

# Technology and experiences in manufacturing highly advanced carbon fiber prepreg

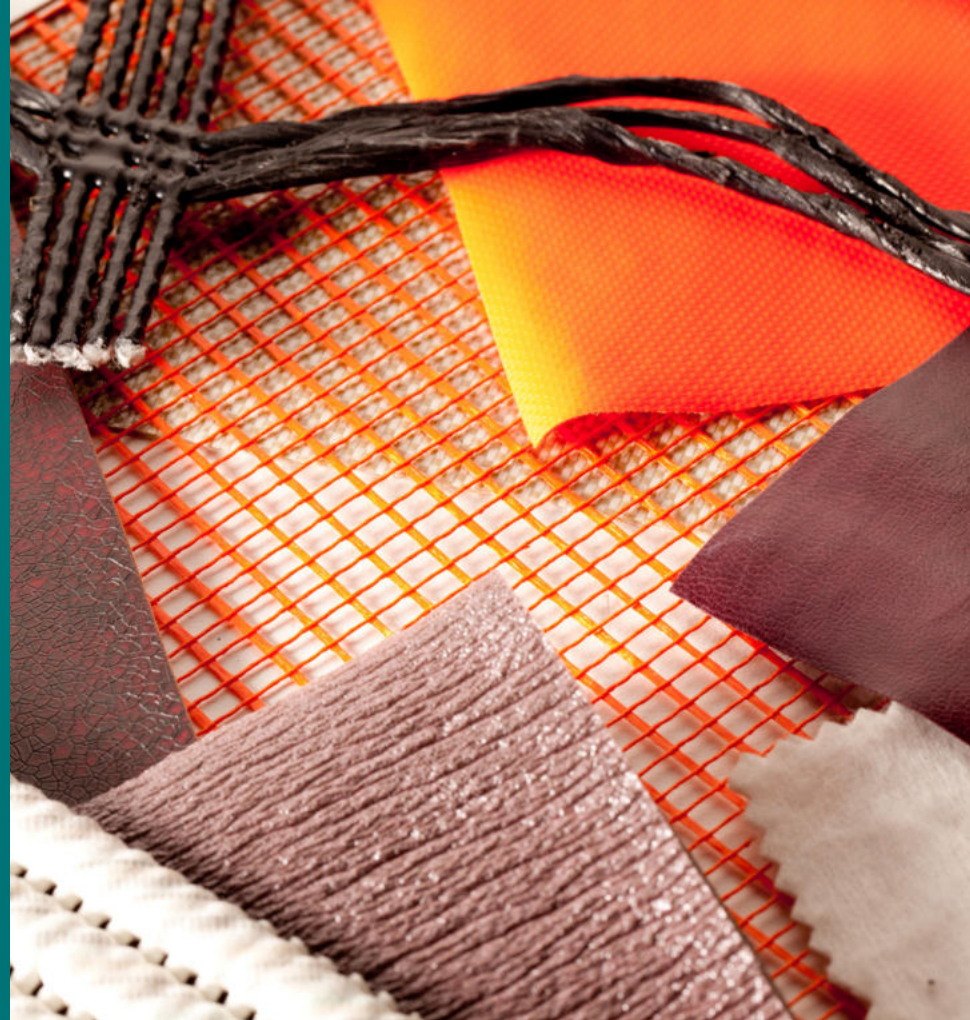
04/03/2024

MEMBER OF ATH

***Coatema***

# Agenda

1. Introduction
2. Market background
3. Technology background
4. Spreading technologies
5. Coating technologies
6. Impregnation technologies
7. Curing / High temperature systems
8. Pilot line layout
9. Proof of concept
10. Summary



# 1.

## Introduction



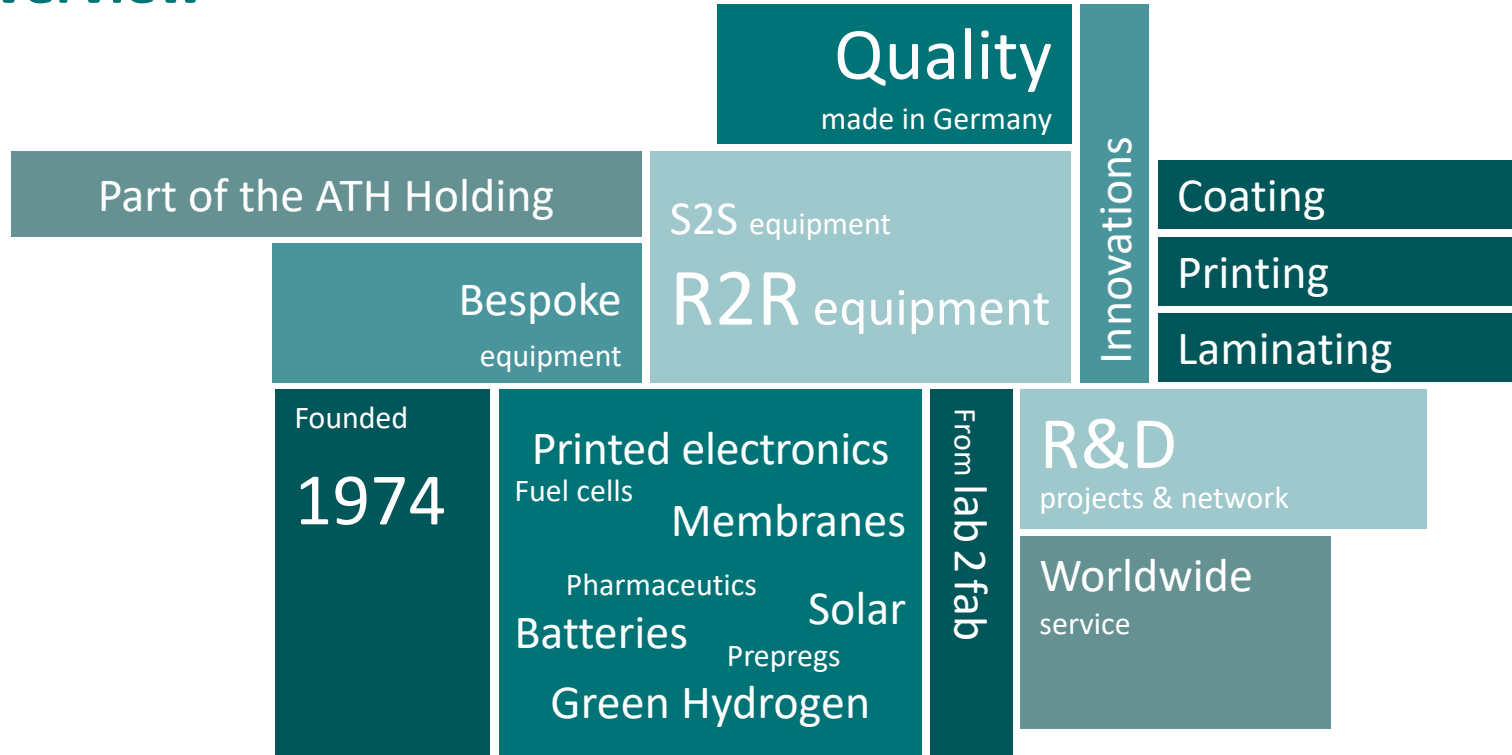
# Thomas Kolbusch, Director Sales, Marketing, Technology, VP



**Thomas  
Kolbusch**

**COATEMA Coating  
Machinery GmbH**

# Overview



## Group of companies

**ATH** ALTONAER  
TECHNOLOGIE  
HOLDING

 **KROENERT**

- ✓ Founded 1903
- ✓ Approx. 200 employees
- ✓ Located in Hamburg

**DRYTEC**

- ✓ Founded 1995
- ✓ Approx. 50 employees
- ✓ Located in Norderstedt

**Coatema**<sup>®</sup>  
Coating Machinery GmbH

- ✓ Founded 1974
- ✓ Approx. 50 employees
- ✓ Located in Dormagen

## Represented worldwide



# Coatema equipment platform strategy for lab2fab



Lab

- ✓ State-of-the-art research and development equipment
- ✓ Sheet-to-sheet to roll-to-roll systems on small scale & footprint



Pilot

- ✓ Proven processes for printing, coating and laminating equipment
- ✓ Highest-quality pilot lines enable stable pilot production and reduce cost of operation
- ✓ Scaling laboratory equipment to enable pilot production



Production

- ✓ Full-scale production lines
- ✓ Optimize the manufacturing process, including streamlining assembly, reducing material waste, and optimizing the carbon footprint



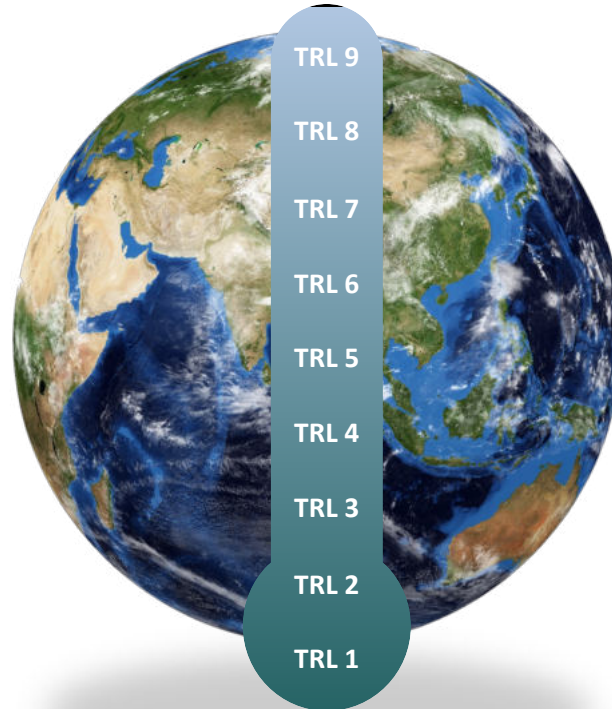
## Our markets – Coatema focus areas

Green Hydrogen

Fuel cells

Batteries

Solar



Sustainability

Digital fabrication

Printed  
electronics

The next thing

# R&D centre USP



## Process development

- ✓ Feasibility study
- ✓ Ink – process study
- ✓ Process analysis
- ✓ Slot die coating simulations
- ✓ Proof of concept
- ✓ Small scale prototype



## Test production

- ✓ Prototyping
- ✓ Near to market testing
- ✓ TRL evaluation
- ✓ Training of staff



## Education

- ✓ Coating conference
- ✓ Partner trainings
- ✓ Education of students
- ✓ Workforce training



## Development of custom-made design for equipment

- ✓ Prototyping
- ✓ Proof of concept



## Public funded research projects know-how

- ✓ German funded
- ✓ Horizon 2020
- ✓ Global 2+2 projects
- ✓ B2B projects

# Introduction – R&D centre



# R&D customers



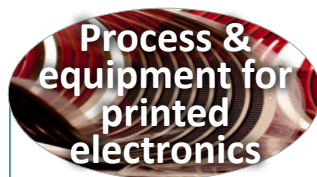
## R&D projects overview 2022 – 2024



In-line and real-time digital nano-characterization for flexible organic electronics

### NOUVEAU PROJECT

The NOUVEAU project will develop solid oxide cells (SOCs) with innovative La- and PMG-free electrode materials



R2R production line for OPV solar with integrated backend



Development of near-field electro hydrodynamic nanowire printing



Implementation of laser drying processes for lithium-ion battery production



R2R process optimization for solid state batteries



Plasmonically enhanced photocatalysis for wastewater treatment

### RetroWin

R2R Process and machinery development for retrofit window films for lower production costs



The WaterProof project aims at developing an electrochemical process that converts CO<sub>2</sub> emission



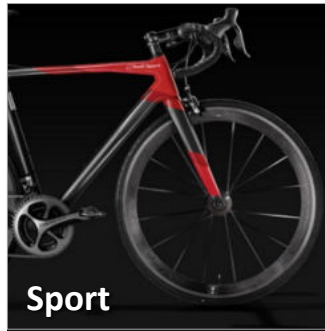
Creating an open-innovation testbed for sustainable packaging

# 2.

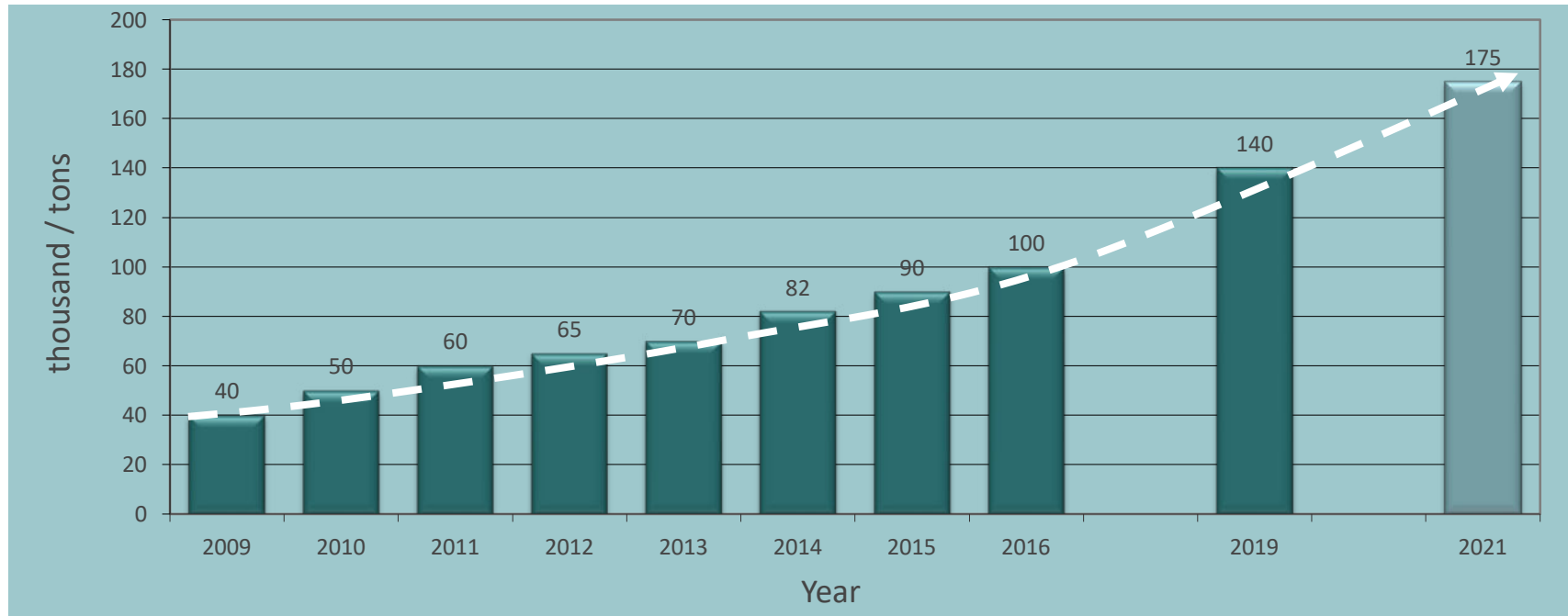
## Market background



# The market for prepreg

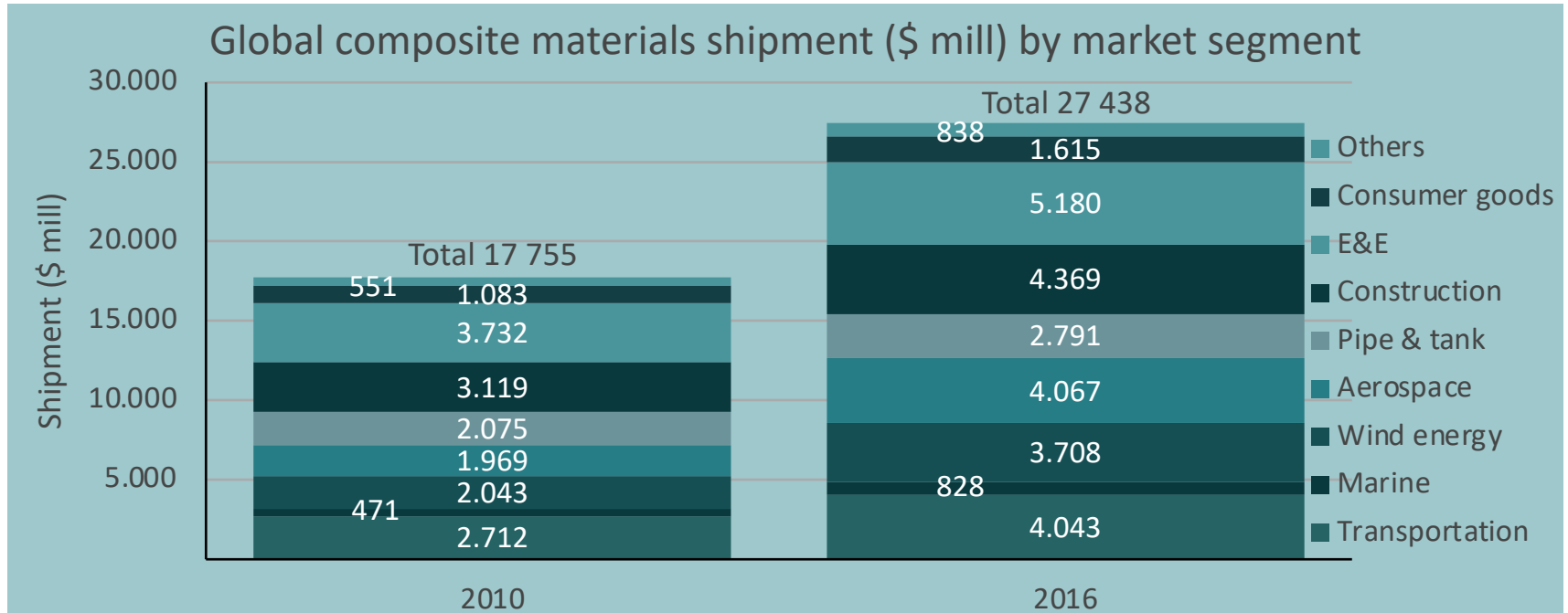


## The market for prepreg – the market in total



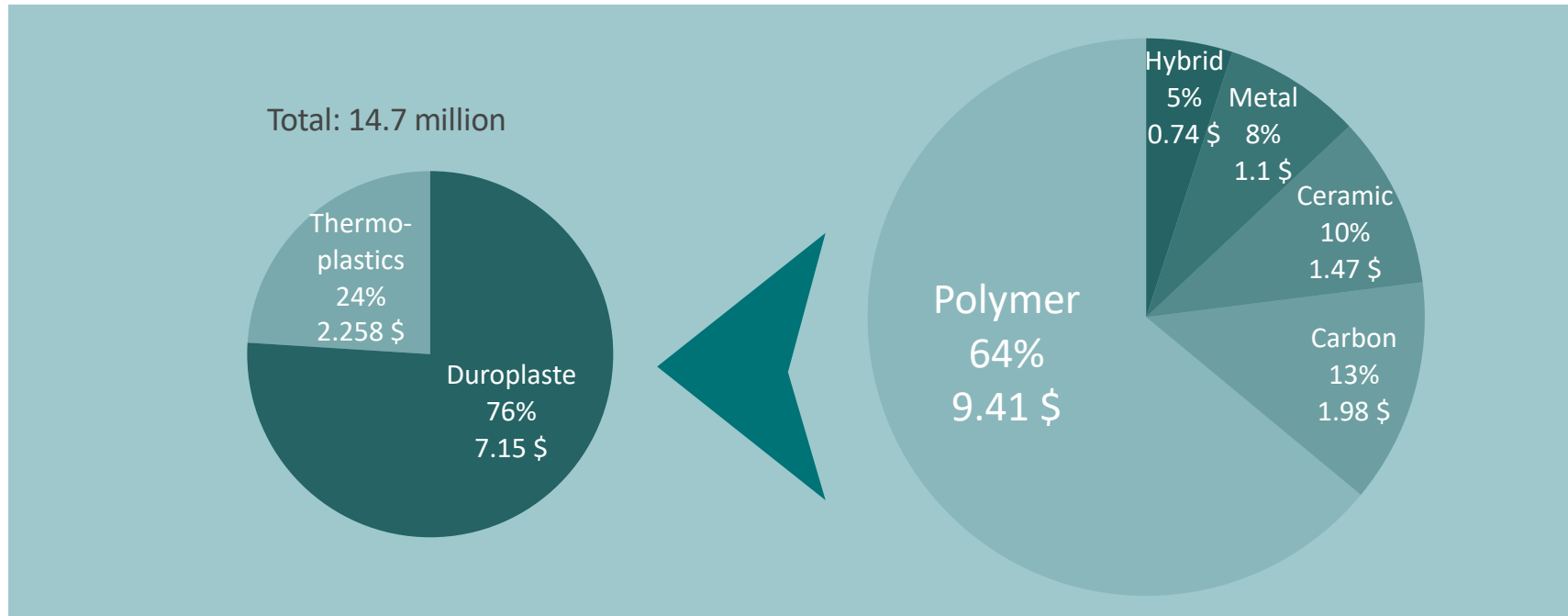


# The market for prepreg – the market in total



Source: Lucintel

## Current turn over in Bill. US\$ for different matrix materials (2013)

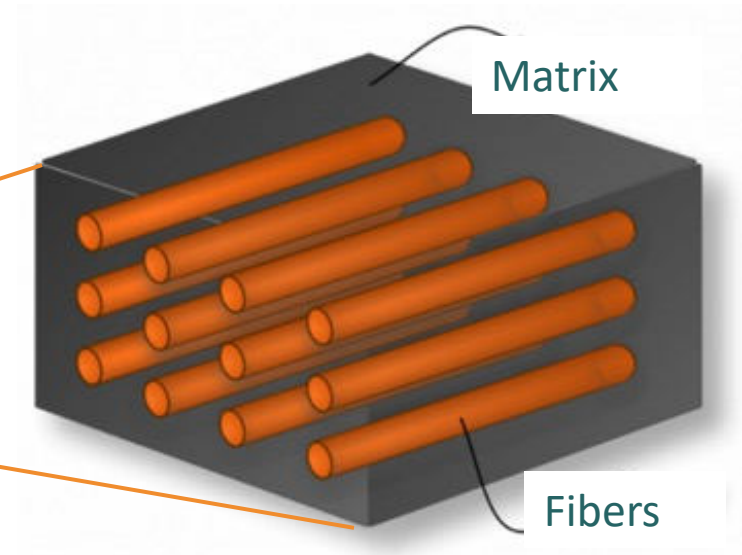
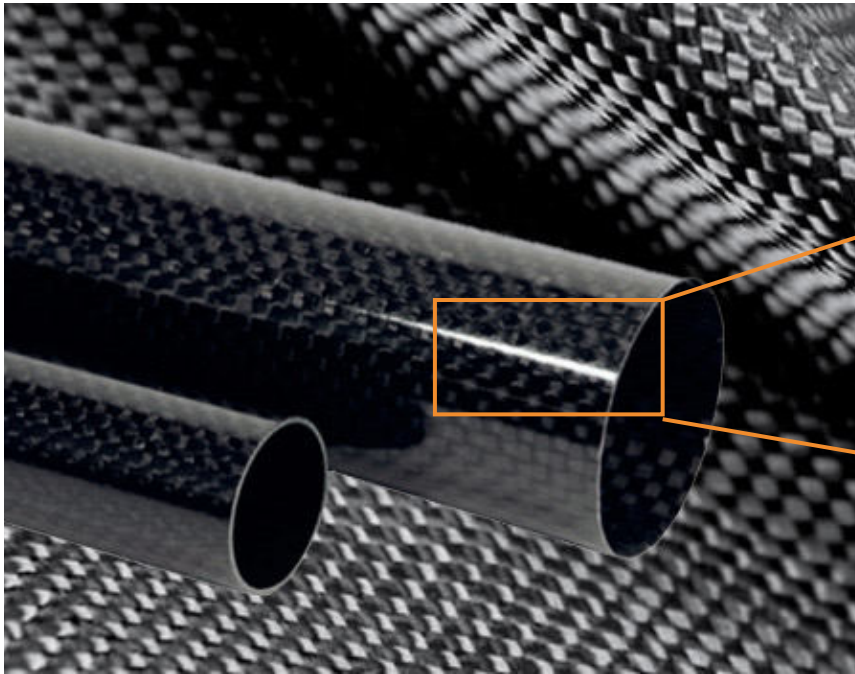


# 3.

## Technology background



## Prepreg



## Types of material

Today there are 3 major composite systems

### ✓ **Thermosetting (duroplastic) resins:**

A polymer that cannot be remolten or reformed once it has been cured.

Curing creates a molecular cross-linking, which is irreversible.

Version B-stage:           Curing stops at incomplete crosslinking

                                    Final curing to complete crosslinking after shaping

### ✓ **Thermoplastic resins:**

A polymer in which the molecules are not cross-linked, or they are cross-linked to a weaker degree. A thermoplastic polymer can be reshaped or reformed by reheating the polymer.

### ✓ **Hybrid systems**

## Fibres and substrates

### Reinforcement – man made fibres

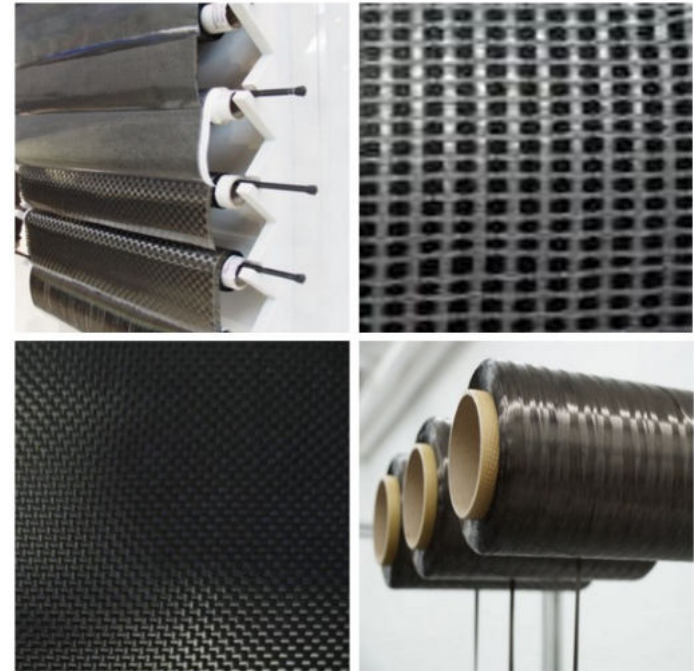
- ✓ Carbon
- ✓ Glass
- ✓ Polyamide (Nylon R)
- ✓ Aramid (Kevlar R)
- ✓ Basalt



## Rovings and textile structure

### Rovings and textile structure of the substrate

- ✓ Uni- and Bi-directional structures
- ✓ Woven substrates
- ✓ Multi-directional fibers construction
  - ✓ Layer (cross) structures
  - ✓ Sewed knitted structures
  - ✓ Nonwovens
- ✓ Products with more than one orientation direction, this is influenced by the later desired strength direction



## Thermosetting materials

### Thermosetting (duroplastic) resins:

- ✓ Solvent based epoxy resins also as chemical or physical B-stage
- ✓ Hotmelt and solvent free epoxy resins
- ✓ Phenol systems solvent or water based
- ✓ Cyanate Ester systems
- ✓ Polyester / vinyl ester / acrylic resin
- ✓ 1K and 2K products (mostly resins)

→ **Disadvantages:**  
**Rigid, not meltable, recycling problems**



## Specs for thermosetting materials

### Specs for thermosetting (duroplastic) systems:

- ✓ **Variation of the coating weight both sides**  
10 – 300 g/m<sup>2</sup>
- ✓ **Range of viscosity**  
100 – 50 000 mPas
- ✓ **Temperature range**  
40 – 250 °C, standard application temperature 60 – 120 °C
- ✓ **Speed range for different production processes**  
average speed 50 – 80 m/min for film coating process  
average speed 5 – 15 m/min for combined coating and laminating lines  
average speed 5 – 25 m/min for impregnation average speed
- ✓ **Temperature accuracy**  
± 1K roller surface temperature and dryer accuracy

## Thermosetting materials advantages

- ✓ High amount of formulations are possible for every demand
- ✓ Specials are possible
- ✓ Durable and long live time
- ✓ Shiny systems for visible parts
- ✓ High temperature resists for Cyanat ester systems till 350 °C

## Thermoplastic materials

### Thermoplastic systems

- ✓ PE Polyethylen
- ✓ PP Polypropylen
- ✓ PC Polycarbonat
- ✓ POM Polyoxymethylen
- ✓ PEEK Polyetheretherketon
- ✓ PA Polyamide
- ✓ PEI Polyetherimid
- ✓ PTFE Polytetrafluorethylen

→ **Disadvantages:**  
**high viscosities, change of systems for appliance, not finally certified**

## Specs for thermoplastic materials

### Specs for thermosetting systems

powder like materials

- ✓ solvent thermoplastic resins
- ✓ extruded thermoplastic resins

### Variation of the coating weight

- ✓ 10 to 300 g/m<sup>2</sup>

### Range of viscosity

- ✓ 100 – 200 000 mPas depending on coating or extrusion technology

### Temperature range

- ✓ 80 – 400 °C ± 1K

### Speed range

- ✓ Average speed range for impregnation 0.1 – 10 m/min.

## Advantages for thermoplastic materials

- ✓ High toughness
- ✓ High formability for 3D applications
- ✓ Low density additional weight reducing
- ✓ Quick hardening possibilities
- ✓ Mistakes are correctable
- ✓ Plenty of times heatable and formable

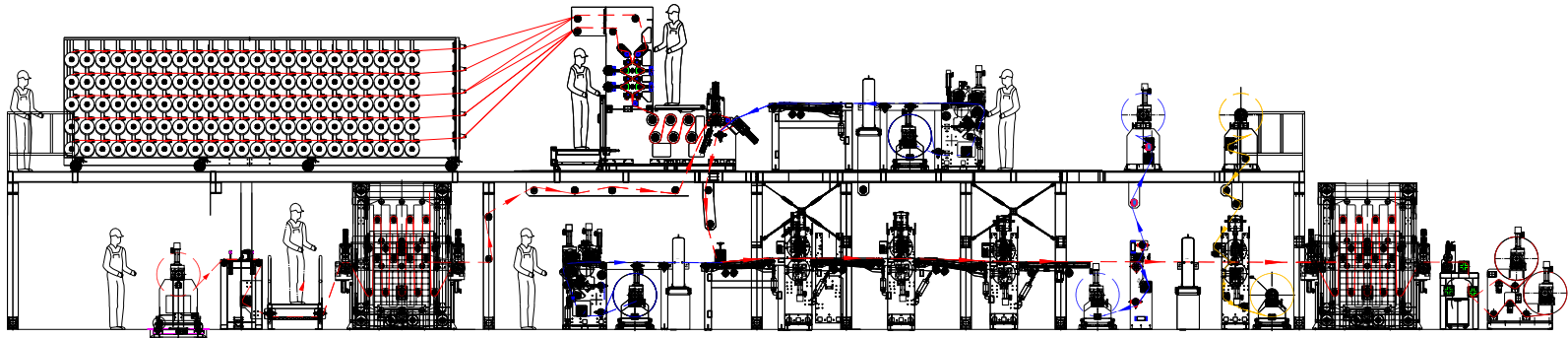
# 4.

## Spreading technologies

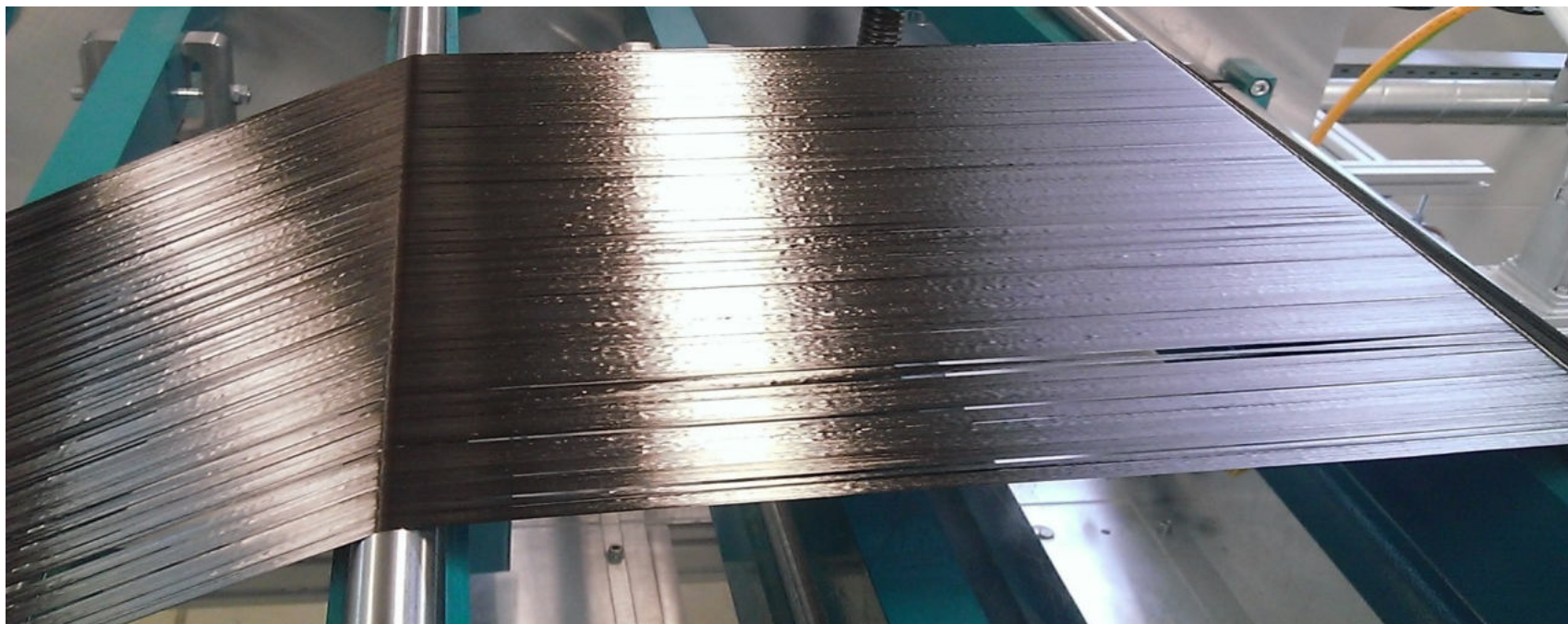


# Advantages for thermoplastic materials

1. Spreading of fibre
2. Coating the resin
  - a) Thermosetting (duroplastic) resins
  - b) Thermoplastic resins
3. Impregnation into the matrix

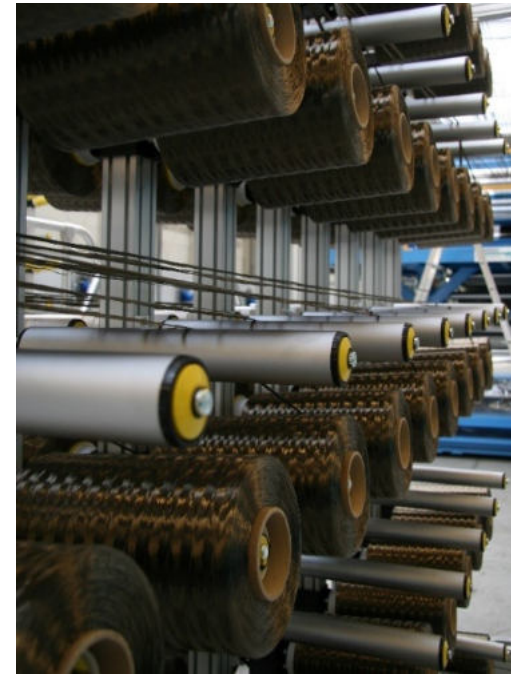


## Spreading technology





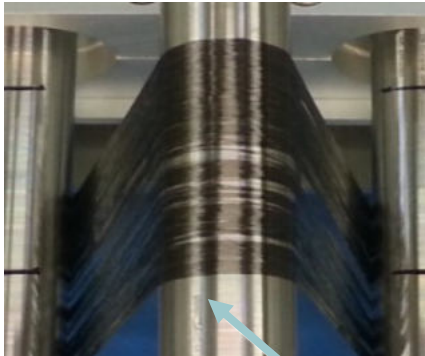
## Creel station for carbon bobins



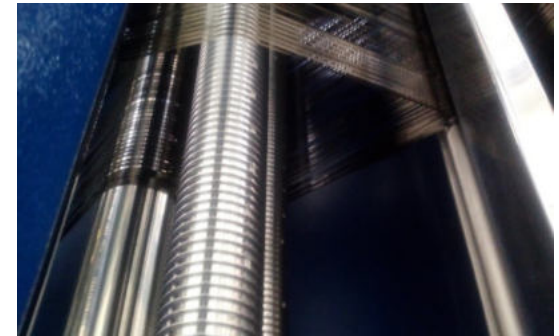
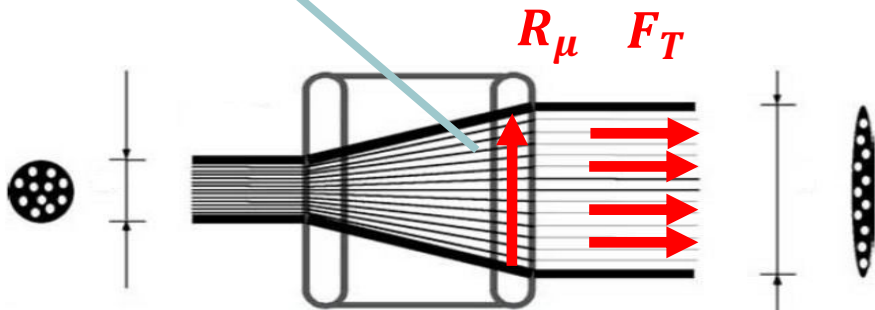
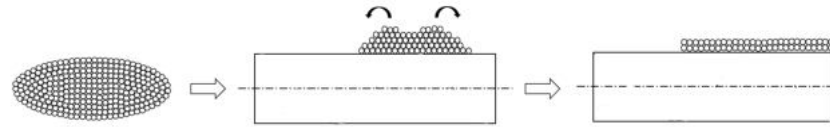
## Substrate weight depending on roving fineness and number

		UD-Width mm	Carbon 1k	Carbon 3k	Carbon 6k	Carbon 6k	Carbon 6k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 50k	Carbon 50k	Carbon 50k	Carbon 50k
Filament Number			1.000	3.000	6.000	6.000	6.000	12.000	12.000	12.000	12.000	24.000	24.000	24.000	24.000	50.000	50.000	50.000	50.000
Fineness (tex)	g/1000m		67	200	400	400	400	800	800	800	800	1.600	1.600	1.600	1.600	3.500	3.500	3.500	3.500
Roving Number	pro 1 m		300	200	150	200	250	62	100	125	166	62	83	94	125	34	43	63	71
<b>Substrate weight</b>	<b>g/m<sup>2</sup></b>		<b>20</b>	<b>40</b>	<b>60</b>	<b>80</b>	<b>100</b>	<b>50</b>	<b>80</b>	<b>100</b>	<b>133</b>	<b>100</b>	<b>133</b>	<b>150</b>	<b>200</b>	<b>120</b>	<b>150</b>	<b>220</b>	<b>250</b>
Roving Number	for DU width	<b>600</b>	180	120	90	120	150	37	60	75	100	37	50	56	75	21	26	38	43
Spreading	mm		3,33	5,00	6,67	5,00	4,00	16,00	10,00	8,00	6,02	16,00	12,03	10,67	8,00	29,17	23,33	15,91	14,00
		UD-Width mm	Carbon 1k	Carbon 3k	Carbon 6k	Carbon 6k	Carbon 6k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 12k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 24k	Carbon 50k	Carbon 50k	Carbon 50k	Carbon 50k
Filament Number			1.000	3.000	6.000	6.000	6.000	12.000	12.000	12.000	12.000	24.000	24.000	24.000	24.000	50.000	50.000	50.000	50.000
Fineness (tex)	g/1000m		67	200	400	400	400	800	800	800	800	1.600	1.600	1.600	1.600	3.500	3.500	3.500	3.500
Roving Number	pro 1 m		300	200	150	200	250	62	100	125	166	62	83	94	125	34	43	63	71
<b>Substrate weight</b>	<b>g/m<sup>2</sup></b>		<b>20</b>	<b>40</b>	<b>60</b>	<b>80</b>	<b>100</b>	<b>50</b>	<b>80</b>	<b>100</b>	<b>133</b>	<b>100</b>	<b>133</b>	<b>150</b>	<b>200</b>	<b>120</b>	<b>150</b>	<b>220</b>	<b>250</b>
Roving Number	for DU width	<b>1200</b>	360	240	180	240	300	75	120	150	199	75	100	112	150	41	51	75	86
Spreading	mm		3,33	5,00	6,67	5,00	4,00	16,00	10,00	8,00	6,02	16,00	12,03	10,67	8,00	29,17	23,33	15,91	14,00

# Spreading process



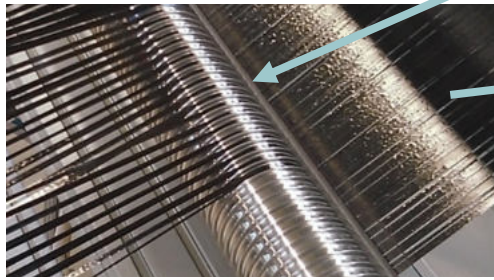
$R_\mu$  Friction effect  
 $F_T$  Pulling / traction for fibre



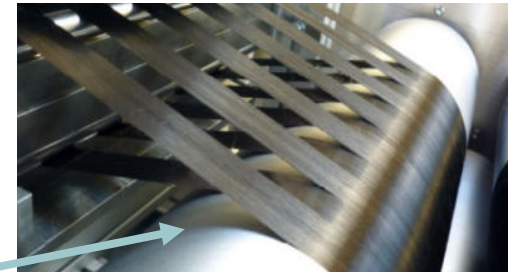
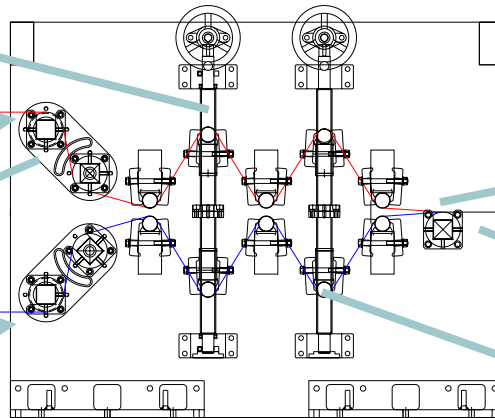
# Spreading process



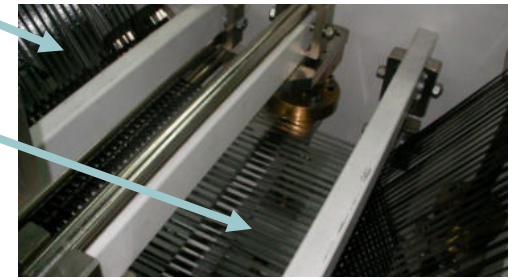
Top spreading rods



Positioning roller

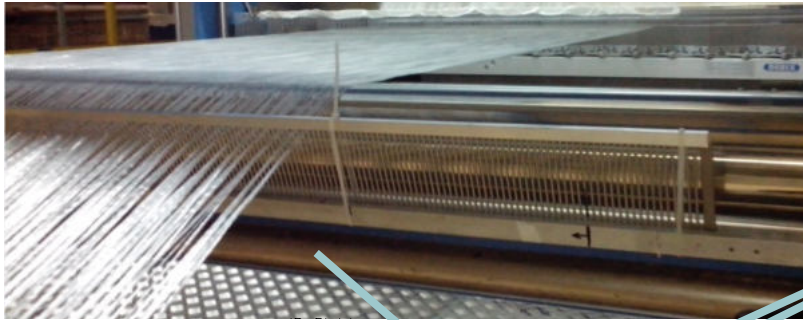


Transfer roller

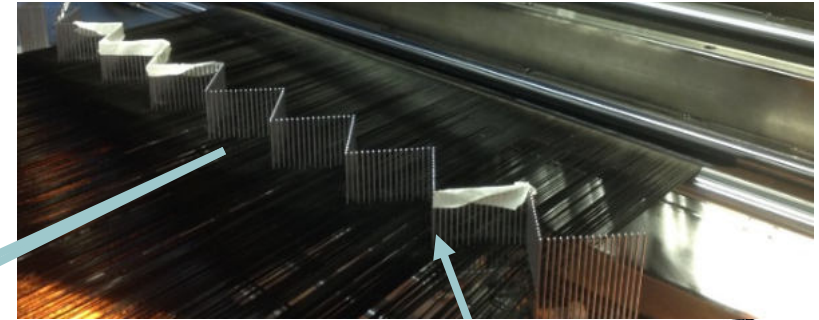


Bottom spreading rods

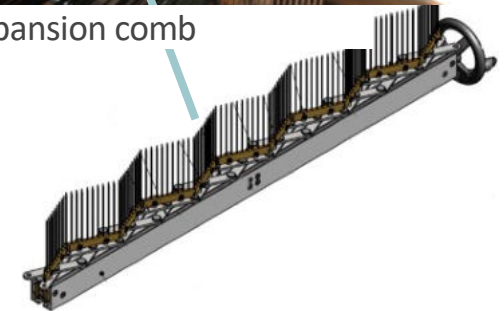
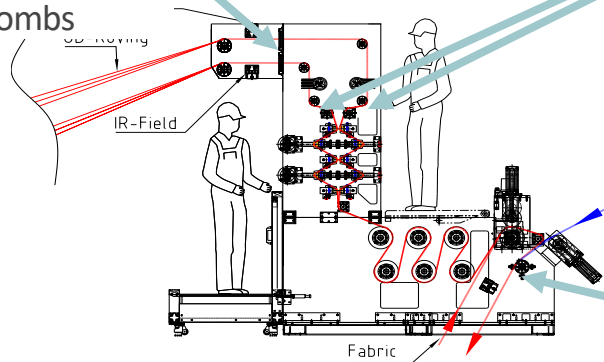
# Spreading device



Two units Combs

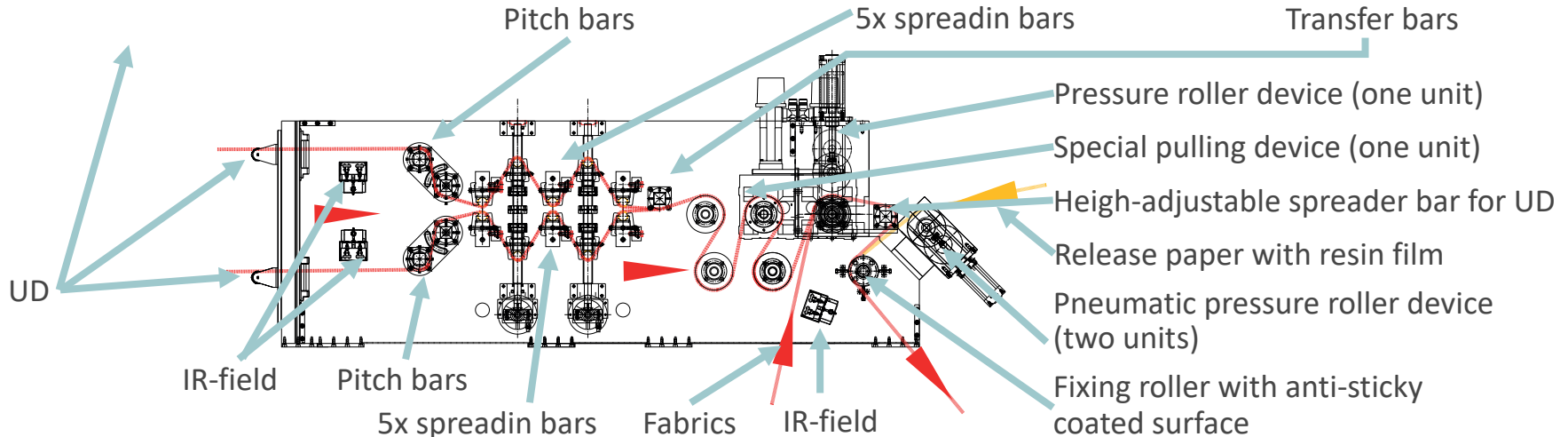
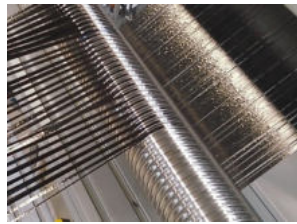


Two units Zig zag expansion comb

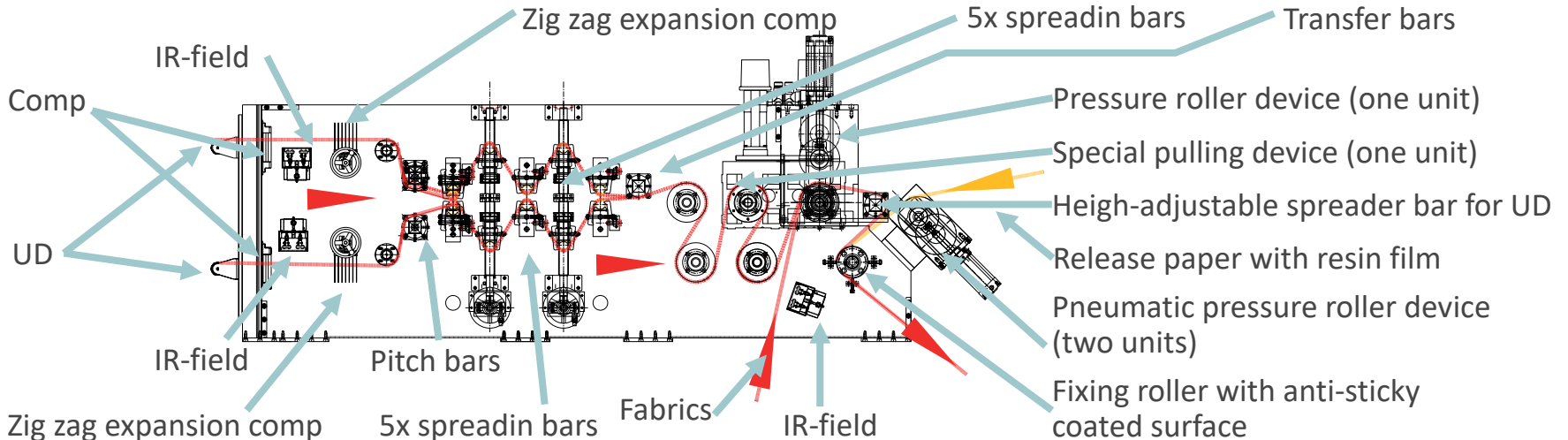
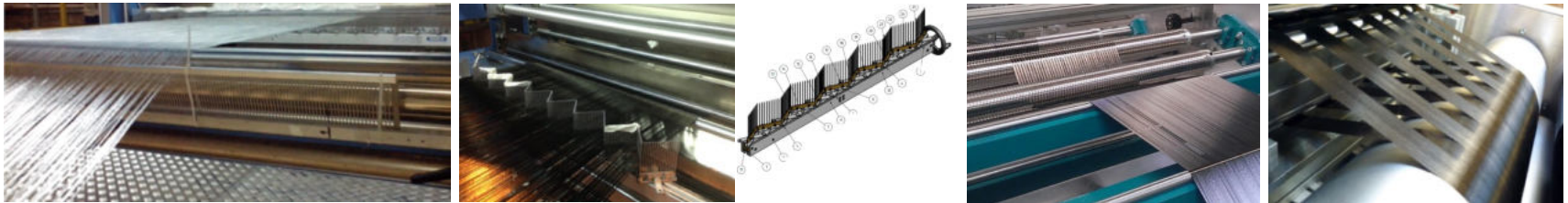


Roller with teflon coated surface

# Spreading device with pitch bars



# Spreading device with zig zag expansion comb



## Additional possibilities

- ✓ Ultrasonic devices
- ✓ Vibrations bars
- ✓ Cooled bars for higher traction force
- ✓ Topocrom surface of the bars for reducing traction



# 5.

## Coating technologies

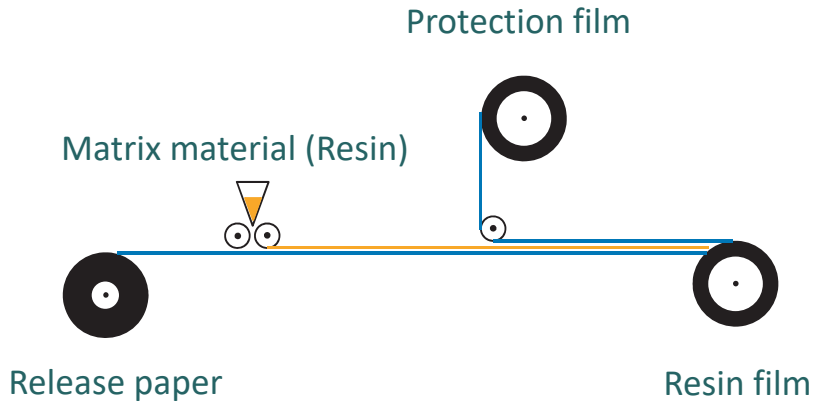


## Substrate weight depending on roving fineness and number

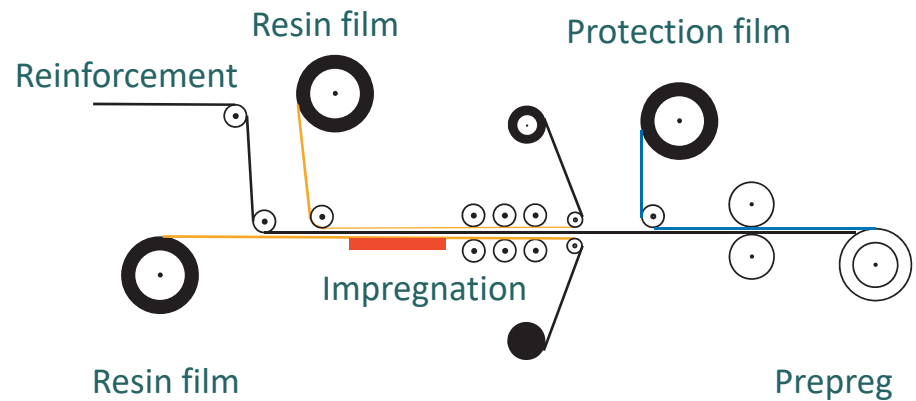
- ✓ 12K spreading per roving to 8 mm add up to 100 g/m<sup>2</sup>
- ✓ 12K spreading per roving to 10.7 mm add up to 75 g/m<sup>2</sup>
- ✓ 24K spreading per roving to 8 mm add up to 200 g/m<sup>2</sup>
- ✓ 24K spreading per roving to 10.7 mm add up to 150 g/m<sup>2</sup>
- ✓ 24K spreading per roving to 16 mm add up to 100 g/m<sup>2</sup>

# Film transfer method

Step1: Matrix film coating

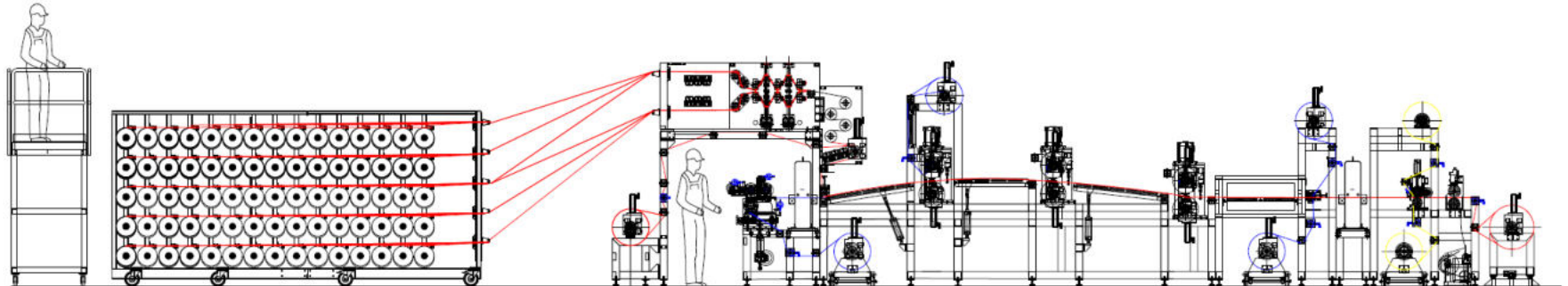


Step2: Prepreg impregnation



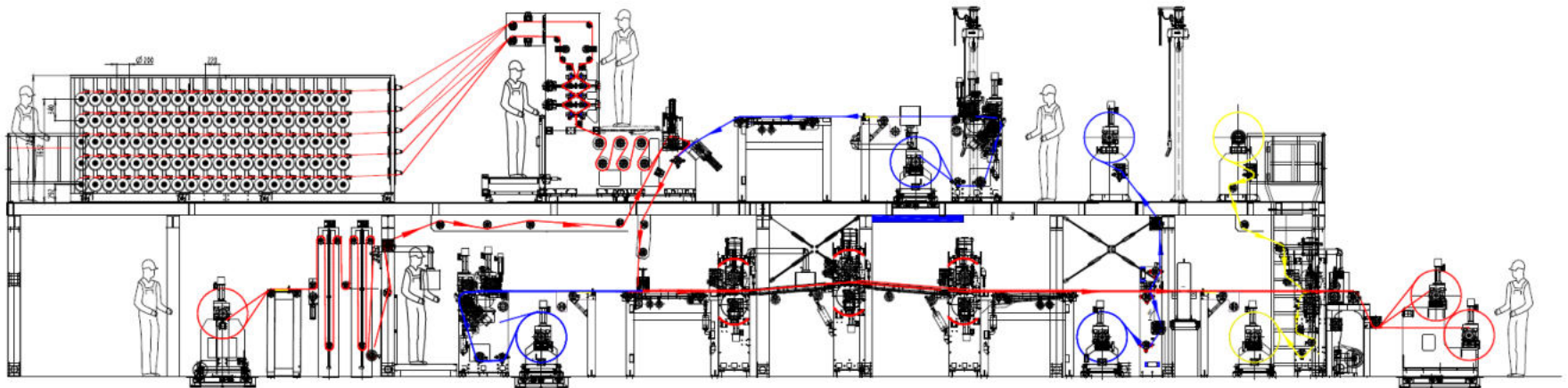
# Film transfer method

Lab prepreg coating line



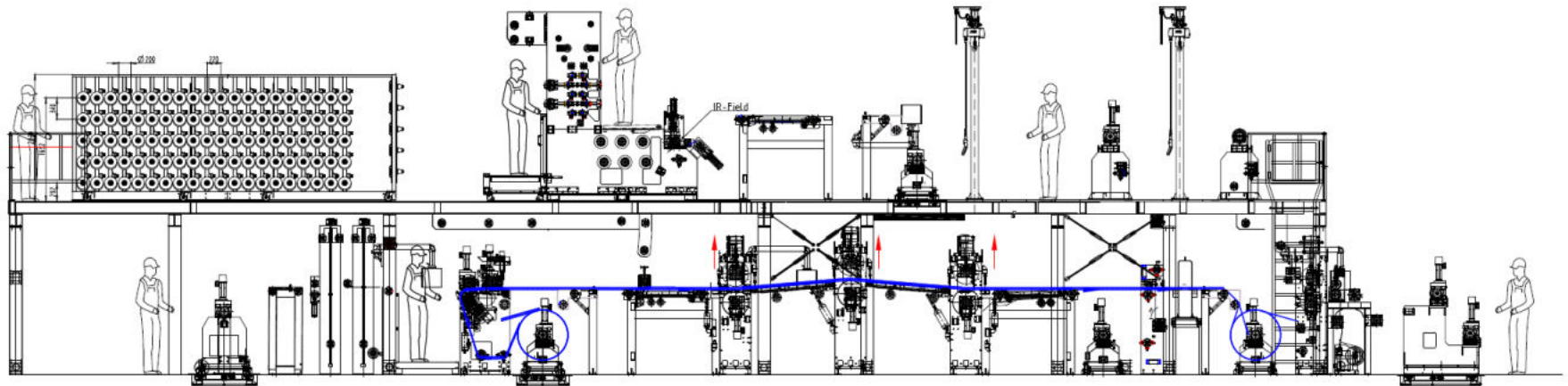
# Film transfer method

## 1 Step process



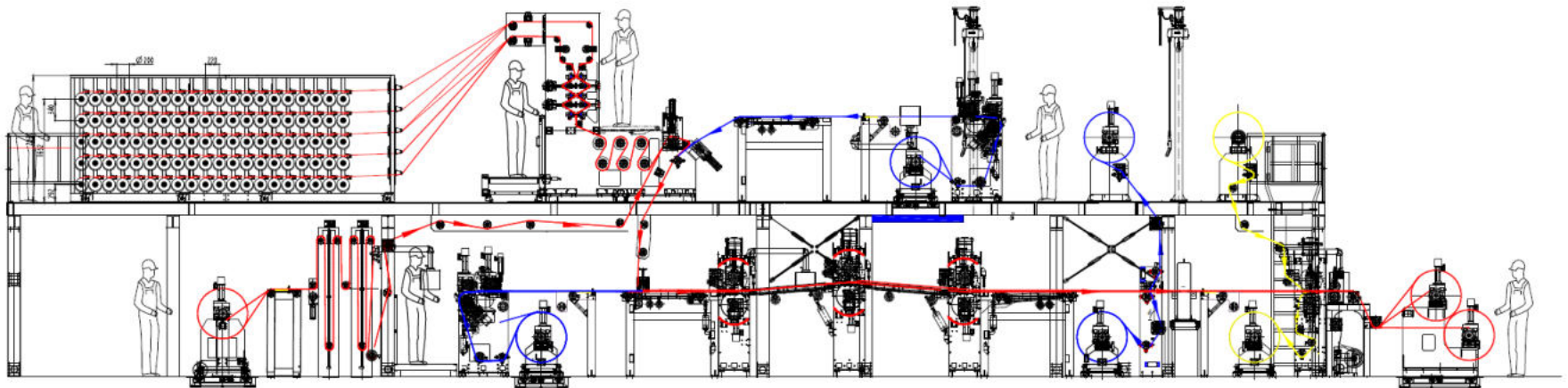
## Film transfer method

2 Step process: resin-film coating



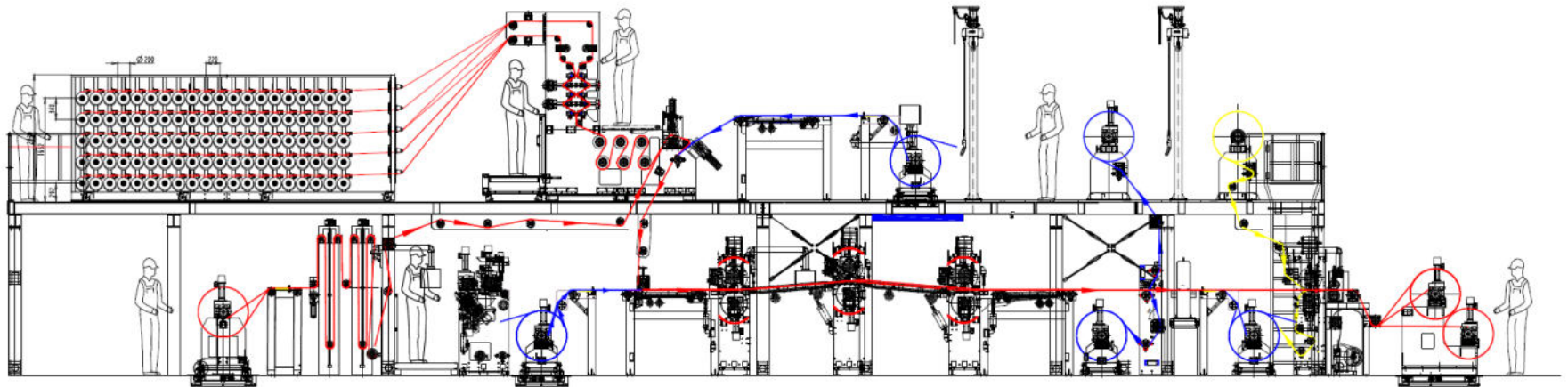
# Film transfer method

2 Step process: 1. direct – 2. indirect



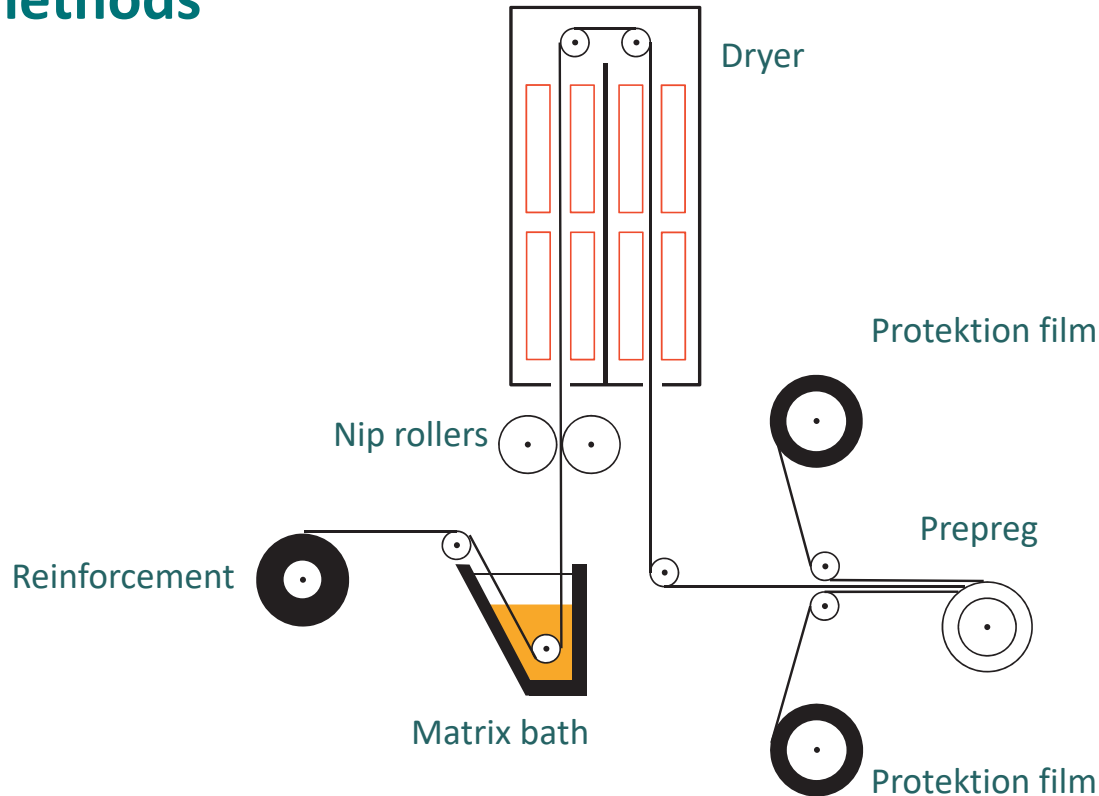
# Film transfer method

2 Step process: 1. indirect – 2. indirect



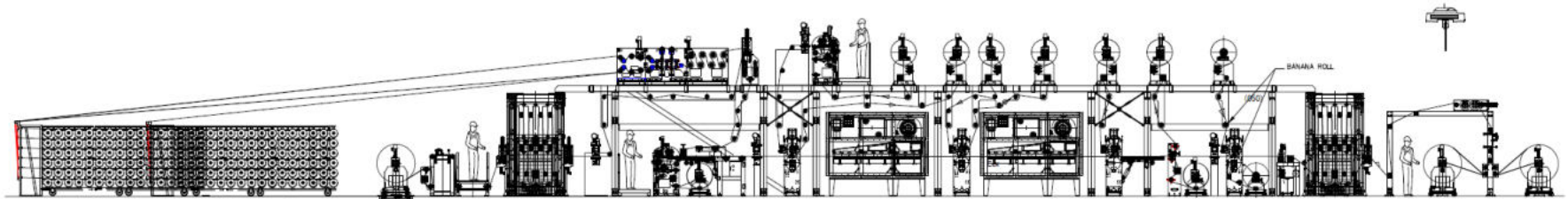


# Solvent methods

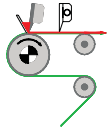


## Film transfer method

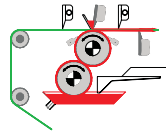
1 Step process for solvent



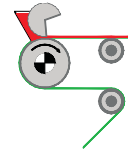
## Coating systems



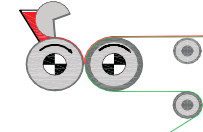
Knife system



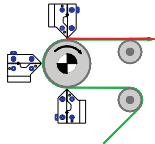
Double side coating system



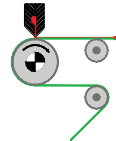
Commabar system



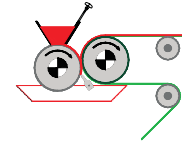
Reverse commabar system



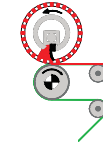
Slot die system



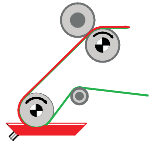
Curtain coating system



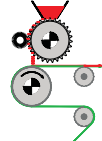
Case knife system



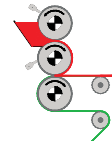
Rotary screen system



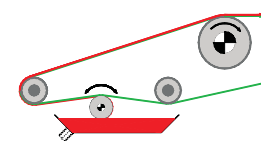
Dipping system (Foulard)



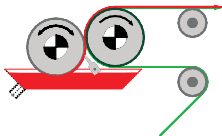
Powder scattering system



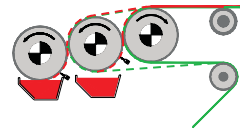
Reverse roll coating system



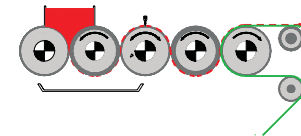
Micro roller coating system



2-roller coating system

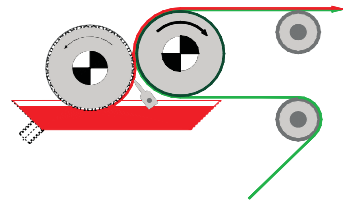


3-roller combi coating system

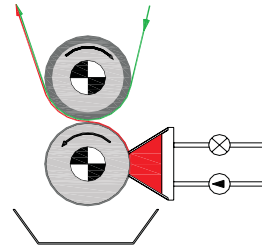


5-roller coating system

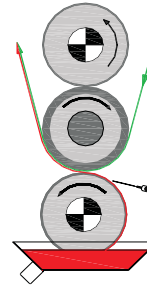
# Printing systems



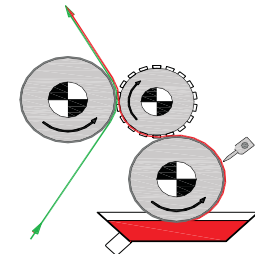
Engraved roller system



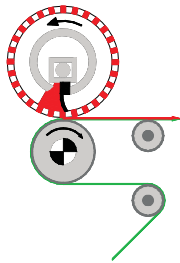
Gravure roller system



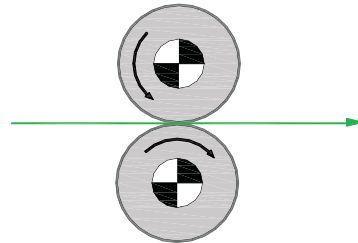
Gravure indirect system



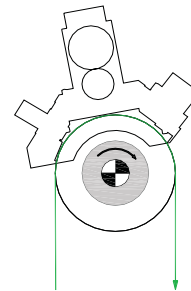
Flexography system



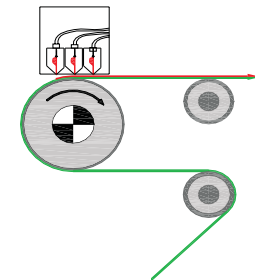
Rotary screen system



Hot embossing system



Nanoimprint system

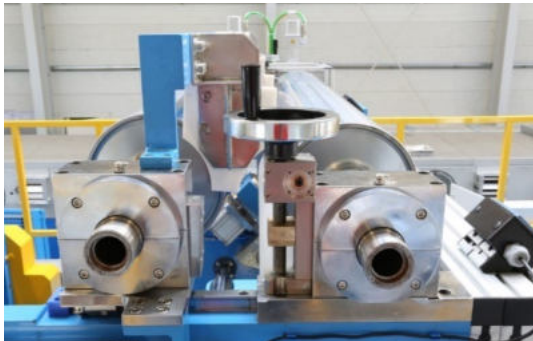
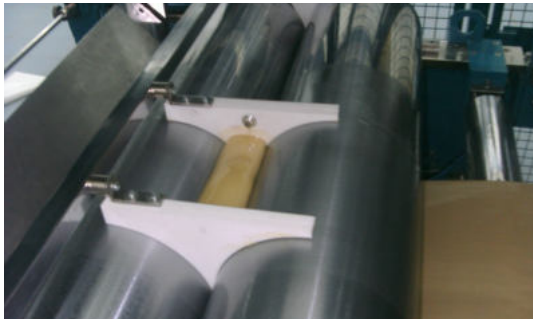


Inkjet system

## Indirect coating – concept:

- ✓ Coating is being done on a carrier film
- ✓ Easy to pre-meter the coating thickness
- ✓ Transport on a support carrier to the next steps
- ✓ High accuracy
- ✓ Reproducibility

## Indirect coating



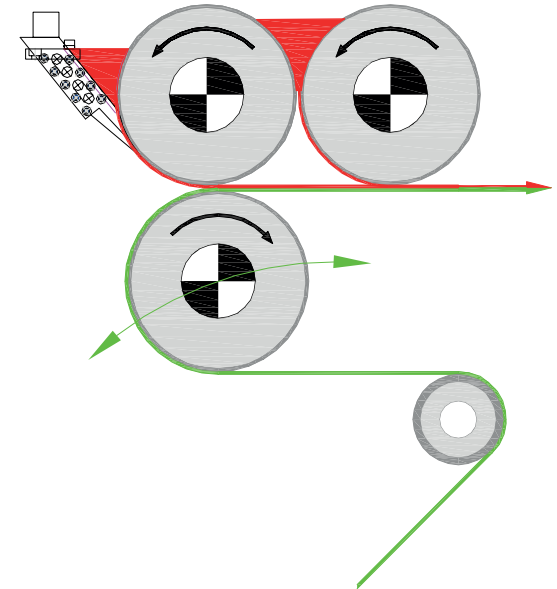
**Modular coating system  
for prepreg**

**Viscosity**

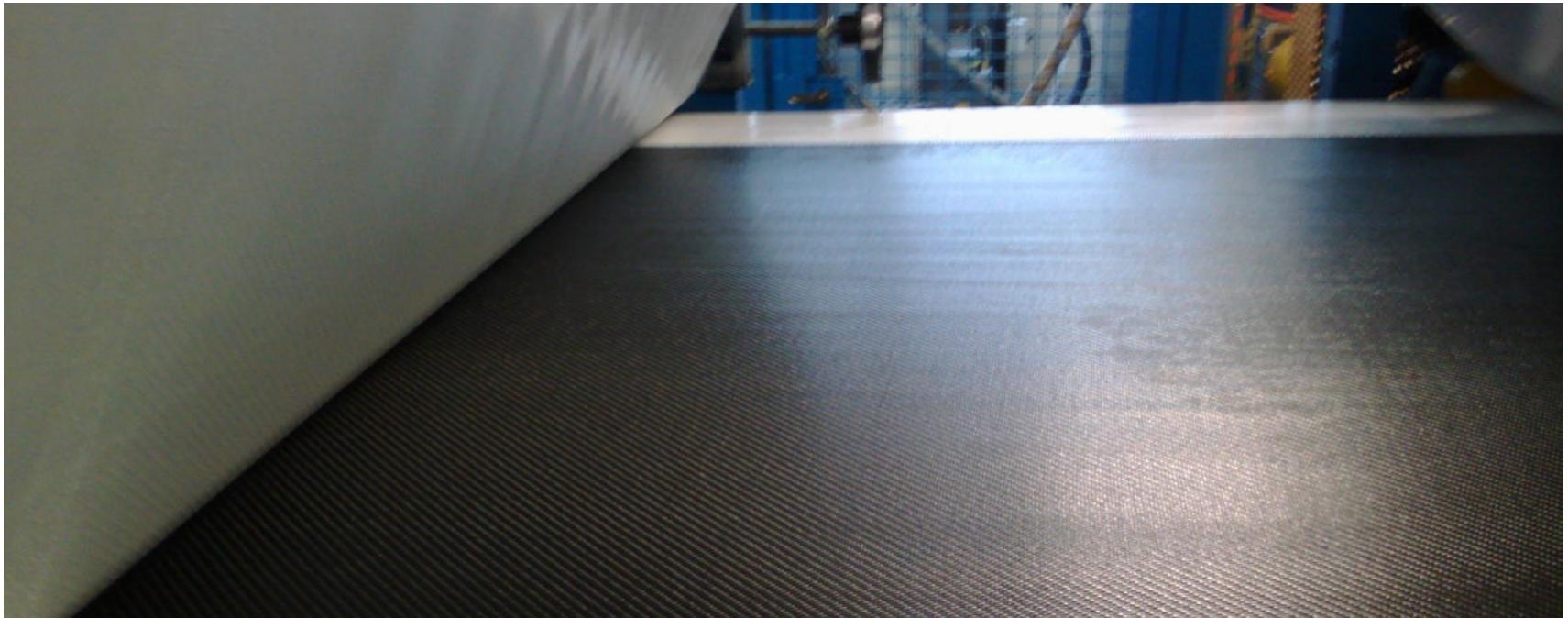
✓ 100 – 200 000 mPas

**Temperature range**

✓ RT – 250°C

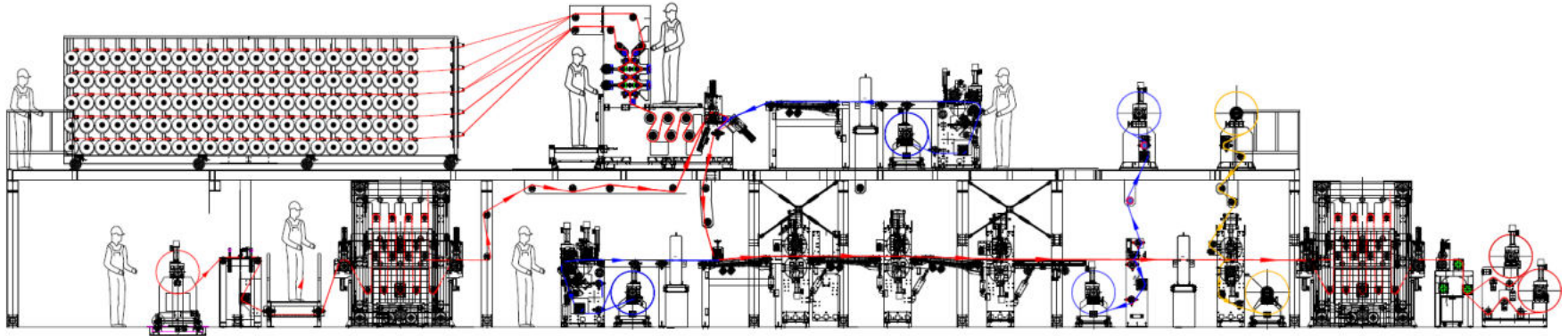


## Thermosetting technology



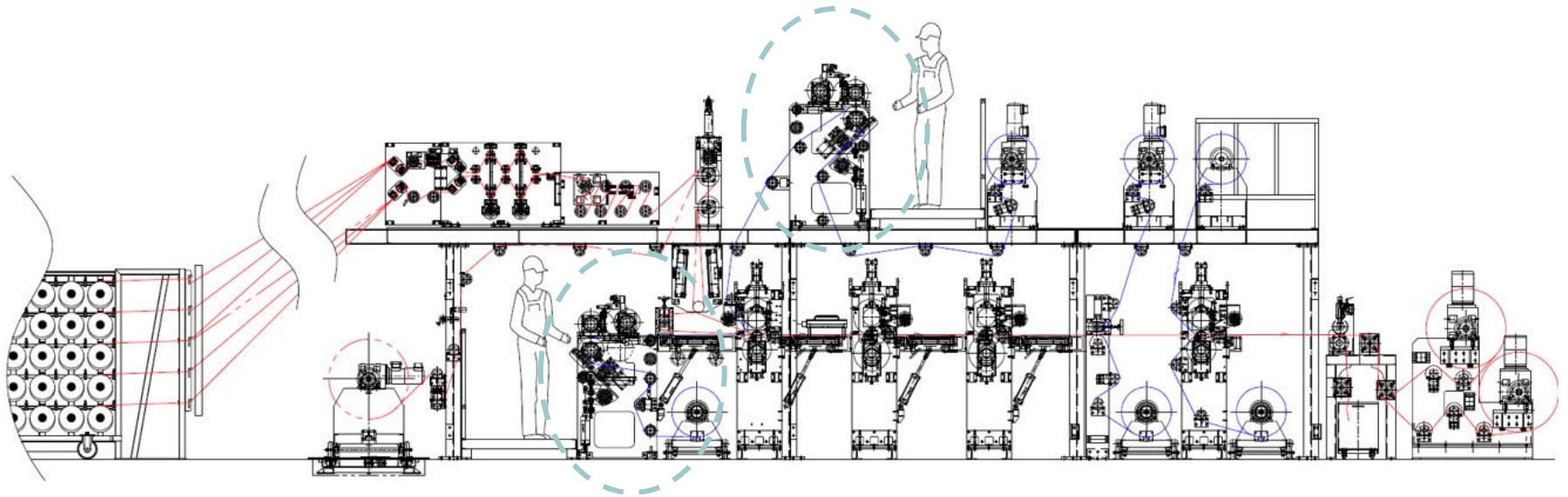
# Thermosetting technology

1. Spreading of fibre
- 2. Coating the resin**
  - a) Thermosetting (duroplastic) resins
  - b) Thermoplastic resins
3. Impregnation into the matrix

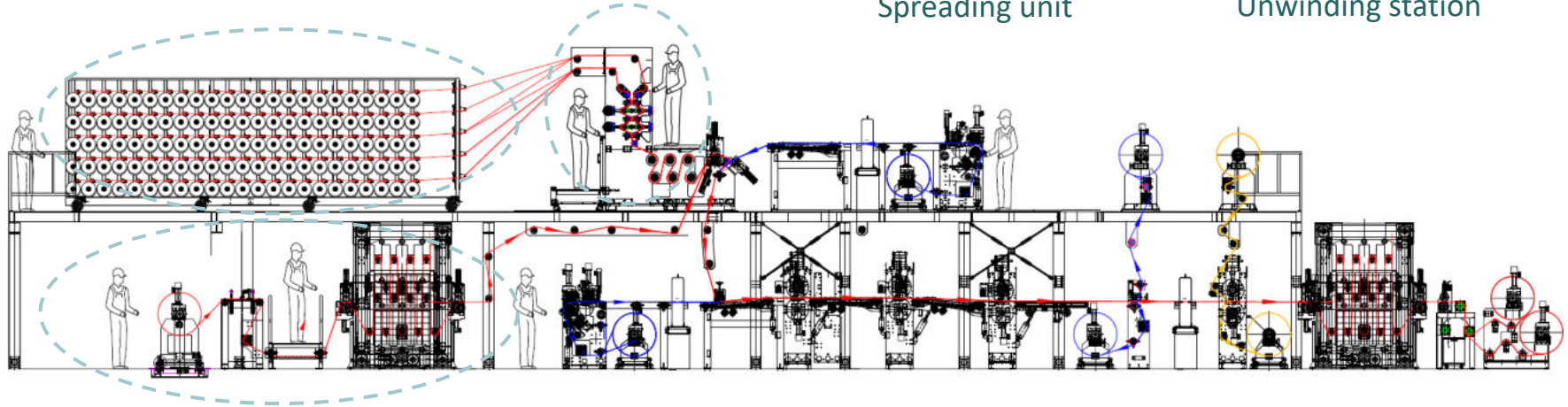
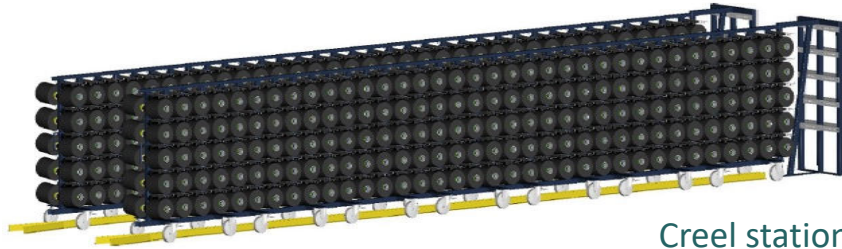




# Indirect coating prepreg line



# Technology background – layout for thermosetting production line



# Technology background – layout for thermosetting production line



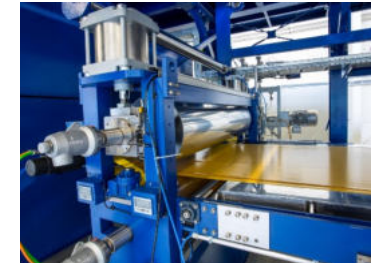
Coating system 1



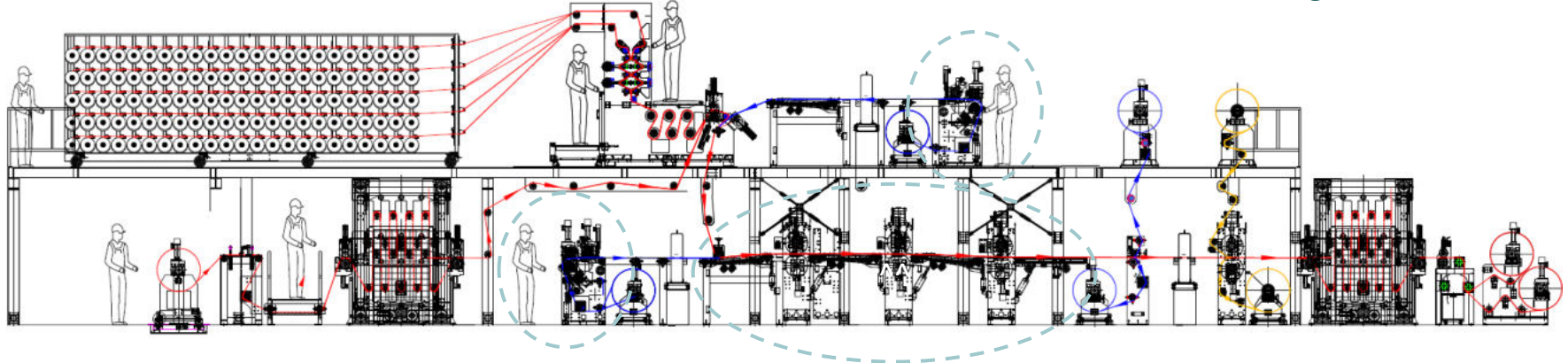
Coating system 2



Hot calender



Heating table



# Technology background – layout for thermosetting production line



De-lamination + Lamination station



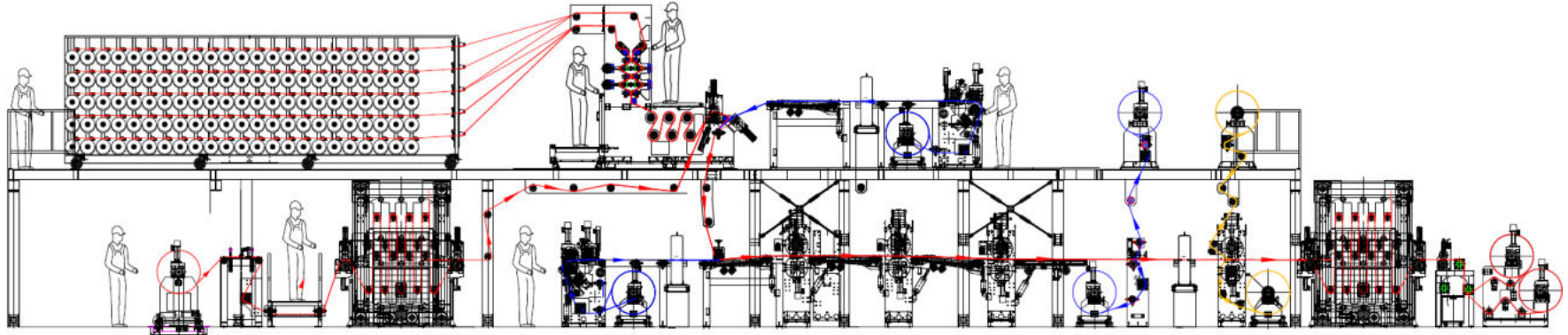
Winding-station



Cutting device

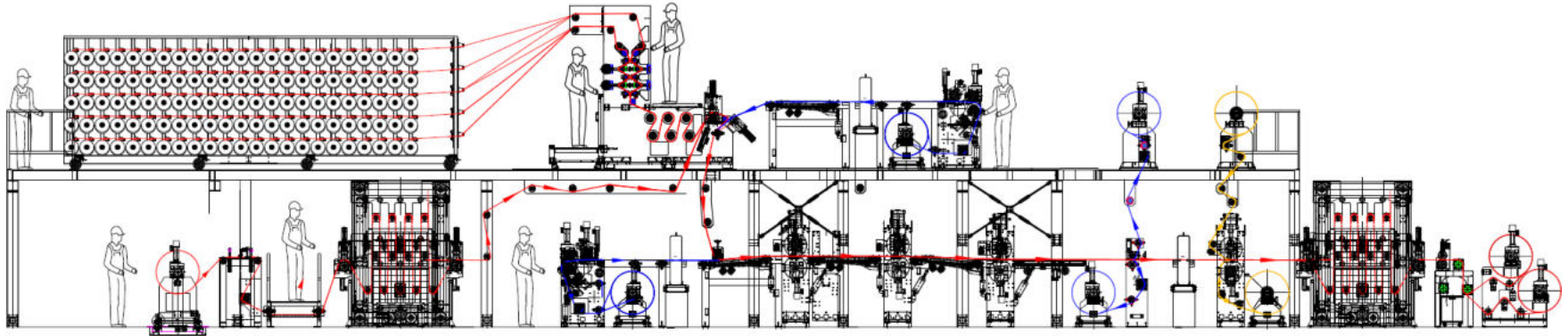


Rewinding station

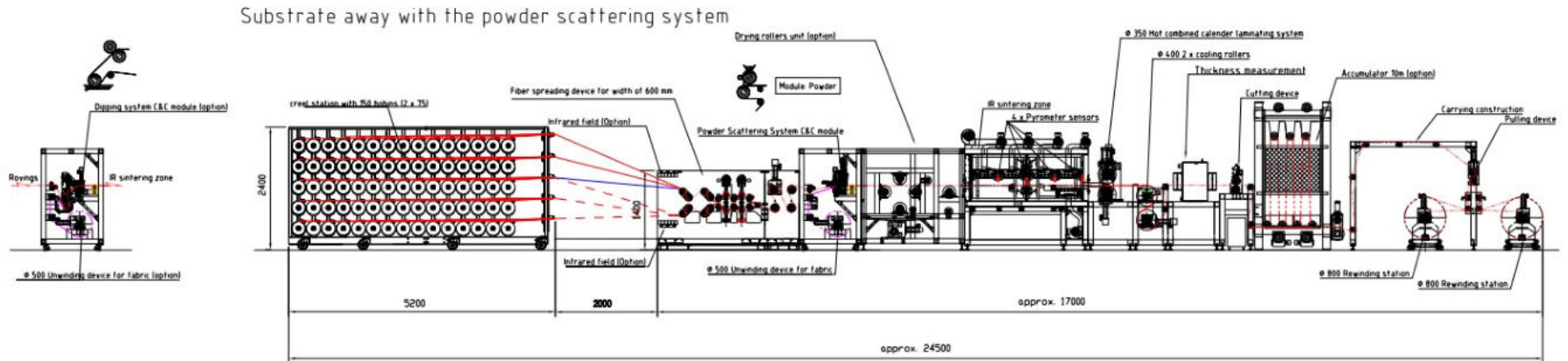


# Thermosetting technology

1. Spreading of fibre
- 2. Coating the resin**
  - a) Thermosetting (duroplastic) resins
  - b) Thermoplastic resins
3. Impregnation into the matrix

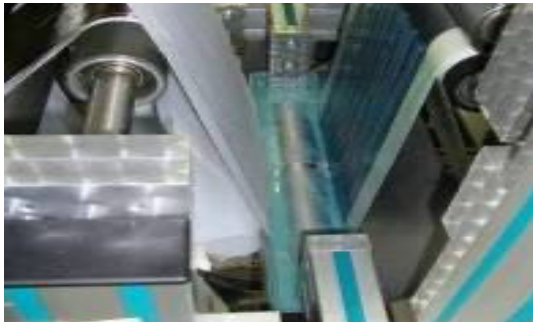


# Production line layouts – thermoplastic process



Wed direction

## Dipping / Foulard



### Variation of the impregnation weight

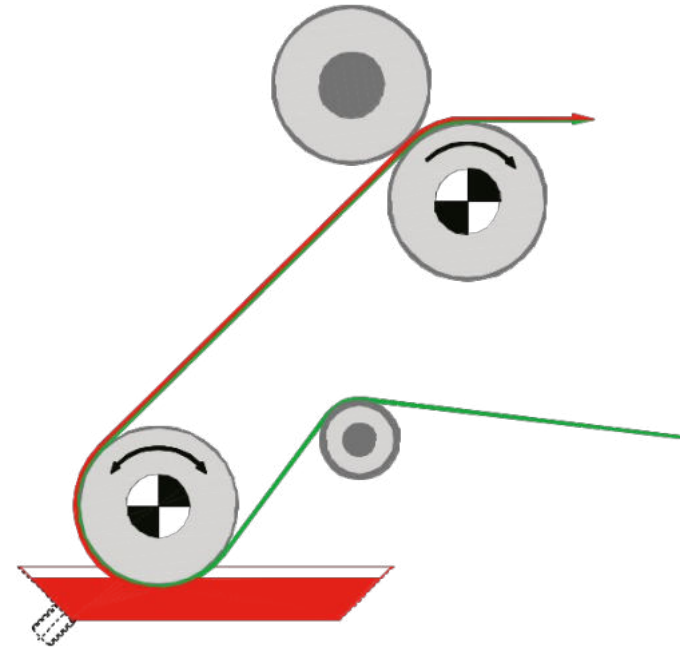
- ✓ Depending on the fabric / UD tape

### Range of Viscosity

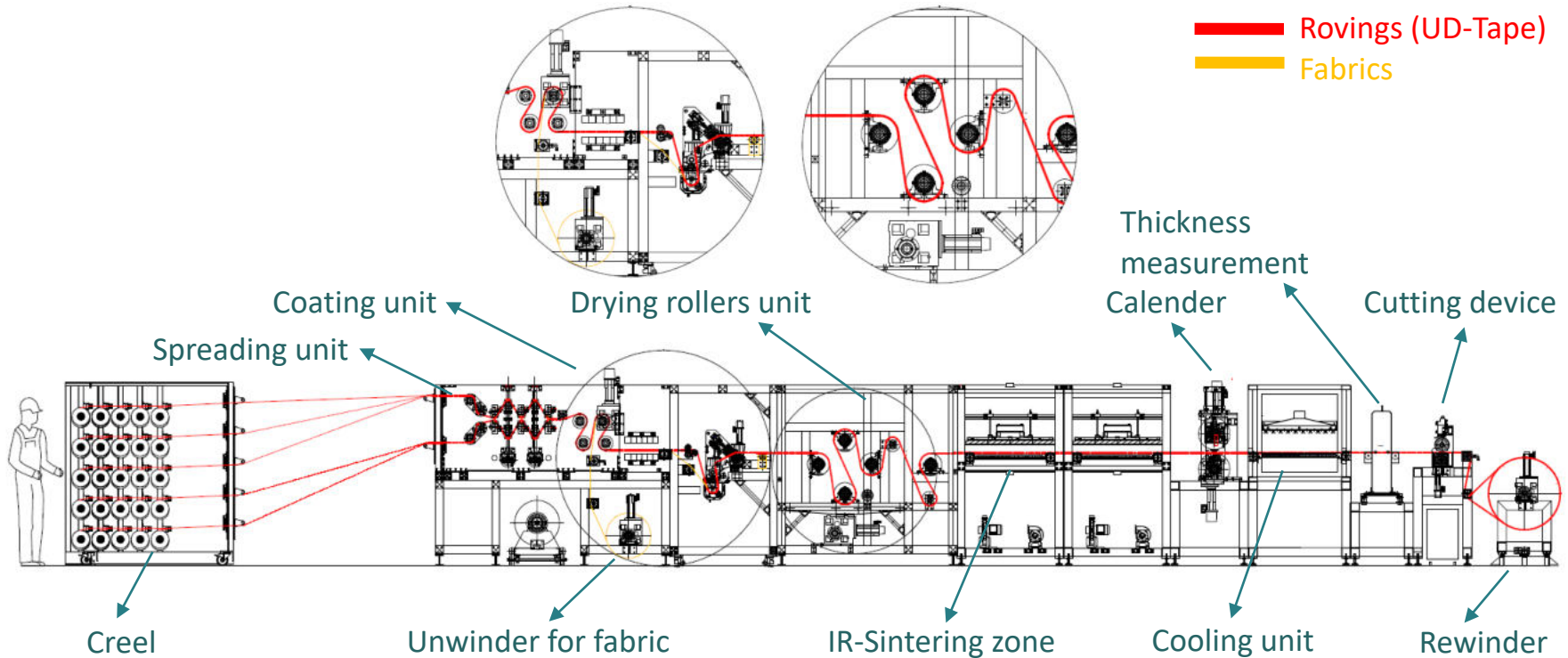
- ✓ 100 – 10 000 mPas

### Temperature range

- ✓ RT – 250°C

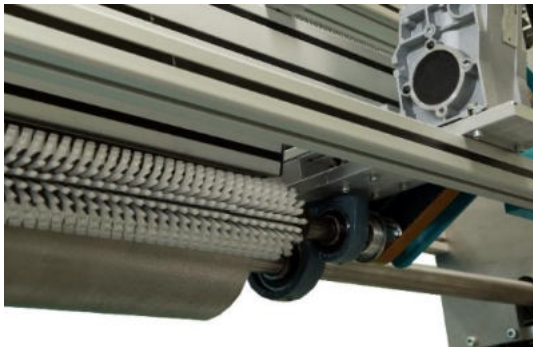


# Dipping / Foulard prepreg line



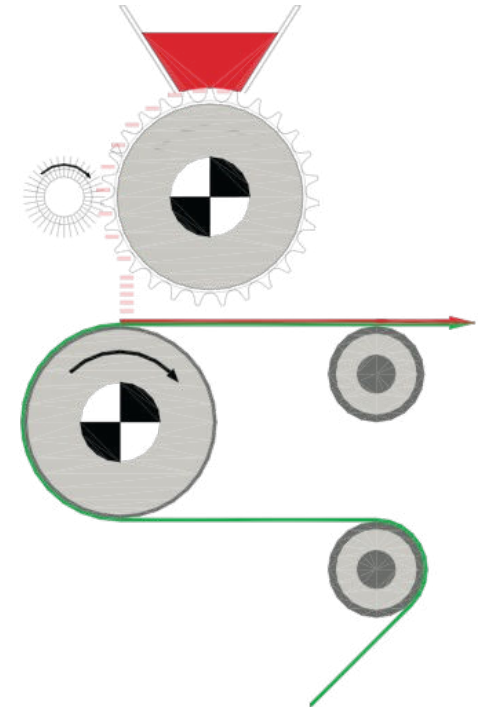


## Powder Scattering

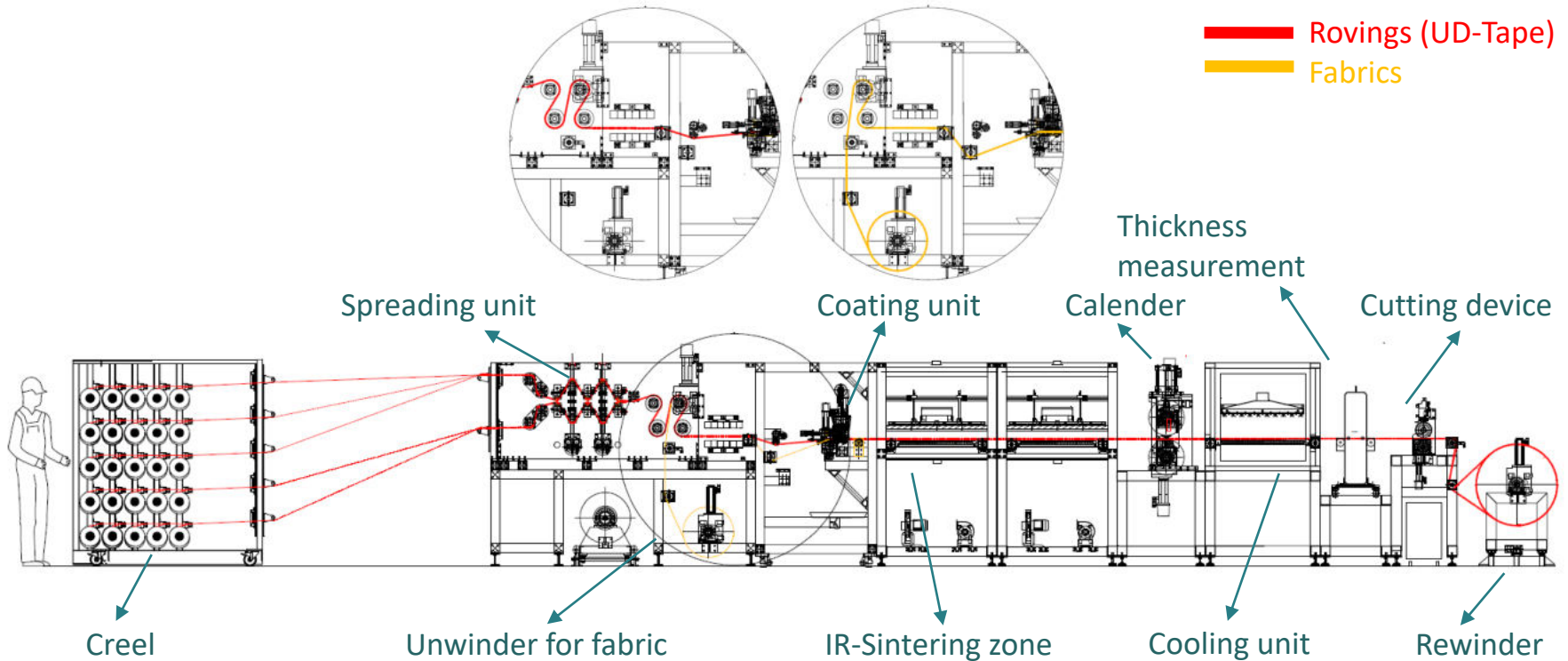


Variation of the  
impregnation weight

✓ 10 – 300 g/m<sup>2</sup>



# Powder scattering prepreg line



## Hotmelt / Extrusion



### Variation of the impregnation weight

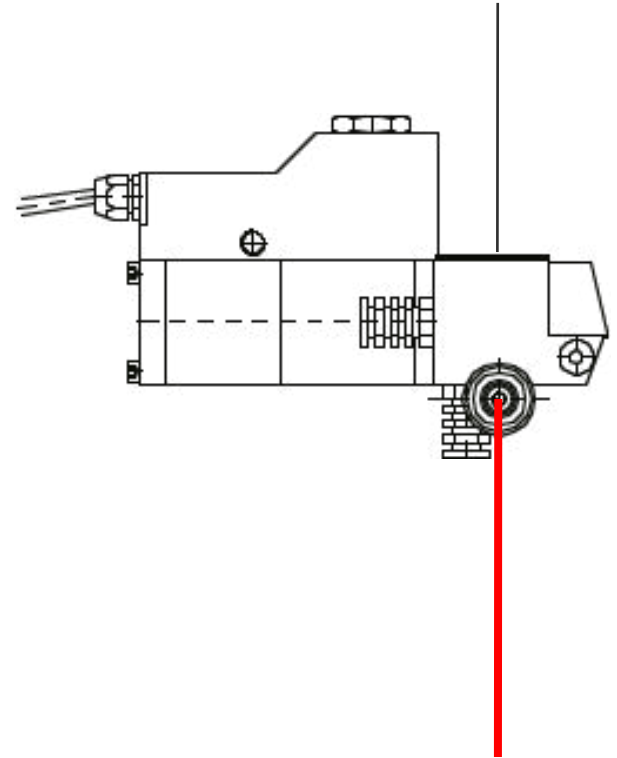
- ✓ Depending on the fabric / UD tape

### Range of Viscosity

- ✓ 100 – 10 000 mPas

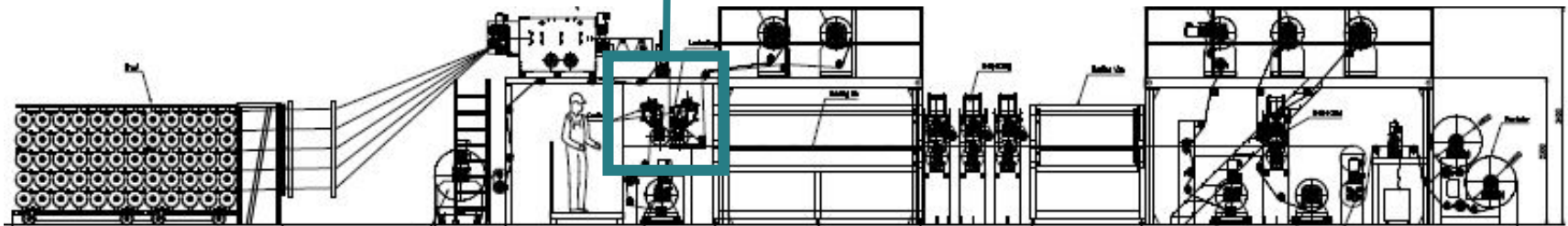
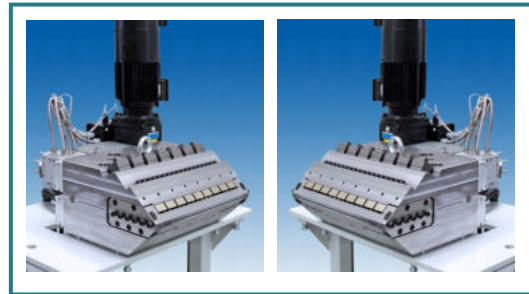
### Temperature range

- ✓ RT – 400°C



# Extrusion die / Hotmelt

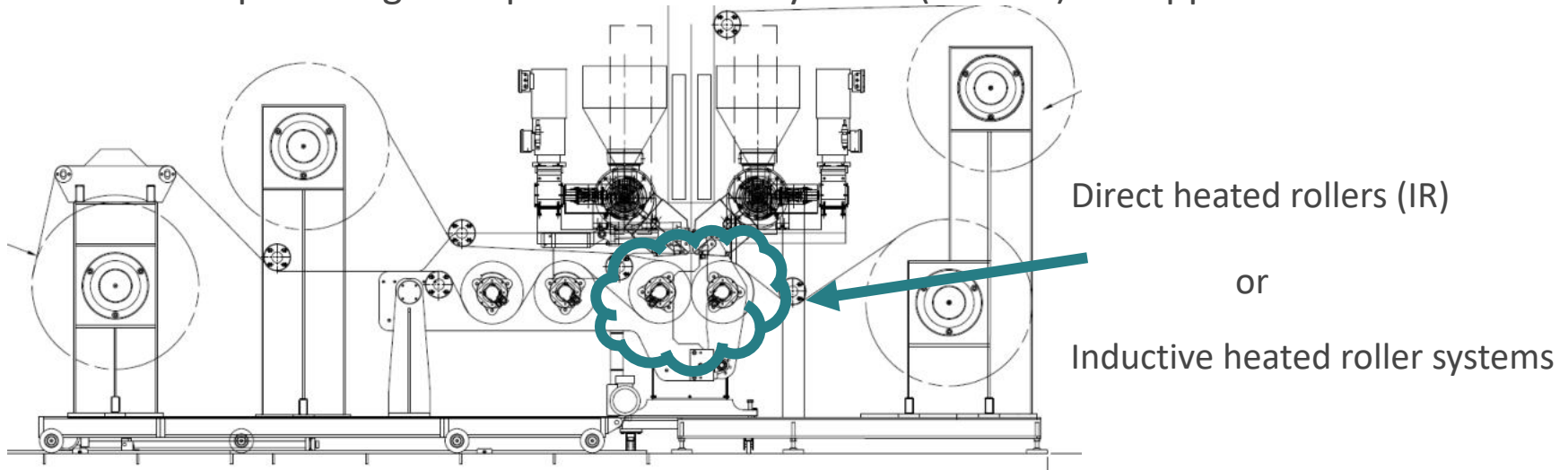
Double Side Extrusion of thermoplastic resins



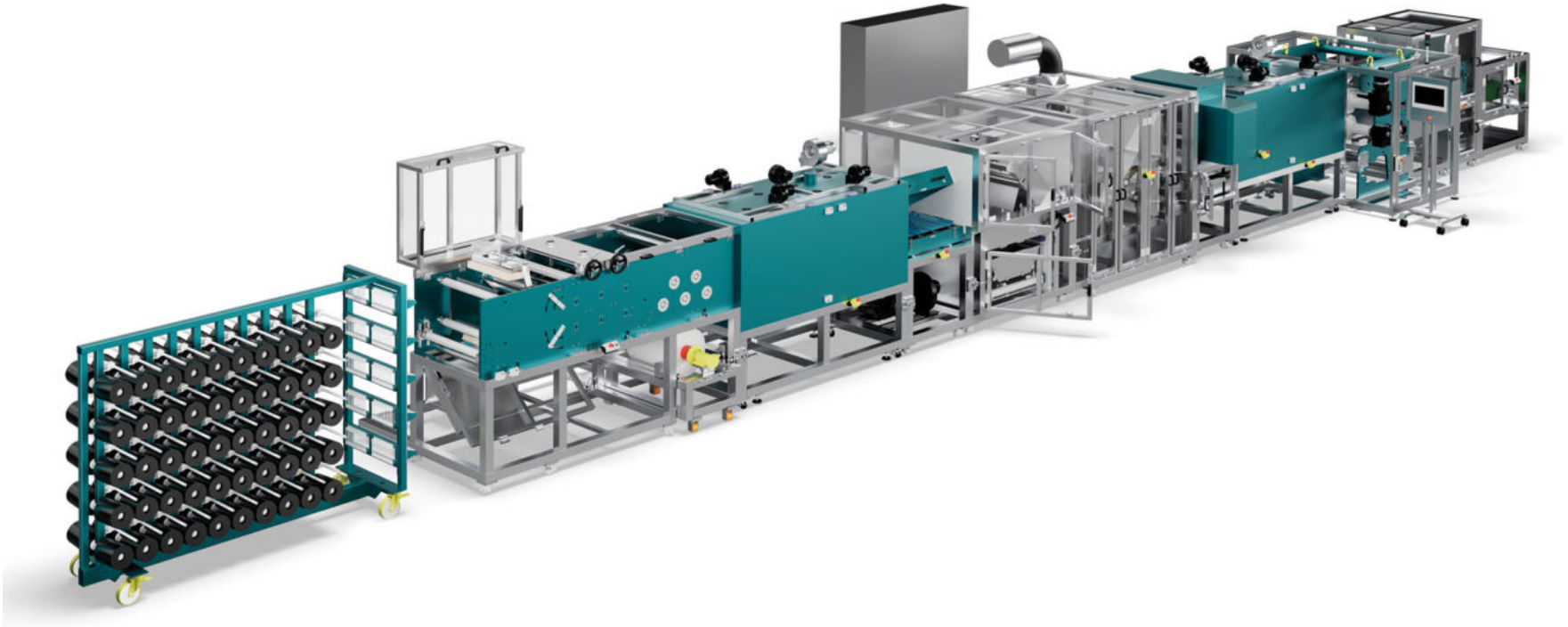
## Curing / High temperature systems

For the curing / impregnation process of high-tech polymers (PEEK, PEK, PTFE) temperatures from room temperature up to 400°C are needed

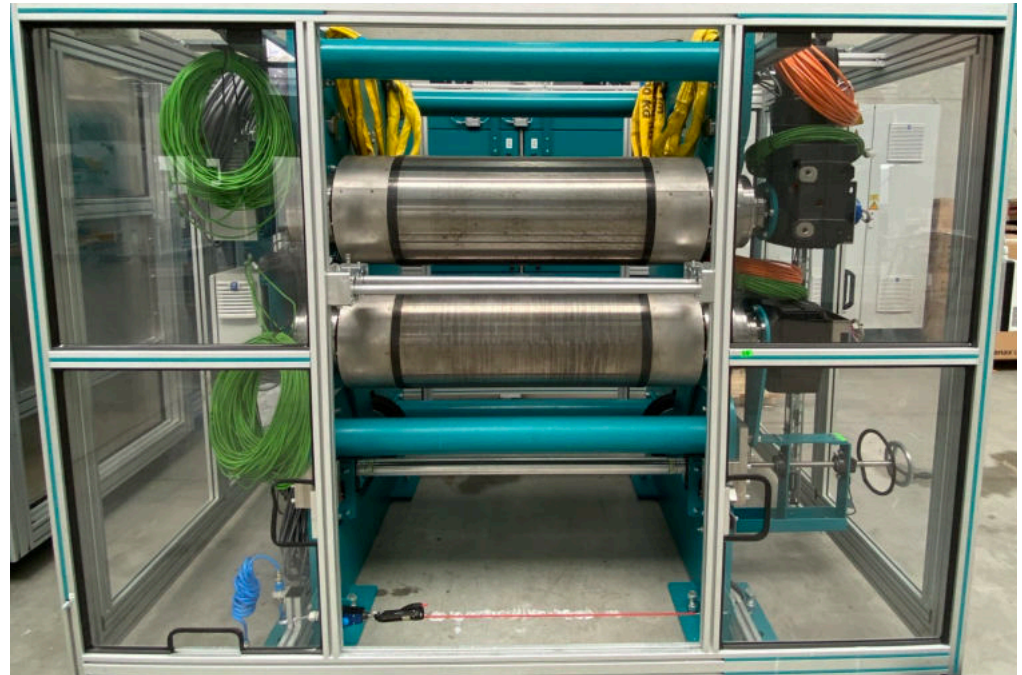
→ Therefore special high temperature roller systems (>300°C) are applied



# Click&Coat™ for Prepreg production



## Calendering production scale / High temperature layout – up to 450°C



# 6.

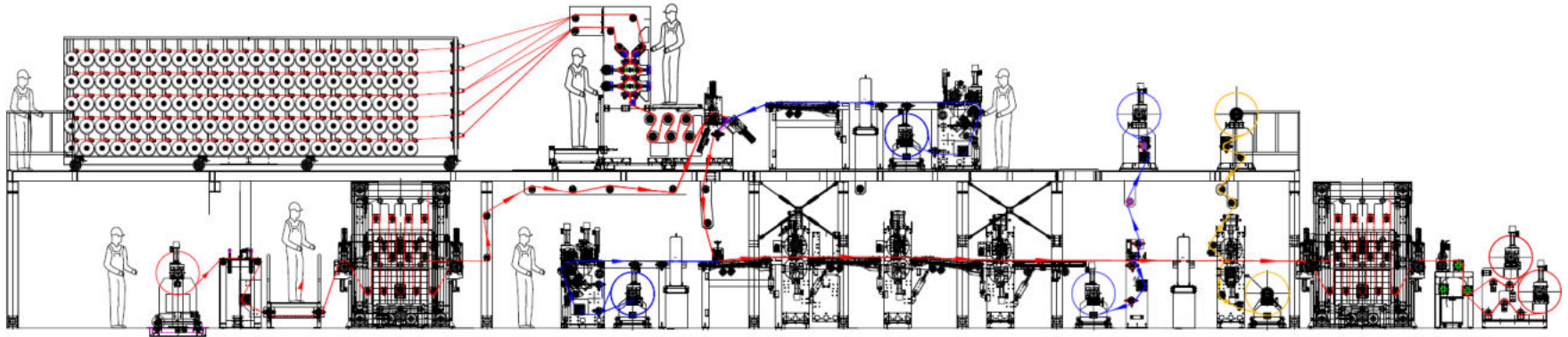
## Impregnation technologies



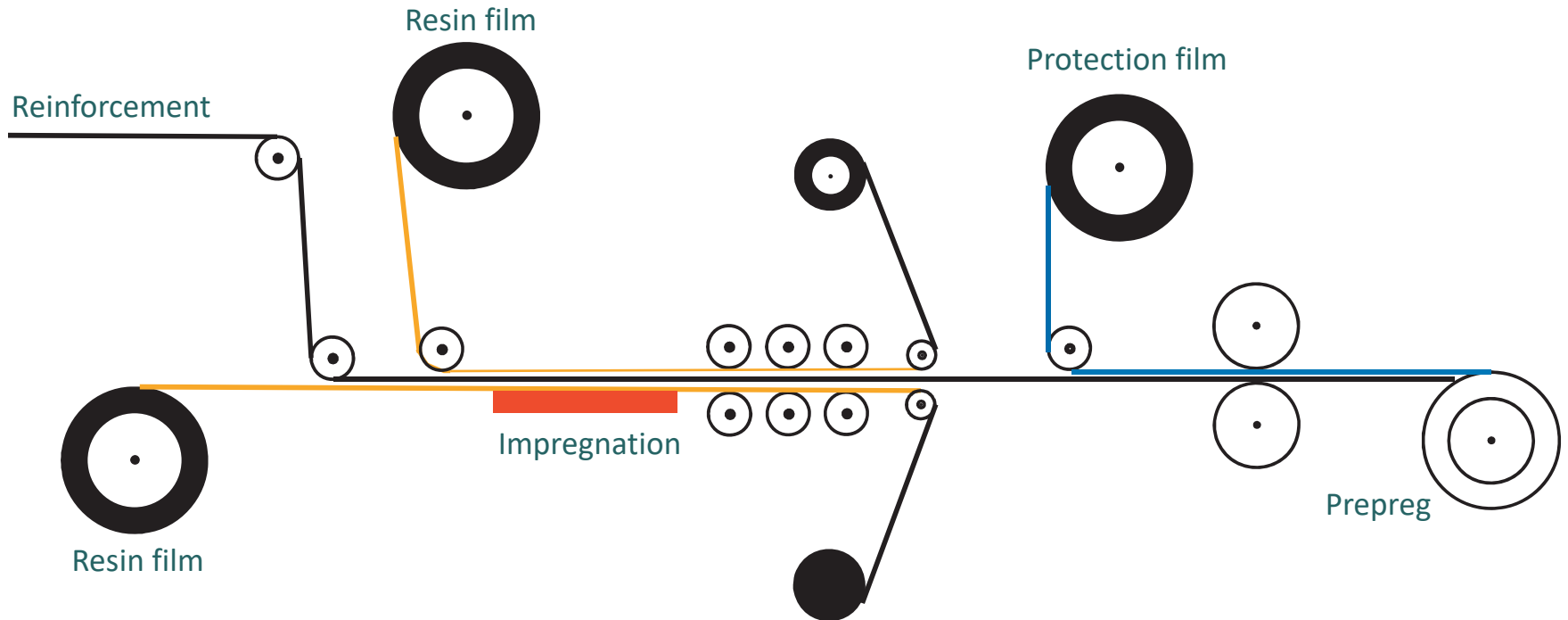


## Thermosetting technology

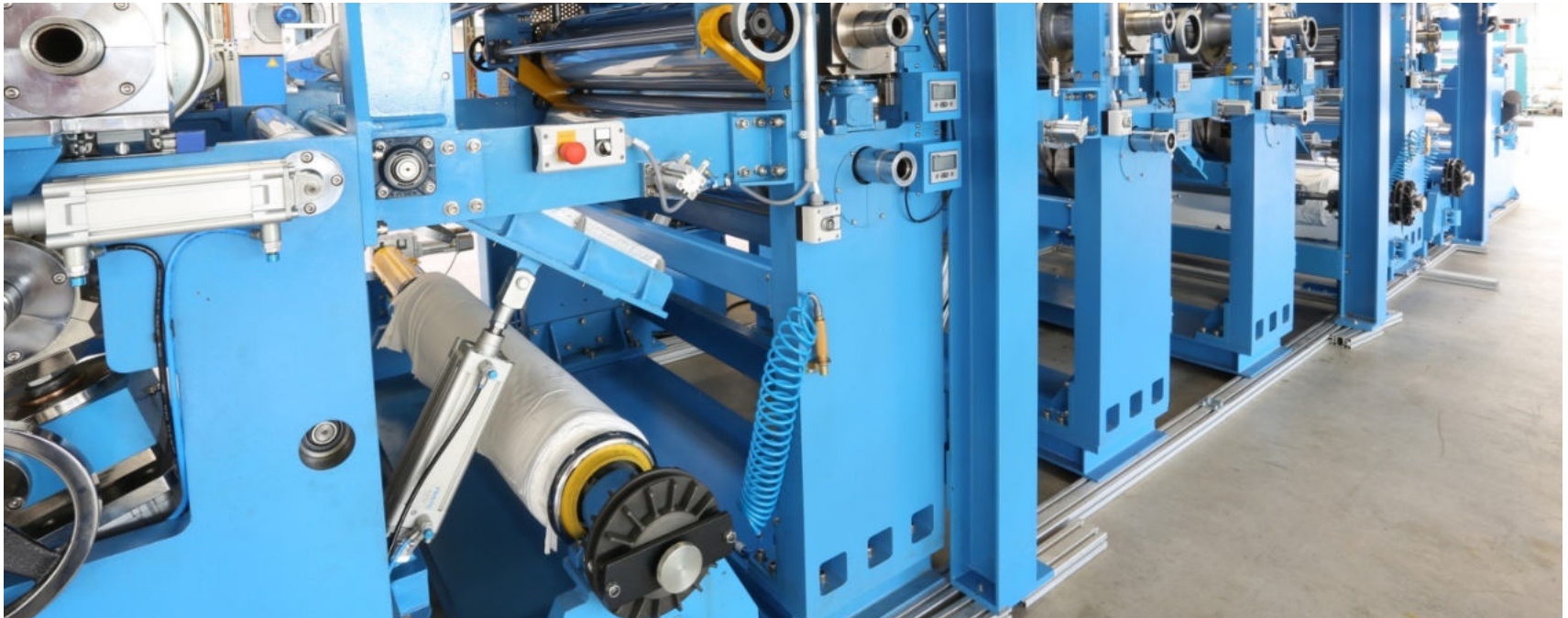
1. Spreading of fibre
2. Coating the resin
  - a) Thermosetting (duroplastic) resins
  - b) Thermoplastic resins
3. Impregnation into the matrix



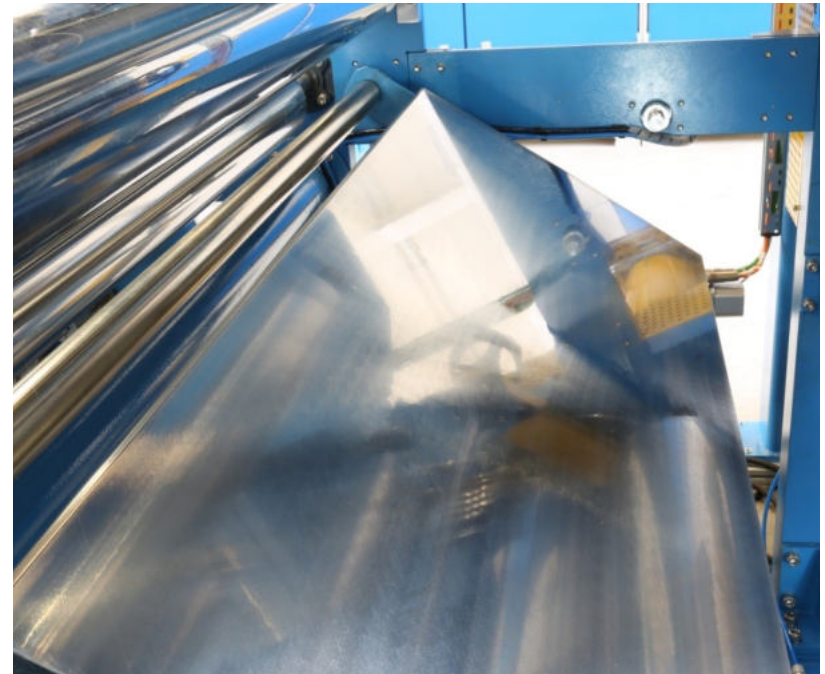
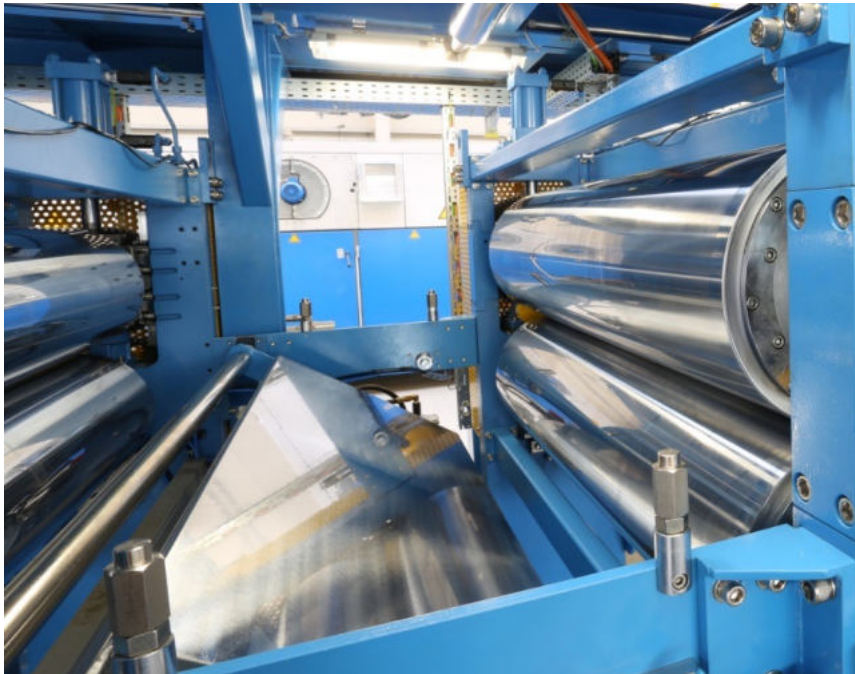
# Impregnation technologies



## Impregnation zone

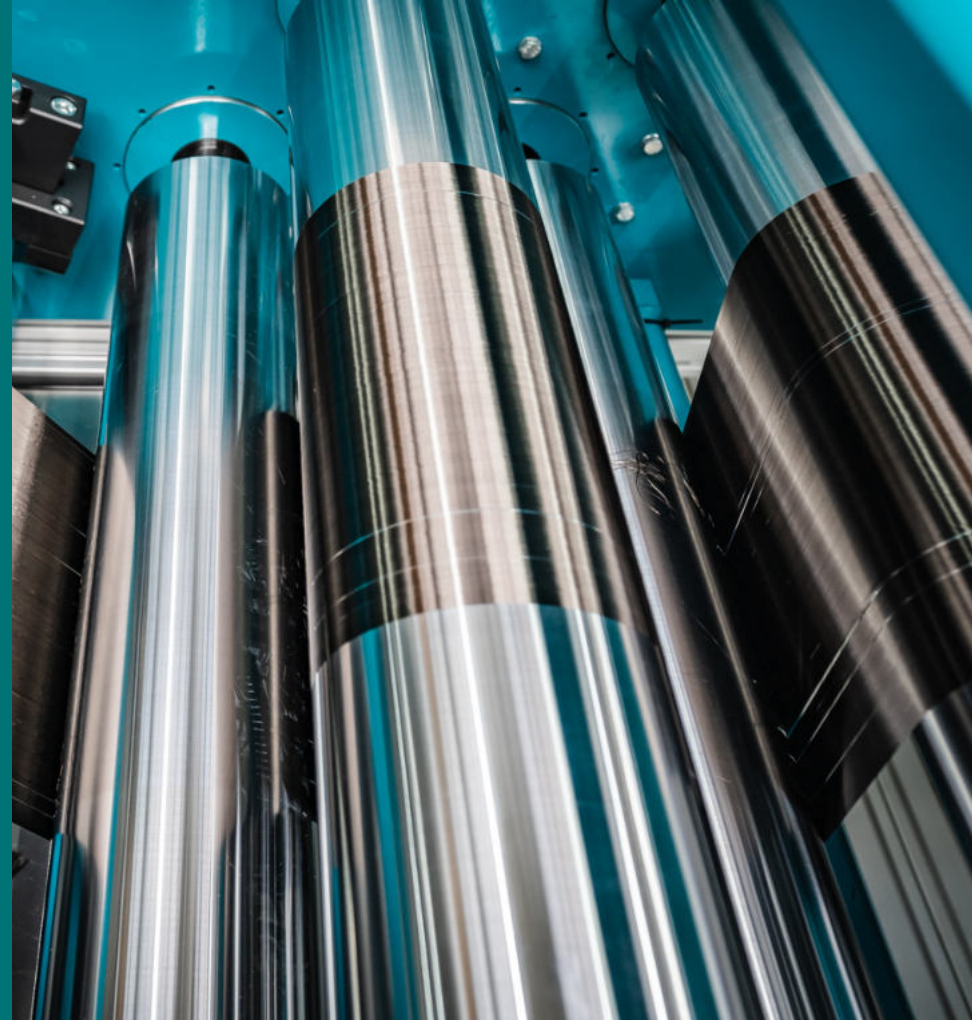


## High precise calender systems with heating table



# 7.

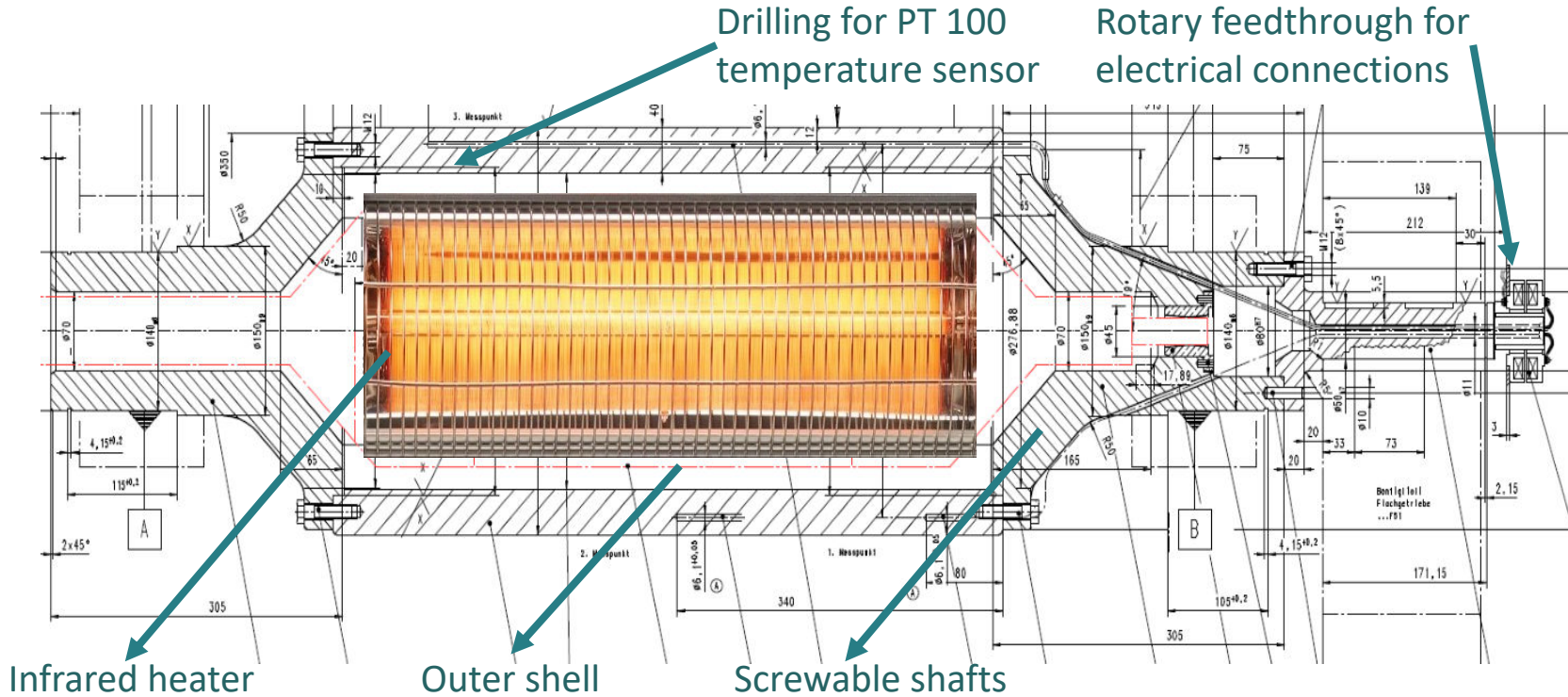
## Curing / High temperature systems



## Roll design parameters

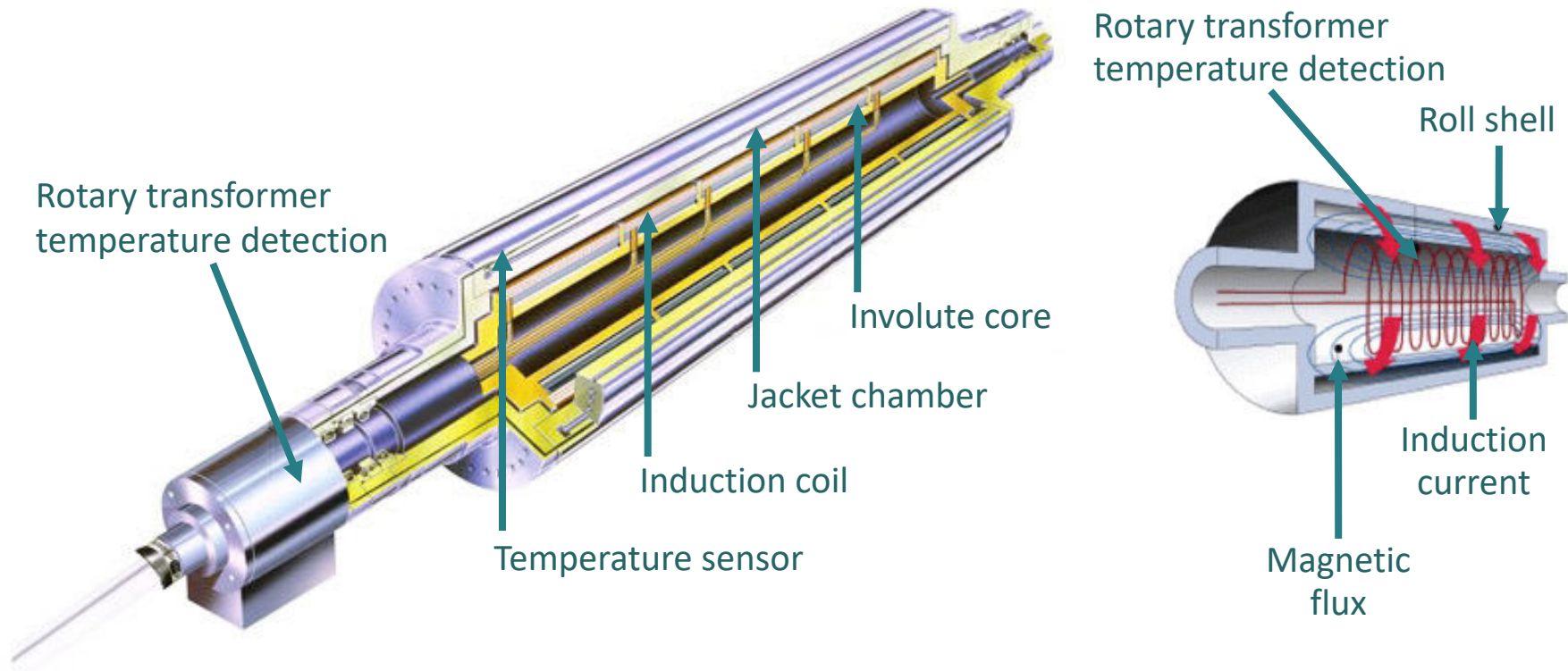
- ✓ Geometrical Dimensions
  - ✓ Diameter, surface width (WOB), journals
- ✓ Media
  - ✓ Type, flow amount, flow speed, pressure, temperature range
- ✓ Roll material for shell, journals and interior
  - ✓ Stainless steel, carbon steel, 42CrMo4 with hardened surface
- ✓ Tolerances
  - ✓ True running, cylindricity, surface roughness
- ✓ Surface coating
  - ✓ Chrome, teflon, ceramic, rubber, etc...

# Direct heated roller (IR)



Source: Wumag textroll

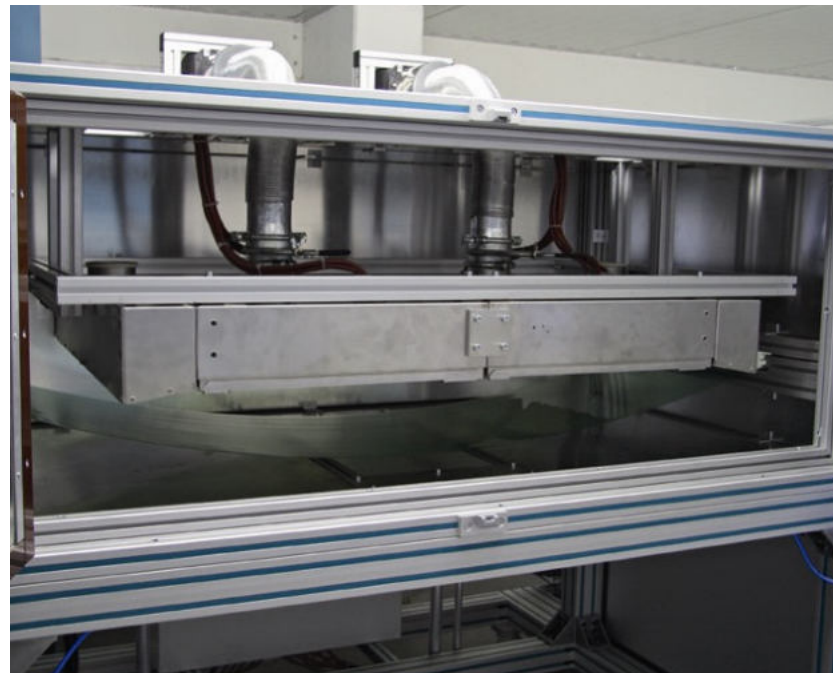
## Direct heated roller (IR)





Curing / High temperature systems

## Drying with IR technology

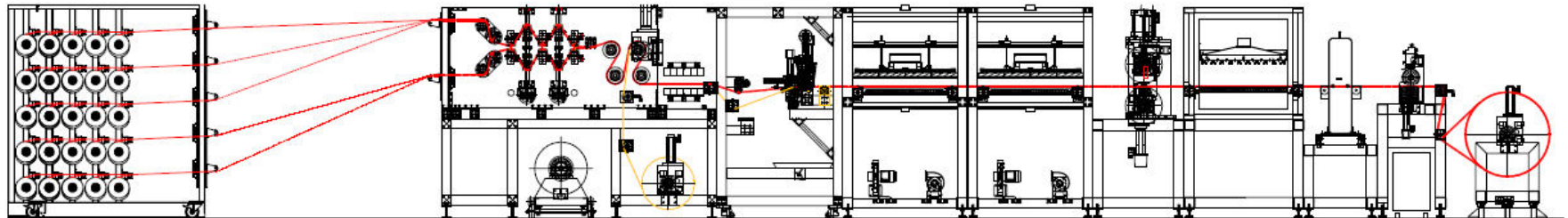


## Drying with IR technology



# Production line layouts – thermoplastic process

High precise calender systems with IR-sintering dryers



# 8.

## Pilot line layout



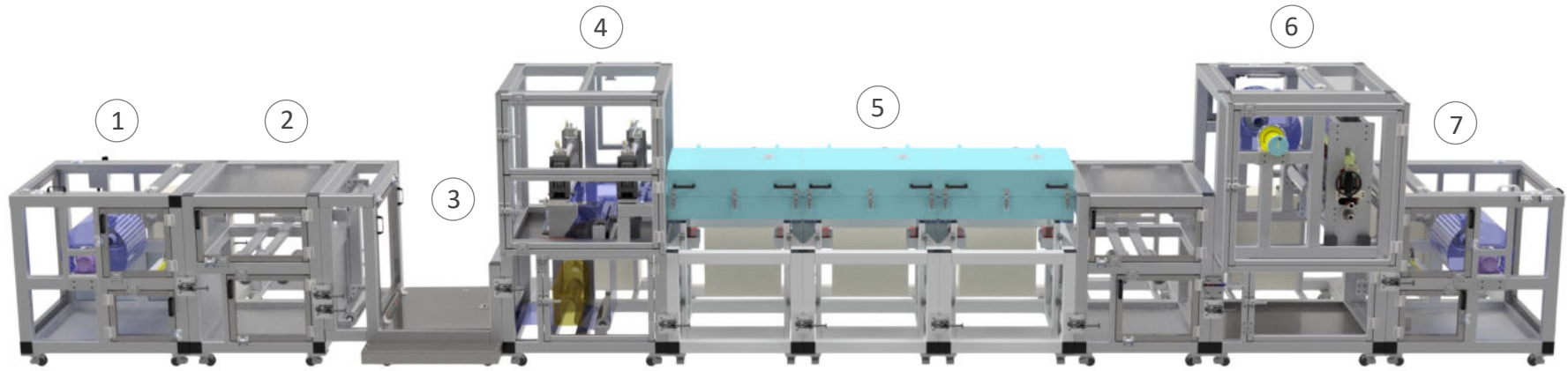
# All line layouts in Click&Coat™ design



- Here are a few benefits of the Click&Coat™ approach:
- ✓ Over 40 coating, printing and ancillary modules available
  - ✓ Award winning C&C design for connecting and aligning modules
  - ✓ Easy three – wire electrical connectors
  - ✓ Siemens S7 software solution
  - ✓ Fast set up time for new processes or increased through-put
  - ✓ Over 40 coating and printing systems for plug in and out
  - ✓ Patented C&C design for connecting the modules

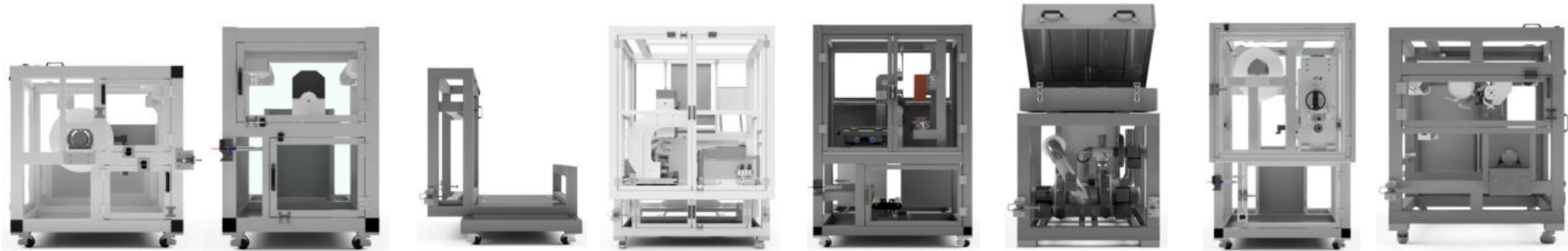
## Overview of product features & options for Click&Coat™

LAYOUT FEATURES (as shown in drawing above)						
1	Unwinder	4	Coating station	7	Laminating and rewinding	
2	Edge guiding system	5	Dryer			
3	Podestral	6	Edge guiding system			



Click&Coat™ R2R

# Click&Coat™ your own ideas



Winder

Corona

Podestral

Coating

Inkjet

Dryer

Laminator

Rewinder



Chemical treatment bath



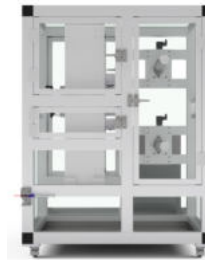
Inert Coating and laminating



Registration control



Turning device

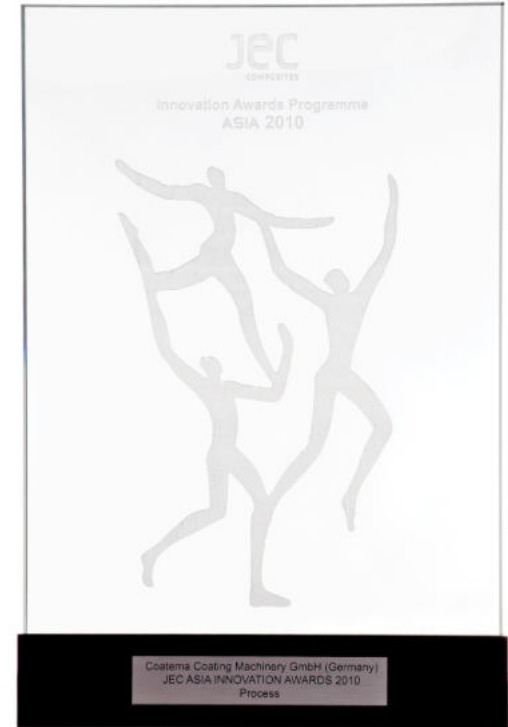


Lamination



Cutting

# Click&Coat™ for Prepreg production

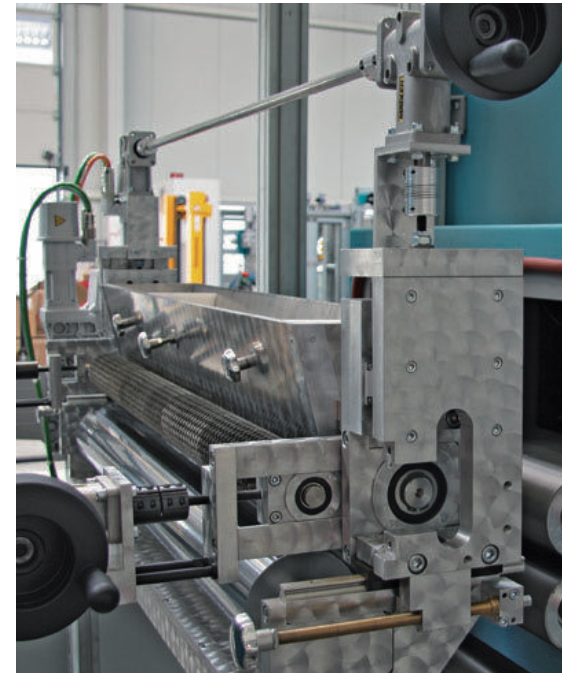
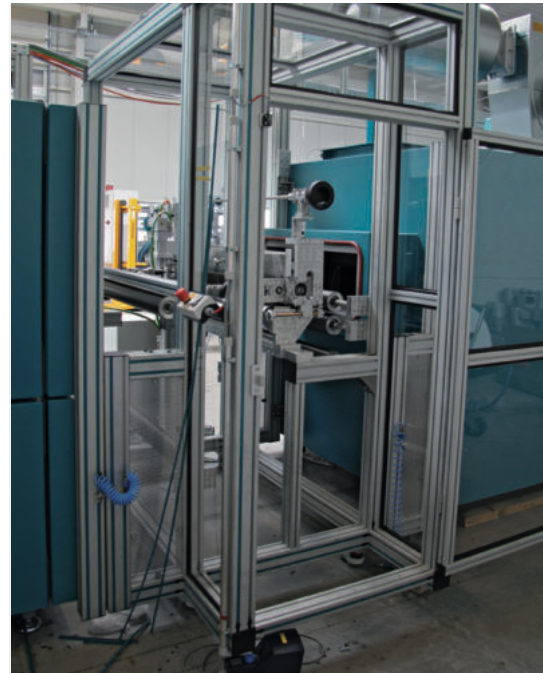




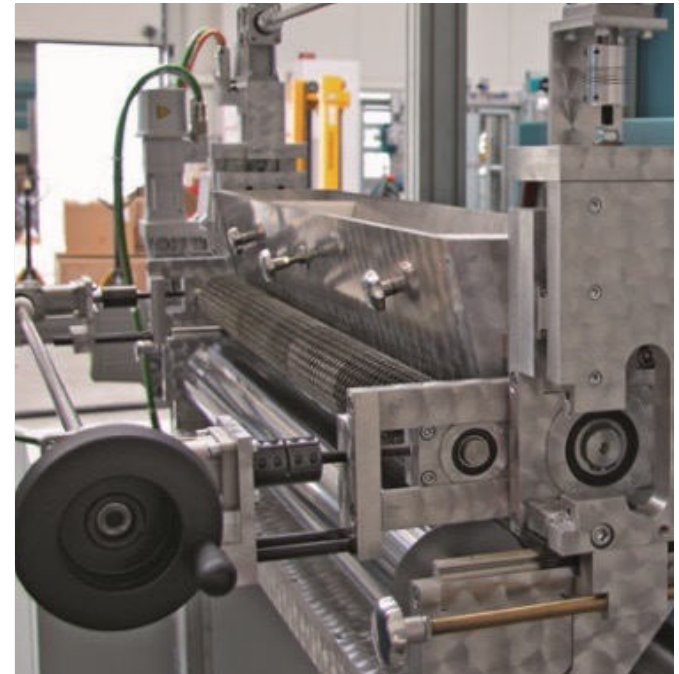
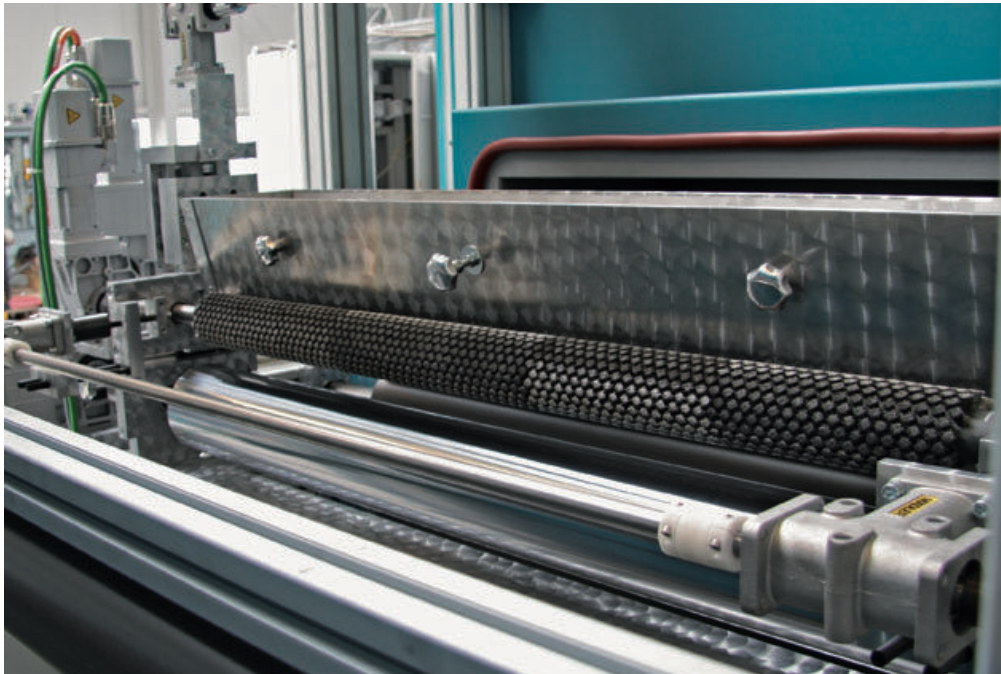
## Click&Coat™ for Prepreg production



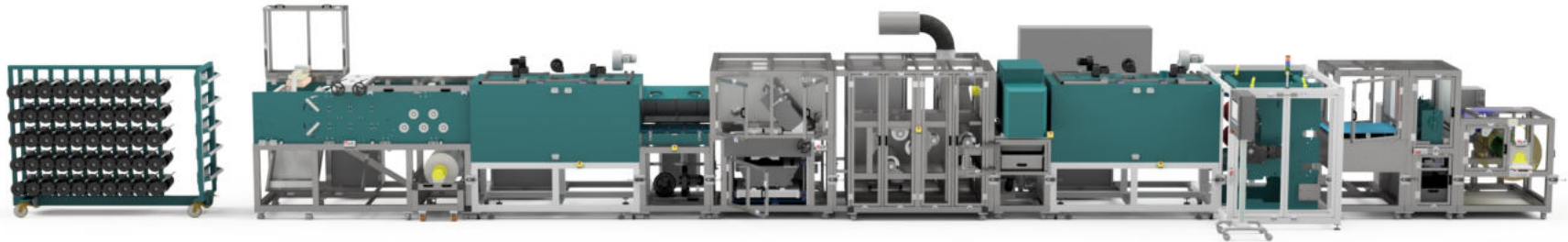
## Click&Coat™ for Prepreg production



## Click&Coat™ for Prepreg production



## Click&Coat™ for Prepreg production



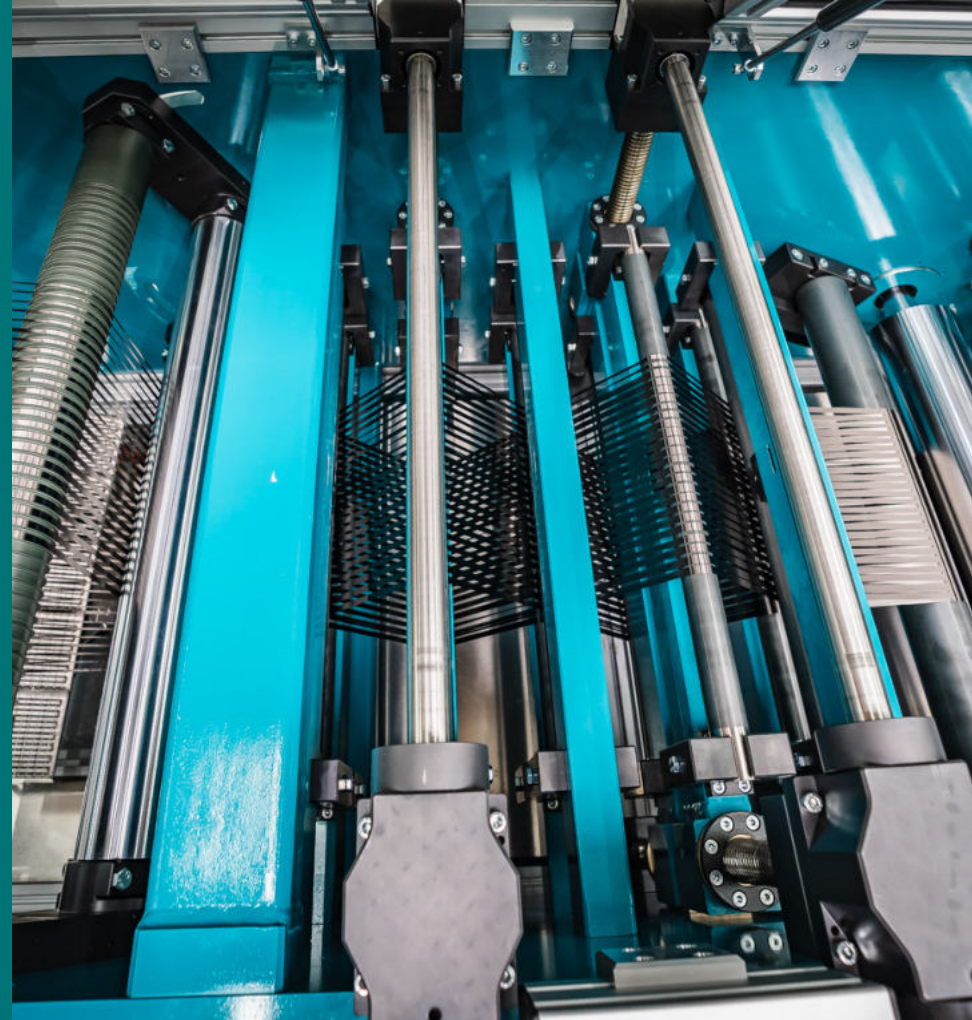
# Pilot line layout



Press Button to  
show the video

# 9.

## Proof of concept



Proof of concept

## Production line layouts – thermoplastic process



## Production line layouts – thermoplastic process





Proof of concept

## Production line layouts – thermoplastic process



Proof of concept

## Production line layouts – thermoplastic process



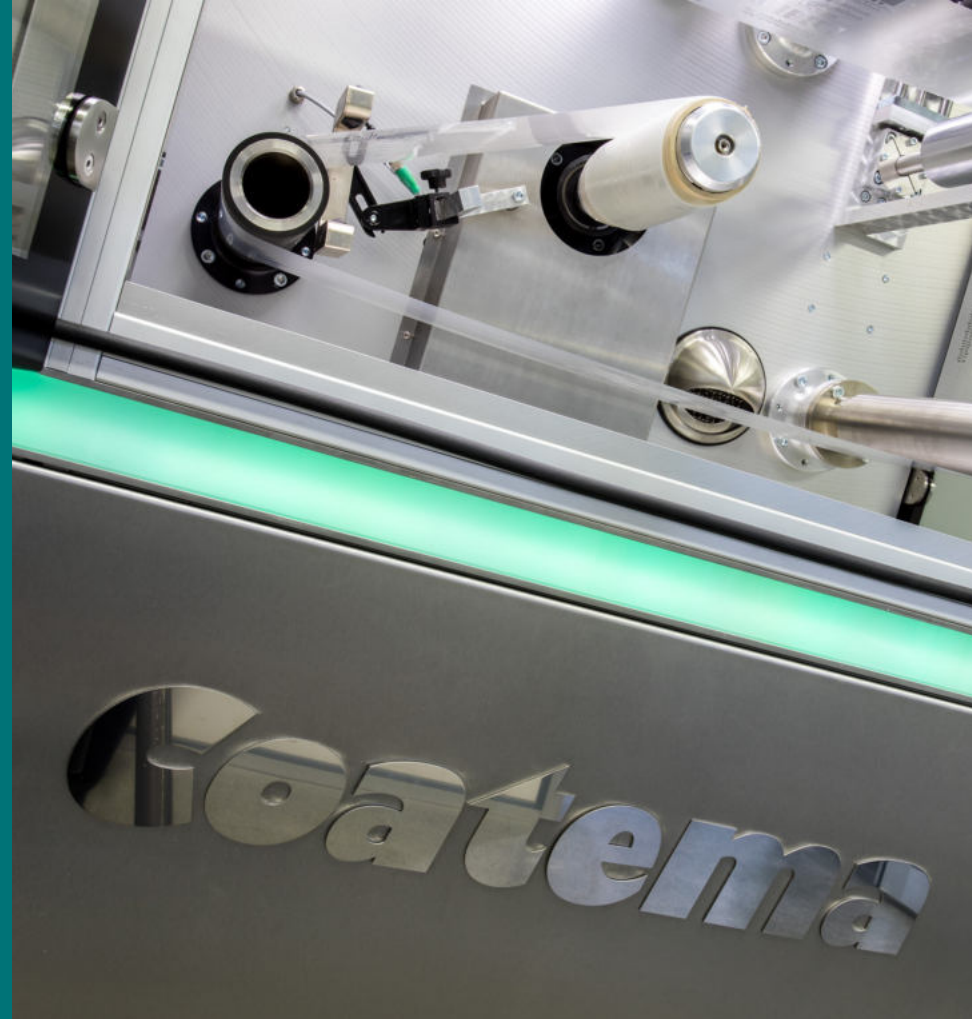
Proof of concept

## Production line layouts – thermoplastic process



# 10.

## Summary



## Bridging the gap

### Needed for success in prepreg processes:

- ✓ Pilotscale to Production scale product portfolio is key, Coatema is offering this.
- ✓ Reproducible results in every step of scale?
- ✓ Reality check if the approach is really scalable?
- ✓ Is the approach an approach for the real life production environment or is it rocket science?
- ✓ Are economies of scale reachable and when?
- ✓ High temperature thermoplastic prepregs are the future, development needed here.
- ✓ Coatema can demonstrate high temperature thermoplastic applications, ask us.

## Do not hesitate to contact us!



Anything missing?

Let us know and we will make it happen!

Our R&D centre is worldwide the most versatile centre for coating, printing and laminating.

Sales department:  
[sales@coatema.de](mailto:sales@coatema.de)

## Download brochures & presentations



# Coatema

## Thank you

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T +49 21 33 97 84 - 0 ▪ [info@coatema.de](mailto:info@coatema.de)

[www.coatema.com](http://www.coatema.com)

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