



ENABLING THE SUSTAINABLE PRODUCTION OF  
THE MATERIALS AND FUELS OF A CLEANER TOMORROW



# The Team

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Jason  
Hallett

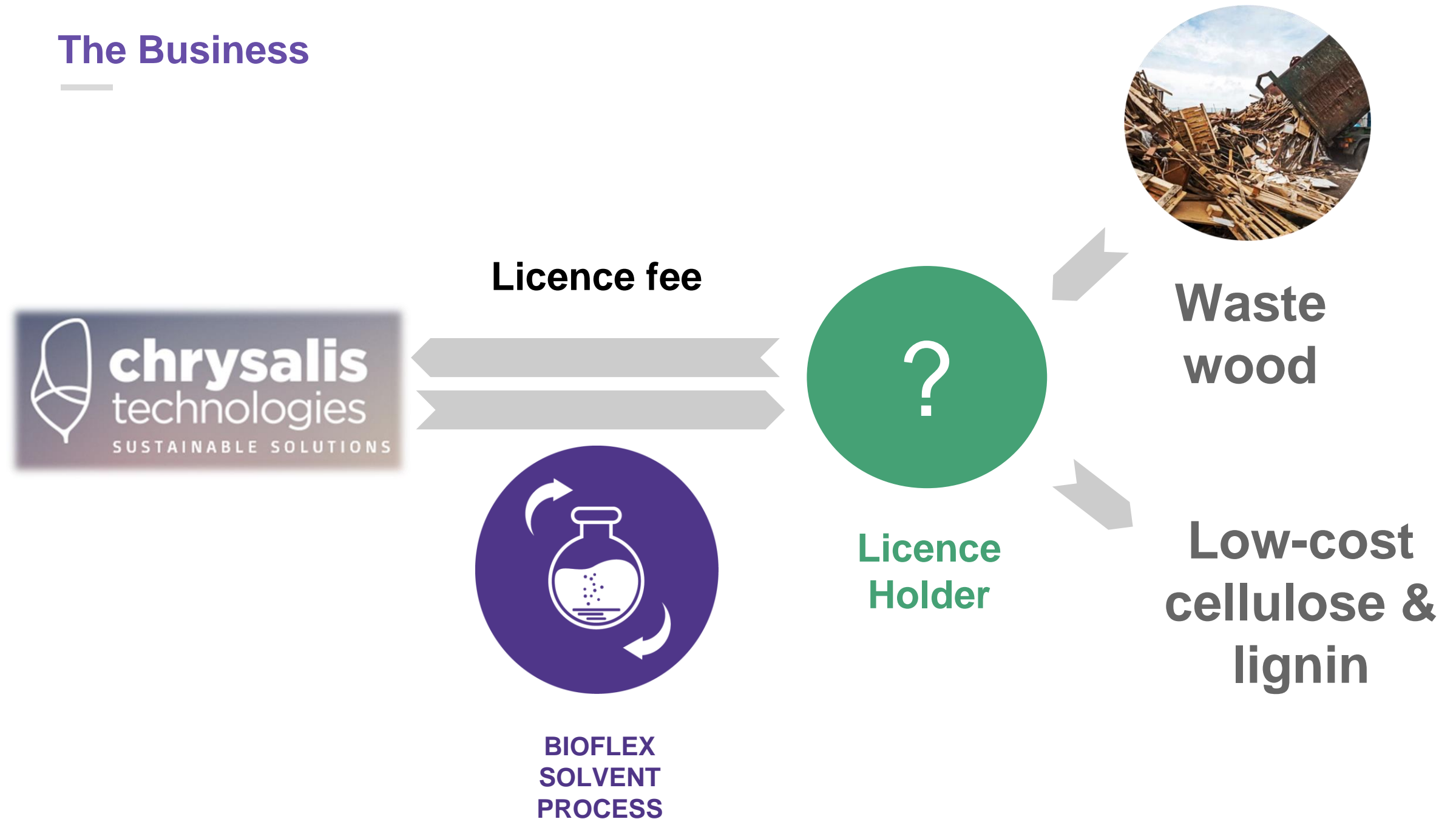
Florence  
Gschwend

Agi  
Brandt-Talbot





# The Business



## Our customers and partners



Biofuel, bioelectricity and biochemical producers who want a more sustainable feedstock and increased profits



Waste processors who want to offer higher recycling rate



Waste producers who want to decrease their cost



**4.5 m tonnes**  
**£1350 m**

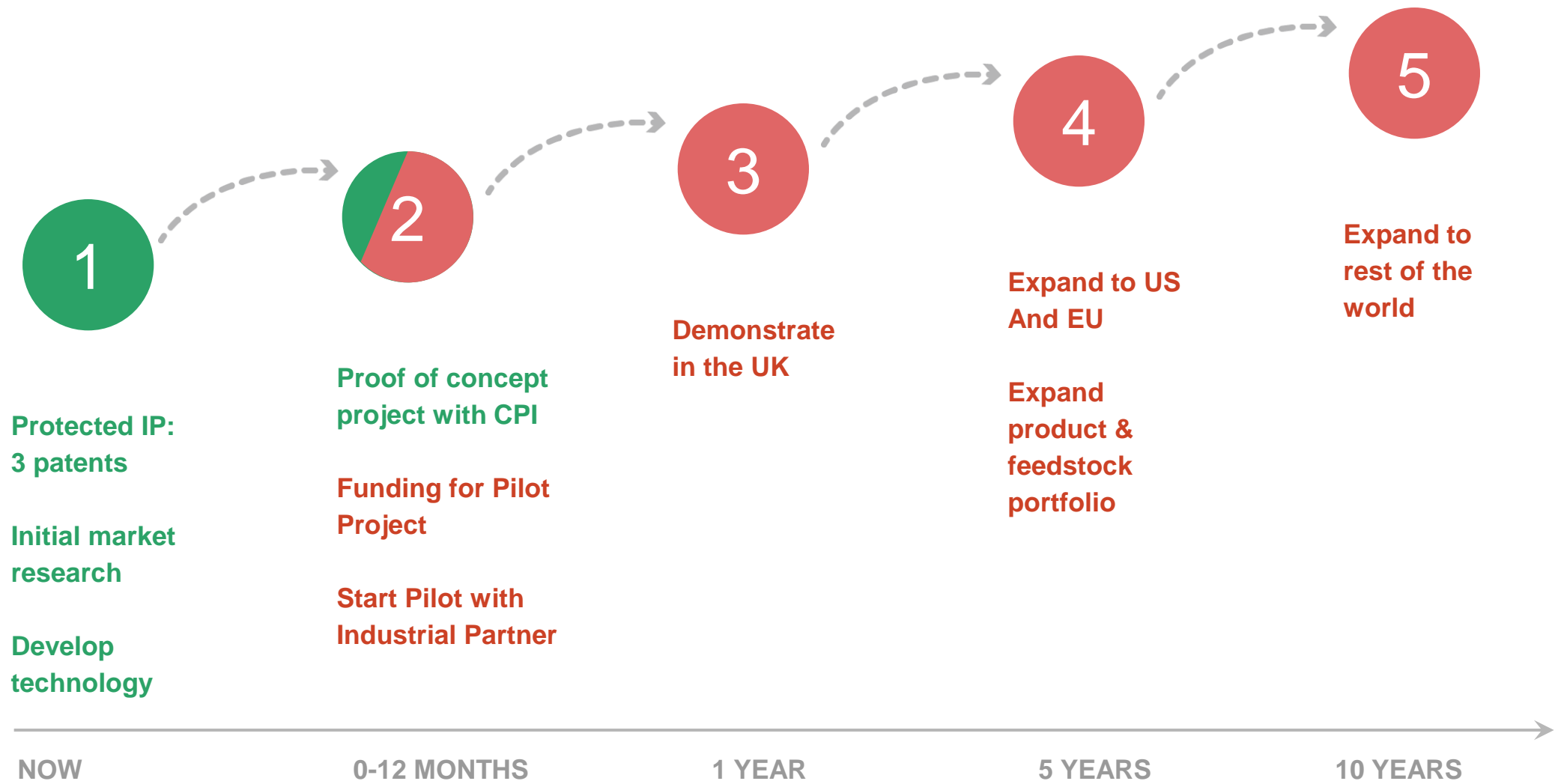


**Ca. 70 m tonnes**  
**£21 bn**



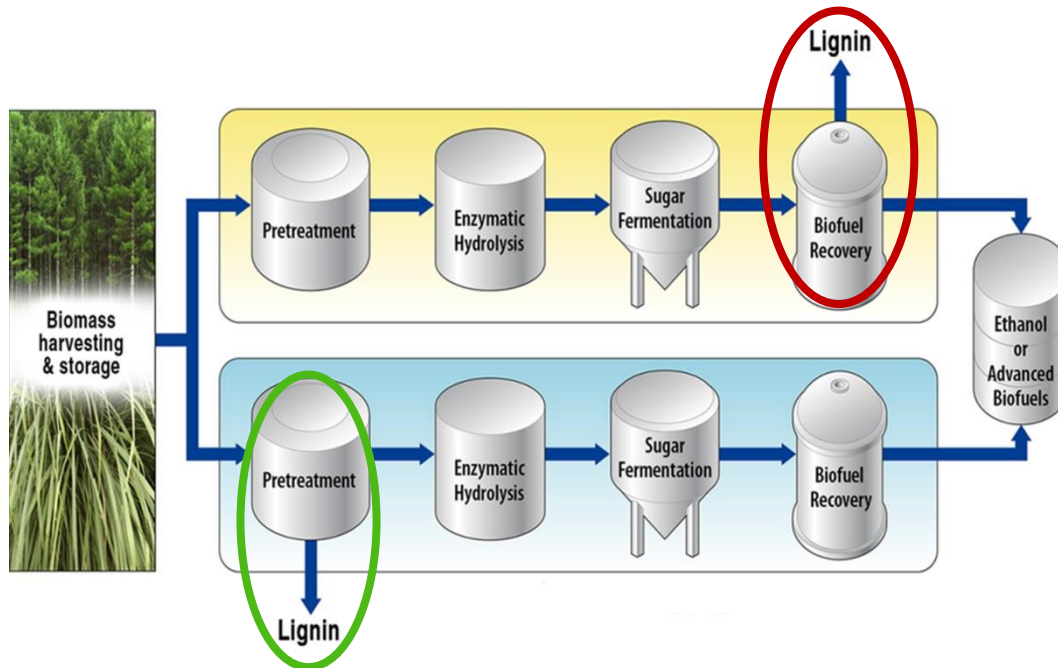
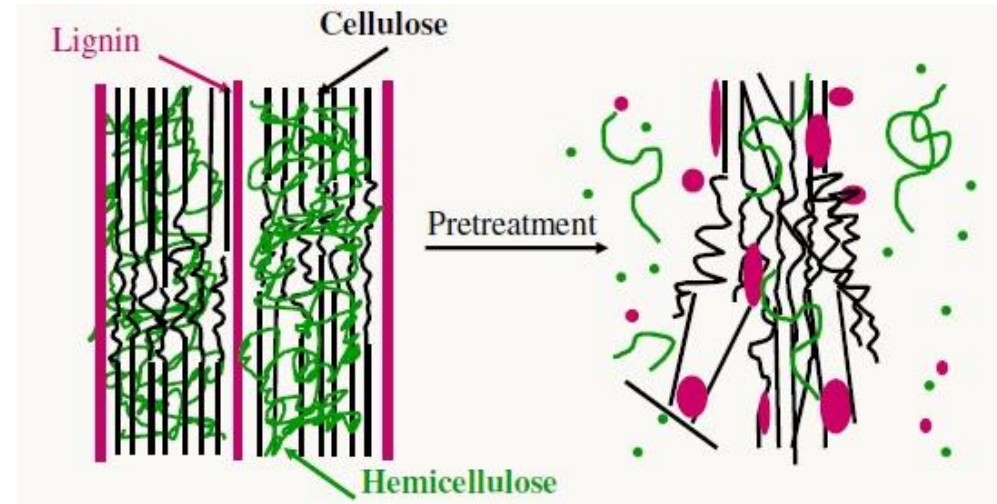
**Ca. 60 m tonnes**  
**£18 bn**

# Where we stand



# The need for pretreatment

- Disruption of biomass
- Making cellulose accessible for further conversion

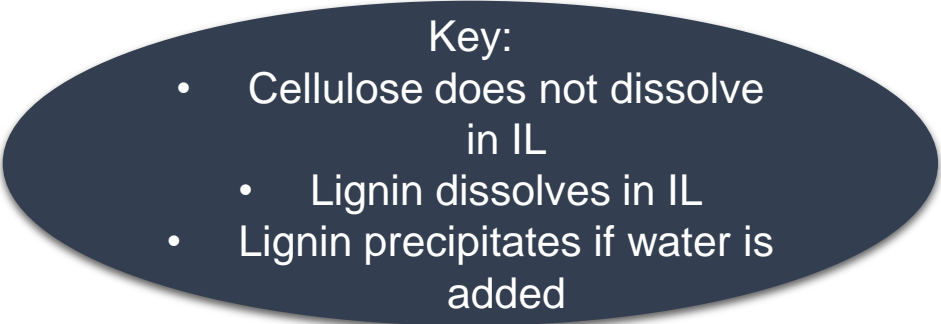


**Traditional**  
**Steam explosion**  
**Dilute acid**

- Lignin removal after fermentation
- Large fermentation reactor

**Organosolv**  
**ionoSolv**  
**treatment**

- Early removal of lignin
- Smaller fermentation reactor



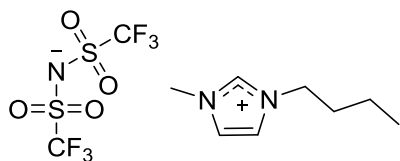




# What are ionic liquids

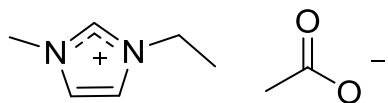
“Green solvents”: Salts melting below 100°C

- Non volatile
- Recyclable
- Tunable
- Very expensive

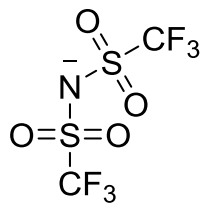


\$3000/kg

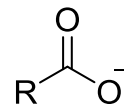
For biomass applications



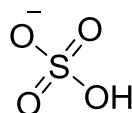
\$60/kg (bulk estimate)



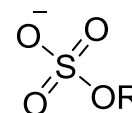
bis(trifluoromethylsulfonyl)imide  
[NTf<sub>2</sub>]<sup>-</sup>



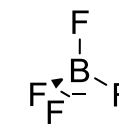
carboxylate



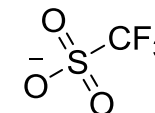
hydrogensulfate  
[HSO<sub>4</sub>]<sup>-</sup>



alkylsulfate  
[RSO<sub>4</sub>]<sup>-</sup>



tetrafluoroborate  
[BF<sub>4</sub>]<sup>-</sup>



trifluoromethylsulfonate  
[OTf]<sup>-</sup>



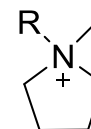
hexafluorophosphate  
[PF<sub>6</sub>]<sup>-</sup>



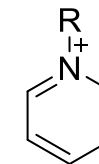
halide



1-alkyl-3-methylimidazolium  
[C<sub>n</sub>C<sub>1</sub>im]<sup>+</sup>



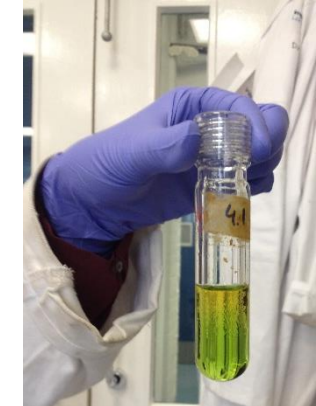
1-alkyl-1-methylpyrrolidinium  
[C<sub>n</sub>C<sub>1</sub>pyrr]<sup>+</sup>



1-alkylpyridinium  
[C<sub>n</sub>pyr]<sup>+</sup>

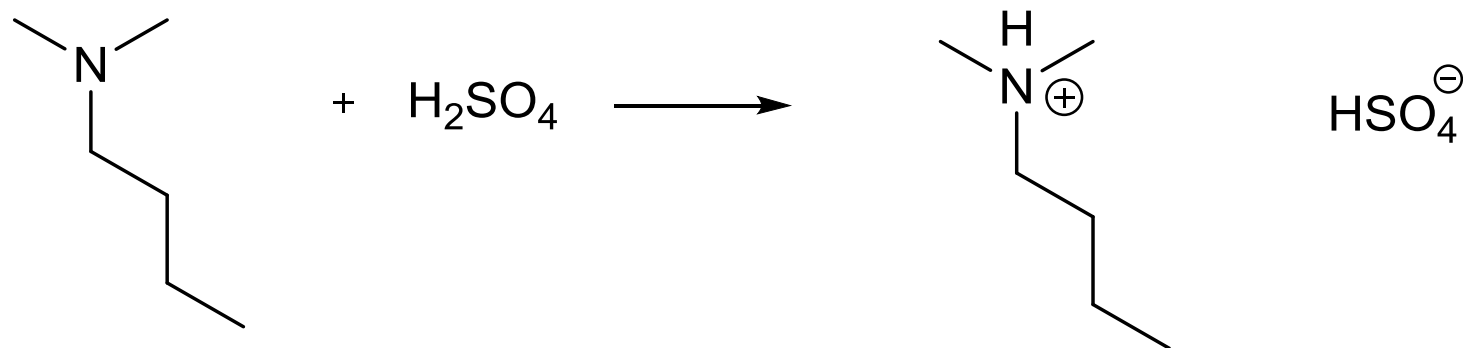
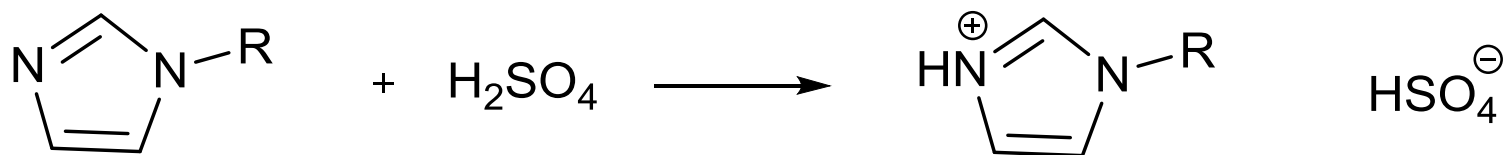


tetraalkylammonium  
[C<sub>4</sub>N]<sup>+</sup>



## Our Ionic Liquids: tuned to be cheap

Made in a one step acid-base reaction between an **amine/imidazole** and a **mineral acid**:



*N,N*-dimethylbutylammonium hydrogensulfate: <\$1/kg (bulk estimate)

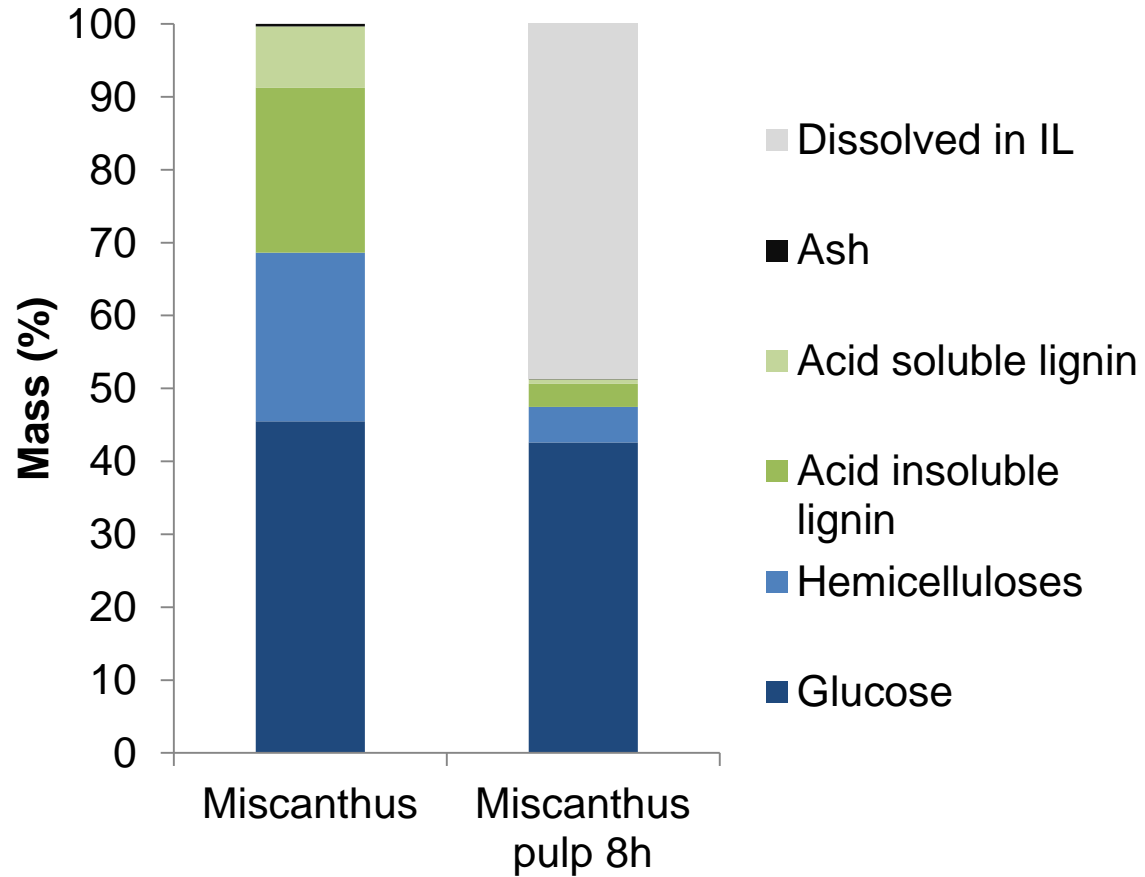
# BioFlex Process Economics



	Waste wood/ton	Virgin wood/ton
Plant size	20,000 tpa	100,000 tpa
Cellulose	£ 90	£ 90
Lignin	£ 94	£ 94
Hemic/Furfural	£ 38	£ 38
Gate fee	£ 54	-
<b>REVENUE</b>	<b>£ 276</b>	<b>£ 222</b>
Solvent	£ 11	£ 11
Biomass	-	£ 56
Water	£ 4	£ 4
Capital	£ 43	£ 26
Energy	£ 55	£ 55
<b>COST</b>	<b>£ 113</b>	<b>£ 152</b>
PROFIT	<b>£ 163</b>	<b>£ 70</b>
<b>GROSS MARGIN</b>	<b>59%</b>	<b>32%</b>



# Pretreatment of herbaceous biomass



Gschwend *et al.*, A low-cost ionic liquid for lignocellulose pretreatment, in preparation

- ✓ Pretreatment under mild conditions (120°C)
- ✓ Fast Pretreatment (<30 min) at higher temperature (170°C)
- ✓ Up to 99% glucose yield



# Pretreatment of Softwoods and Metal Treated Timber

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- ✓ Fast Pretreatment (<30 min) at high temperature (170°C)
- ✓ Up to 99% glucose yield
- ✓ 98-99% extraction of Cr, Cu and As
- ✓ Recovery of metals possible



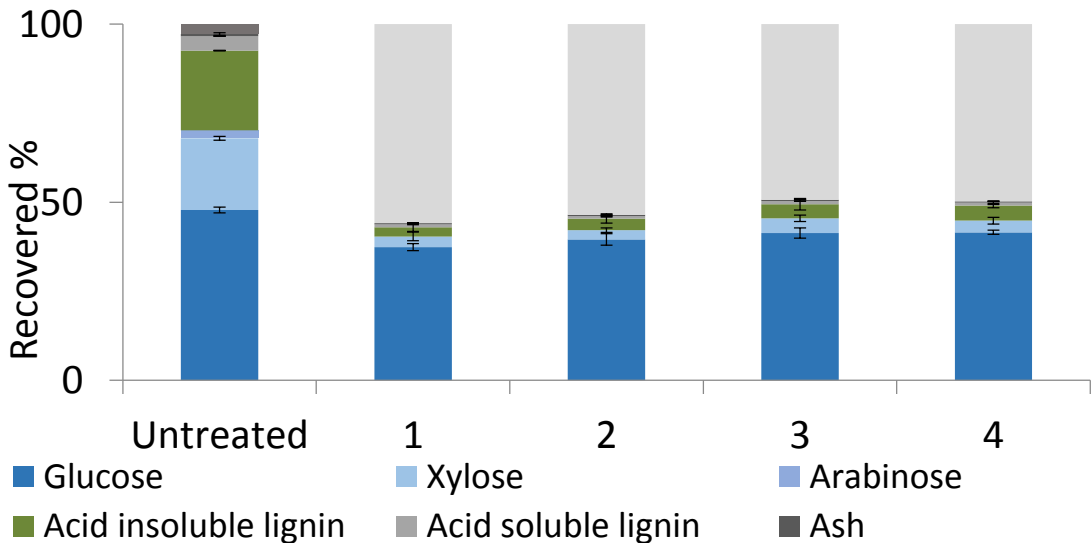
# Recycling of Ionic Liquid

	IL Recovery (%)	
1 <sup>st</sup> use	99.0	±3.7
2 <sup>nd</sup> use	97.9	±1.7
3 <sup>rd</sup> use	99.4	±8.4*
4 <sup>th</sup> use	99.3	±0.9

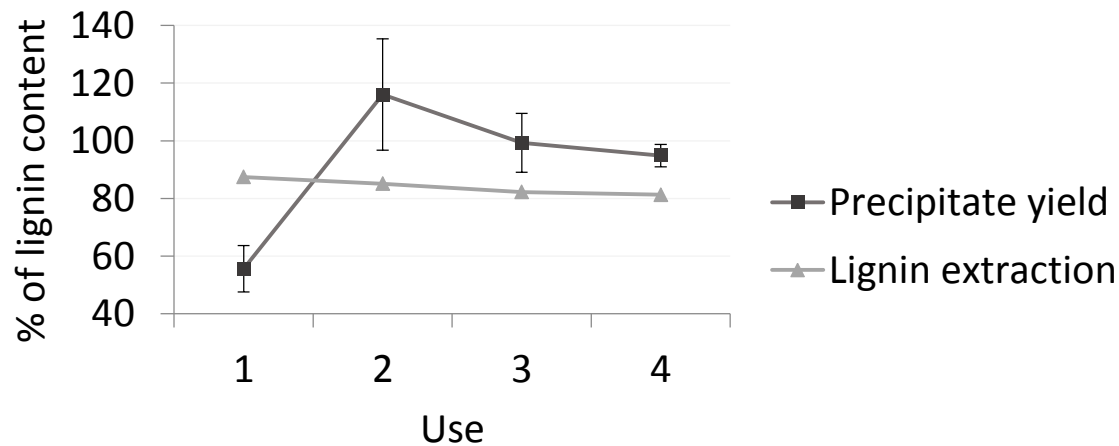
\* error due to mixing two replicates during pulp washing

Reuse essential for any solvent based process

## Cellulose



## Lignin





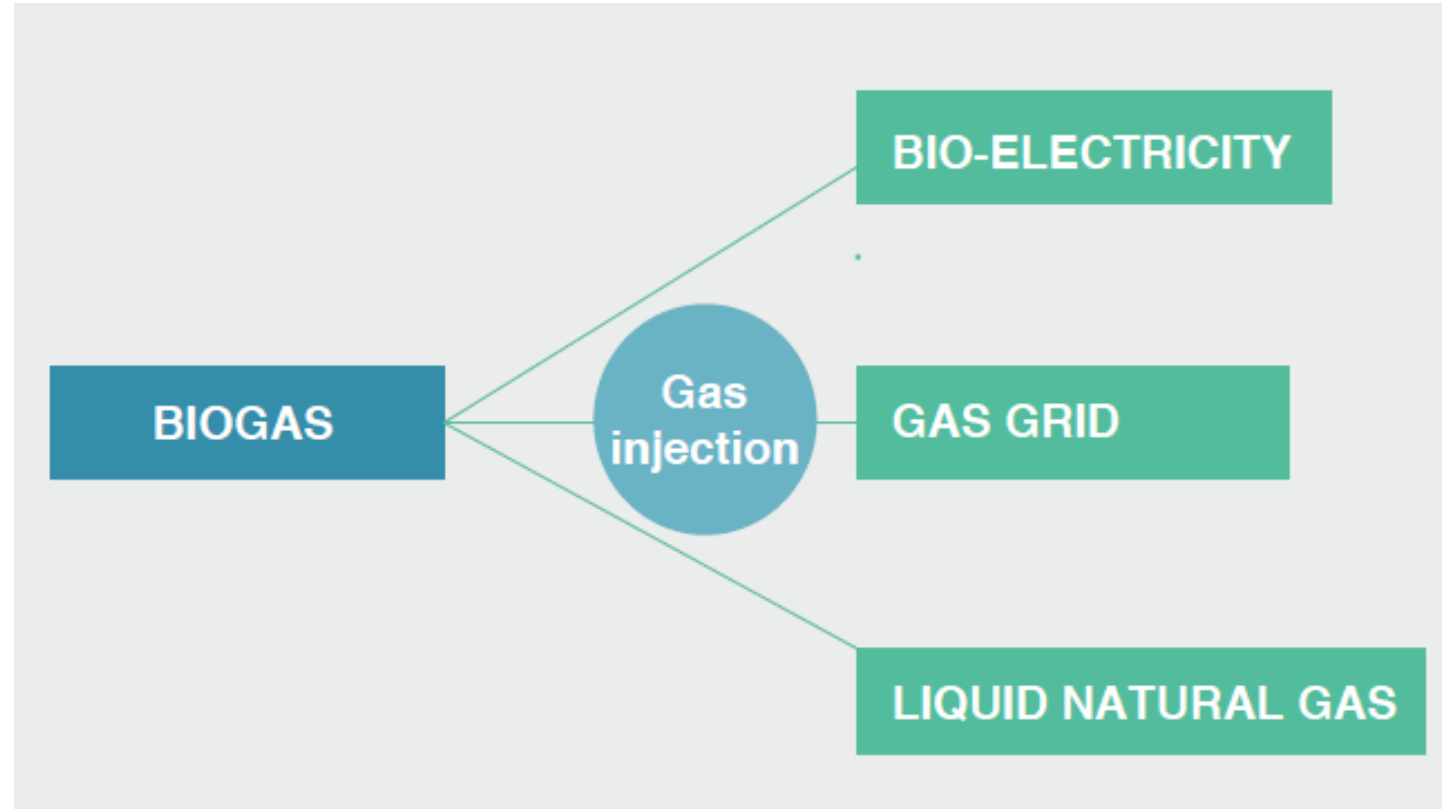
## Downstream Processing: Opportunities for Collaboration

Cellulose derived products

- Biogas
- Cellulosic materials
- Sugar platform: Ethanol, PLA, HMF

Lignin derived products

- Electricity/Heat
- Binders, adhesives
- High value products



Biogas:

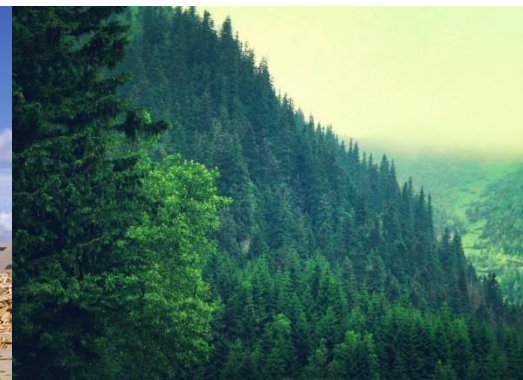
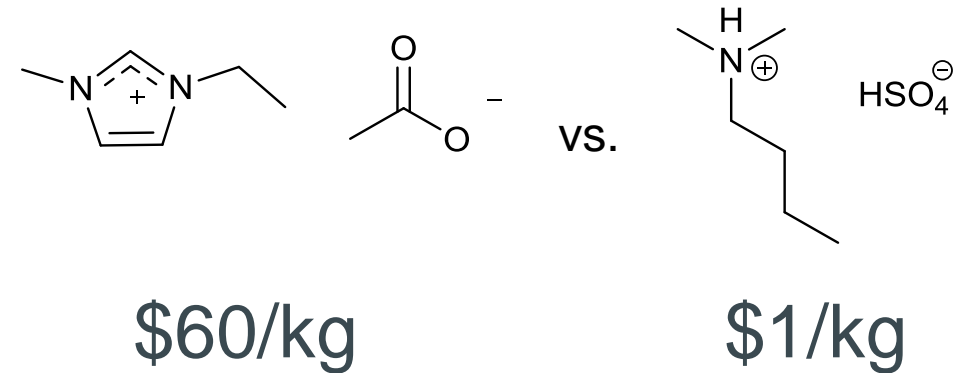
Mature technology

Fast growing market

Incentives

# Summary: Advantages of ionic liquid based fractionation

- High lignin solubility
- Very high solvent recovery: low vapour pressure, water tolerant, thermally stable
- Excellent performance for different types of lignocellulose
- Low-cost ionic liquids
- Electrochemically stable



THANK YOU!

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