Wood Modification
- State of the art and future trends in Europe

Mats Westin
Research Manager,
SP Wood Technology
Outline of presentation

Modified Wood
- Thermally modified
- Furfurylated
- Acetylated

Biorefineries
- A mega-biorefinery concept will be presented
Thermally modified wood

**Dominating application areas:**
- Cladding
- Decking & Railing
- Joinery products
- Garden furniture
- Saunas
Production of thermally modified timber (TMT)

- In 2010 the world production reached almost 450,000 m³
- In 2014 – half a million m³?
Production of thermally modified timber in Europe

No 1. Finland
- 20 plants
- 145 000 m³

No 2. Germany
- 9 plants
- 55 000 m³

No 3. France
- 13 plants
- 25 000 m³

No 4. Estonia
- 5 plants
- 19 000 m³

No 5. The Netherlands
- 3 plants
- 13 000 m³
The biggest brand: ThermoWood®
ThermoWood – Market, wood species, treatment classes

Wood species
- 47% Scots pine
- 47% spruce
- 6% Other

Treatment Class
- TW D (86%)
- TW S (14%)
Durability of Thermally Modified Timber

LABORATORY TESTS
- Good resistance to most fungi (except Postia placenta)

FIELD TESTS
- In soil contact (In-ground stake tests and commodity testing)
  - Poor durability
  - Usually failure within 5-8 years
- Resistance to termite attack
  - None
- Resistance to Marine borers (shipworms, gribbles (Limnoria), etc)
  - None in most cases
  - Some after oil-heat-treatment with old rapeseed oil
- In above ground situation (Use Class 3)
  - See following slides
Report on COST E37
Round Robin Tests
- Comparison of results from lab and field tests

Mats Westin,
## Participants in the COST E37 Round Robin

<table>
<thead>
<tr>
<th>Participant</th>
<th>Country</th>
<th>Lab test</th>
<th>Field test</th>
<th>Field Region</th>
<th>Responsible</th>
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<tbody>
<tr>
<td>BRE</td>
<td>UK</td>
<td>X</td>
<td>X</td>
<td>Mid Europe</td>
<td>Ed Suttie</td>
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<tr>
<td>CATAS</td>
<td>IT</td>
<td>X</td>
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<td></td>
<td>Elena Conti</td>
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<tr>
<td>CNR-Ivalsa</td>
<td>IT</td>
<td>-</td>
<td>X</td>
<td>South Europe</td>
<td>Sabrina Palanti</td>
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<tr>
<td>DTI</td>
<td>DK</td>
<td>X</td>
<td>X</td>
<td>Nordic</td>
<td>Morten Klamer</td>
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<tr>
<td>LNEC</td>
<td>PT</td>
<td>-</td>
<td>X</td>
<td>South Europe</td>
<td>Lina Nunes</td>
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<td>LS IWC</td>
<td>LV</td>
<td>X</td>
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<td>Ilze Irbe</td>
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<td>NO</td>
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<td>X</td>
<td>Nordic</td>
<td>Per Otto Flaete a</td>
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<tr>
<td>Poznan Univ.</td>
<td>PL</td>
<td>-</td>
<td>X</td>
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<td>Bartłomiej Mazela</td>
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<tr>
<td>SHR</td>
<td>NL</td>
<td>X</td>
<td>X</td>
<td>Mid Europe</td>
<td>Jos Creemers b</td>
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<tr>
<td>SP</td>
<td>SE</td>
<td>X</td>
<td>X</td>
<td>Nordic</td>
<td>Mats Westin</td>
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<tr>
<td>TI (form. BFH)</td>
<td>DE</td>
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<td>X</td>
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<td>Eckhard Melcher c</td>
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<td>Ladislav Reinprecht</td>
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<td>VTT</td>
<td>FI</td>
<td>X</td>
<td>X</td>
<td>Nordic</td>
<td>Hannu Viitanen</td>
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<td>Wolman</td>
<td>DE</td>
<td>X</td>
<td>X</td>
<td>Mid Europe</td>
<td>Ralf Moeller</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>15</strong></td>
<td><strong>10</strong></td>
<td><strong>12</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

*a Initially started by Fred Evans  
*b Initially started by Bas Holleboom  
*c Initially started by Andreas Rapp
# Materials

**Scots pine sapwood** (*Pinus sylvestris* L.)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Untreated</td>
</tr>
<tr>
<td>Organic Low</td>
<td>Metal free preservative, UC3 retention</td>
</tr>
<tr>
<td>Organic High</td>
<td>Metal free preservative, UC4 retention</td>
</tr>
<tr>
<td>CCA medium</td>
<td>CCA preservative, &lt;UC4 retention</td>
</tr>
<tr>
<td>CCA high</td>
<td>CCA preservative, &gt;UC4 retention</td>
</tr>
</tbody>
</table>

**Norway spruce** (*Picea abies* L.)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMT-UC2</td>
<td>Thermally modified, 200°C peak temp</td>
</tr>
<tr>
<td>TMT-UC3</td>
<td>Thermally modified, 212°C peak temp</td>
</tr>
</tbody>
</table>
Methods – Laboratory decay tests

EN 113 (European agar-block method)

2 methods of preconditioning
- EN 84 leaching in water for 2 weeks
- CEN/TS 15397 1 year field exposure
Methods – Above ground field test

Horizontal double layer test

- Stainless steel profiles 30x60 mm
- Light weight concrete blocks 120x190 mm
- Geo textile
# Results – EN113

Average valid Mass Loss values (%) for the 10 laboratories

<table>
<thead>
<tr>
<th></th>
<th>Coniophora puteana</th>
<th>Postia placenta</th>
<th>Trametes versicolor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EN 84 leached</td>
<td>Field exposed</td>
<td>Control</td>
</tr>
<tr>
<td>Int. Control</td>
<td>34</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Organic Low</td>
<td>2</td>
<td>14</td>
<td>41</td>
</tr>
<tr>
<td>Organic High</td>
<td>0</td>
<td>7</td>
<td>41</td>
</tr>
<tr>
<td>TMT-UC2</td>
<td>6</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>TMT-UC3</td>
<td>3</td>
<td>5</td>
<td>43</td>
</tr>
<tr>
<td>CCA Medium</td>
<td>0</td>
<td>0</td>
<td>41</td>
</tr>
<tr>
<td>CCA High</td>
<td>0</td>
<td>0</td>
<td>46</td>
</tr>
</tbody>
</table>
Results – EN113

"Natural durability class" calculated from average ML values

<table>
<thead>
<tr>
<th>&quot;Durability Class&quot;</th>
<th>Coniophora puteana</th>
<th>Postia placenta</th>
<th>Trametes versicolor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EN 84 leached</td>
<td>Field exposed</td>
<td>EN 84 leached</td>
</tr>
<tr>
<td>Int. Control</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Organic Low</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Organic High</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>TMT-UC2</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>TMT-UC3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CCA Medium</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CCA High</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Results – Field test

The deck in Watford, UK
Results – Field test

The deck in Sinzheim, Germany – opened up
Results – Field test

The controls performs rather equal in all fields
- Mostly moderate to severe decay

The controls stakes in Denmark
Results – Field test

Medium thermally modified spruce (TMT-UC2)

Index of decay, %

Years

- Nordic fields
- Mid European
- Average, all fields
- South European
Results – Field test

Exterior grade thermally modified spruce (TMT-UC3)

Index of decay, %

Years

Nordic fields
Mid European
Average, all fields
South European
Results – Field test

TMT-UC3 in Italy

Moderate to severe decay
Results – Field test

TMT-UC2 in Italy

Severe decay or failure due to decay

A failed stake
Results – Field test

TMT-UC2 in a Nordic field

Sound to slight decay
Results – Field test

Average values for all fields

- CCA (High retention)
- CCA (Med retention)
- Organic (High ret.)
- Organic (Low ret.)
- TMT-UC3
- TMT-UC2
- Control

Index of decay, %

0 25 50 75

0 5 10 15 20 25 30 35 40 45 50

0 2.5 5 7.5 10 12.5 15

Years
Comparison of results from laboratory and field

Laboratory

- **Postia placenta**
  - EN 84
  - Field leached
- CCA High: 1 (leached), 1 (exposed)
- CCA Medium: 5 (leached), 9 (exposed)
- Organic High: 0 (leached), 5 (exposed)
- Organic Low: 2 (leached), 12 (exposed)
- TMT-UC3: 11 (leached), 13 (exposed)
- TMT-UC2: 19 (leached), 18 (exposed)
- Int. Control: 29 (leached), 29 (exposed)

Field

- **Average values for all fields**
  - CCA (High retention)
  - CCA (Medium retention)
  - Organic (High retention)
  - Organic (Low retention)
  - TMT-UC3
  - TMT-UC2
  - Control

![Graph showing decay index over years for different treatments](image-url)
Conclusions – TMT above ground durability

Lab tests: The poorer performance with Postia placenta best reflects the field performance.

Field tests: TMT in rather good condition in the Nordic fields but moderate to severely decayed in Southern European fields
Trends for Thermally Modified Timber production:
- More indoor applications. Other wood species.

Example: TMT Ash
Furfurylated wood (Kebony)

Dominating application areas:
- Decking & Railing
- Cladding
- Boat decks and interiors
- Public flooring
- Joinery products
- Garden furniture
Products made of furfurylated wood

High-furfurylated beech (Kebony Black, WPG=100)

Medium-furfurylated wood (Kebony SYP, Maple, Beech, Ash, Maple and SYP, respectively)
Products from furfurylated Scots pine (Kebony pine)
Production of furfurylated wood

One Kebony factory in Norway:
- 25,000 m³ capacity
- Discussions on building a second plant

Patents for similar process (Keywood) owned by Arch/Lonza:
- Pilot plant with small capacity (1,000 m³)
- If restrictions/legislation on traditional preservatives change Ach/Lonza will support building of plants
History of wood furfurylation

- First process developed by Goldstein & Stamm in the late 1950s (only worked with veneers or very small timber dimensions)
- Small production in US in the 1960s – Laboratory bench tops
- Early 1990s, Marc Schneider and Mats Westin simultaneously developed similar new processes
- 2001 – Schneider and Westin jointly developed patents for Kebony
- 2004 – Small scale production in Norway
- 2009 – Full scale production in Norway
Properties of furfurylated wood

SP Wood Technology has performed more tests of furfurylated wood than any other research group

- Mechanical testing
- Dimensional stability and EMC
- Mold and blue stain tests
- Microbial decay tests in laboratory
- Insect tests in laboratory
- Field tests in soil contact and above ground (8 fields)
- Field tests in sea water (resistance to marine borers, 3 fields)
- Field tests with subterranean termites (2 fields)
- Field tests with different coatings on furfurylated wood (2 fields)
Laboratory tests of furfurylated wood

### Durability – Lab test of fungal decay resistance
(Expanded ENV 807: 3 soil types, TMCs)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>WPG (after curing)</th>
<th>Mass loss during leaching</th>
<th>Mass loss in TMC 1 (Compost soil)</th>
<th>Mass loss in TMC 2 (Brown rot soil)</th>
<th>Mass loss in TMC 3 (White rot soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(%)</td>
<td>%ML (st.dev.)</td>
<td>%ML (st.dev.)</td>
<td>%ML (st.dev.)</td>
<td>%ML (st.dev.)</td>
</tr>
<tr>
<td>Control</td>
<td>untreated</td>
<td>2.4</td>
<td>61.8 (± 7.8)</td>
<td>61.2 (± 1.3)</td>
<td>20.1 (± 2.0)</td>
</tr>
<tr>
<td>Furfurylated</td>
<td>22</td>
<td>2.4</td>
<td>1.6 (± 0.3)</td>
<td>2.9 (± 1.0)</td>
<td>8.5 (± 0.5)</td>
</tr>
<tr>
<td>Furfurylated</td>
<td>41</td>
<td>1.7</td>
<td>1.0 (± 0.2)</td>
<td>1.8 (± 0.2)</td>
<td>5.0 (± 0.7)</td>
</tr>
<tr>
<td>Furfurylated</td>
<td>60</td>
<td>0.6</td>
<td>0.7 (± 0.3)</td>
<td>1.6 (± 0.3)</td>
<td>1.9 (± 0.4)</td>
</tr>
</tbody>
</table>
Mass loss (%) of pine control, Cu/Cr, 2.5 kg/m3, Cu/Cr, 5 kg/m3, Cu/Cr, 10 kg/m3 (NTR-A), CCA (NTR-AB), CCA (NTR-A), furfural, WPG=25, and furfural, WPG=37 in Compost soil, Simlångsdalen soil, and Conifer forest soil over 40 weeks exposure in an ENv 807 test.
Natural durability class (based on EN807 run at two institutes)

value above bars – Nat durability class based on AWPA E10 test

5 – Non-durable
4 – Slightly durable
3 – Moderately durable
2 – Durable
1 – Very durable
SP Wood Technology’s Own test fields
+
other test fields where we have ongoing tests

Hilo, Hawaii
Ingvallsbenning
Ås, Norway
KMF
SP, Borås
Simlångsdalen
Hannover, DE
Ultuna
Bogesund
Poznan, Poland
Field test of furfurylated wood

Weight loss due to termite attack for wood mini-stakes (8 x 20 x 200 mm) in the Bogor test field in Indonesia after 6 months of exposure.
Field test of furfurylated wood

Termite attack on wood mini-stakes (8 x 20 x 200 mm) in the Bogor test field in Indonesia after 6 months of exposure.
Field test of furfurylated wood

Index of Decay (0-100%) in Simlångsdalen test field

Results from material produced in pilot scale in the 90s

- Control
- CCA - 2
- FA 15
- FA 30
- FA 50
- FA 100
- CCA - 9

Index of Decay

Years

0 1 2 3 4 5 6 7 8
Field test of furfurylated wood

Material from production site in Norway

ECOMOD EN 252 field test in Borås. Started 2005

Index of decay, %

Years

0 5 10

CCA 9.0 kg/m³
Kebony WPG=50
Kebony WPG=40
Kebony WPG=30
Kebony WPG=20
AB-ref (CX8)
Robinia pseudoaccacia
ThermoWood D
Untreated pine sapwood
Marine field tests of modified wood

Test rigs being taken up
Marine field tests of modified wood
# Marine field tests of modified wood

<table>
<thead>
<tr>
<th>Modification</th>
<th>1 yr</th>
<th>4 yr</th>
<th>8 yr</th>
<th>11 yr</th>
<th>14 yr</th>
<th>Overall Serv. life</th>
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<tbody>
<tr>
<td>Control (untreated Pine sap)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>Failed 1.0</td>
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<tr>
<td>Furfurylation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>15% WG</td>
<td>1.0</td>
<td>3.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Failed 4.0</td>
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<tr>
<td>29% WG</td>
<td>0.0</td>
<td>0.0</td>
<td>0.6</td>
<td>1.0</td>
<td>1.2</td>
<td>Slight</td>
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<tr>
<td>50% WG</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>0.2</td>
<td>Sound</td>
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<tr>
<td>120% WG</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>Sound</td>
</tr>
<tr>
<td>Acetylation</td>
<td></td>
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<tr>
<td>21% acetyl</td>
<td>0.2</td>
<td>0.4</td>
<td>1.4</td>
<td>2.4</td>
<td>2.8</td>
<td>Severe</td>
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<tr>
<td>ThermoWood D</td>
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<tr>
<td></td>
<td>2.8</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
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<tr>
<td>CCA - (NWPC Class AB)</td>
<td>0.3</td>
<td>4.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Failed 3.6</td>
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<tr>
<td>CCA - (NWPC Class M)</td>
<td>0.0</td>
<td>0.2</td>
<td>0.5</td>
<td>2.3</td>
<td>3.3</td>
<td>Severe</td>
</tr>
</tbody>
</table>
Trends for furfurylated wood

- Less focus on Kebony Scots pine and cladding/decking application
- More focus on Kebony SYP and Maple for higher value applications
Acetylated wood

Dominating application areas:
- Decking & Railing
- Joinery products
- Cladding
- Large constructions
Production of Acetylated wood

Accoya® (Accys Technologies)
- 10-20,000 m³/year
- Produced in Arnhem, The Netherlands

Perennial wood® (Eastman Chemical Co)
- 5,000 m³ in 2013
- Production in US now shut down!
Example of a forest mega-biorefinery concept

- Logs
- Forest harvesting residuals
- Agro residuals

Sawmill / Pulp mill

- Sawn timber
- Biocomposites (wood fiber based)
- Dissolving Pulp

Chemical industry 1

- Lignin
- Hemicellulose
- Tall oil, tannins, etc.

- High value chemicals
- Pellets
- Bio-diesel, Jet fuel, ethanol

Chemical industry 2

- Bio-binders
- Bio-coatings
- Bio-plastics
- Functionalized green aromatics

Wood Modific. industry

- Modified wood
Thank you for the attention!

Questions?