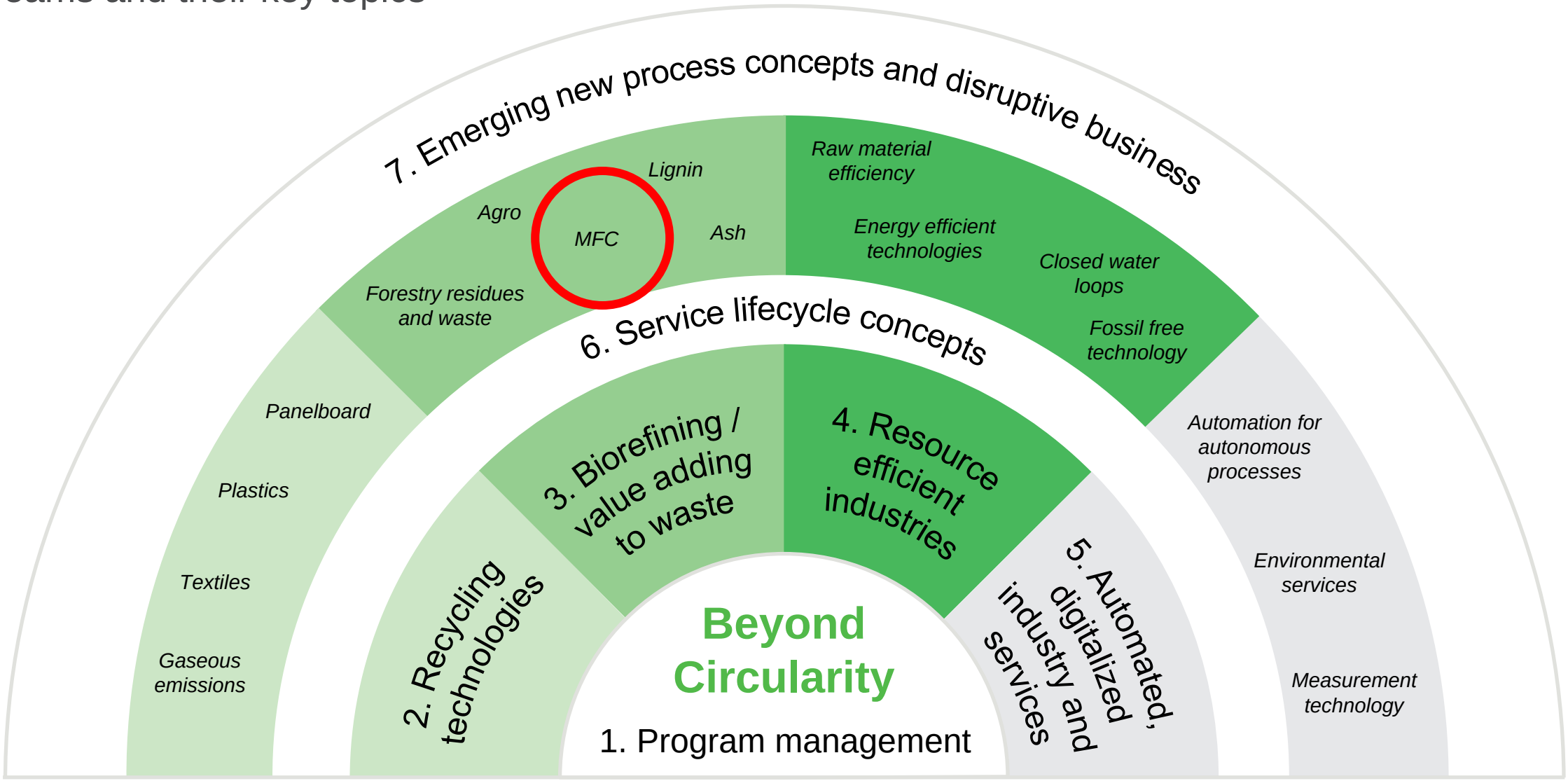
A new green transition ecosystem is to be built as part of this program to

- create value and growth for the participants
- expand competences to new areas
- encourage best national and international partners in the field to join in

When a project is accepted to the Beyond Circularity ecosystem (with Valmet approval), Business Finland funding can be applied for the project.

Beyond Circularity is implemented through 7 streams

Streams and their key topics



SUSBINCO

Sustainable Binders and Coatings

- Coordinated by CLIC Innovation, funded by Business Finland.
- Objectives:
  - To enable 80-100% bio-based content in the developed binders and coatings.
    - Raw materials include e.g. suberin, MFC, hemicellulose, lignin. Scale-up of processing from lab to bench or pilot scale.
    - 2-5 proof-of-concepts for converting processes (coated paper or board).
    - Sustainable and safe bio-based functional resins for abrasives and wood coatings.
  - To test and evaluate environmental impacts, end-of-life and safety issues of the new materials and products for sustainable binders and coatings in packaging product demos.
- Valmet's role: Technology provider, R&D partner, steering

CEBIPRO

New Analysis technologies for Circular Economy Biorefineries

- Coordinated by XAMK (South-Eastern Finland University of Applied Sciences), funded by Business Finland.
- Main objective is to develop new knowledge, technologies and competencies for the fiber ecosystems to optimize the processing efficiency and product qualities for rapidly growing new cellulose and fiber grades (dissolved fibers, MM controlled fibers and micro- and nano fibers).
- To develop and deepen fiber engineering analysis methods in collaboration between academy and industry.
- To deepen the knowledge on industrial analytics in co-operation with leading industrial companies for environmental efficiency in fiber manufacturing process suspensions and filtrates.
- Valmet's role: support development of analytics (Valmet Automation), support in MFC technology (Valmet Technologies).

XAMK Kaakkois-Suomen ammattikorkeakoulu

Valmet

AQUAFLOW

WETEND Technologies

FIBERX FINLAND

rethink. storaenso

UPM BIOFORE BEYOND FOSSILS

valmet

REDYSIGN

Resource-efficient processes for the production and circularization of innovative RECYclable-by-DeSIGN fresh meat smart packaging from wood

- Coordinated by Tecnalia (ES), funded by European Commission under the Horizon Europe frame programme and Circular Bio-based Europe Joint Undertaking.
- 13 partners from 7 countries; 3 RTOs, 4 SMEs and 6 Large industrial partners.
- Objectives:
  - Develop a circular, recyclable-by-design fresh meat fiber-based packaging (FBP) able to replace non-circular, plastic-made current products.
  - Develop innovative resource-efficient processes to produce high-performing lignocellulosic materials (functional fibers and wood constituents) and out of them, the bio-based lignocellulosic intermediate products (LIP).
  - Develop smart fresh meat FBP to reduce food spoilage, both at home and during distribution, improve classification operations prior to recycling and allow traceability and data management.
  - Develop an efficient paper recycling process for FBP contaminated with organic waste and demonstrate the circularity of the new product through the production of new FBP with the recycled fibers.
  - Commercialize the solutions, unveil maximum exploitation potential of each in other applications and issue guidelines for maximizing recycling.
- Valmet's role
  - Development of conical refining process by designing new refiner segments for low energy LCMNF production, target is 0.5 MWh/t.

Next in focus

Future research interests

Ongoing research in several areas

New, **alternative raw materials**

→ Agro-based materials, such as hemp and cotton

Screening technologies

Dewatering and drying technologies

Screening technologies

On-going research

Motivation

- Decrease the total energy consumption of MFC refining cycle

Idea

- Run the MFC LC-refining process to different refining degrees, separate the fines from coarser fibers by fractionation with the pressure screen and continue refining the coarse fraction

Variables in pilot trials

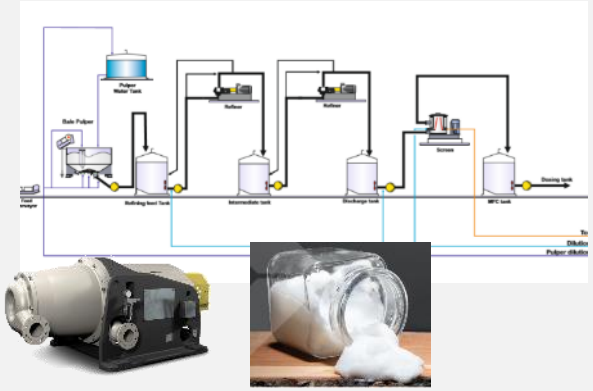
- Refining degree: Cumulative SEC from ~230 kWh/t to 1000 kWh/t
- Screen baskets (different sizes and configurations; slotted, hole)
- Rotors
- Process variables: rotor rpm, volumetric reject ratio, feed consistency

First results

- Screen size: too big – no fractionation. Smaller – fractionation successful but feed consistency low reducing production capacity. Too small – plugging.
- Optimal combination of basket and rotor can be found.
- Benefits of fractionation are apparent when processing pulps from the earlier parts of the LC refining process. However, screening does not generate fines so they need to be present at the starting material.
- Less benefit for fractionation when processing pulps processed with higher energy levels as the pulp is already highly refined and less coarse material remains.

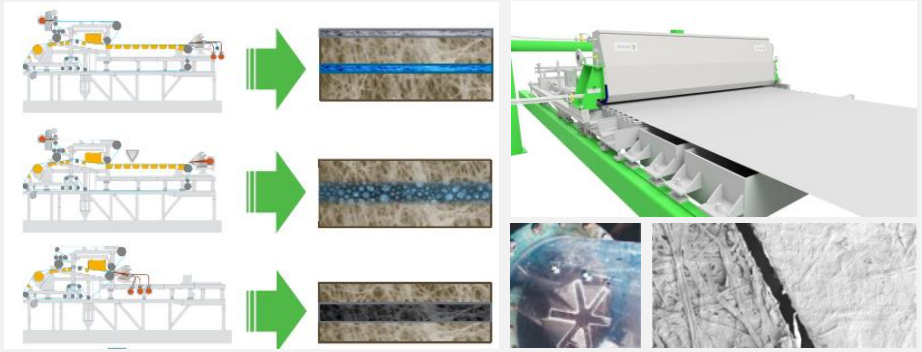
Valmet´s MFC offering

One supplier for complete production and services



Production lines for multiple end uses

- Concepts
- Key technologies
- Industrial Internet



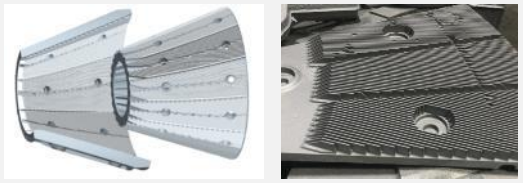
Application to board, paper and tissue

- Approach flow system mixing solutions
- Head boxes and drying solutions
- Wet and dry end application technologies

Drying technology for textile filaments

Analyzers

- Analyzers for lab and online measurements



Services

- Fillings
- Refiner upgrades

Piloting in Technology Centers and on the sites

- Fiber technology centers: Inkeroinen, Tumba, Sundsvall
- Paper technology centers: Rautpohja, Järvenpää and Karlstad

Valves & Special pumps


Valmet
FORWARD