Framtidsskogens kvalitet

Kemikallieindustrin

Pedro Fardim
Laboratoriet för fiber- och cellulosateknologi
Åbo Akademi

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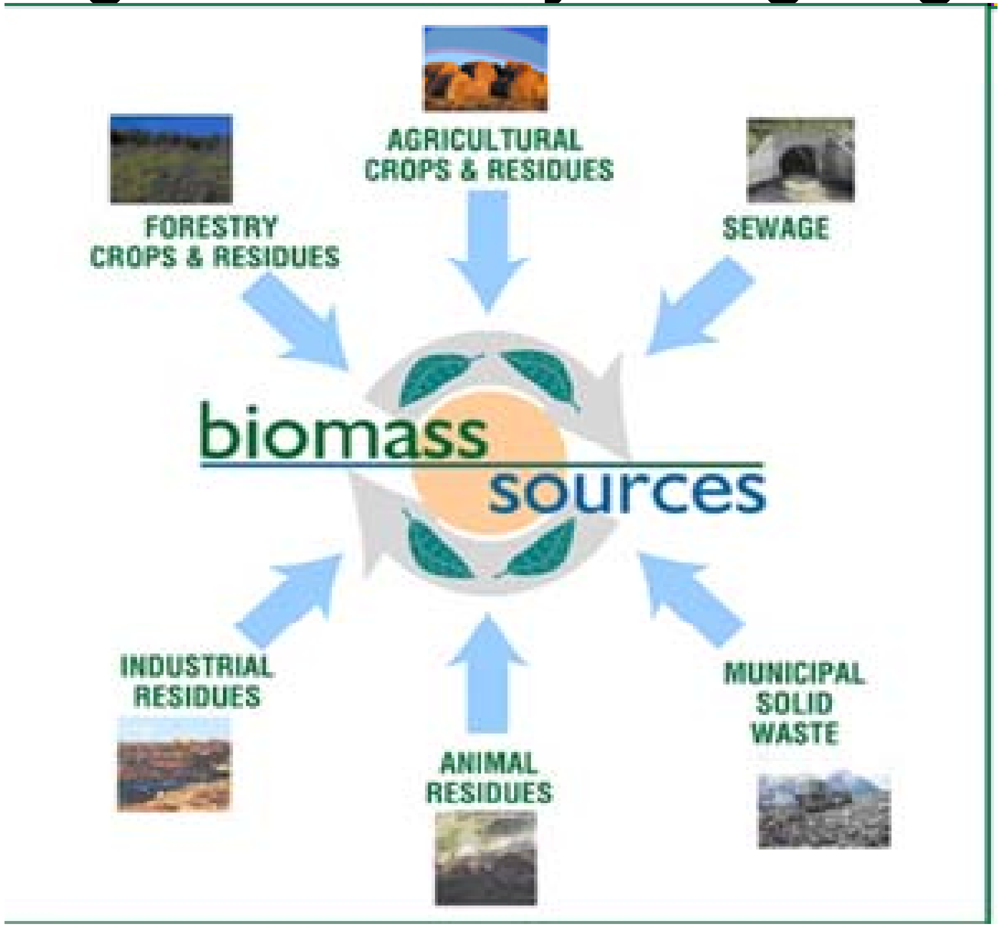
My background

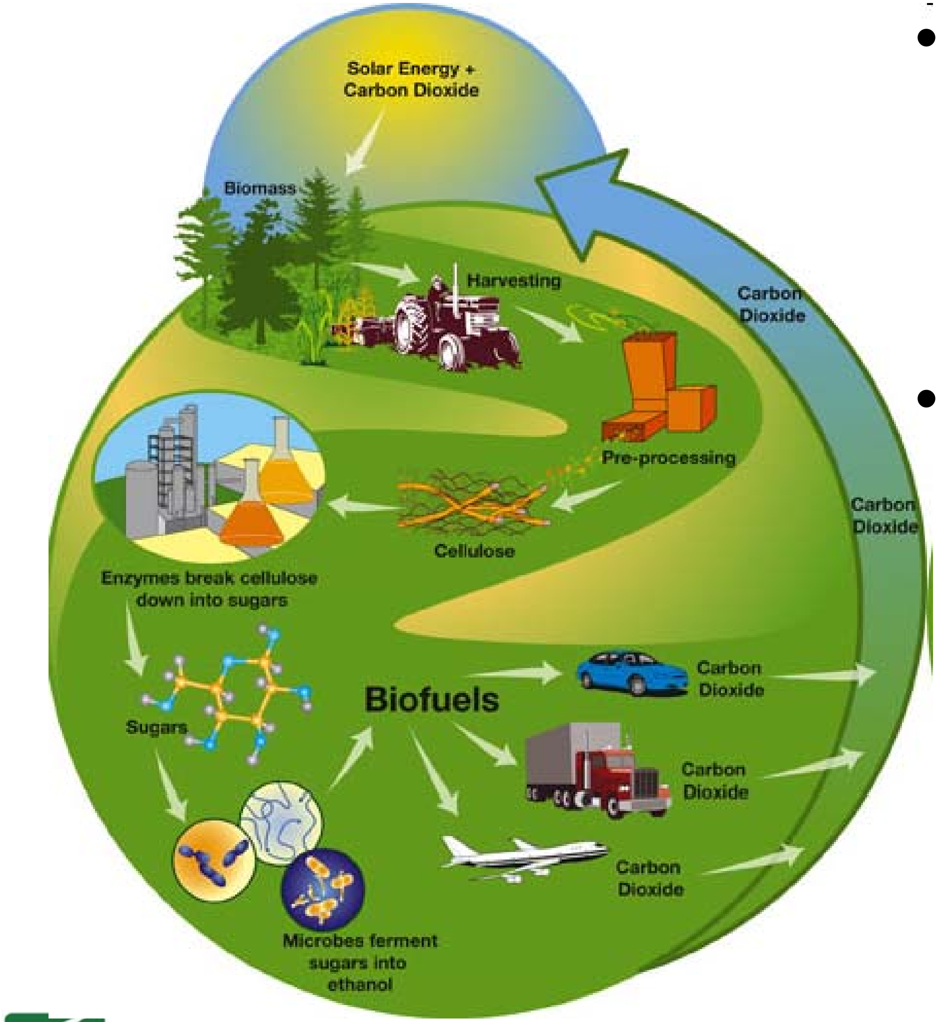
- Born in Brazil (Italian + Portuguese + Native)
- Educated at UNICAMP, Campinas, Brazil
- Worked 9 years at Suzano-Bahia Sul (R&D)
- PhD (50% industry + 50% university)
- Working and living in Finland since 2000
- Professor (Head of Lab.) since 2005
- Vice-president of European Polysaccharide Network of Excellence (EPNOE)
- Chair of International Master Program in Chemical Engineering (Åbo Akademi)

Biomass

- *Biomass* is biological material derived from living, or recently living organisms.



Renewable Energy



- More than 40 countries have passed laws and regulations setting targets for renewable energy production and use.
- Between 2001 and 2005, renewable energy production increased 11% a year, while total energy production increased just 1.6% a year. If such growth rates persist, renewable energy could account for some 20% of total world energy consumption by 2030.

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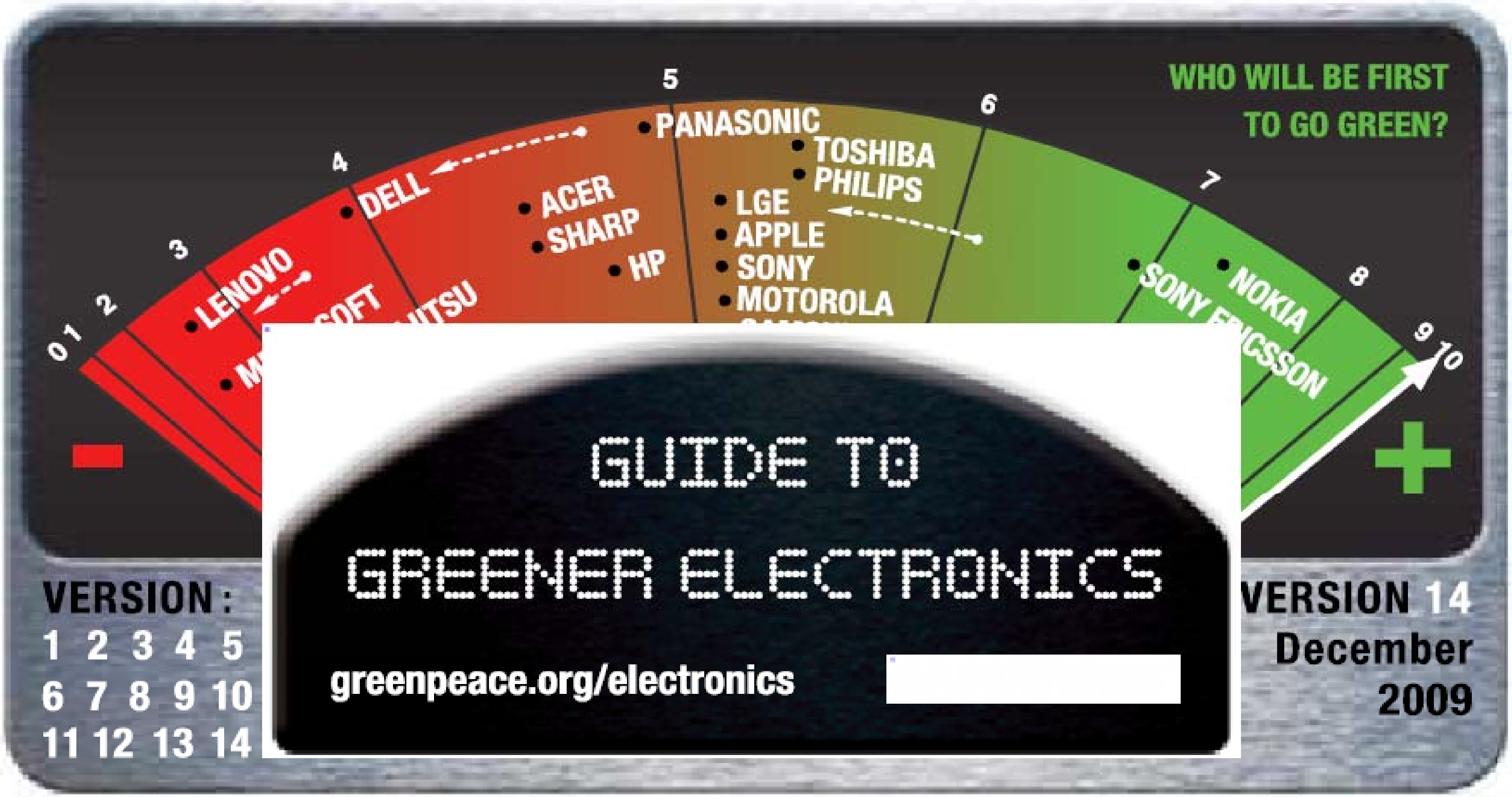
Sustainability

- The word sustainability is derived from the Latin *sustinere* (*tenere*, to hold; *sus*, up)
- Brundtland Commission of the United Nations: “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Greener Electronics



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nature
Vol 463|7 January 2010

OPINION

2020 visions

For the first issue of the new decade, *Nature* asked a selection of leading researchers and policy-makers where their fields will be ten years from now. We invited them to identify the key questions their disciplines face, the major roadblocks and the pressing next steps. Visit go.nature.com/htW8uM to respond and to add your vision.

> "An experimental minority of search queries will be through the direct monitoring of brain signals."

Search

Peter Norvig*
Director of research at Google

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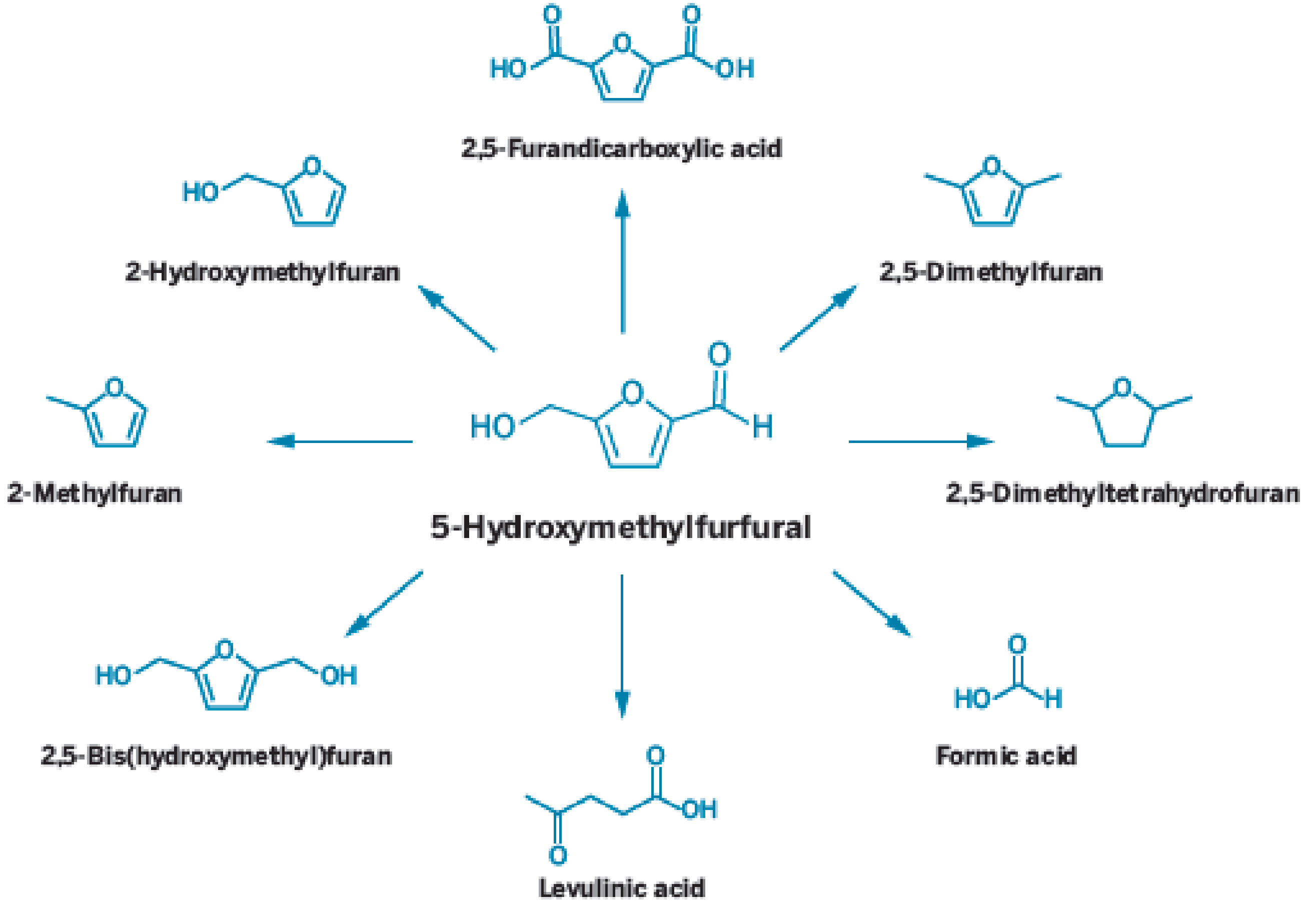
Bioderived chemicals

- 70-100 billion USD (3-4% of global market today)
- Possible increase to 17% of global market in 2025
- Oil price and type of energy to power the vehicles impact the market

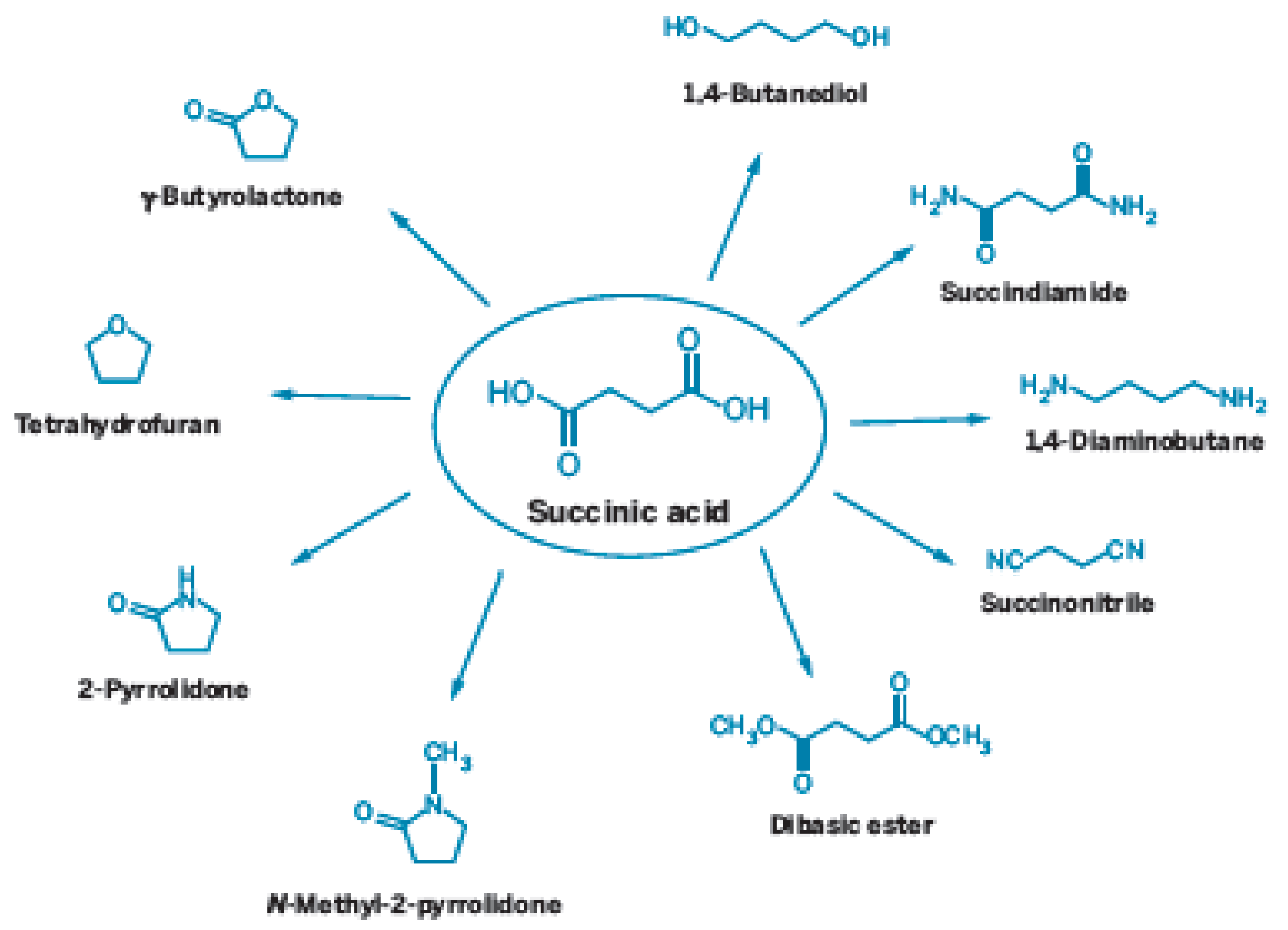
Bioderived chemicals

WHICH WAY TO GO?

Derived from biomass, 5-hydroxymethylfurfural (HMF) can be converted into many types of compounds now obtained from petroleum sources.



Bioderived chemicals



LAUNCH PAD Succinic acid can be converted to many commercial chemicals.

SOURCE: Department of Energy

Ample opportunities for bio-based materials

	Fully fossil-based	*Partially Biobased*	*Fully Biobased*
Fully Biodegradable	-PBS -PBSL -PBSA	**-Starch blends** **(with biodegradable fossil-based coplymers)** -Vegetable-oil based polyesters	**-Thermoplastic starch (TPS)** **-Starch blends** (with biobased and biodegradable copolymers) **-Cellulose** -PLA -PHA/PHB
Partially Biodegradable			
Non-Biodegradable	-PE -PP -PET -PVC -PUR -ABS -Epoxy resin -Synthetic rubber	-Biobased PTT, PBT -Biobased PET -Biobased PVC -Biobased PUR -Biobased polyacrylates -Biobased ABS -Biobased Epoxy resin -Biobased SBR -Alkyd resin	-Biobased PE -Biobased PP -Biobased PA -Biobased PB -PO3G

Total polymer cons. Western Europe:
~50 million t p.a.

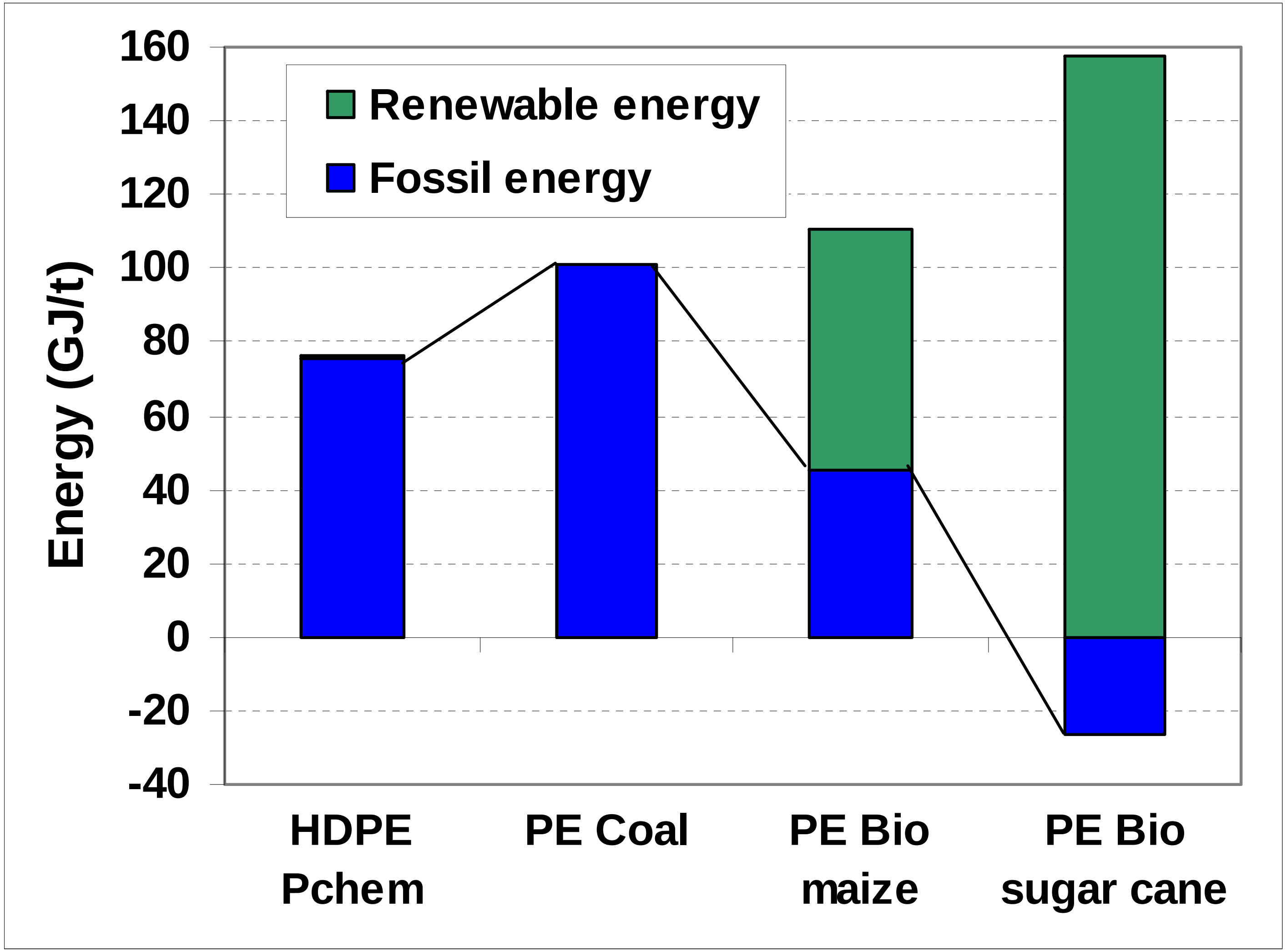
Technical potential bio-based:
~42 million t p.a. (85%)

Biodegradability

Biobased raw material

PRO-BIP Study (2009) / EPNOE

Polyethylene from oil, coal and biomass



M. K. Patel, based on BREW Study (2006) and Ph.D. thesis Tao Ren (2009).

Energy resources today and tomorrow

- Total primary energy use worldwide today (fossil, renewable, nuclear): ~500 EJ (of which 10% biomass)
- Biomass potentials in year 2050:
  - Extreme: 100 EJ – 1500 EJ
  - Most probable: 200 EJ – 500 EJ
- Total primary energy use worldwide 2050: 600 – 1040 EJ
- Expected energy demand is smaller than supply estimates (only biomass <US$ 3GJ/t are more attractive than wind, CCS and nuclear), i.e. 50 EJ – 250 EJ

→ Potentially 150 – 250 EJ for bio-based materials

- Netherlands Biomass Assessment, Lysen and van Egmond (eds.), 2008
- Bindraban et al., Can biofuels be sustainable by 2020?, 2009

Three sources of bioderived chemicals

1) Direct production
2) Biorefinery
3) Expression in plants

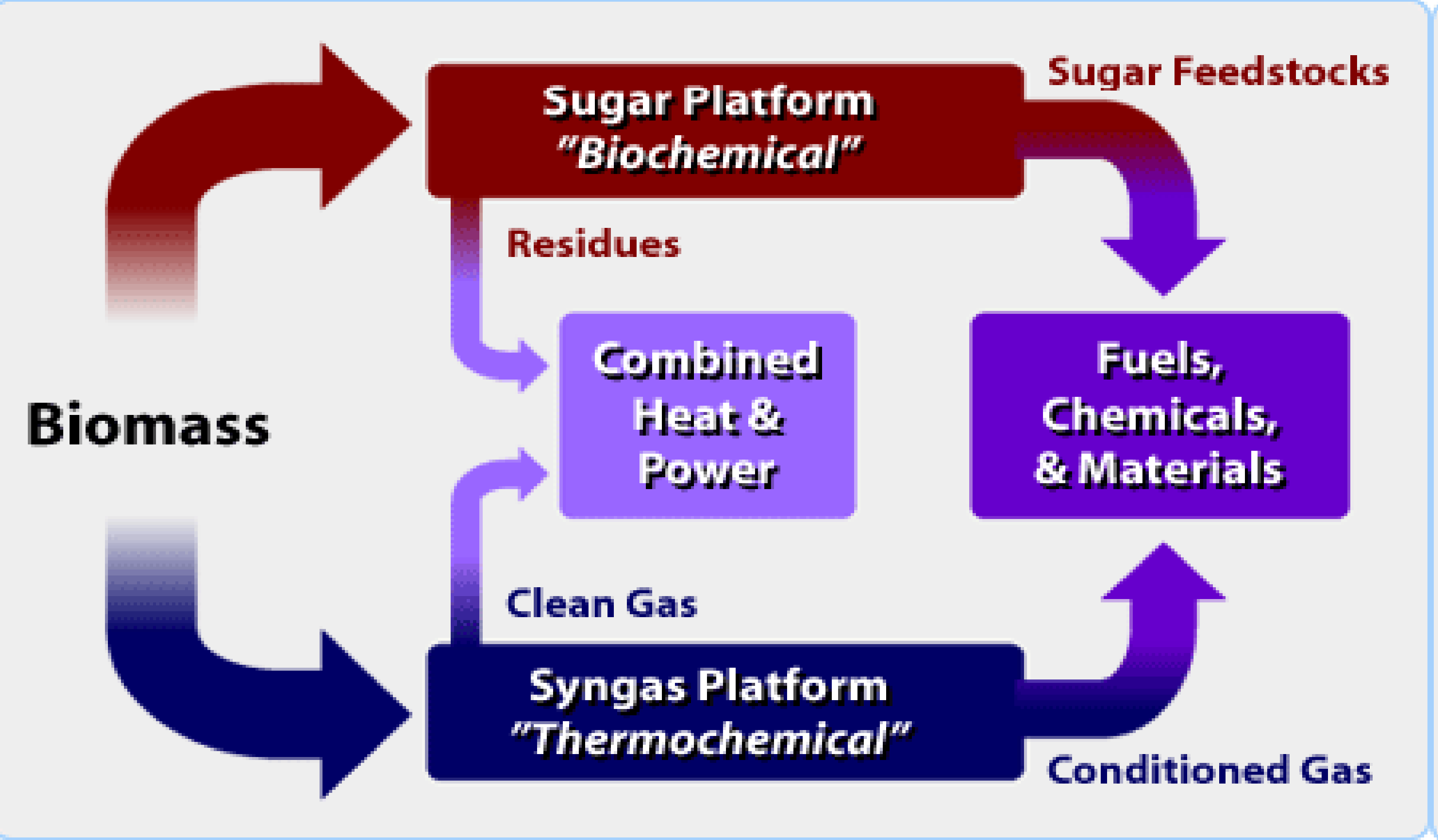
Direct production

- Biotechnology and chemical technology combined
- Propane-diol produced from corn-derived glucose (DuPont/Tate&Layle)
- Glucose converted into polylactic acid (Cargill)

Biorefinery

- A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass.
- The biorefinery concept is analogous to today's petroleum refineries, which produce multiple fuels and products from petroleum.
- Industrial biorefineries have been identified as the most promising route to the creation of a new domestic biobased industry.

Biorefinery Concept



Biomass

Sugar Platform
"Biochemical"

Sugar Feedstocks

Residues

Combined Heat & Power

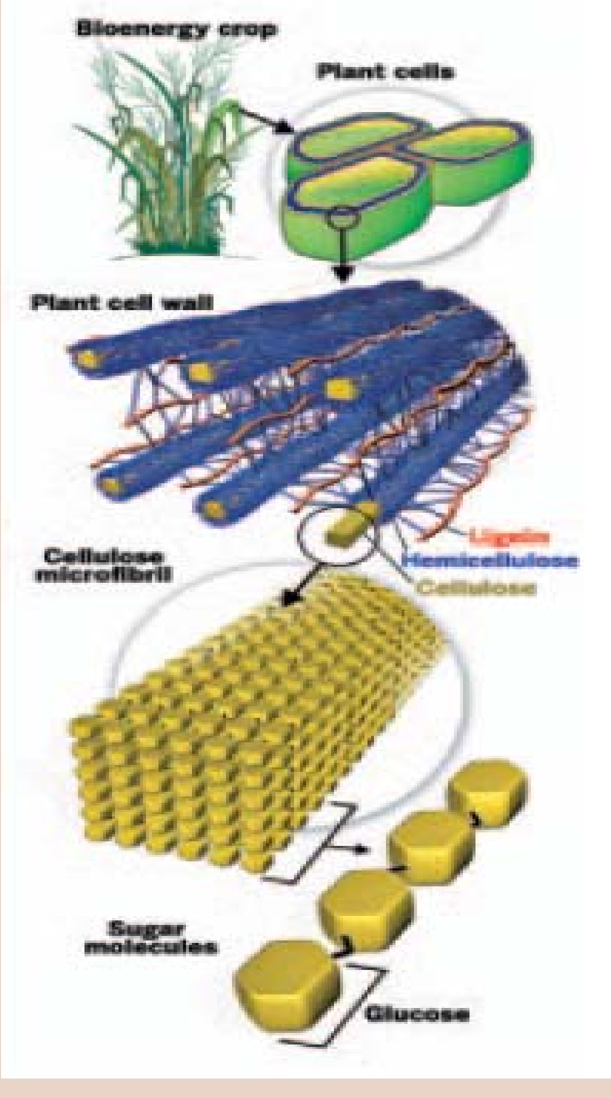
Fuels, Chemicals, & Materials

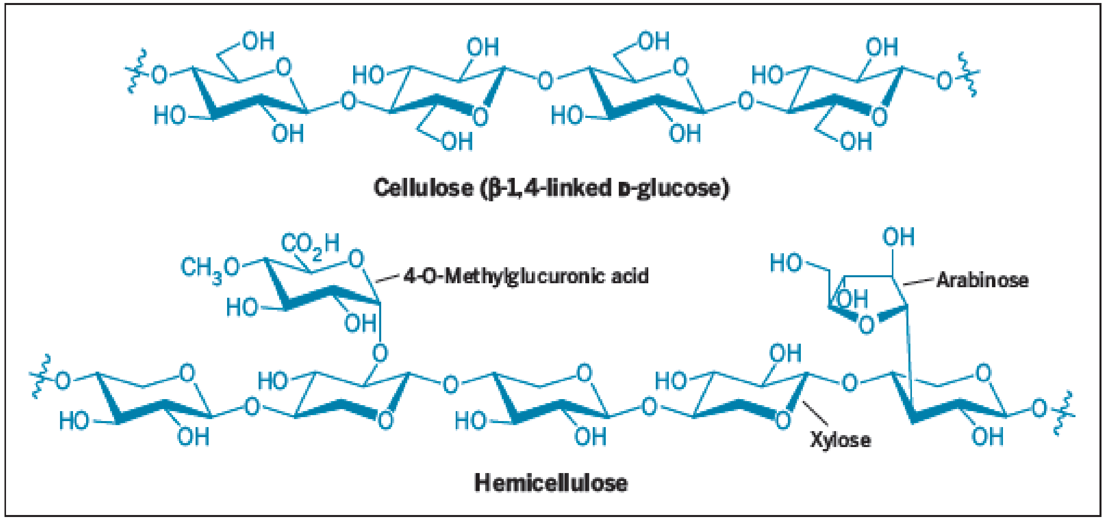
Clean Gas

Syngas Platform
"Thermochemical"

Conditioned Gas

Recalcitrance in plant cell walls





Cellulose (β-1,4-linked D-glucose)

Hemicellulose

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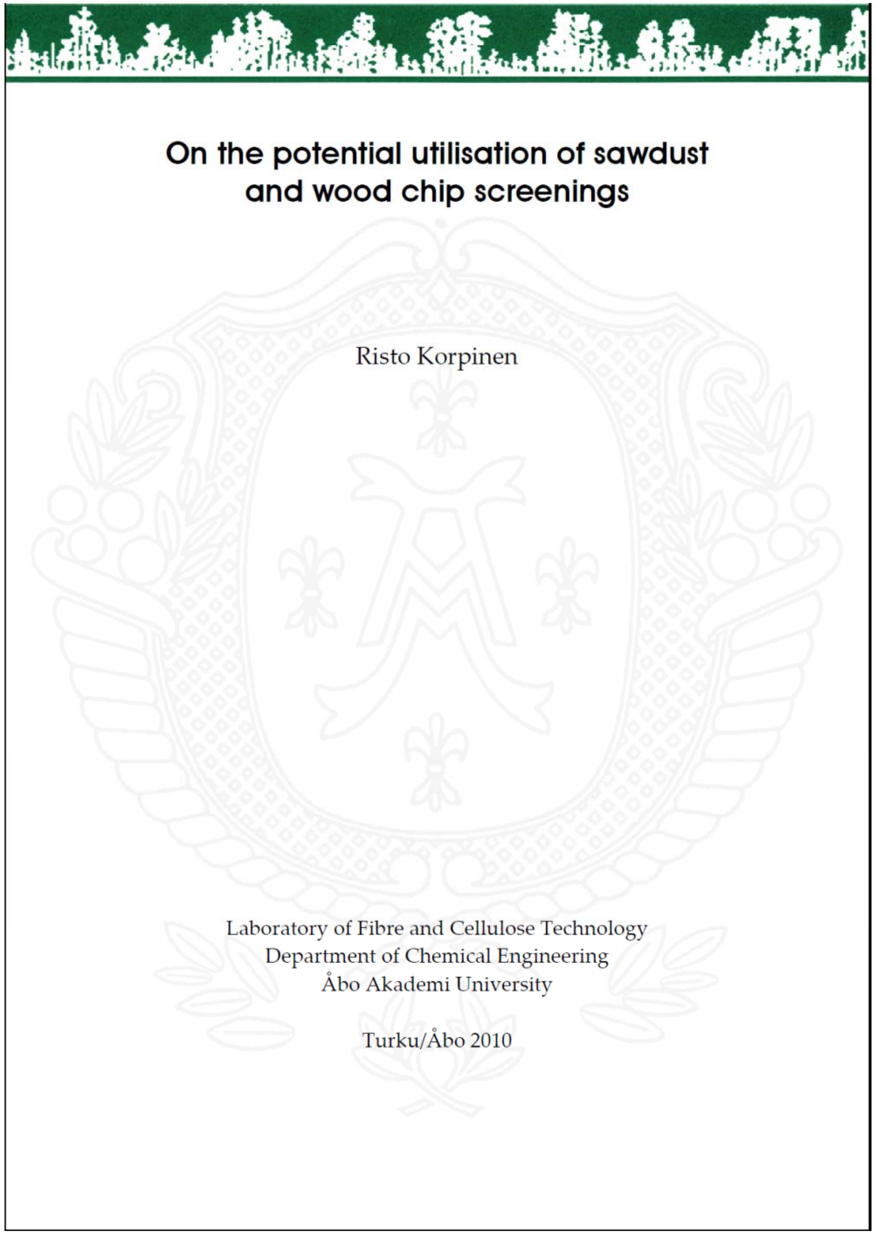
Biorefinery concept

- Fuel and chemicals/materials platform
- Fractionation into biopolymers and biomolecules has a key role
- Not limited to forest sector
- Chemical co-products by genetic modification of yeasts (e.g. isobutanol as co-product of ethanol)
- Pilot stage

Expression in Plants

- Chemicals expressed in genetically enhanced plants
- More suitable for annual crops?
- Impact of environment
- Early stage



On the potential utilisation of sawdust and wood chip screenings

Risto Korpinen

Laboratory of Fibre and Cellulose Technology
Department of Chemical Engineering
Åbo Akademi University

Turku/Åbo 2010

Biorefinery concept based on wood residues

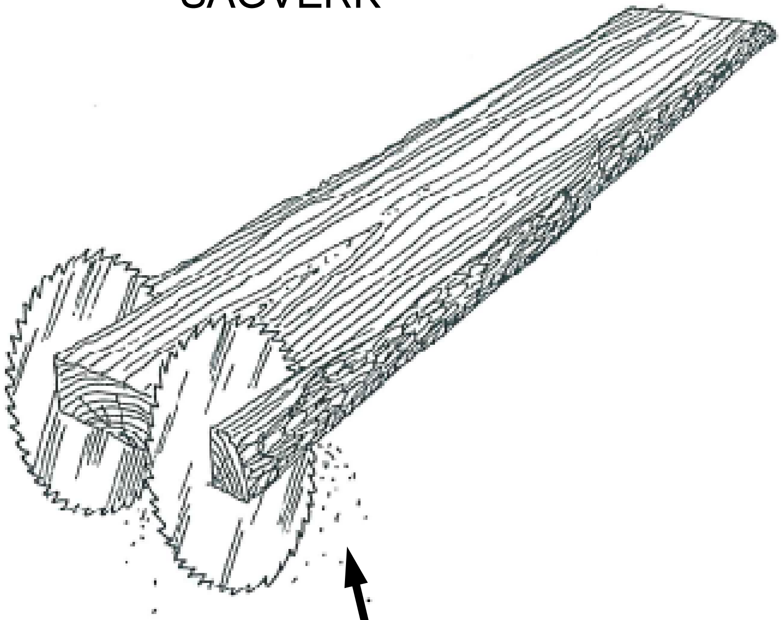
Finnish scenarium

- Årlig industriell vedförbrukning i Finland ca. 65 miljoner m^3
  - 3–4 miljoner m^3 sågspån
  - 1 miljon m^3 finspån

- **Ca. 1 miljon ton** torrtänkt vedmaterial
  - 50 000 kg extraktivämnen
  - 300 000 kg lignin
  - 250 000 kg hemicellulosor
  - 400 000 kg cellulosa

Källor för spån

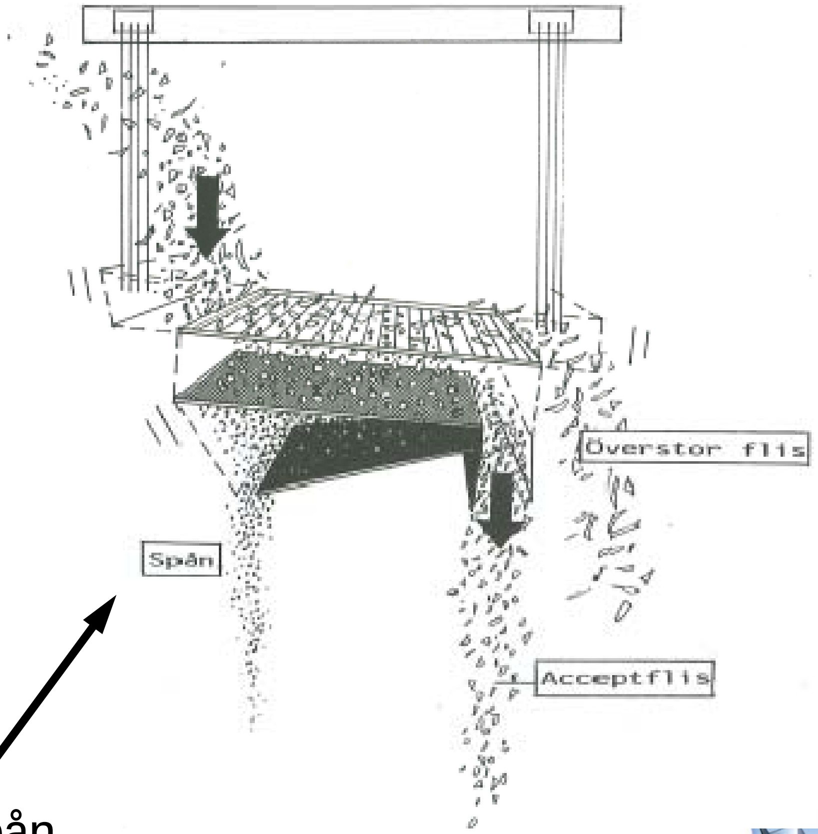
SÅGVERK



Sågspån

MASSABRUK

Flissållning



Finspån

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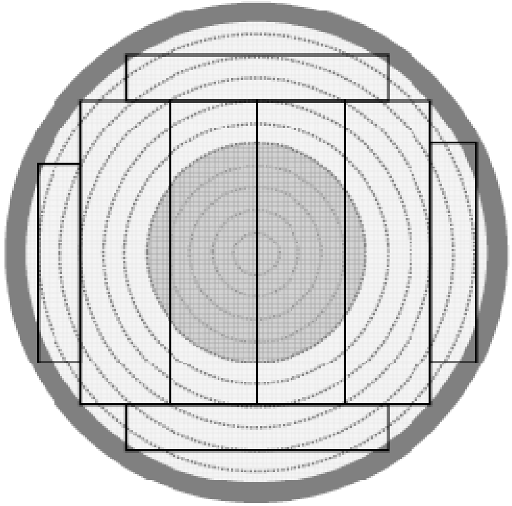
Sågspån

Virkesproduktion av barrträd i Finland 2000–2008

År	Virke 10^6 m^3f	Flis 10^6 m^3f	**Sågspån 10^6 m^3f**	Bark 10^6 m^3f
2000	13.3	9.3	**4.0**	2.7
2001	12.7	8.9	**3.8**	2.5
2002	13.3	9.3	**4.0**	2.7
2003	13.7	9.6	**4.1**	2.7
2004	13.5	9.4	**4.0**	2.7
2005	12.2	8.5	**3.7**	2.4
2006	12.2	8.5	**3.6**	2.4
2007	12.4	8.7	**3.7**	2.5
2008	9.8	6.9	**2.9**	2.0

m^3f = kubikmeter fast mått



2,2 m^3f stock

1,0 m^3f sågvirke

0,7 m^3f flis

0,3 m^3f spån

0,2 m^3f bark

Martikainen 2002; Finnish Forest Industries Federation 2009

Finspån

Sulfatmassaproduktion i Finland 2000–2007

År	**Blekt barrved** **10^6 ton**	Blekt lövved 10^6 ton	Oblekt 10^6 ton	**Finspån** **10^6 m^3/fub**
2000	**3.50**	2.90	0.71	**0.18–0.60**
2001	**3.28**	2.62	0.64	**0.17–0.56**
2002	**3.55**	2.90	0.69	**0.18–0.60**
2003	**3.76**	2.93	0.66	**0.20–0.64**
2004	**3.96**	3.15	0.67	**0.21–0.67**
2005	**3.47**	2.78	0.53	**0.18–0.59**
2006	**4.11**	3.20	0.64	**0.21–0.70**
2007	**4.18**	2.92	0.60	**0.22–0.71**

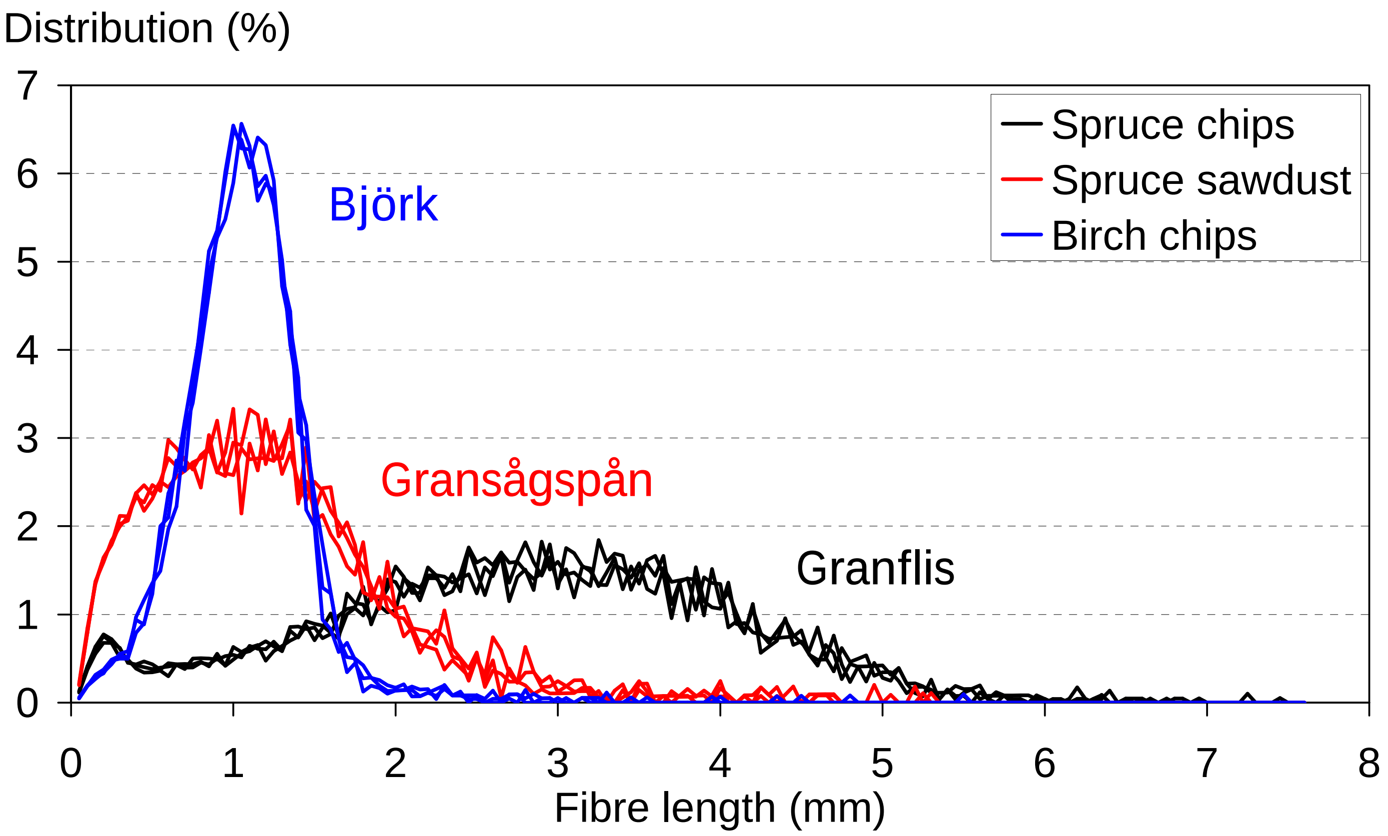
Finspån

- 0,052–0,170 m^3fub/admt = **20,6–68,0 o.d. kg/admt**
  - – Densitet 400 kg/m^3fub
  - – Torrhalt 50 %

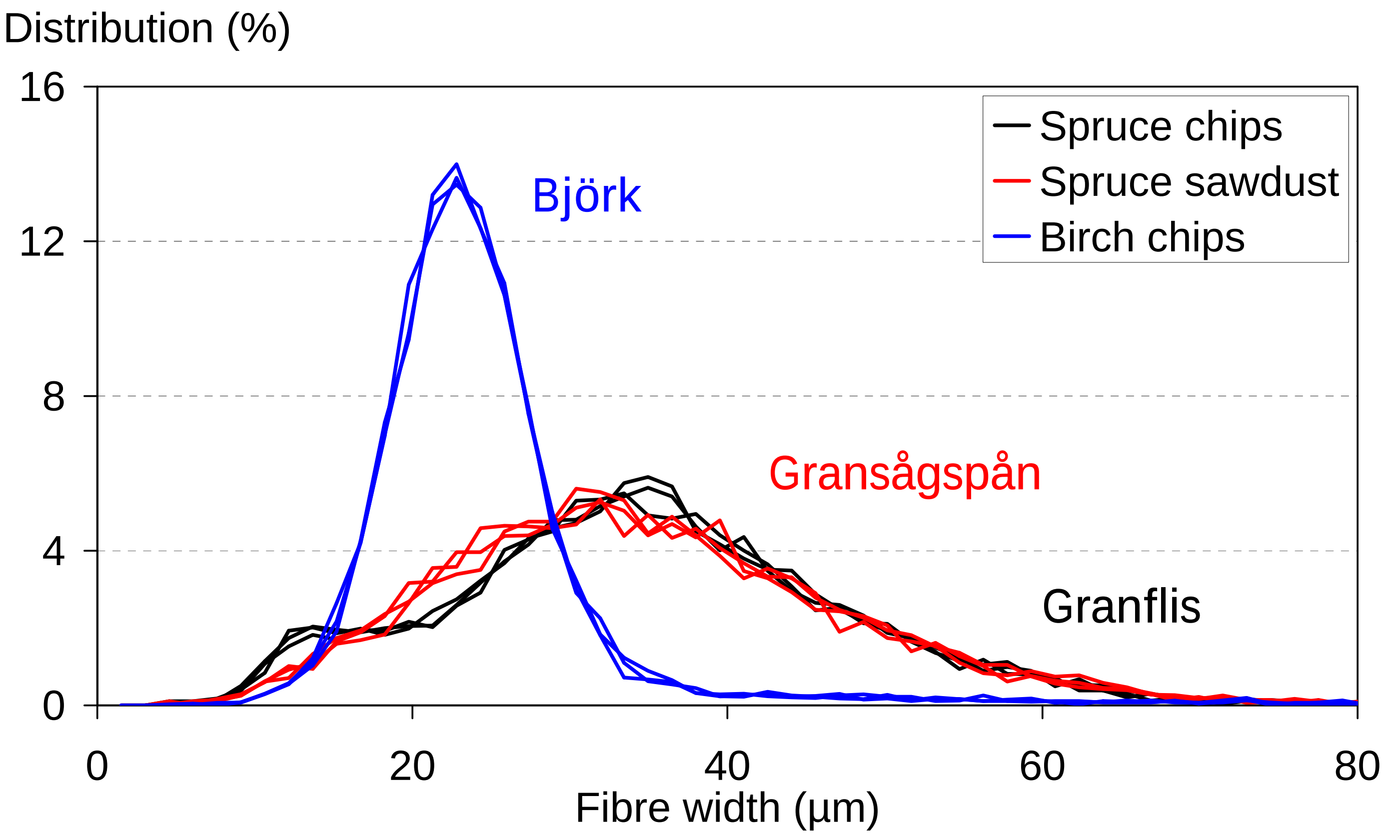
- Årlig massaproduktion 500 000 admt
  - – 10 300–68 000 o.d. t/a finspån

Duchesne et al. 1997

Fördelning av fiberlängd



Fördelning av fiberbredd



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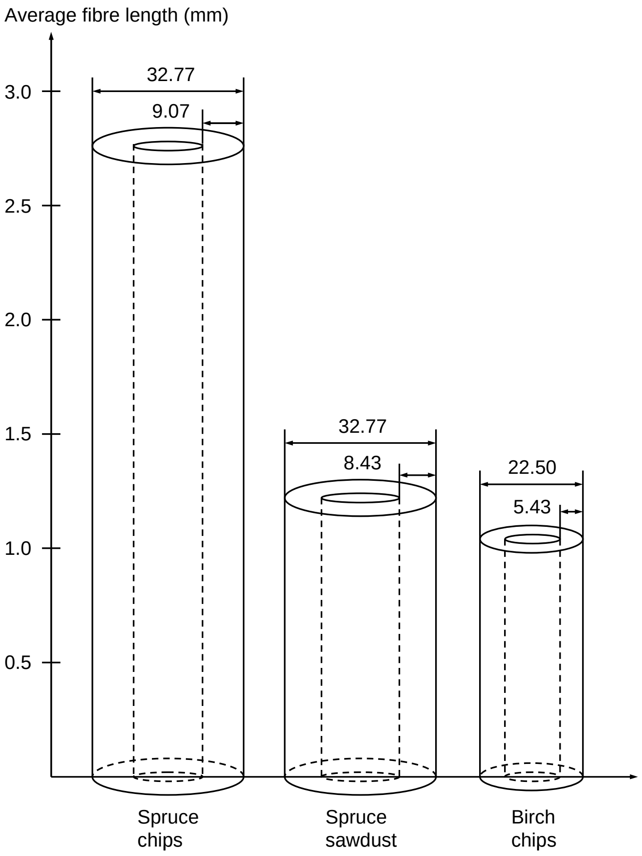
Genomsnittliga fiberdimensioner



Levlin and Jousimaa 1988

Egenskaper	Björk flis	Gran sågspån	Gran flis
Fiberlängd (mm)	1,05	1,21	2,77
Fiberbredd (µm)	22,50	32,77	32,77
Fibervägg (µm)	5,43	8,43	9,07
Lumendiameter (µm)	11,63	15,90	14,63
Längd/bredd	46,67	36,92	84,53
Coarseness (mg/m)	0,10	~0,17	0,17
Fibrer i ved (million/g)	10	>10	2

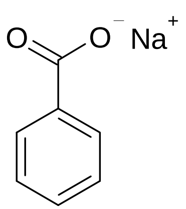
Användningen av spånmassor

Pappersslag	**Använd massa**	**Vanligaste vedslag**	**Användningsområde**
tidningspapper	mekanisk, 65–100 %	gran	tidningar, telefonkatalogpapper
tidskriftspapper	mekanisk, 75 %	gran	tidskrifter, kataloger
finpapper	kemisk, över 90 %	tall och **björk**	kopierings- och brevpapper
konsttryckpapper	kemisk, 100 %	tall och **björk**	broschyrer, affischer, kalendrar
hygienpapper	kemisk, en del returmassa	tall och **björk**	hushålls- och WC-papper, handdukar
specialpapper	oftast kemisk	tall och **björk**	etiketter, adhesivpapper, smör- och bakplåtspapper
förpackningspapper	kemisk, en del returmassa	tall och **björk**	papperspåsar, -kassar och -säckar
industripapper	kemisk	tall och **björk**	köksmöblernas laminatytor
förpackningskartong	kemisk och mekanisk	tall, **björk** och gran	kartongpaket, vätskeförpackningar, wellpappslådor

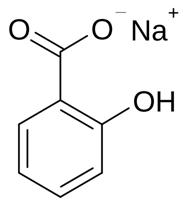
Hydrotropisk extrahering av lignin

- Hydrotroper förbättrar lösligheten av organiska ämnen i vatten (t.ex. lignin)
- Hydrotropernas struktur är likadant som surfaktanternas struktur
- Amfifiliska ämnen byggda av hydrofila och lipofila fuktionella grupper

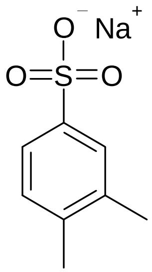
Hydrotroper



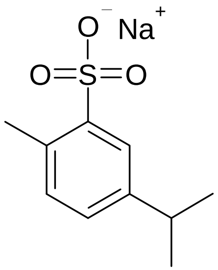
a)



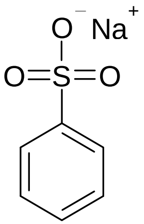
b)



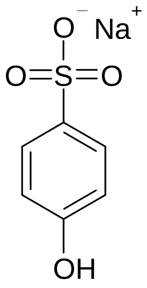
c)



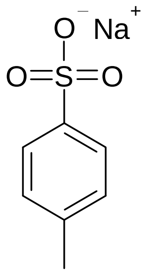
d)



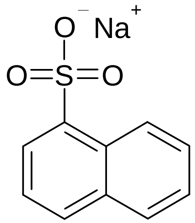
e)



f)



g)



h)

McKee 1943; Traynard 1955

Extraktion

- Natriumxylensulfonat (SXS) är den mest använda hydrotropen
- SXS lösning kan användas 6 gånger före den måste återvinnas
  - Lösningen blir mättad av lignin
  - Ca. 350 g lignin per 1000 ml lösning

Extraktion, forts.

- Lignocellulosa material behandlas vanligen vid 150 °C i 11–12 timmar
  - 30 % SXS lösning
- Massan måste tvättas med färsk SXS lösning
  - Lignin kan utfälla på fibrerna
- SXS lösning fungerar bättre för lövved än barrved
  - Lignin i lövved (syringyl) är mera reaktiv

Extraktion, forts.

- Återvinning av lösningen är enkelt
- Lösningens koncentration minskas från 30 % till 10 % med vatten
- Ligninet utfälls och kan filtreras bort
- Lösningen indunstas till den ursprungliga koncentrationen
  - 30 %

Utfällning av lignin

Hydrotropiskt lignin

- Innehåller obetyliga mängder
  - Svavel
  - Vedens sockerarter
- Mycket intressant material för
  - Biobränsleproduktion
  - Produktion av kemikalier och andra material

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Vision 2030

- Increase of productivity in Nordic Forests
- Controll of assembly of cell wall components
- Biobased materials has a share of 20-40% of the market
- Biobased chemicals (direct production + expression in plants + biorefineries)
- Biomass take partially the role of oil as raw material for polymers
- Chemicals from wood residues

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Vision 2080

- Growth rate much superior than in 2010
- Tailored Nordic forests (materials, chemicals, nanomaterials, fuels)
- Full disassembly of wood components in a few steps (chemical or biochemical)
- Biomass takes over oil (as a base for polymer industry)

The Black Swan Events (Anytime)

Unexpected developments, coming out of nowhere, for which no one has any kind of contingency plan.