Session: High Performance Lignin

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Outline

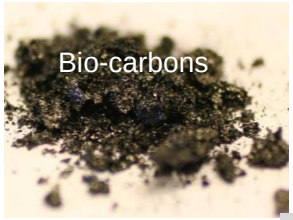
- Background
- R&D projects
- Test beds
- Lignin opportunities?

Background

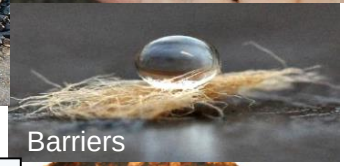
Opportunities for kraft lignin

Lignin

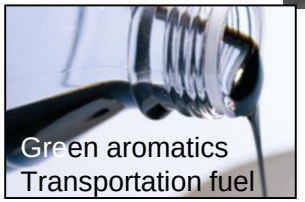
Lignin as carbon source/-structure



Bulk lignin (polymer)

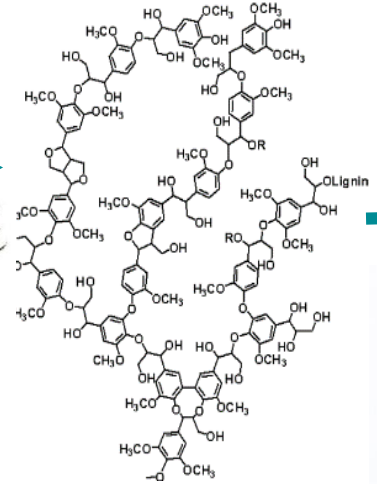


Depolymerised lignin



Lignin

– Biopolymer (20-30% in wood) with a high C content & high aromaticity



Different Lignins

Kraft lignin

Organosolv lignin

Different Technical Lignins

Different Applications

- Chemicals
- Materials
- Energy

Lignosulfonate lignin

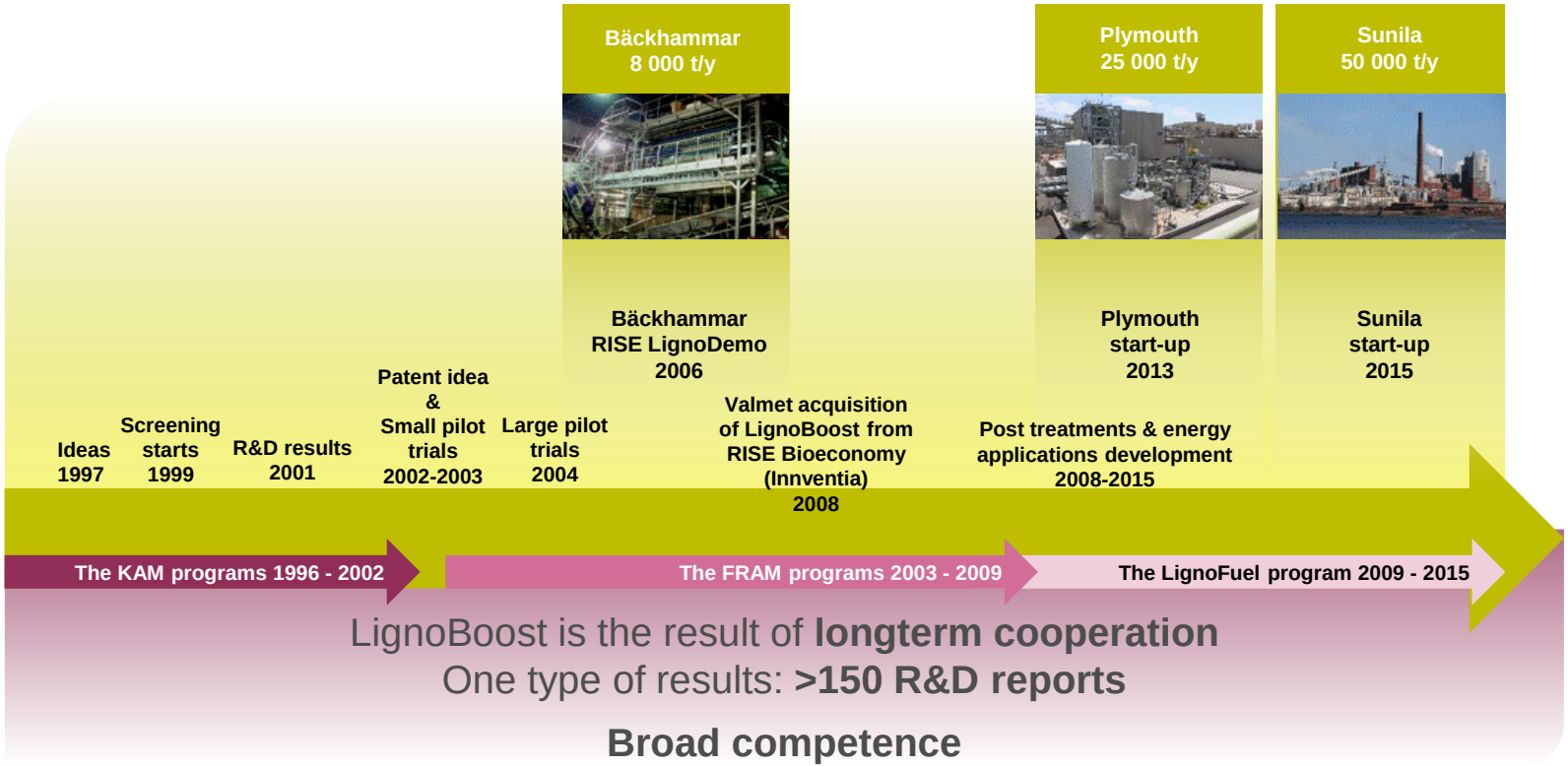
Soda lignin

+ "Lignin" from future

Different processes will result in ”lignin” with different properties

Many organisations work on valorization of different ”lignins”

Our main platform – the development of the LignoBoost process



LignoBoost is the result of **longterm cooperation**

One type of results: **>150 R&D reports**

Broad competence

R&D projects

Bioeconomy Research Program 2018-2020

38
COMPANIES

12
COUNTRIES

21
M€

INDUSTRIAL, INTERNATIONAL, INNOVATIVE AND INDEPENDENT

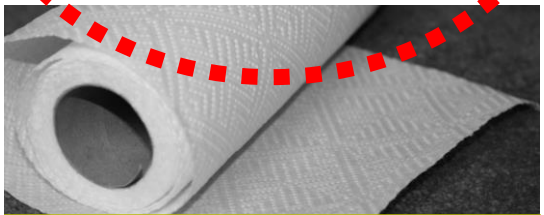
PROGRAMME AREA TOPICS

Pulp & cellulose

Lignin

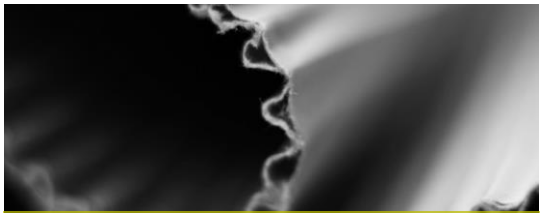
Nanocellulose

Papermaking



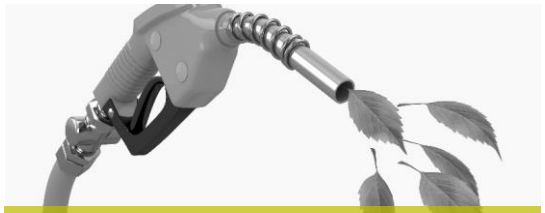
Tissue

Packaging



Corrugated board

Bioplastics & barriers



Bioenergy, fuels & chemicals

Invitation to our Research Program 2018-2020

Area: Lignin refining for high value applications (12 companies)

Pre-competitive research (PCR)

- Separation concepts
- Industrial lignin characterization
- Modification of lignin by Green Chemistry
- Electrospun carbon fibers
- Outlook – “The lignin world”

Application-oriented research (AOR)

- Resins
- Coatings
- Bilateral projects

<u>Related projects:</u>

- Carbon fibres (GreenLight)
- Bio-based electronics
- Etc, etc….

Other Research Areas/Projects

- **Carbon fibres, Carbon nano fibres, Carbon powder**

Melt spinning 100 filaments & winding of 100% SW lignin (no additives)

Source: GreenLight

Other Research Areas/Projects

- **Thermoplastics**

Early extrusion trial of modified lignin & polymers

List of polymer blends with a specific modification of kraft lignin (early trials):

Polymer	Renol content	Polymer content	Injection moulding
LDPE	0%	100%	Ok
	10%	90%	Ok
	40%	60%	Mostly ok, some specimens broke
PP (Inspire 114 EU)	0%	100%	Ok
	10%	90%	Ok
	40%	60%	Too weak, all specimens broke
PP (Inspire 215)	0%	100%	Ok
	10%	90%	Ok
	40%	60%	Too weak, all specimens broke
PLA	0%	100%	Ok
	10%	90%	Ok
	40%	60%	Ok
ABS	0%	100%	Ok
	10%	90%	Ok
	40%	60%	Ok
PBAT	0%	100%	Ok
	10%	90%	Ok
	40%	60%	Too soft, specimens deformed
PBS	0%	100%	Ok
	10%	90%	Ok
	25%	75%	Not attempted
	40%	60%	Too soft, specimens deformed
	50%	50%	Not attempted
	65%	35%	Not attempted
	75%	25%	Not attempted

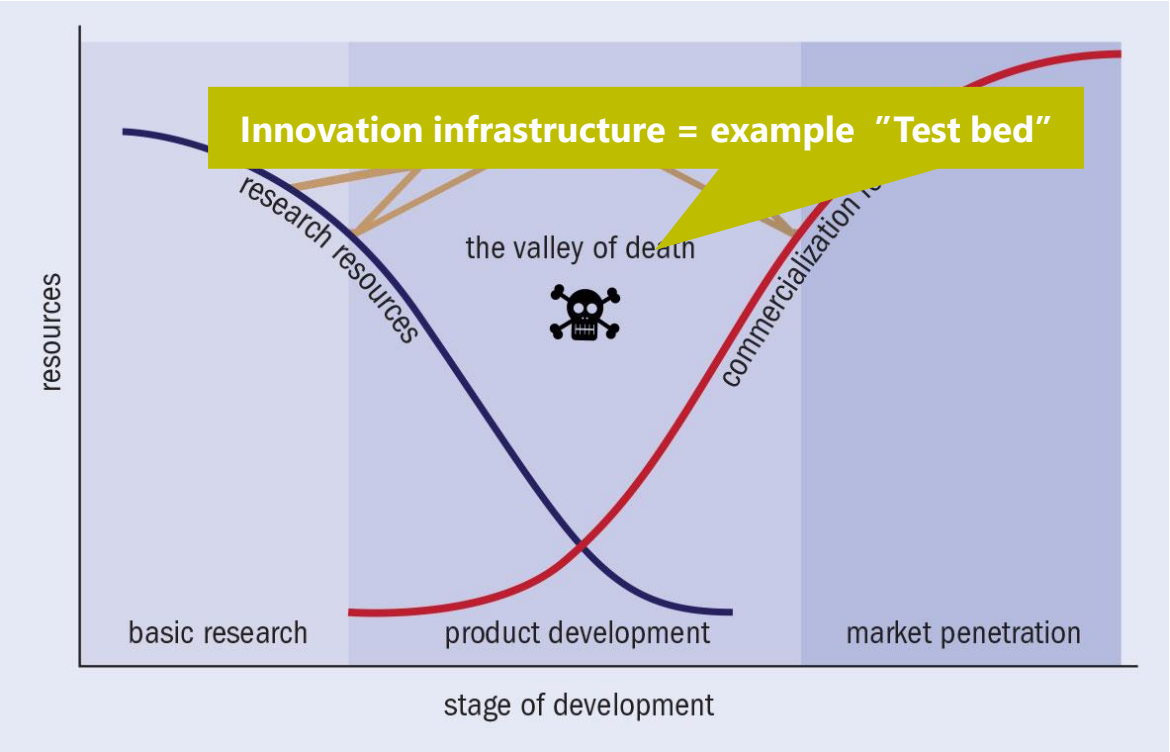
Extrusion equipment

Other Research Areas/Projects

- **Transportation fuels**

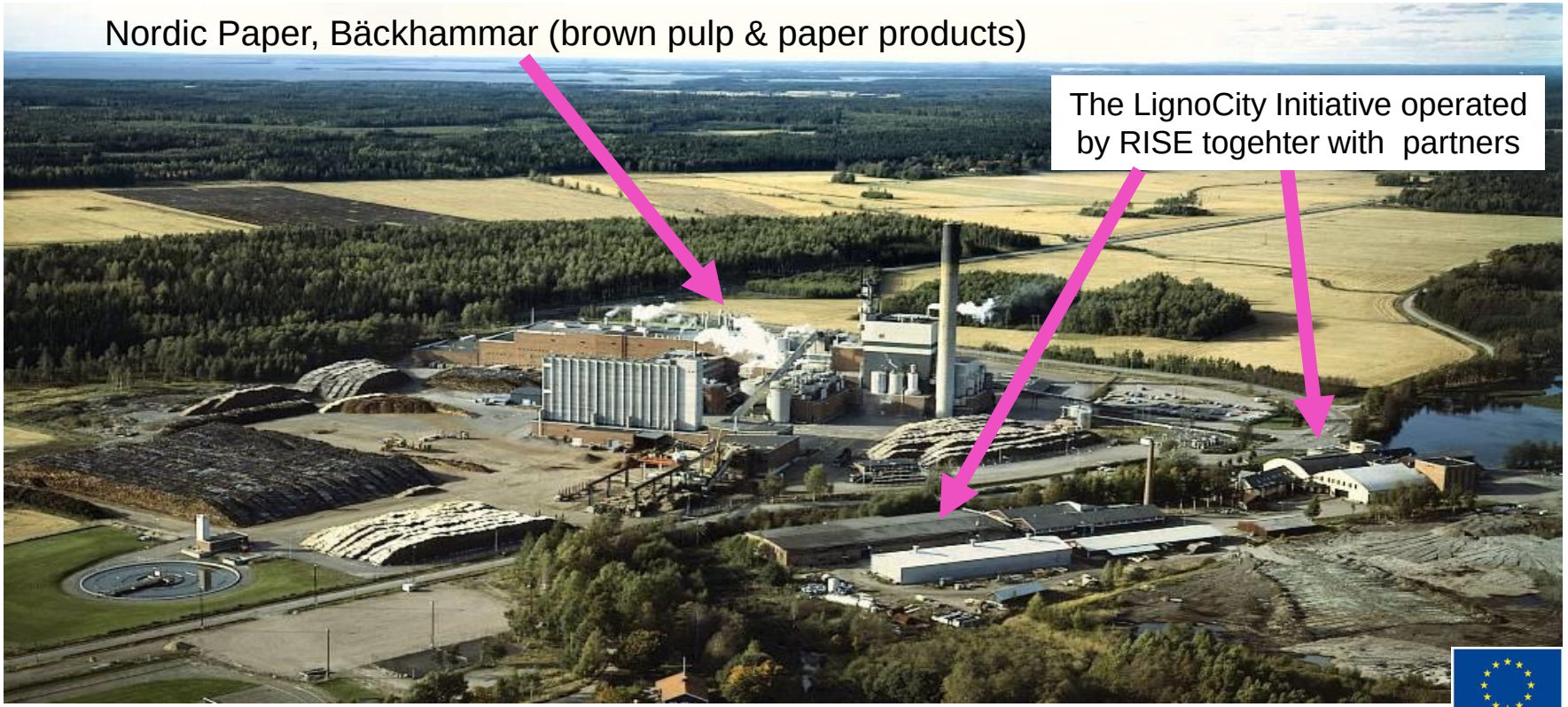
Test beds

Faster from idea to market – ”Test beds”



- **A Test bed** is a critical link between research and the market intrioduction for example by:
  - Prototyping & tests
  - Up-scaling
  - Initial production
- **Test beds** can act as
  - Meeting place
  - Cross connection of sectors and needs
  - Cross connection between large companies and SME:s

The LignoCity-initiative – the core is RISE LignoDemo



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European Regional Development Fund

RI. SE

LignoCity in Kristinehamn & the Region of Värmland

We offer lignin expertise: specialists, tests, develop, verify, scale up & commercialization support. Work in the infrastructure if needed. Build your business concept with our support. We offer a our type of ”open innovation site”.

EUROPEAN UNION
European Regional
Development Fund

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We want LignoCity to result in:

- **faster** development from ideas to market and **to a lower cost**
- **new** SME companies & development of existing ones
- **opening** of value chains for lignin & contribute in creation of markets for lignin
- **a hub** for lignin valorization with focus on upscaling & commercialization
- **growth** in regional activities – labs, offices, equipment, people
- **active & successful work** by companies (incl. SMEs & start-ups) and universities **in** our infrastructure
- a very **effective & implemented commercialisation route** for bioeconomy investments

EUROPEAN UNION
European Regional Development Fund

Lignin Opportunities?

Renewable LineoTM by **Stora Enso** – A step towards the bio-based society

Maria Björk, Kari Nikunen, Mikko Savia, Toni Henriksson, Per Andersson

PAPTAC International Lignin Conference, 18-20 September 2018 (Edmonton, AB)

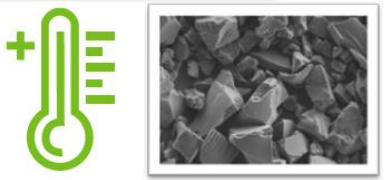
Lignin focus areas

Phenol replacement
Scope to replace 20-50% of phenol in phenolic resins used for plywood, LVL, OSB and laminates

UPM also active in the field!

Carbon fiber
Scope to use lignin and dissolving pulp for carbon fiber in automotive, transport and energy industries

Carbon materials
Scope to convert lignin to carbon materials suitable as activated carbons and for energy storage



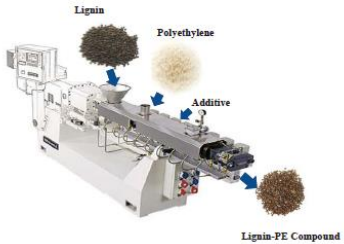
Domtar

OCTOBER 2017

LIGNIN REACTIVE EXTRUSION

- Reaction extrusion of lignin to simultaneously dry and agglomerate crude lignin into fused pellets and also to compound lignin with different thermoplastic polymers.

NRC's Twin-Screw Extruder
(Lab and Pilot Scale)



Domtar's Twin-Screw Extruder
(Demonstration/Commercial Scale)

FIELD TESTING OF LIGNIN-BASED Ag-FILM

- Lignin-based blown film is as good as conventional fossil-based agricultural mulch film in most aspects, and in some even shows superior performance.

In collaboration with University of Guelph

A successful demonstration of lignin substitution into thermoplastics. Cost competitive bio-composites for agricultural film application

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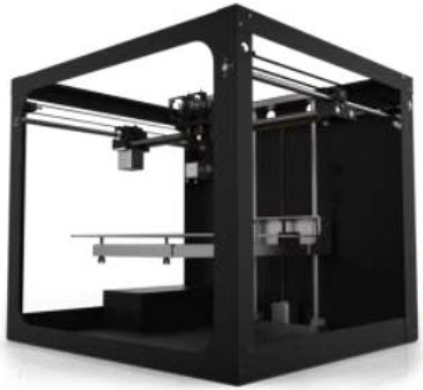
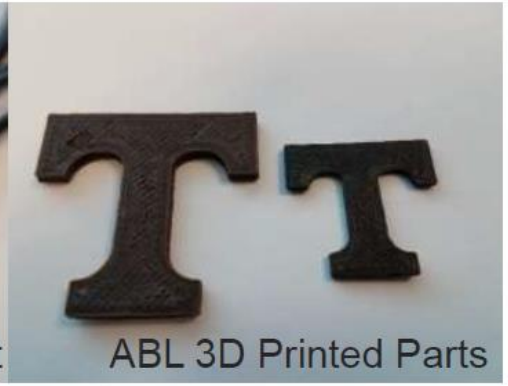
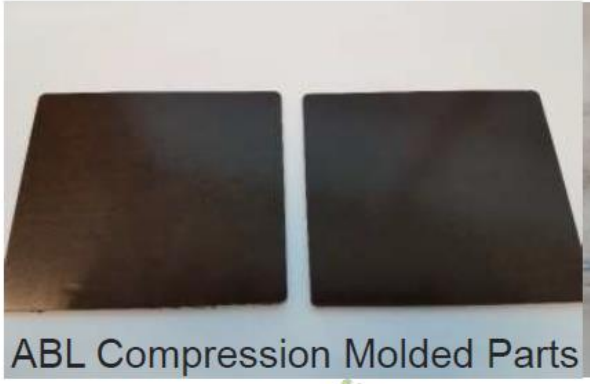
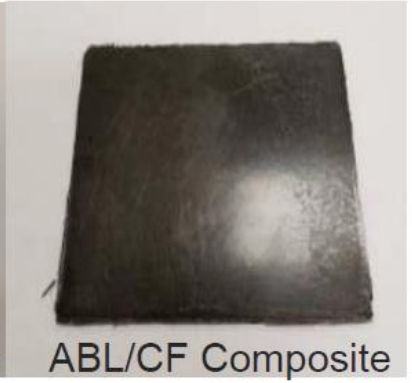
ABL Samples from Valmet Odor Free Lignin



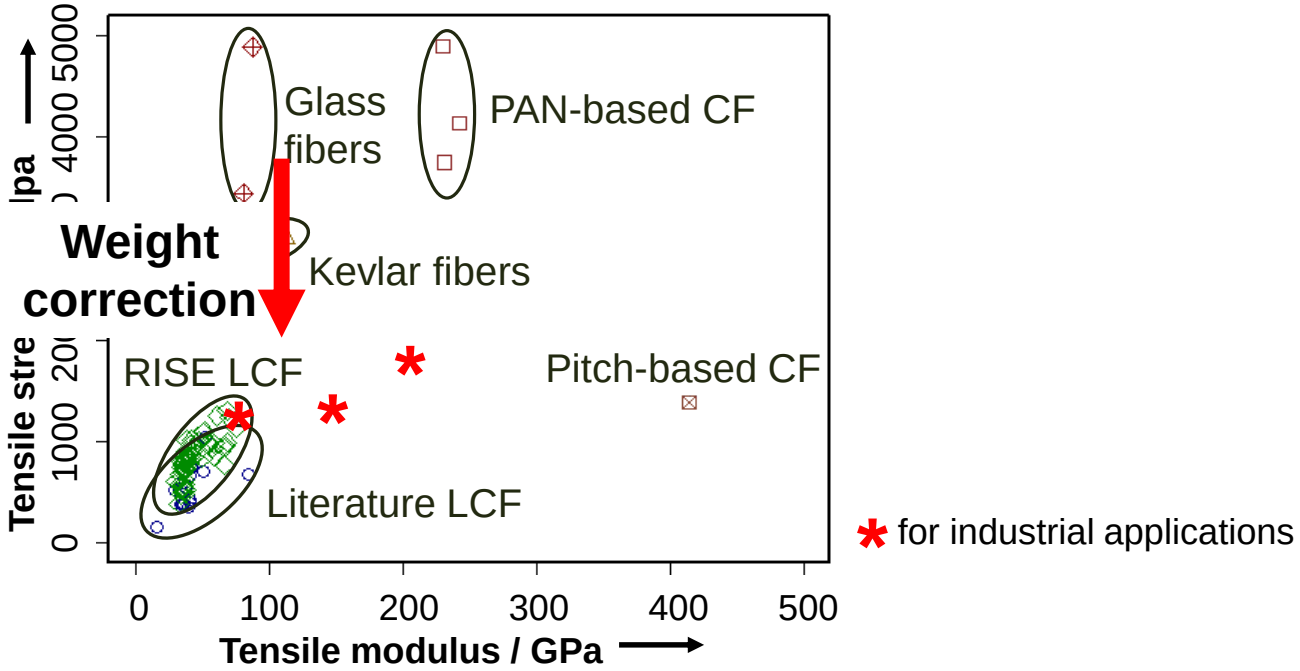






Conversion of Lignin:

- State of the art for Lignin is a batch wise process



- Continuous conversion will improve properties

Alternative use?: Graphite in battery anodes for electric vehicles

	2017 unit sales (global, thousands)	Lithium ion battery size	Anode Material per unit (natural & synthetic combined)	Natural Flake Graphite per unit (30 - 50% yield per kg of anode material)
Plug in Electric Vehicle 	~400	5 - 20kWh	5 - 20kg Balanced proportion of natural and synthetic graphite	10 - 30kg
Full Electric Vehicle 	~400	30 - 45kWh	30 - 45kg Balanced proportion of natural and synthetic graphite	35 - 50kg
Electric Commercial Truck 	~120	40 - 70kWh	40 - 70kg Balanced proportion of natural and synthetic graphite	40 - 80kg
Premium Electric Vehicle 	~150	75 - 100kWh	75 - 100kg Higher proportion of synthetic graphite	40 - 50kg
Electric Bus 	~105	150 – 350kWh	150 – 350kg Balanced proportion of natural and synthetic graphite	150 – 380kg

Source: Syrah Resources

SYRAH RESOURCES

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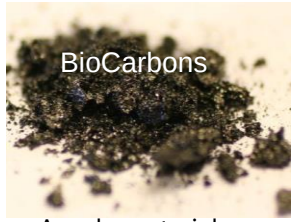
Opportunities for kraft lignin

Lignin

Lignin as carbon source/-structure

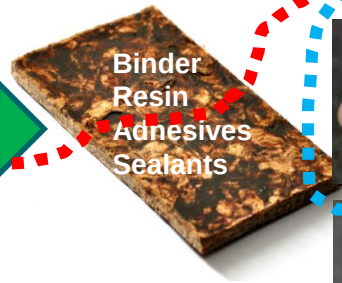
Bulk lignin (polymer)

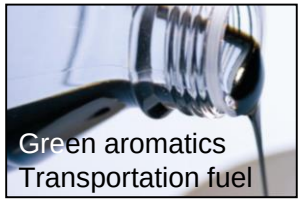
Depolymerised lignin



- Anode materials
- Supercaps
- Gas storage/emission control
- Fertilizer/biocarbon

- Composites
- Anode materials
- Supercaps
- Gas storage/emission control





-Speciality chemicals

Important Strategy:

- **A Portfolio of Opportunities!**
- **Production cost/market price? Please!**
- **Where are the innovations & joint ventures?**

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