

**MARKET & PRODUCT DEVELOPMENT OF CROSS-LAMINATED TIMBER IN THE USA**

KARL KONSTANTIN GRASSER  
*M.S. Candidate*  
UNIVERSITY OF TENNESSEE  
DEPARTMENT FORESTRY, WILDLIFE AND FISHERIES  
April 16, 2014 - 12:20 pm  
Plant Biotech 160

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**OUTLINE**

- LITERATURE REVIEW
  - INTRODUCTION TO CLT
  - APPLICATIONS
  - CURRENT STATE OF INDUSTRY
- RESEARCH OBJECTIVES
- METHODS
  - INDUSTRIAL ENGINEERING STUDY
  - PRODUCTION PROCESS
  - CAPABILITY STUDY
- ACKNOWLEDGMENTS
- REFERENCES
- QUESTIONS & ANSWERS

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**LITERATURE REVIEW**

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### INTRODUCTION TO CLT

- CHARACTERISTICS OF CLT
  - PREFABRICATED SOLID ENGINEERED WOOD PANEL
  - OUT OF SOLID-SAWN LUMBER OR STRUCTURAL COMPOSITE LUMBER
  - AT LEAST THREE ORTHOGONALLY BONDED LAYERS
  - BONDED WITH STRUCTURAL ADHESIVES (ANSI/APA,2012)

Transverse Planks      Longitudinal Planks  
(Karacabeyli & Douglas, 2013)

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### INTRODUCTION TO CLT

Solid Timber Construction (STC) – INNOVATION based on TRADITION

load transfer

tradition	bar-like (parallel to grain) timber bar construction (especially in Scandinavia) stave church	bar-like (perp. to grain) timber log construction (especially in Alpine Space) chalet	innovation	slab-like (interaction of "parallel" and "perp." to grain) Solid Timber Construction with CLT detached house Jetter
	vertical	horizontal		vertical + horizontal = Cross Laminated Timber (CLT) (rigidly connected) bonding

(Schickhofer, 2013)

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### APPLICATIONS OF CLT

WALL APPLICATION	CEILING APPLICATION	ROOF APPLICATION

(Schickhofer, 2013)

**ADVANTAGES:**

- PREFABRICATED WALL AND FLOOR PANELS
- DRY AND CLEAN CONSTRUCTION TECHNIQUE
- SHORT ERECTION TIME
- HIGH DIMENSION STABILITY
- POSITIVE ENVIRONMENTAL IMPACT (Karacabeyli & Douglas, 2013) & (Brandner, 2013)

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### OBJECT PRESENTATION "FORTE"

- **LOCATION**
  - VICTORIA HARBOR, MELBOURNE, AUS
- **SCALE**
  - 10 FLOORS, 23 APARTMENTS
  - 32.17 METERS HIGH
  - 485 TONS OF TIMBER
  - 759 CLT PANELS
- **BUILDING PERIOD**
  - BUILDING START IN FEBRUARY 2012
  - COMPLETION IN DECEMBER 2012
  - ERECTED IN 16 WEEKS (Lend Lease, 2013)



(Lend Lease, 2013)

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### FORTE'S ACHIEVEMENTS & CHALLENGES

- **ACHIEVEMENTS**
  - SAFE
  - SUSTAINABLE
  - LIGHT WEIGHT
  - TIME SAVINGS & EFFICIENCIES
  - HIGH QUALITY (Lend Lease, 2013)
- **CHALLENGES**
  - APPROVALS
  - FIRE PERFORMANCE
  - ACOUSTIC PERFORMANCE
  - DURABILITY (Lend Lease, 2013)



(Lend Lease, 2013)

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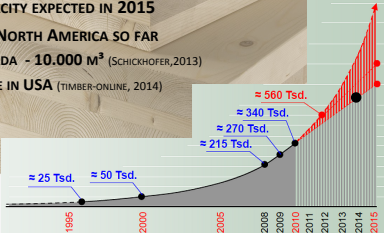
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### CURRENT STATE OF INDUSTRY

- ABOUT 35 PRODUCTION SITES WORLDWIDE WITH AN ESTIMATED TOTAL CAPACITY OF 560.000 M<sup>3</sup>
- 95% OF THE VOLUME IS LOCATED IN MIDDLE EUROPE
- 1 MILLION M<sup>3</sup> CAPACITY EXPECTED IN 2015
- SLOW GROWTH IN NORTH AMERICA SO FAR
  - 2 MILLS IN CANADA - 10.000 M<sup>3</sup> (SCHICKHOFFER, 2013)
  - 1 JOINT VENTURE IN USA (TIMBER-ONLINE, 2014)



Year	Capacity (Tsd)
1995	≈ 25 Tsd
2000	≈ 50 Tsd
2005	≈ 215 Tsd
2008	≈ 270 Tsd
2009	≈ 340 Tsd
2010	≈ 340 Tsd
2011	≈ 340 Tsd
2012	≈ 340 Tsd
2013	≈ 340 Tsd
2014	≈ 340 Tsd
2015	≈ 560 Tsd

(Schickhofer, 2013)

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### INDUSTRIAL ENGINEERING STUDY

- ASSESSMENT OF THE MOST RELEVANT CLT MILLS IN AUSTRIA



- SPECIAL FOCUS ON
  - PRODUCTION PROCESS
  - ADHESIVES
  - FEEDSTOCK QUALITY
  - WOOD SPECIES
  - MOISTURE VARIABILITY
  - PROCESS DESIGN AND CAPABILITY
- COOPERATION WITH PLANT ENGINEERING COMPANIES AND UNIVERSITIES



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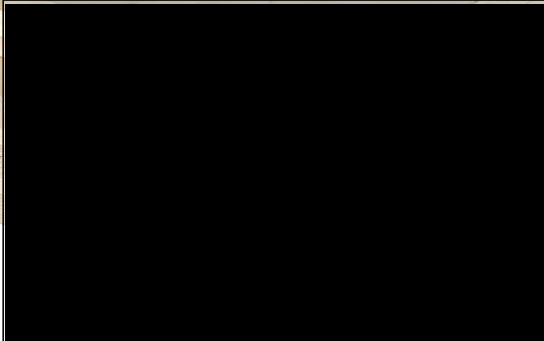
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### PRODUCTION PROCESS OF CLT



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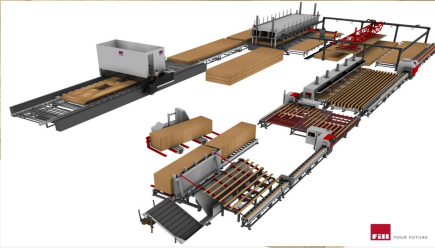
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### INDUSTRIAL ENGINEERING STUDY

- PLANT LAYOUT FOR A MILL IN VIRGINIA SUITABLE FOR YELLOW POPLAR (*Liriodendron tulipifera*) AND OTHER LOW GRADE HARDWOODS
  - SMALL CAPACITY VENTURE
  - LARGE CAPACITY VENTURE



FILL  
(Lend Lease, 2013)

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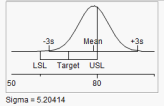
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### CAPABILITY STUDY

- **APPLYING STATISTICAL PROCESS CONTROL** (Forrest & Breyfoege, 1999)
  - RESEARCH HYPOTHESIS: A CLT MILL PRODUCING CLT MADE FROM YELLOW POPLAR WILL HAVE MORE VARIABILITY THAN A CLT MILL USING CONIFERS
  - IS YELLOW POPLAR (*Liriodendron tulipifera*) CAPABLE FOR THE PRODUCTION OF CLT?
  - COMPARISON OF NATURAL TOLERANCES VS. ENGINEERING TOLERANCES
    - RAW MATERIAL FOR GRADE & QUALITY
    - MOISTURE CONTENT IN %
    - DIMENSIONAL STRENGTH & PERFORMANCE (MOE, MOR)



Capability Index	Lower CI	Upper CI
CP	0.641	0.657
CPK	0.083	0.095
CPM	0.329	0.334
CPU	1.188	1.221
CPV	0.083	0.095

Portion	Percent	PPM	Sigma Quality
Below LSL	0.0162	162.3475	5.095
Above USL	40.1938	401937.63	1.748
Total Outside	40.2100	402099.98	1.748

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### ACKNOWLEDGMENTS




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### Acknowledgments



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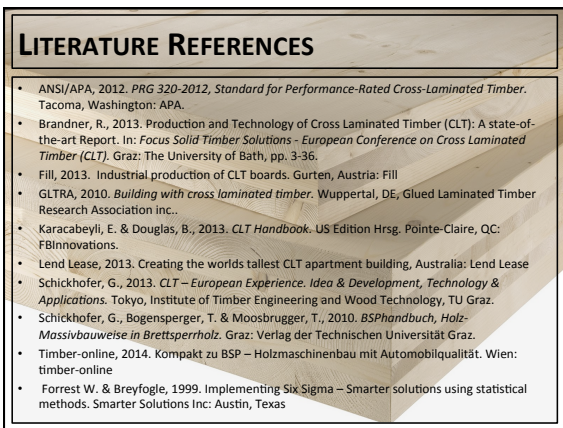
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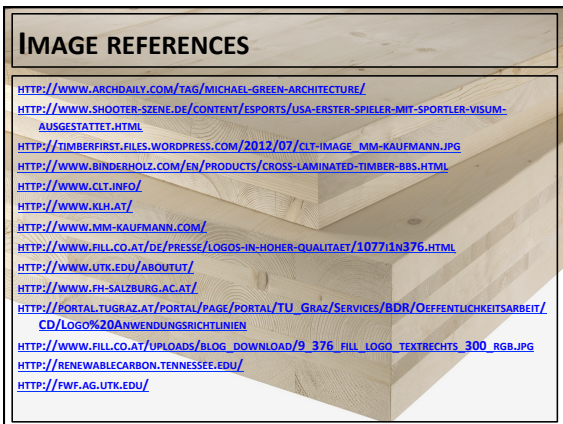
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