Wood Modification

- State of the art and future trends in Europe

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Outline of presentation

Modified Wood

- Thermally modified
- Furfurylated
- Acetylated

Biorefineries

- A mega-biorefinery concept will be presented

Thermally modified wood

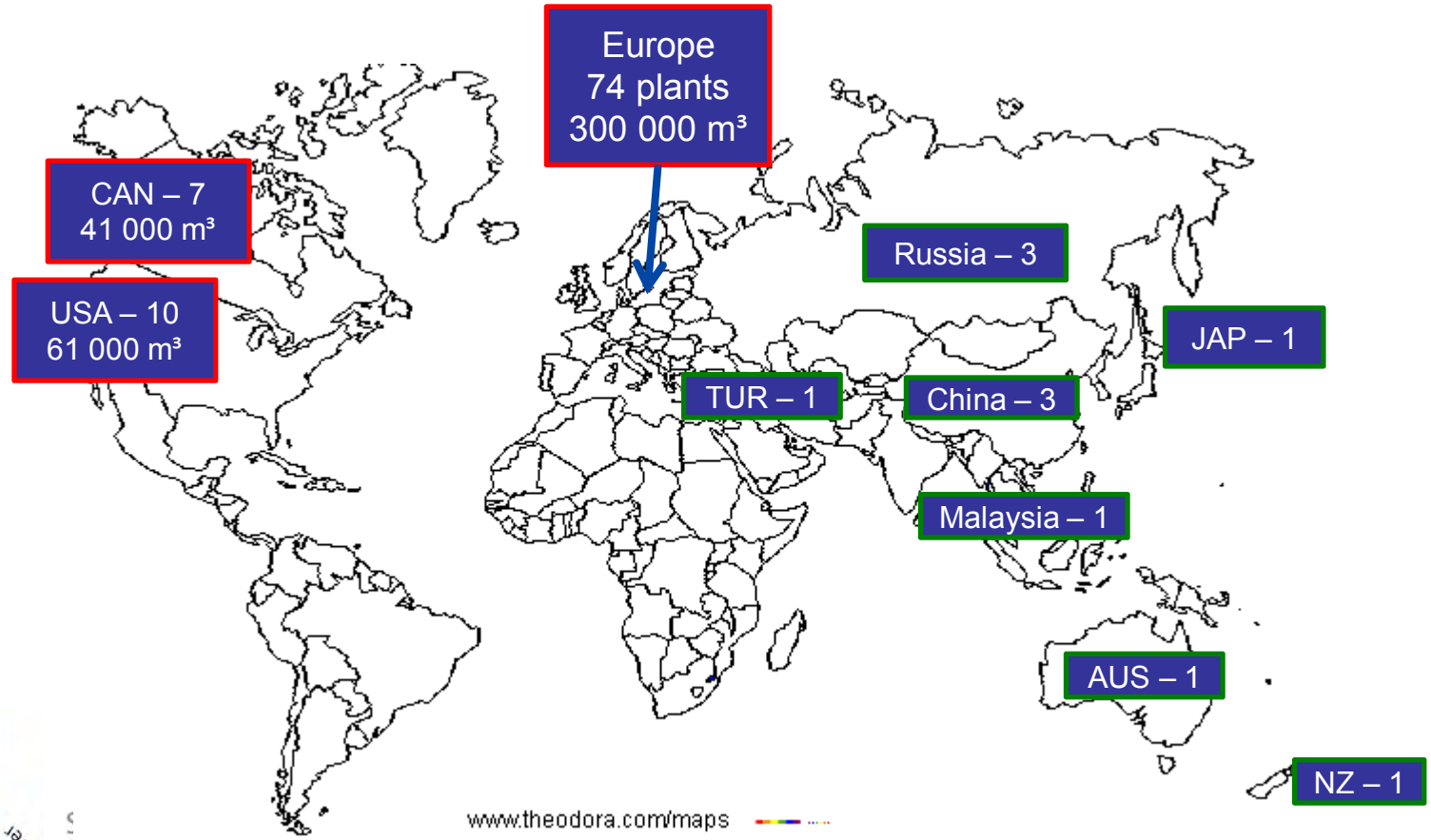
Dominating application areas:

- Cladding
- Decking & Railing
- Joinery products
- Garden furniture
- Saunas

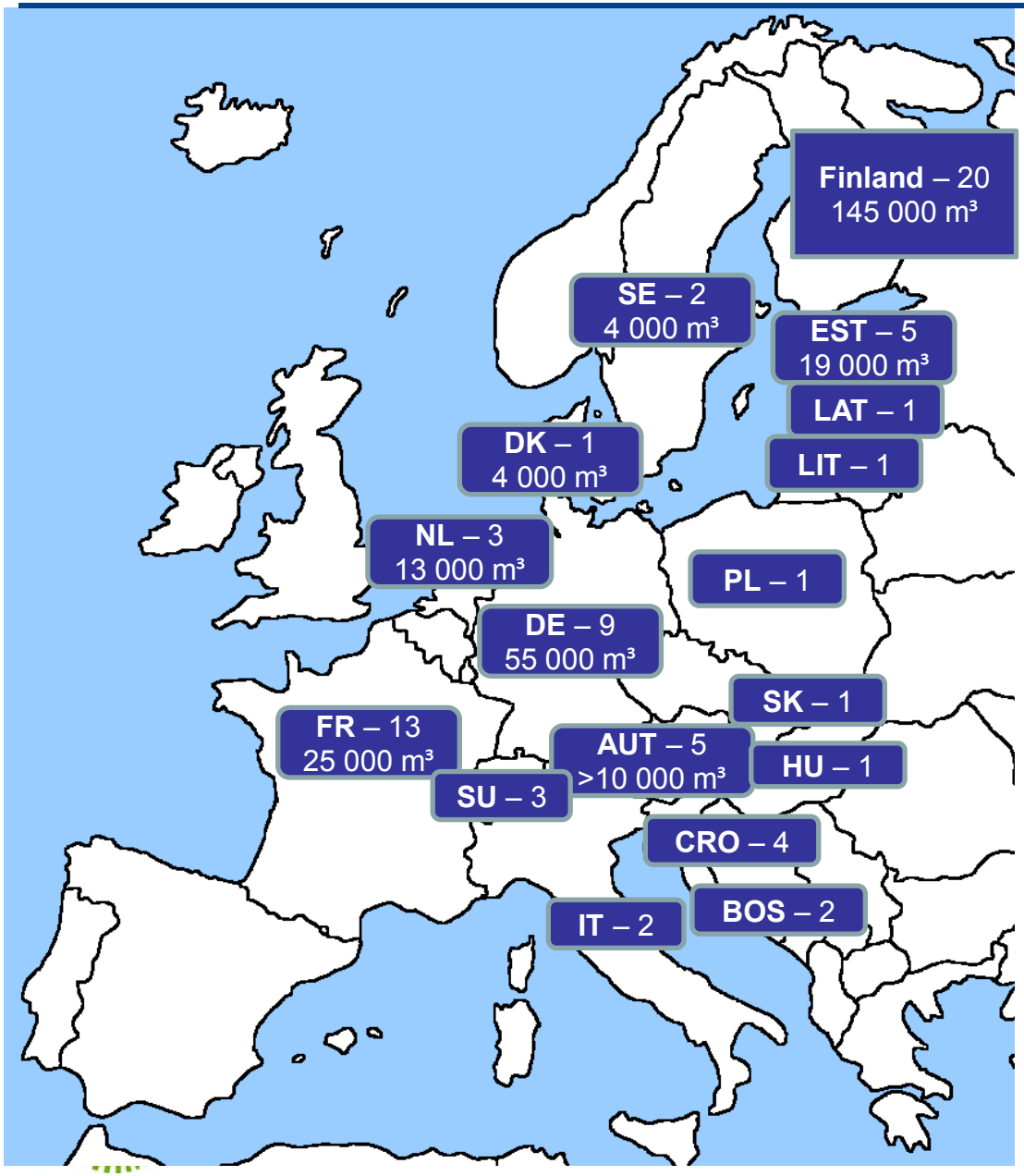
Production of thermally modified timber (TMT)

- In 2010 the world production reached almost 450 000 m³
- In 2014 – half a million m³ ?

2010



Production of thermally modified timber in Europe



No 1. Finland
- 20 plants
- 145 000 m³

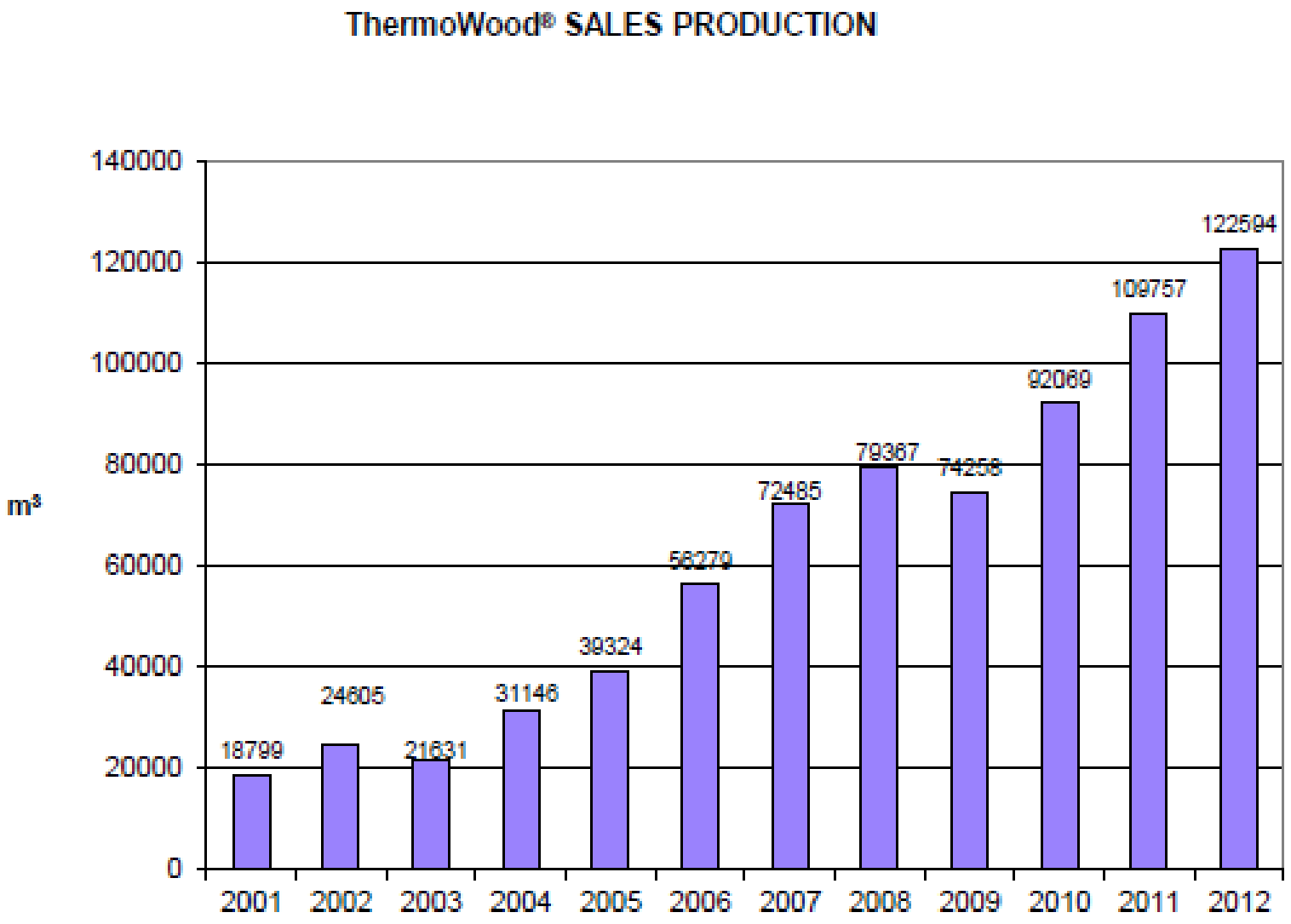
No 2. Germany
- 9 plants
- 55 000 m³

No 3. France
- 13 plants
- 25 000 m³

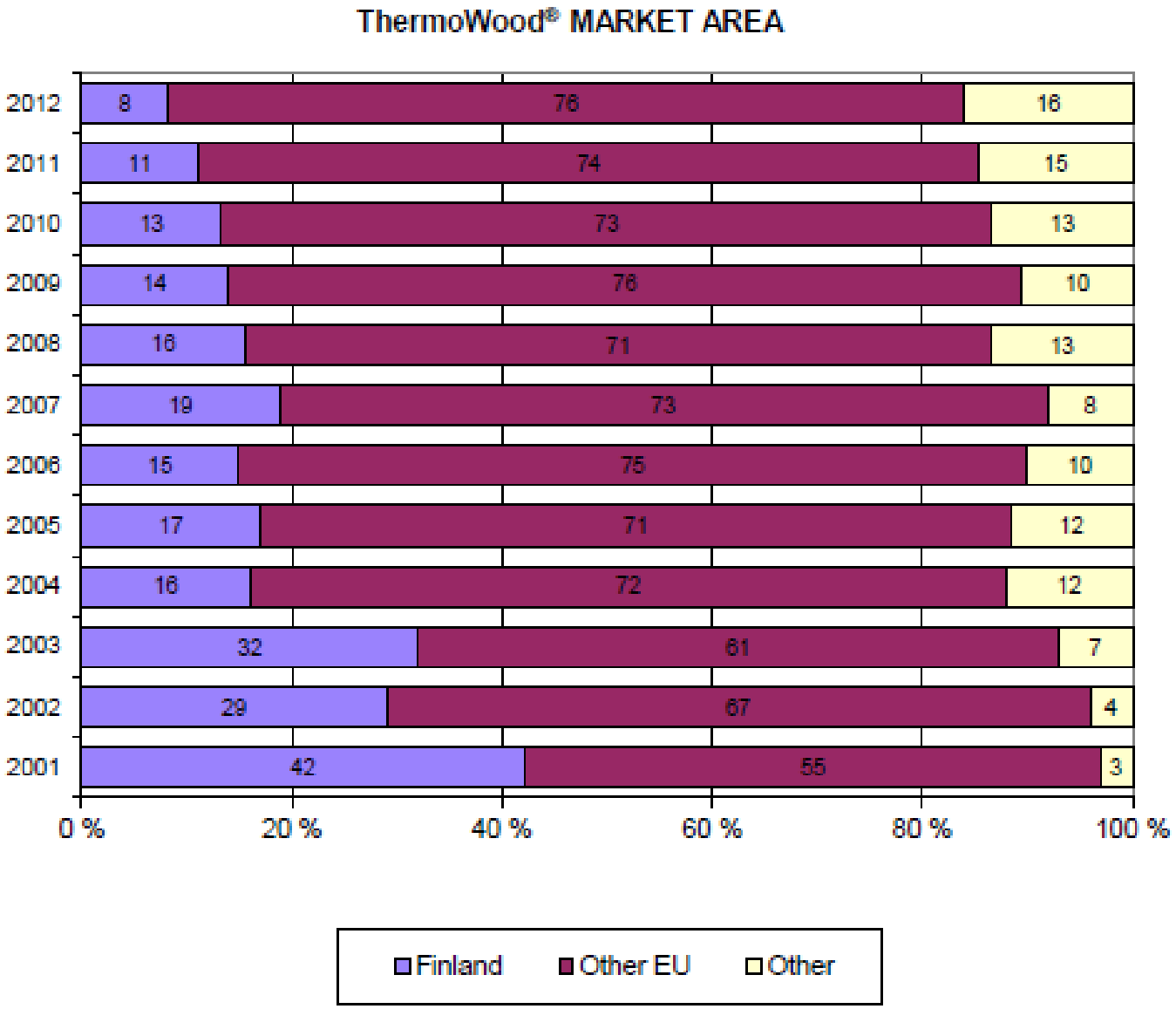
No 4. Estonia
- 5 plants
- 19 000m³

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,

Elena Conti, Jos Creemers, Per-Otto Flæte, Antje Gellerich, Ilze Irbe, Morten Klamer, Bart Mazela, Eckhard Melcher, Ralf Moeller, Lina Nunes, Sabrina Palanti, Ladislav Reinprecht, Ed Suttie, Hannu Viitanen

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Participants in the COST E37 Round Robin

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

[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.)

Control	-	Untreated
Organic Low	-	Metal free preservative, UC3 retention
Organic High	-	Metal free preservative, UC4 retention
CCA medium	-	CCA preservative, <UC4 retention
CCA high	-	CCA preservative, >UC4 retention

Norway spruce (*Picea abies* L.)

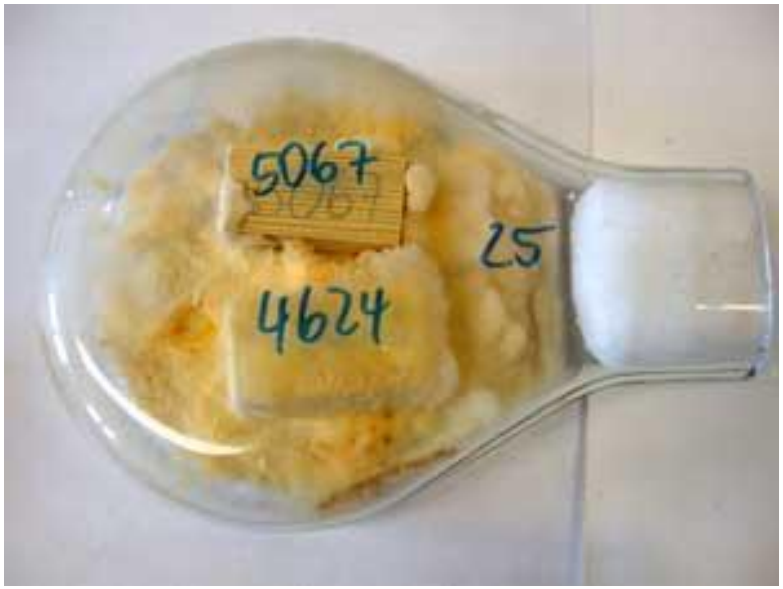
TMT-UC2	-	Thermally modified, 200°C peak temp
TMT-UC3	-	Thermally modified, 212°C peak temp

Methods – Laboratory decay tests

EN 113 (European agar-block method)

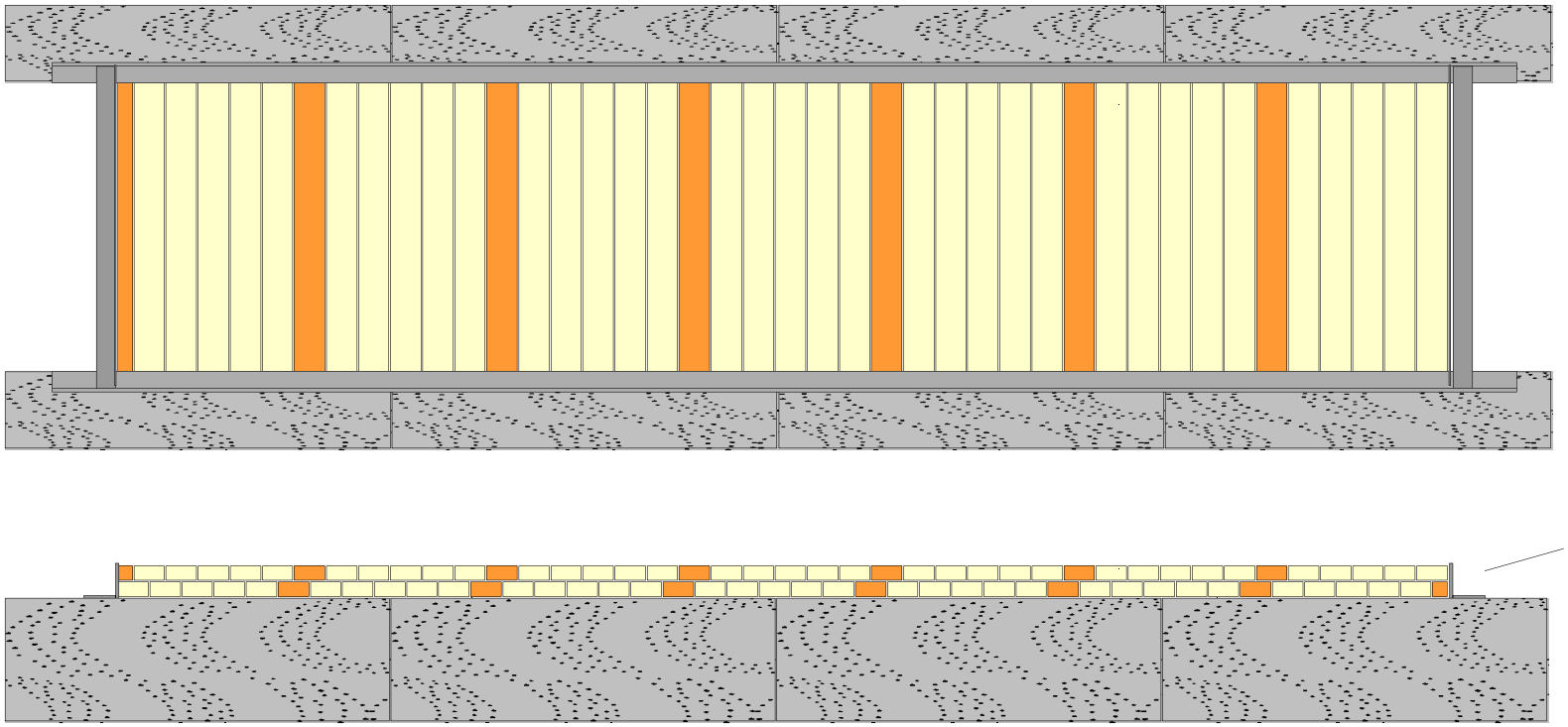
2 methods of preconditioning

- EN 84 — leaching in water for 2 weeks
- CEN/TS 15397 — 1 year field exposure



Methods – Above ground field test

Horizontal double layer test



Results – EN113

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

	Coniophora puteana				*Postia placenta*				*Trametes versicolor*			
	EN 84 leached	Field exposed	Control		EN 84 leached	Field exposed	Control		EN 84 leached	Field exposed	Control	
Int. Control	34	34	34	33	29	29	29	30	23	21	24	21
Organic Low	2	14	41	40	2	12	35	30	4	7	21	20
Organic High	0	7	41	42	0	5	34	32	1	3	25	23
TMT-UC2	6	7	39	40	19	18	30	32	4	3	21	21
TMT-UC3	3	5	43	40	11	13	36	34	2	3	20	20
CCA Medium	0	0	41	46	5	9	37	35	1	1	32	23
CCA High	0	0	46	44	1	1	41	37	0	0	23	20

Results – EN113

”Natural durability class” calculated from average ML values

"Durability Class"	*Coniophora puteana*		*Postia placenta*		*Trametes versicolor*	
	EN 84 leached	Field exposed	EN 84 leached	Field exposed	EN 84 leached	Field exposed
Int. Control	5	5	5	5	5	5
Organic Low	1	3	1	3	2	3
Organic High	1	2	1	2	1	1
TMT-UC2	1	2	4	3	2	2
TMT-UC3	1	1	3	3	1	1
CCA Medium	1	1	1	2	1	1
CCA High	1	1	1	1	1	1

Results – Field test

The deck in Watford, UK

Results – Field test

The deck in Sinzheim, Germany – opened up

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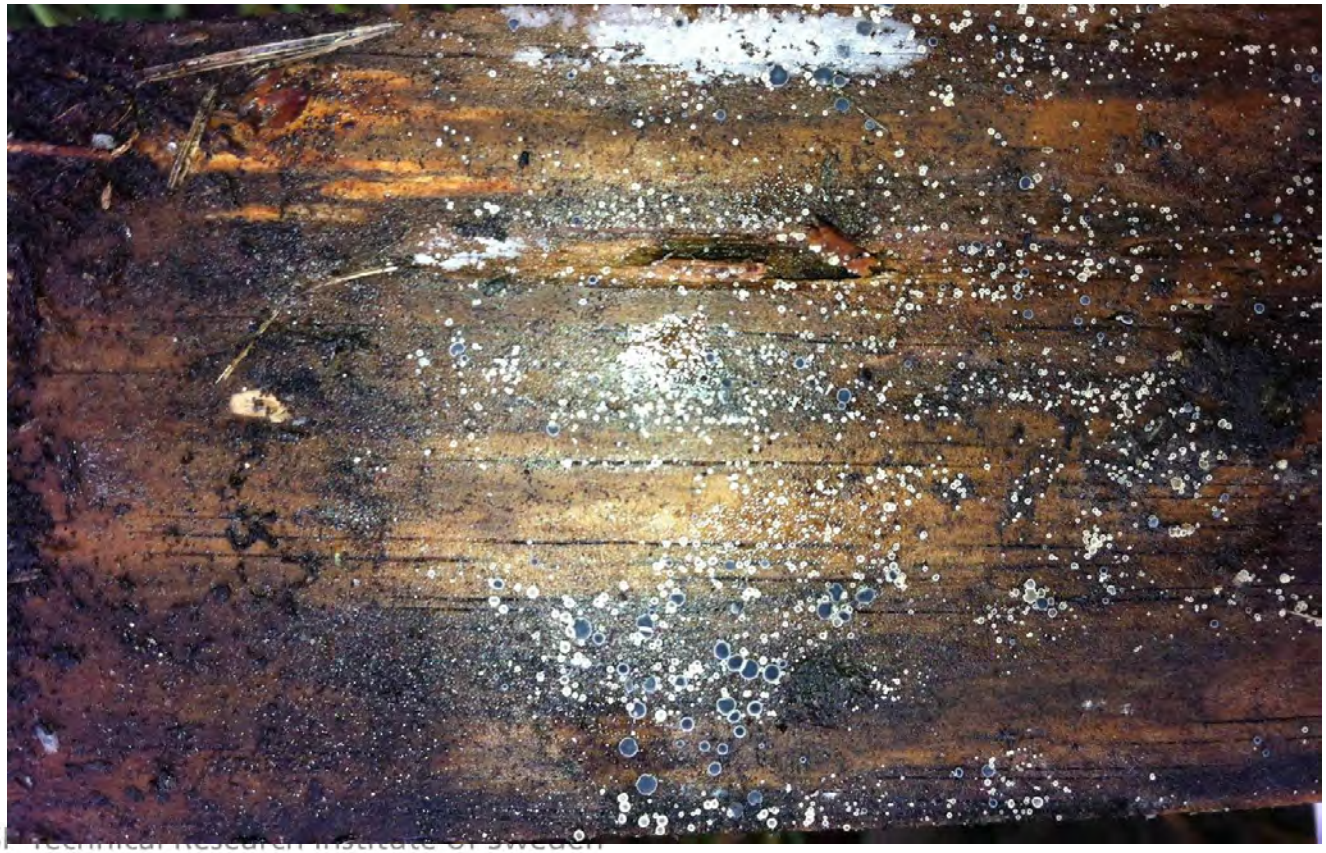
Wolman

Results – Field test

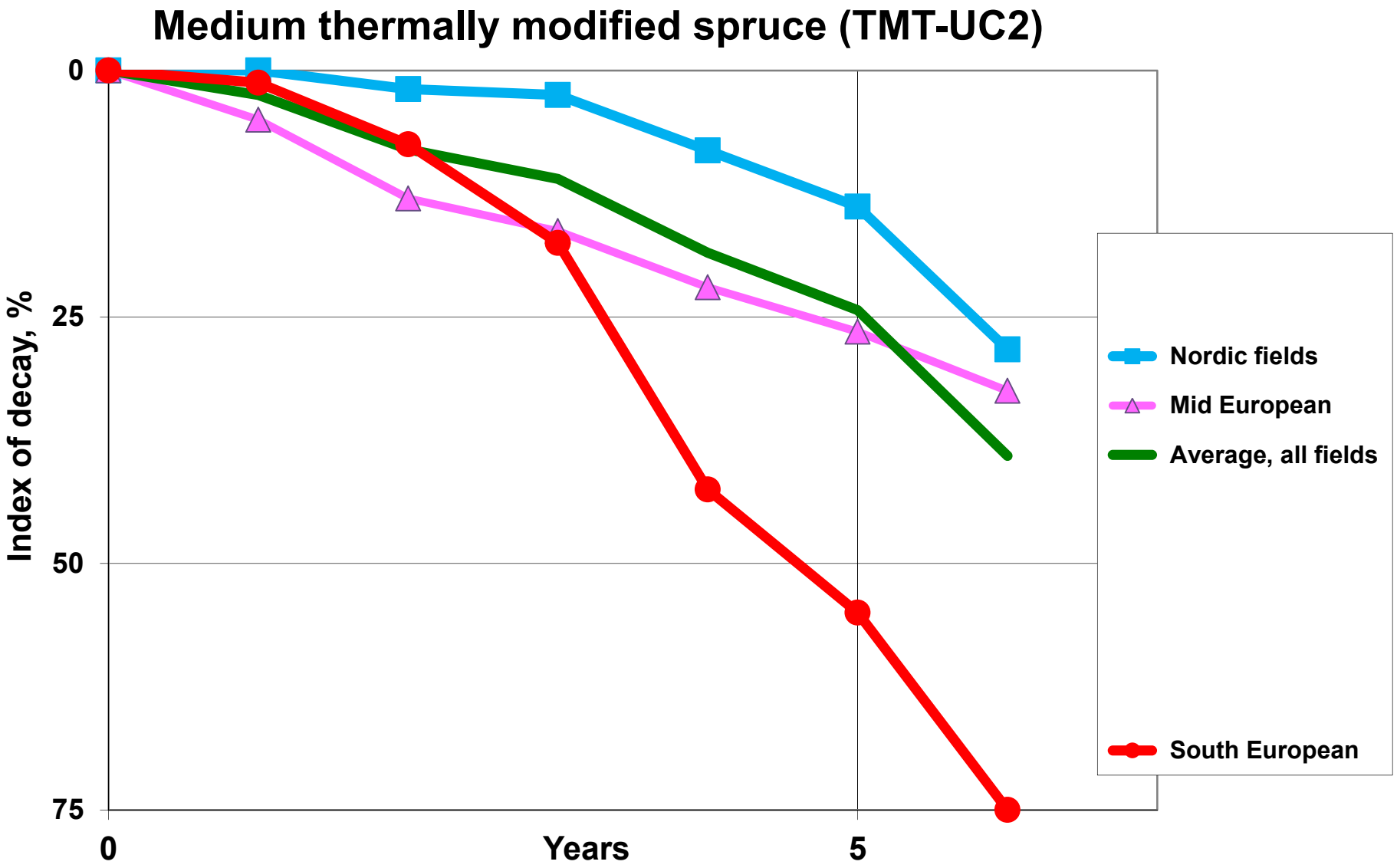
The controls performs rather equal in all fields
- Mostly moderate to severe decay



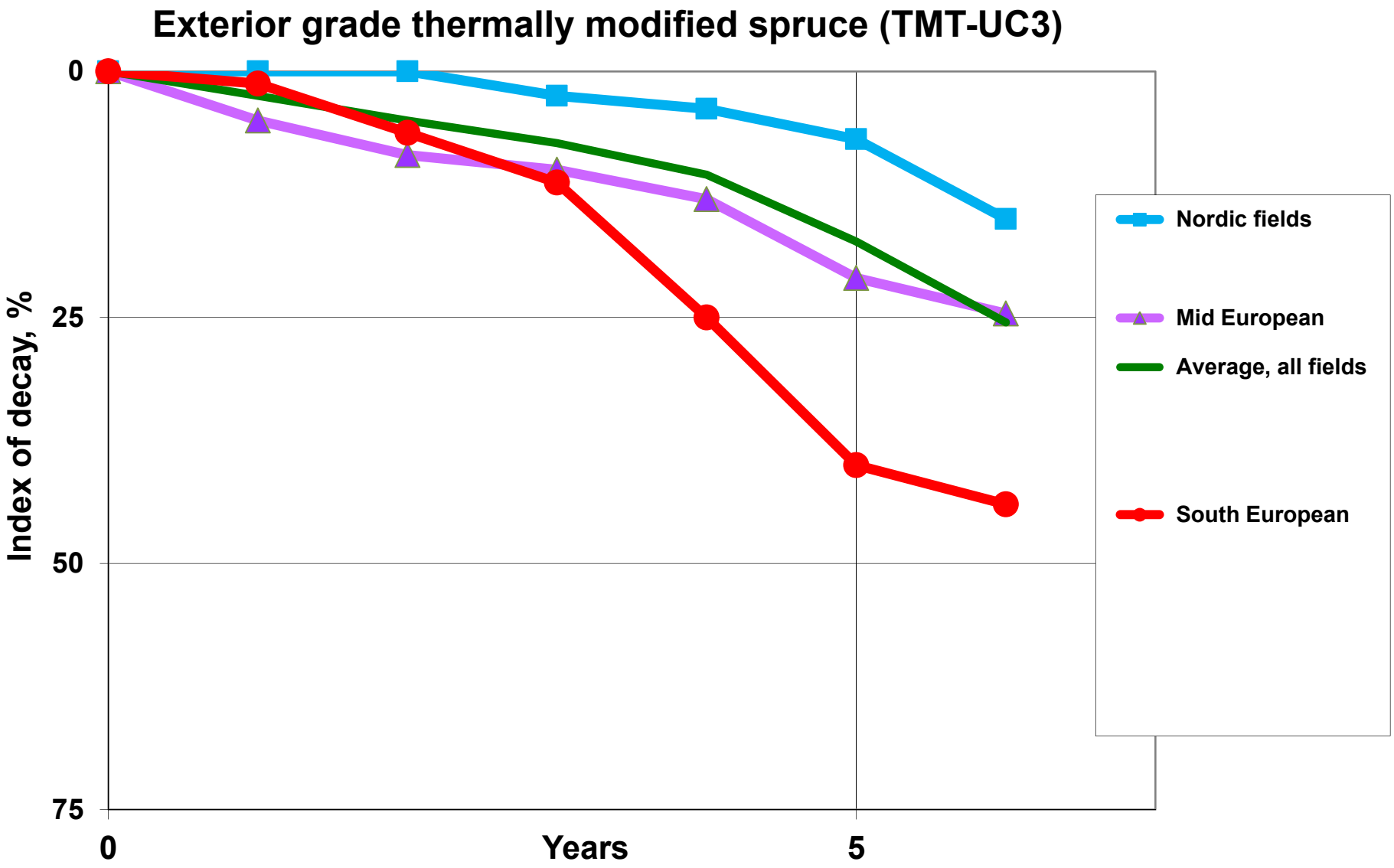
The controls stakes in Denmark

DTI

Results – Field test



Results – Field test



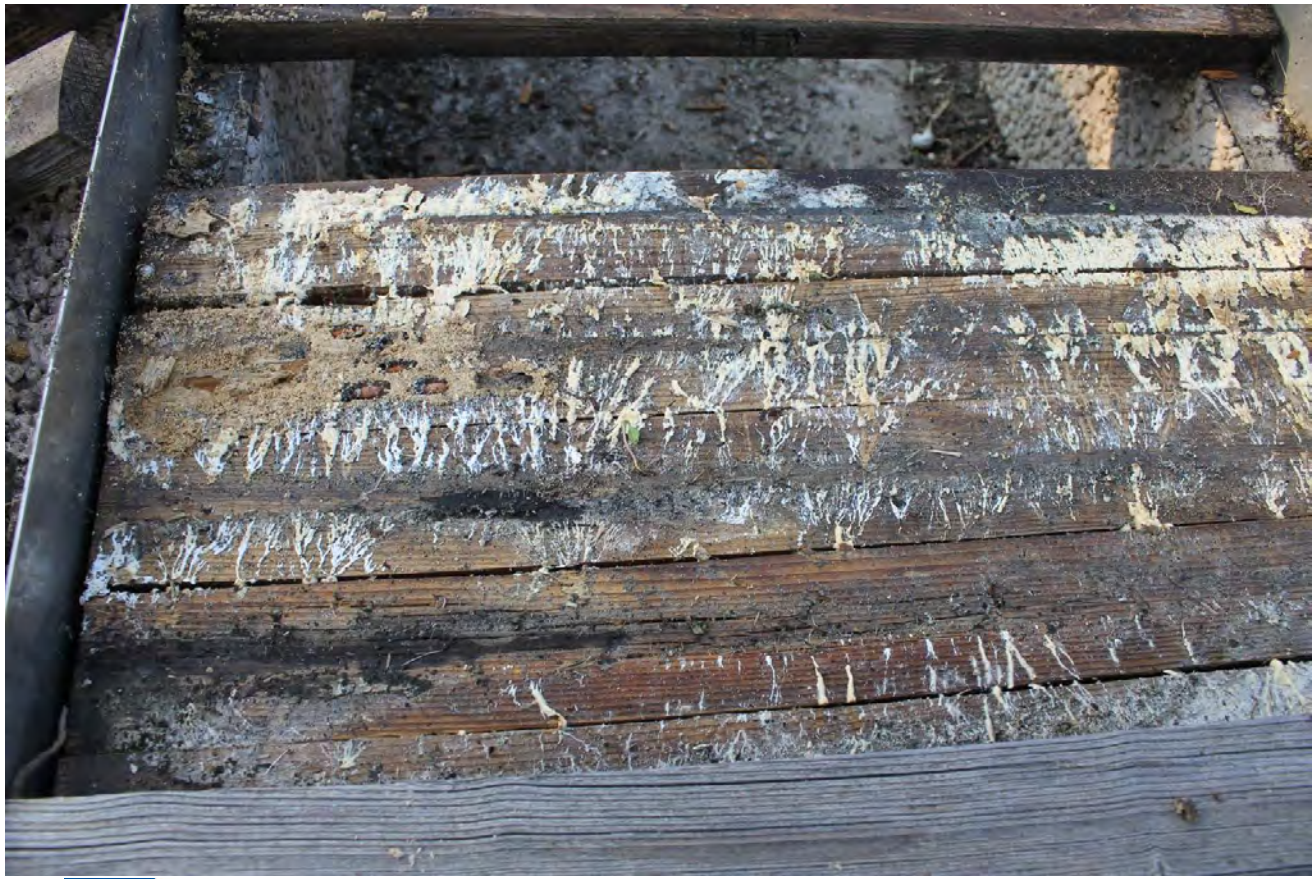
Results – Field test

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

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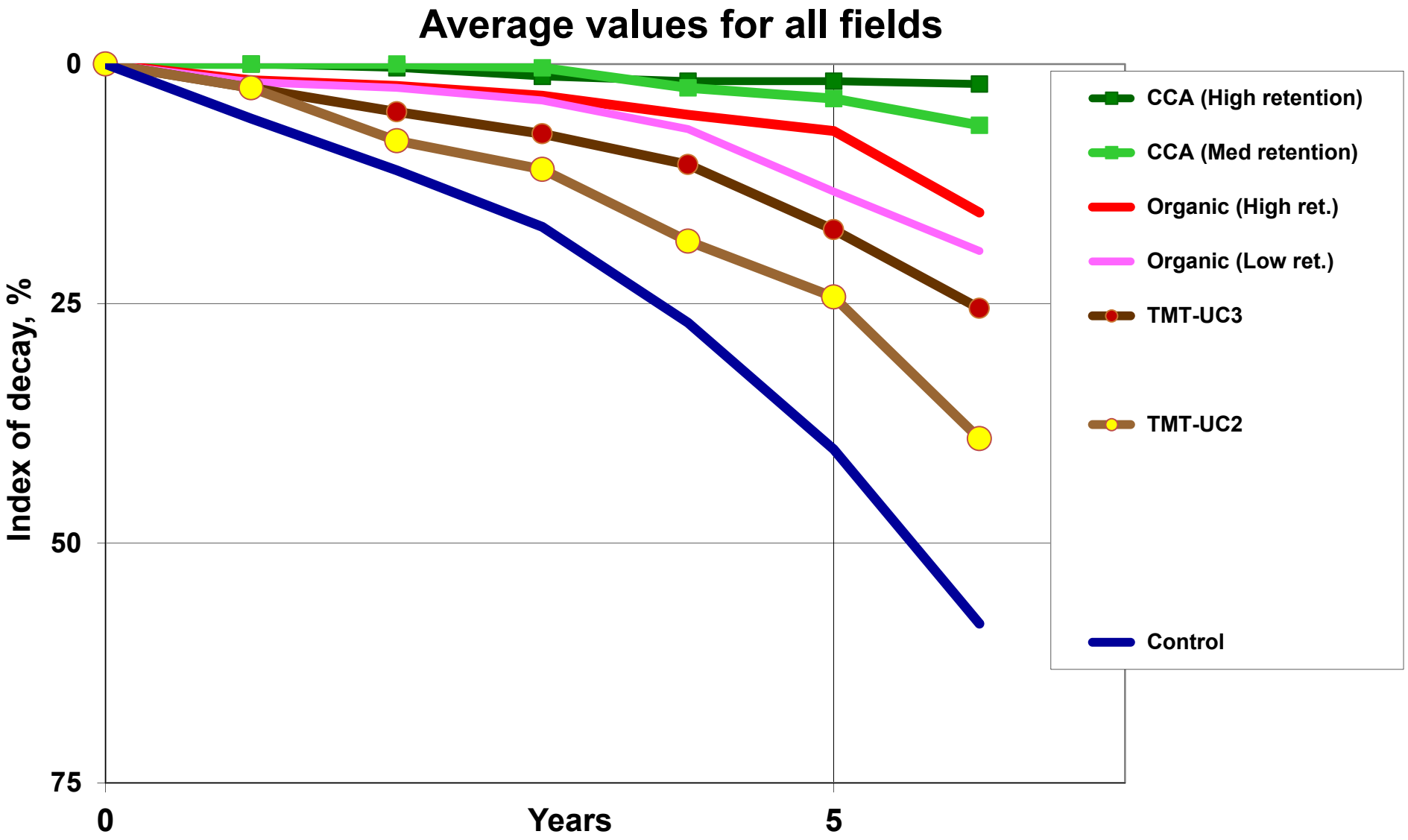
CNR-IVALSA
TREES AND TIMBER INSTITUTE

Results – Field test

TMT-UC2 in a Nordic field

Sound to slight decay

Results – Field test



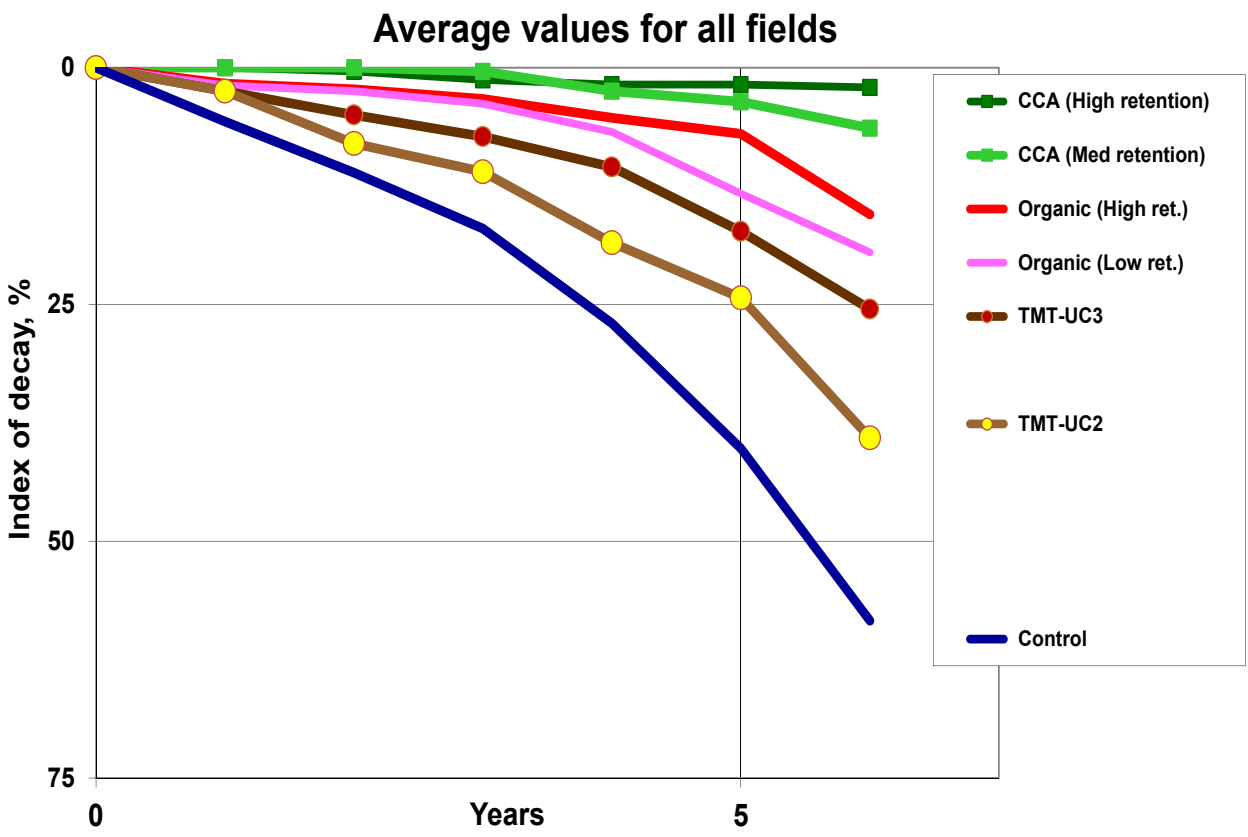
Comparison of results from laboratory and field

Laboratory

Average values for all labs and *Postia placenta* fungus

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

Field



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

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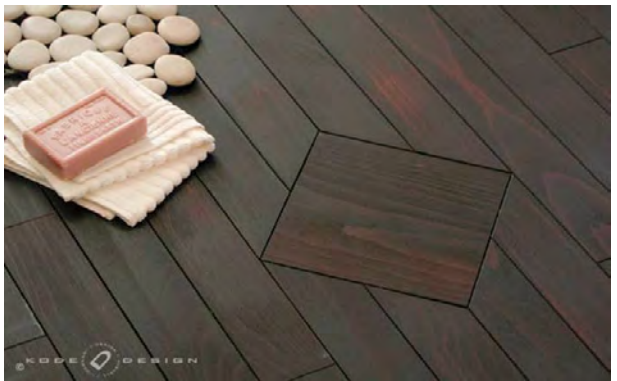
Products made of furfurylated wood

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)

Treatment	WPG (after curing)	Mass loss during leaching	Mass loss in TMC 1 (Compost soil)		Mass loss in TMC 2 (Brown rot soil)		Mass loss in TMC 3 (White rot soil)	
			6 months exposure		6 months exposure		12 months exposure	
		(%)	%ML	(st.dev.)	%ML	(st.dev.)	%ML	(st.dev.)
Control	untreated	2.4	61.8	(± 7.8)	61.2	(± 1.3)	20.1	(± 2.0)
Furfurylated	22	2.4	1.6	(± 0.3)	2.9	(± 1.0)	8.5	(± 0.5)
Furfurylated	41	1.7	1.0	(± 0.2)	1.8	(± 0.2)	5.0	(± 0,7)
Furfurylated	60	0.6	0.7	(± 0.3)	1.6	(± 0.3)	1.9	(± 0.4)

ENv 807 test in three soils, 40 weeks exposure

Mass loss (%)

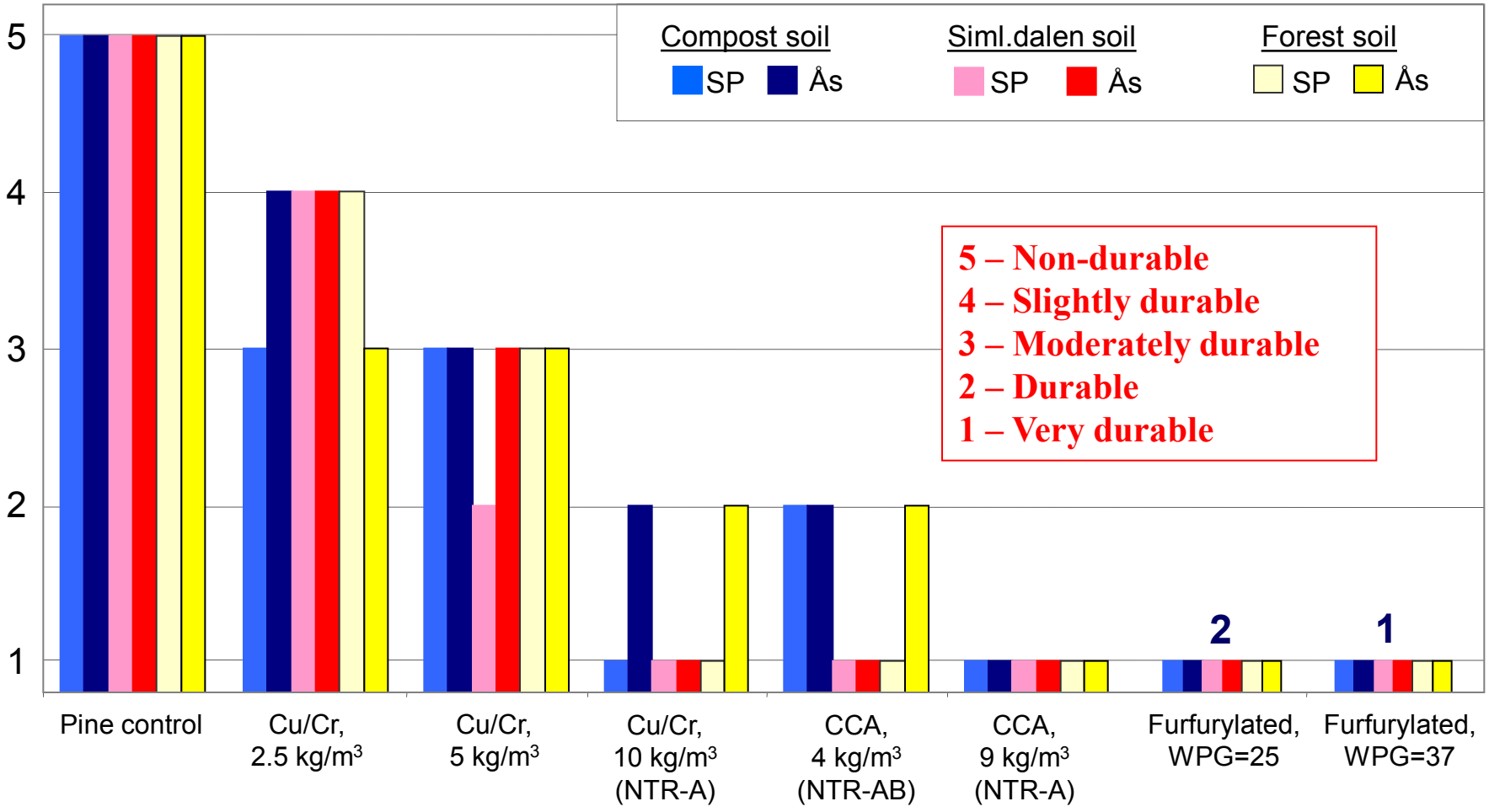
80
70
60
50
40
30
20
10
0

Compost soil (soft rot & tunneling bacteria)
Simlångsdalen soil (dominating brown rot)
Conifer forest soil (dominating white rot)

Pine control
Cu/Cr, 2.5 kg/m3
Cu/Cr, 5 kg/m3
Cu/Cr, 10 (NTR-A)
CCA (NTR-AB)
CCA (NTR-A)
Furf, WPG=25
Furf, WPG=37

Natural durability class (based on EN807 run at two institutes)

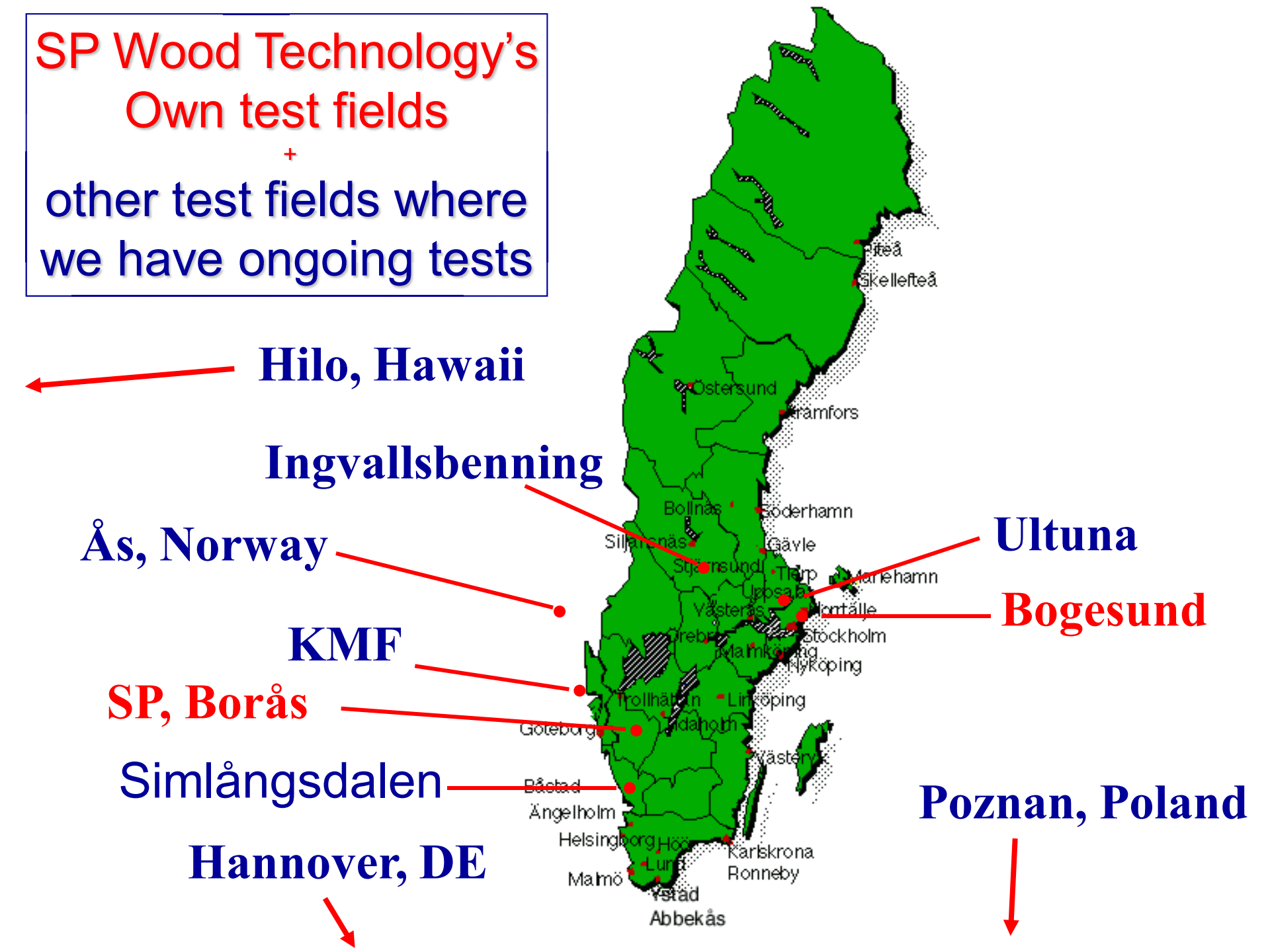
value above bars – Nat durability class based on AWPA E10 test



SP Wood Technology's Own test fields

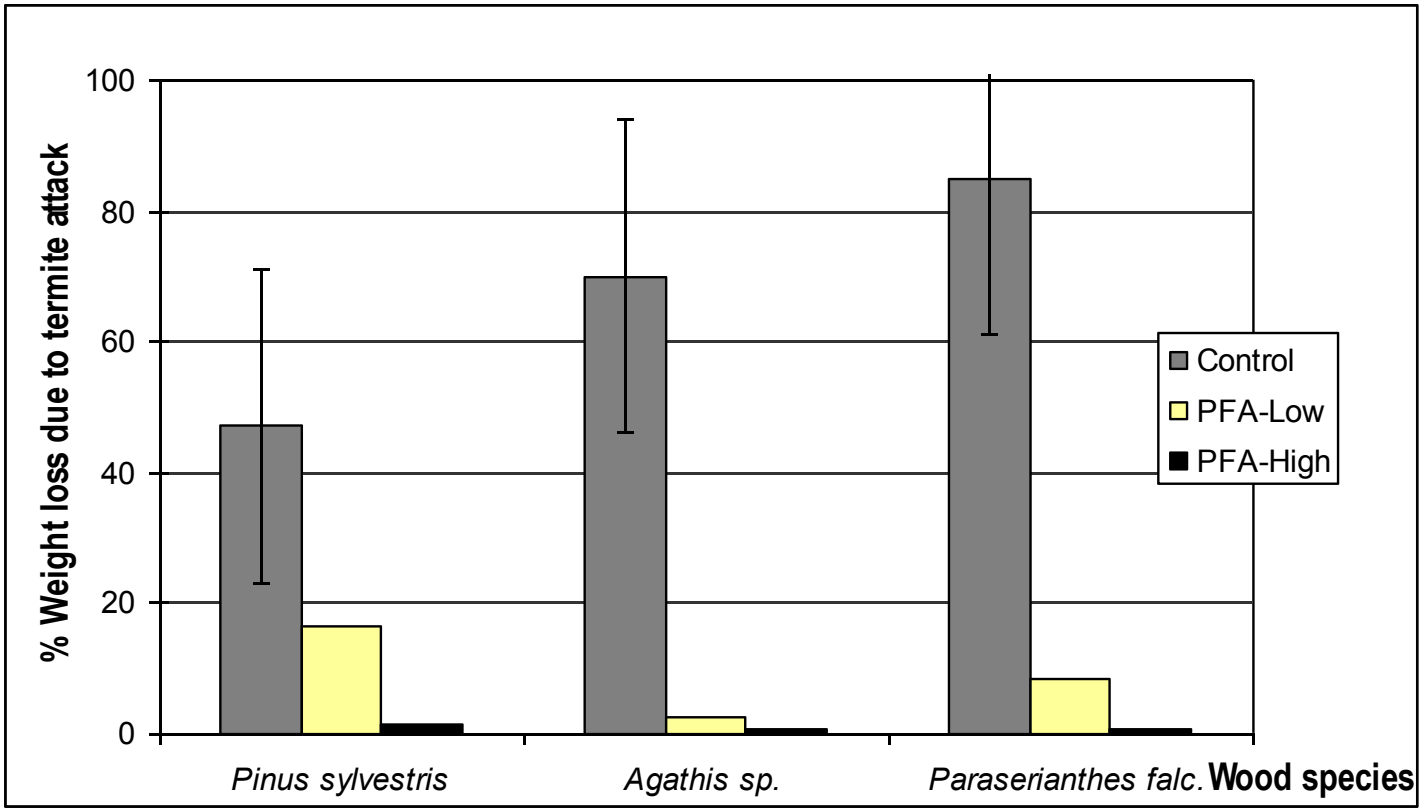
+

other test fields where we have ongoing tests



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

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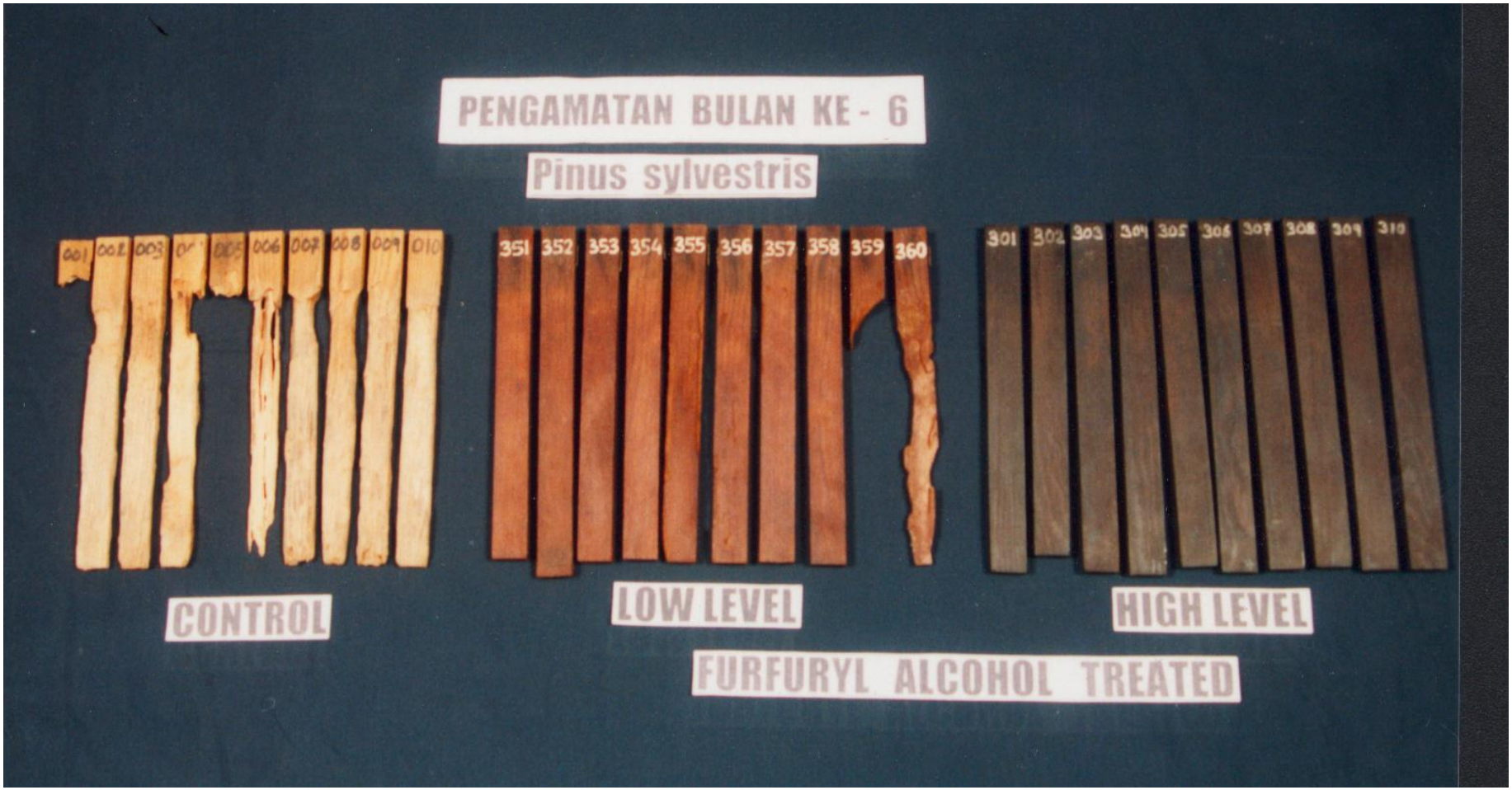
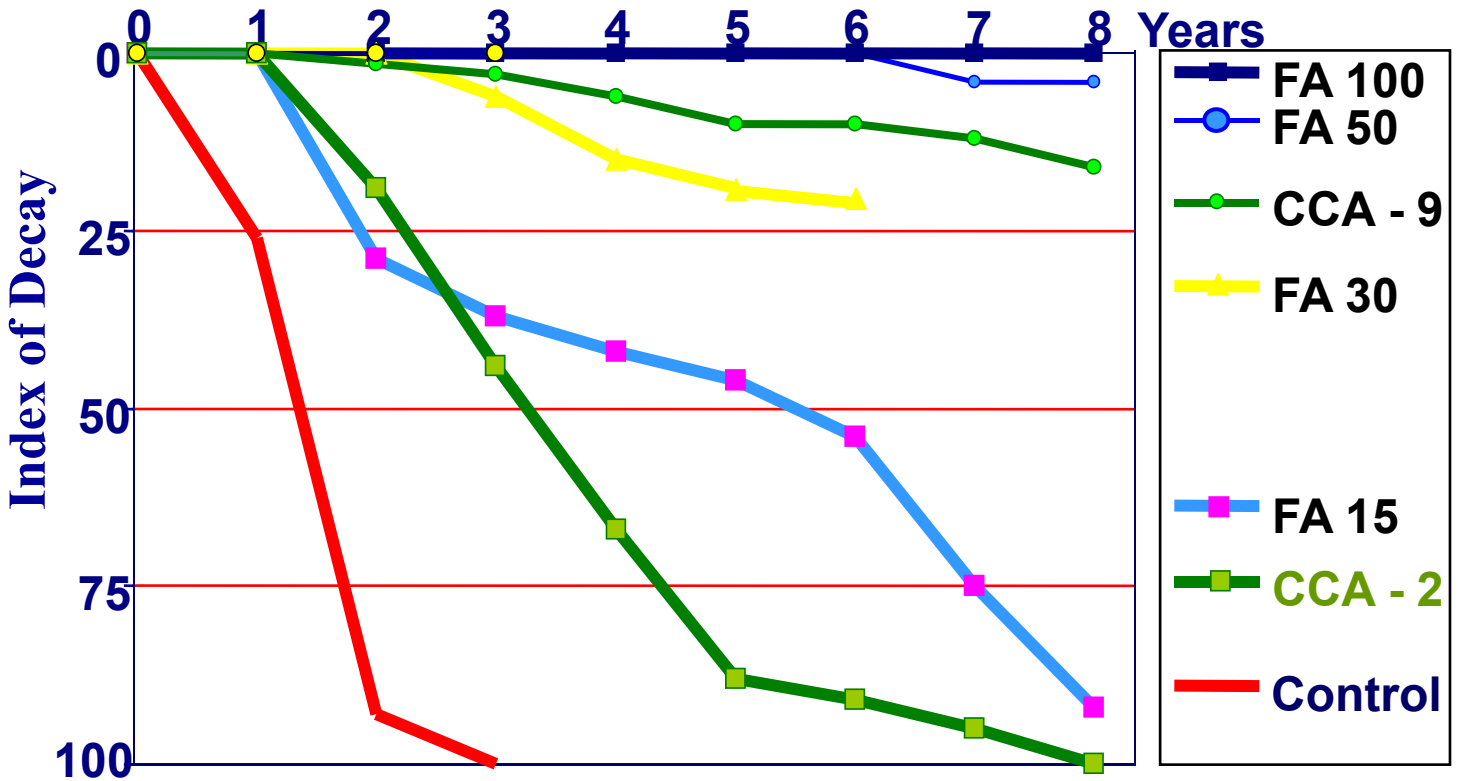


Field test of furfurylated wood

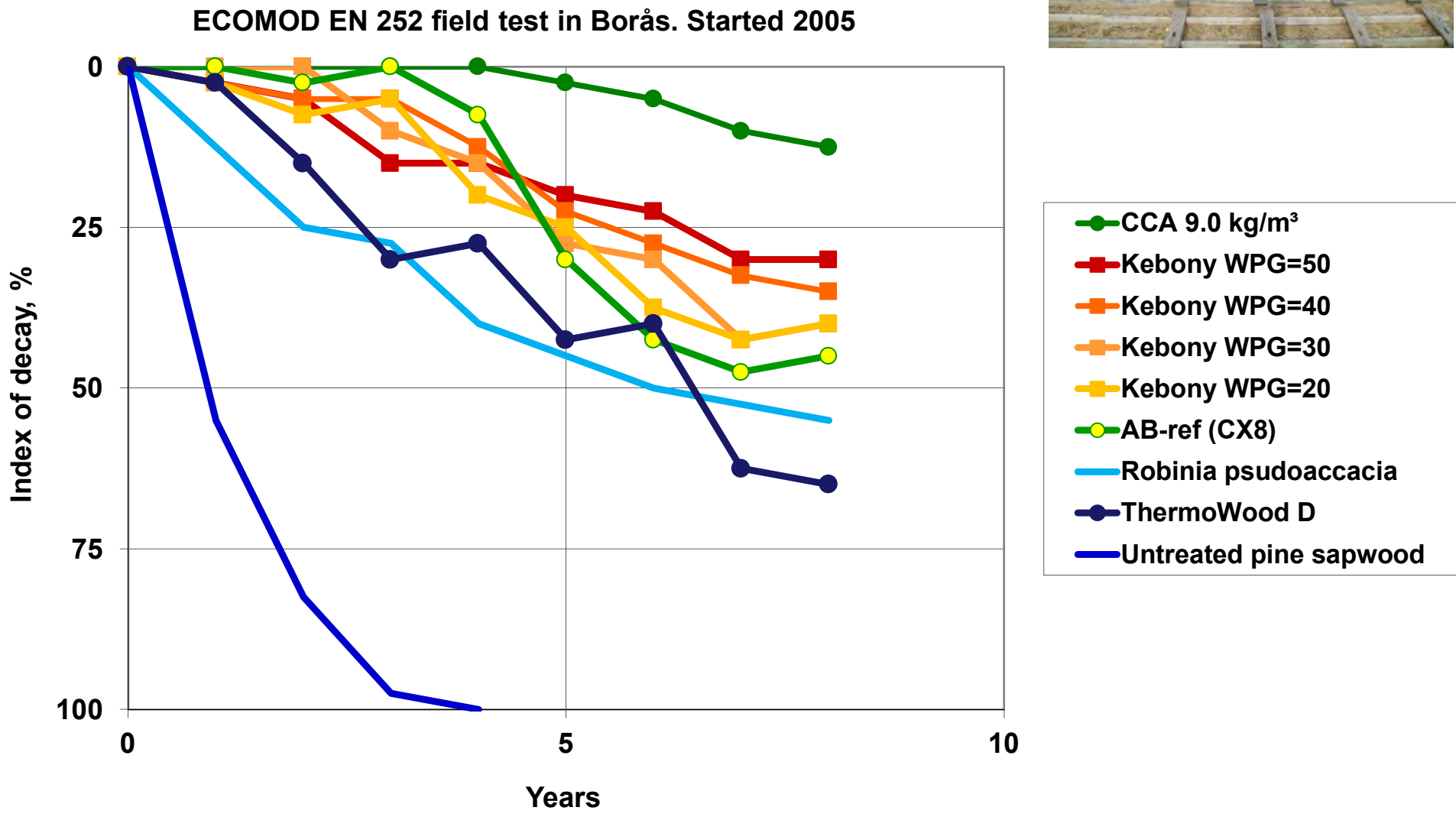
Results from material produced in pilot scale in the 90s

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



Field test of furfurylated wood

Material from production site in Norway



Marine field tests of modified wood

Marine field tests of modified wood

Marine field tests of modified wood

Modification	Average Terenid attack rating (0-4) 1 yr	4 yr	8 yr	11 yr	14 yr	Overall rating	Serv. life
Control (untreated Pine sap)	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**	**Failed**	**1.0**
Furfurylation - (15% WG)	**1.0**	**3.6**	**-**	**-**	**-**	**Failed**	**4.0**
- (29% WG)	**0.0**	**0.0**	**0.6**	**1.0**	**1.2**	**Slight**	
- (50% WG	**0.0**	**0.0**	**0.0**	**0.2**	**0.2**	**Sound**	
- (120% WG)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**Sound**	
Acetylation - (21% acetyl)	**0.2**	**0.4**	**1.4**	**2.4**	**2.8**	**Severe**	
ThermoWood D	**2.8**	**-**					**2.0**
CCA - (NWPC Class AB)	**0.3**	**4.0**	**-**	**-**	**-**	**Failed**	**3.6**
CCA - (NWPC Class M)	**0.0**	**0.2**	**0.5**	**2.3**	**3.3**	**Severe**	

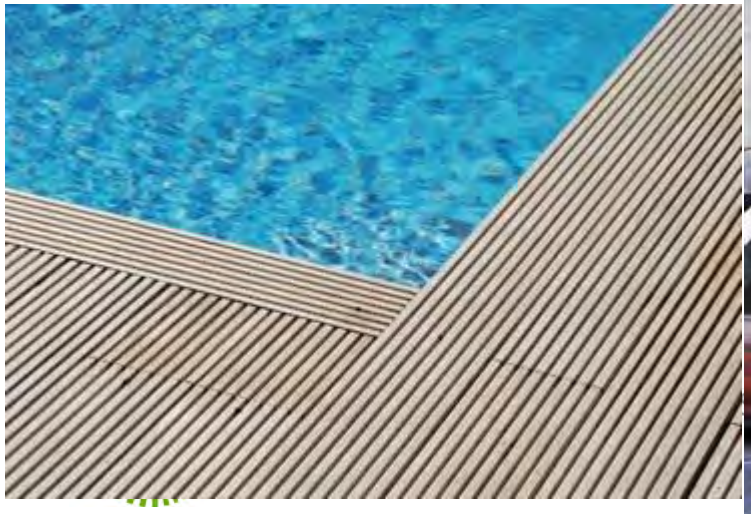
Trends for furfurylated wood

- **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

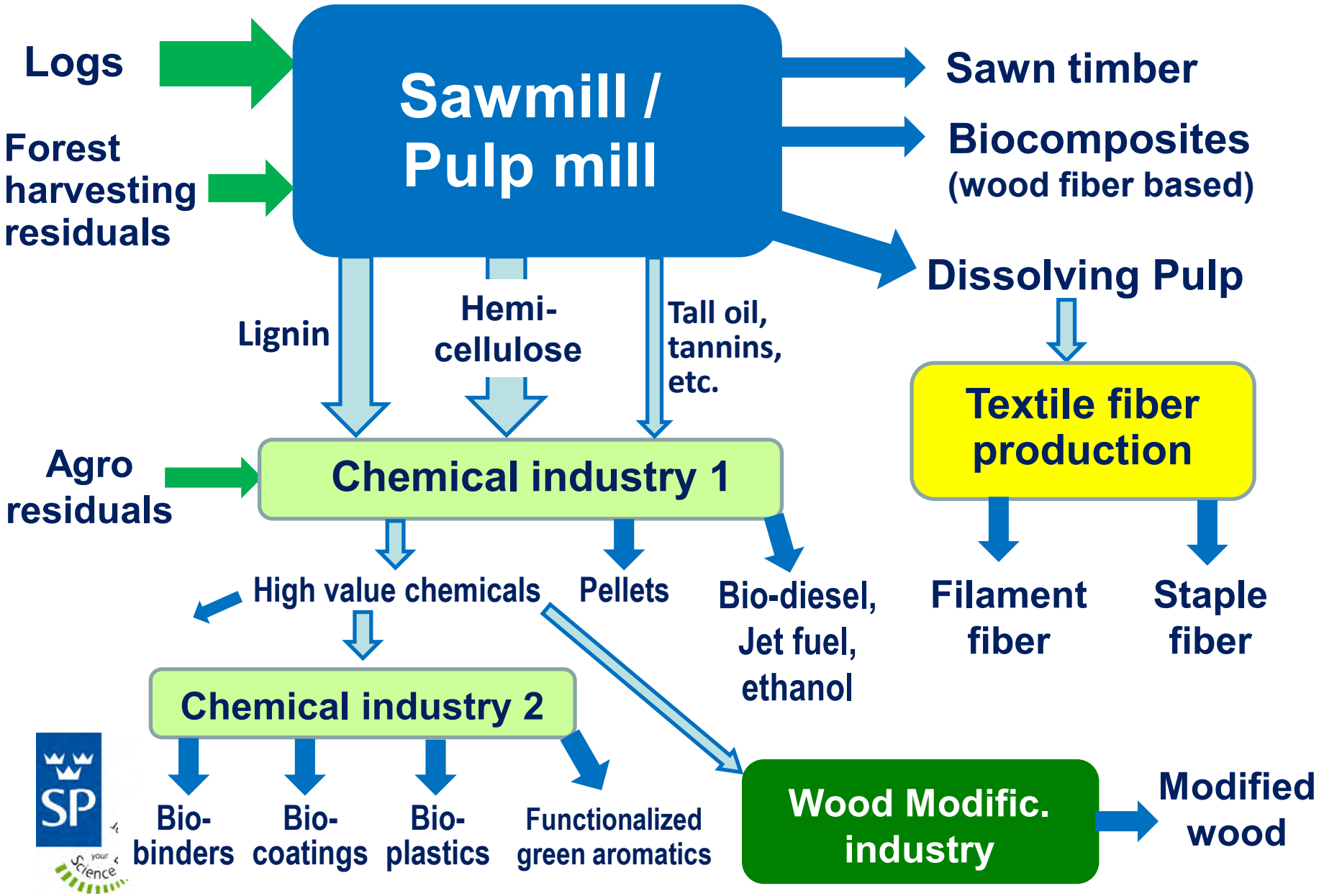
Accoya® (Accys Technologies)

- 10-20 000 m^3/year
- Produced in Arnhem, The Netherlands

Perennial wood® (Eastman Chemical Co)

- 5 000 m^3 in 2013
- Production in US now shut down!

Example of a forest mega-biorefinery concept



Thank you for the attention!

Questions?