

Energy & Process Efficiency of Radio Frequency Glass Lamination

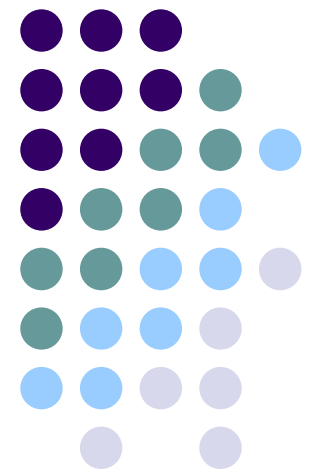
Shawn M. Allan*

Inessa Baranova, Gibran Esquenazi, Morgana Fall, Dr. Holly Shulman

Ceralink Inc.

Rensselaer Technology Park
Troy, New York

ACEEE Summer Study on Energy Efficiency in Industry
Panel 5: The Role of Technology
Session D: Emerging Process Heating Technologies

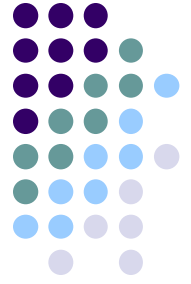


U.S. Department of Energy
Energy Efficiency
and Renewable Energy

Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable

Niagara Falls, New York
July 28, 2011, 9:30 AM

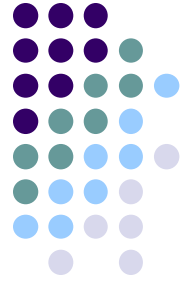




Outline

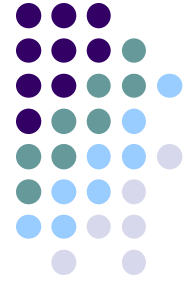
- Ceralink
- Flat glass & auto glass industry
- FastFuse™ RF lamination
- FastFuse™ demonstrations & energy usage
- Potential for glass industry energy efficiency
 - Pilkington case study

Ceralink



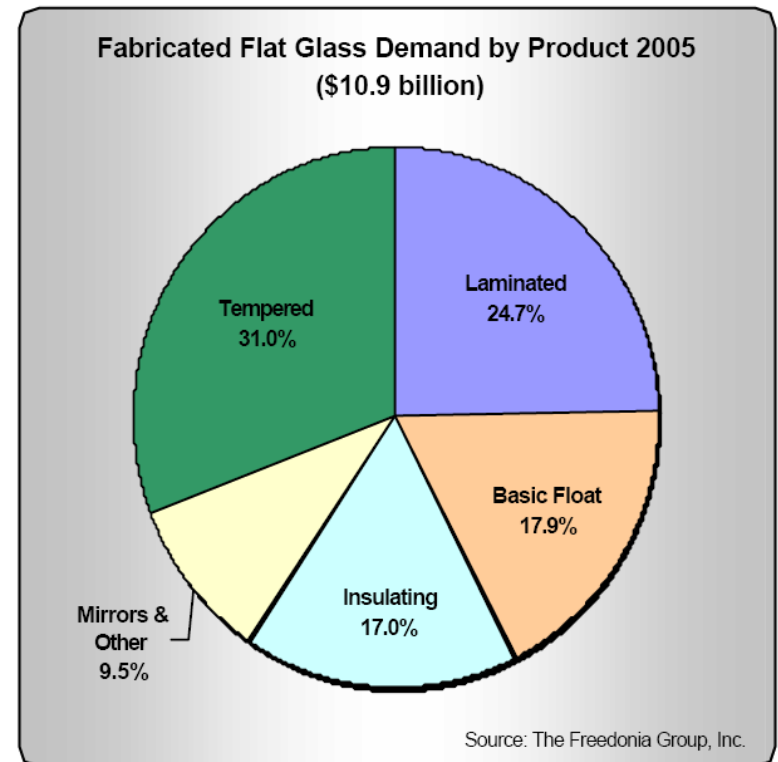
- Materials processing and technology development
- Focus on innovative manufacturing technologies
- Specialize in microwave & RF heating
- Founded in 2000 by Dr. Holly Shulman
- FastFuse™ support from
 - DOE-ITP Industrial Grand Challenge
 - NYSERDA Industrial Process & Product Innovation
 - DOE-ITP Inventions & Innovations





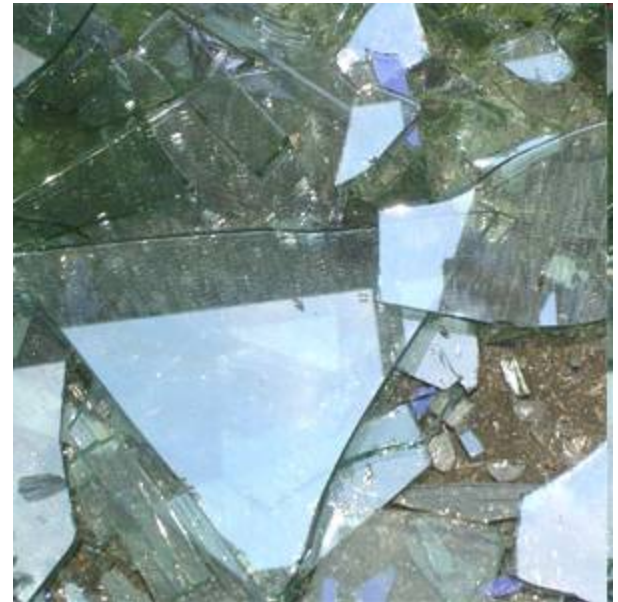
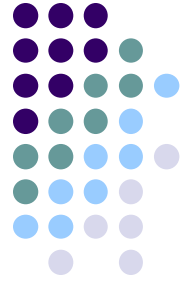
Flat Glass Industry

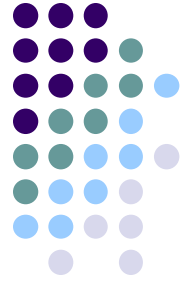
- 2005 Flat Glass Products - \$10.9 B, 8 B ft²
- Three main types of flat glass
 - Annealed – 44%
 - Tempered – 31%
 - Laminated – 25%
 - Higher growth than other types,
 - Approximately 7%*



Annealed Glass

- Typical home windows
- Breaks into large jagged shards
- Made by cooling glass slowly from melt
- Cheapest form of flat glass

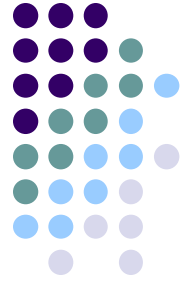




Tempered Glass

- Special high temperature heat treatment at 500-700 °C
 - Rapidly cools outside of the glass
- Much stronger than annealed glass
- Breaks into relatively harmless beads
- Leaves openings unprotected after breakage
- Used in car side & rear windows, shower & bath doors



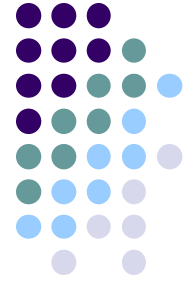


Laminated Glass

- Used for car windshields, bullet proof glass, and solar panels
- 2 sheets of glass bonded with plastic film (interlayer)
- Window holds together when glass breaks
- Trending toward increased use for side windows

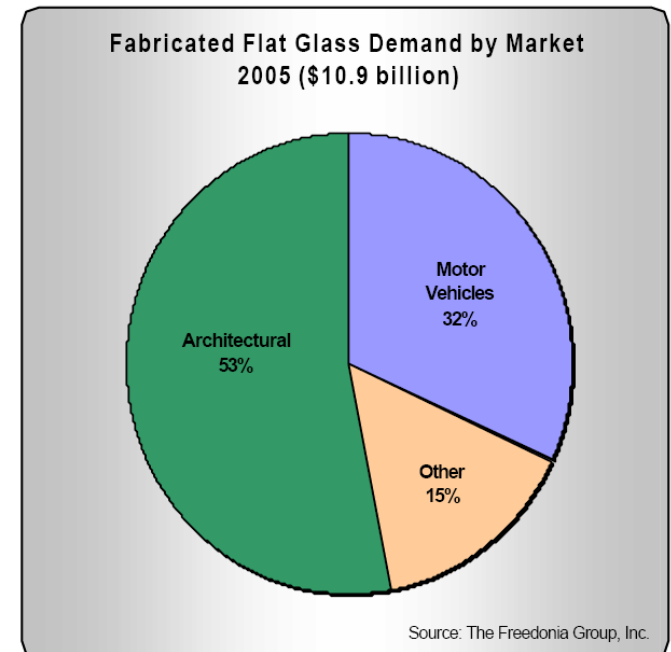


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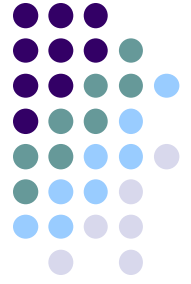
Autoglass Market

- 32% of \$10.9 billion market is autoglass
 - Front windshields are laminated, or 20% of autoglass
 - All other windows tempered, or 80% of autoglass
- Auto industry
 - 26% of laminated glass – 500 million ft²
 - 81% of flat tempered glass – 2 billion ft²
- Tempering uses more energy*
 - 10.3 trillion BTU tempering
 - 0.33 trillion BTU laminating
- All autoglass lamination is by autoclave



*Energy statistics from Department of Energy Manufacturing Energy Consumption Survey, 2006

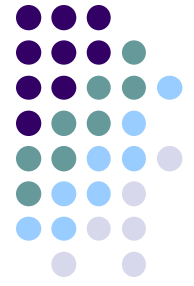
Glass Lamination State-of-the-art



- **Methods**
 - Autoclave → 135 °C, 100 – 300 psi
- **Features**
 - Batch only → **1.5 to 18 hour processes**
 - Slow process development
 - Prevents continuous processing
 - **Energy Intensive**
- **Interlayers**
 - **PVB** - Polyvinyl butyral – **Autoglass**
 - Clear, printed
 - **TPU** - Thermoplastic polyurethane – **Armor**
 - **EVA** - Ethylene vinyl acetate – **Solar, Decorative**
 - Clear, colored, opaque

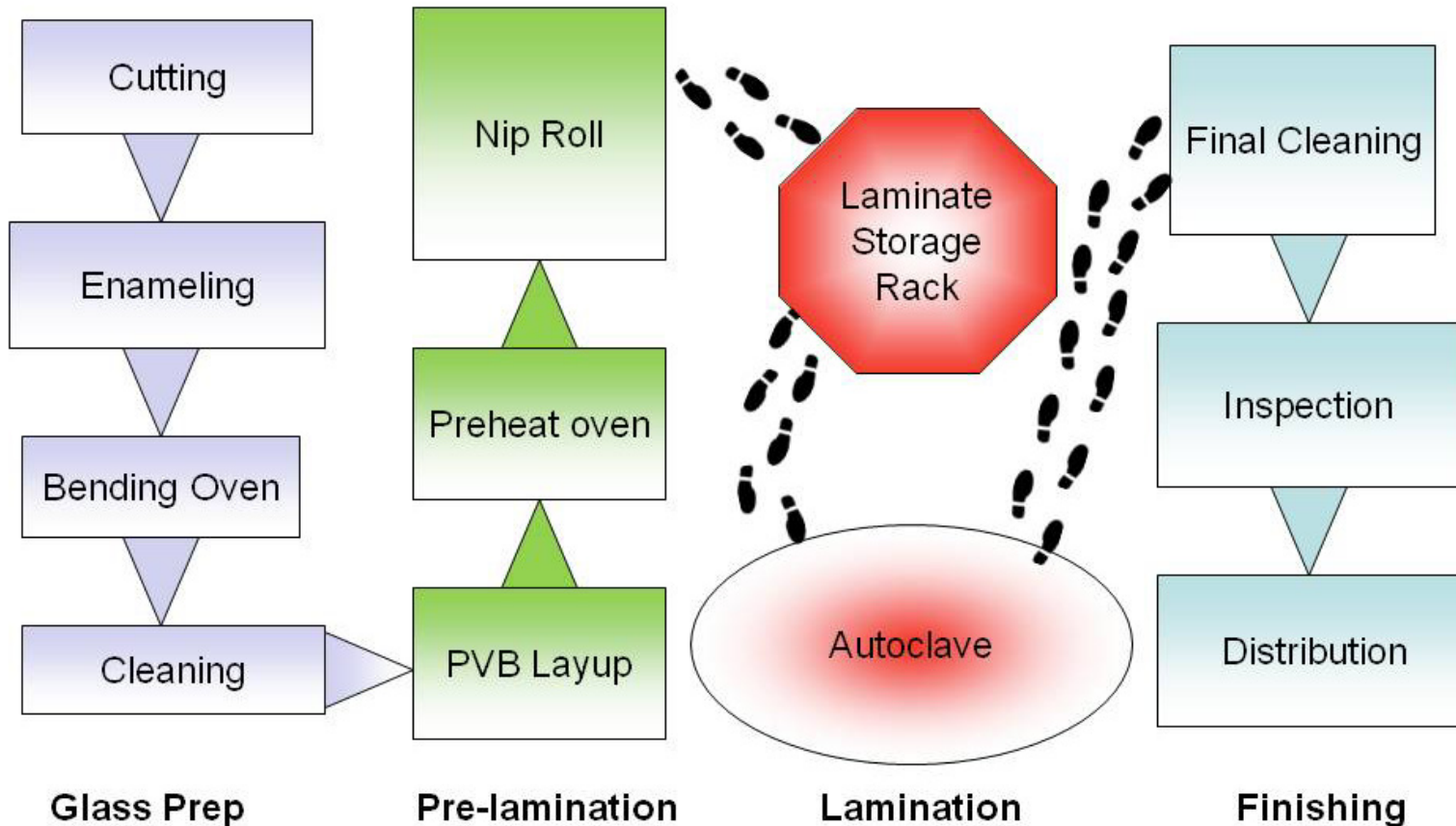


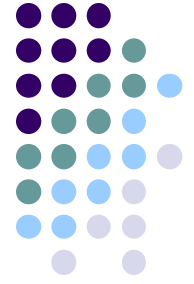
Glass Autoclave



Autoclave Process Flow

Batch Lamination with Autoclave
90 minute Autoclave cycle
240 parts in 90 minutes





FastFuse RF Lamination

Laminates faster and more efficiently

- **0.5 to 3 minute cycles – most products**
- **5 minutes for thick armor panels**
- Cuts energy over **90% vs Autoclave**
- Heats interlayer directly
- New process using existing equipment
- **Allows fast development**
 - 🌀 50+ experiments in 1 day
 - 🌀 Custom one-off manufacturing
 - 🌀 Rapid quality feedback

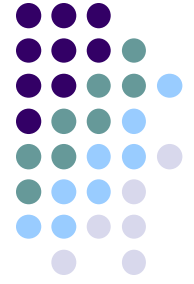


**Thermex Thermanon
RF Press with shuttle**

LAMINATED GLASS

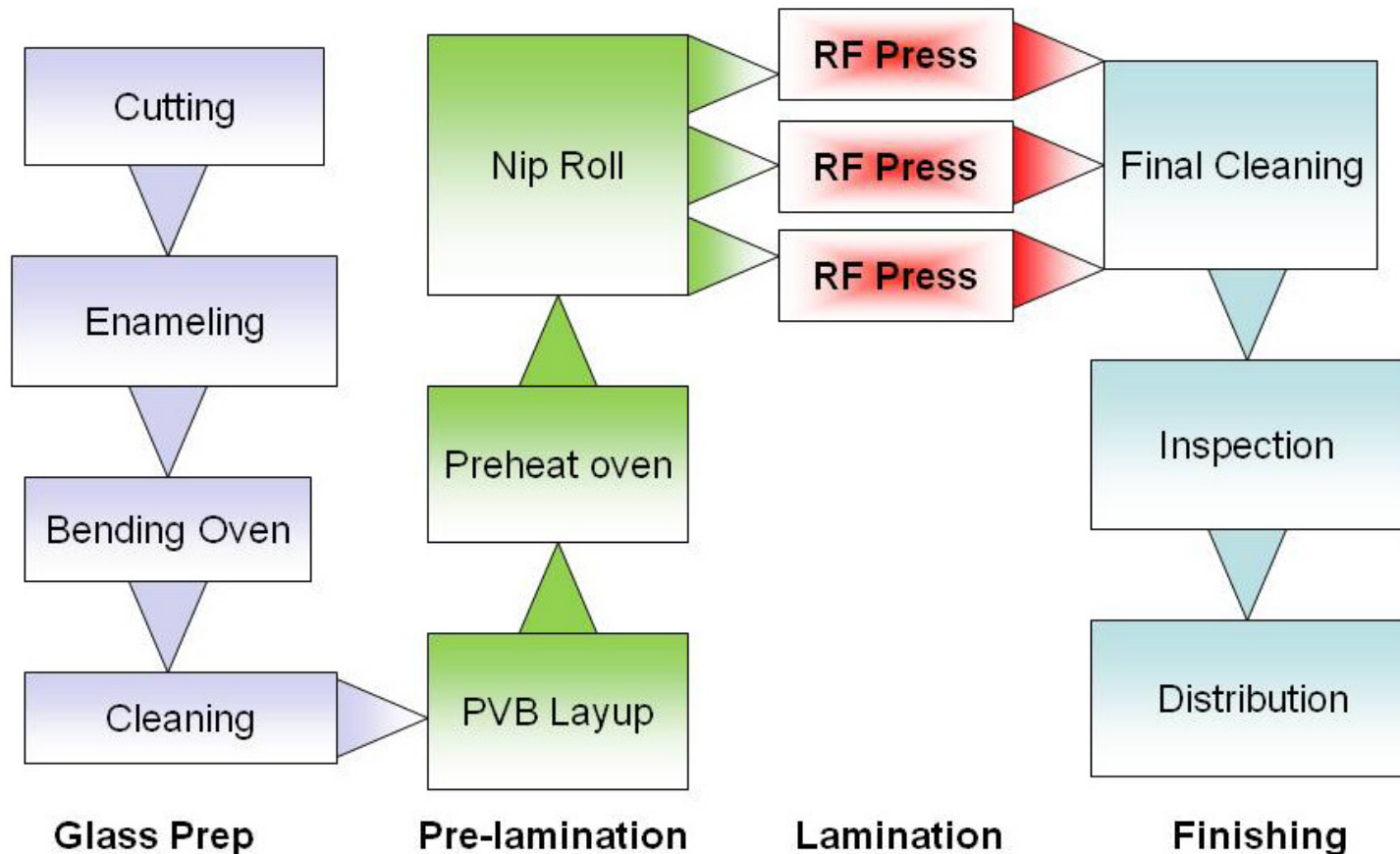
GLASS
PVC
GLASS



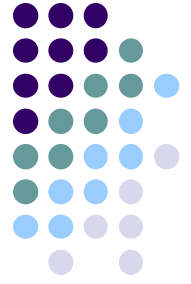


RF Lamination Process

Continuous Lamination with RF
60 second RF press cycle
3 parts every minute with 3 presses
270 parts in 90 minutes



RF Presses



3 ton, 18" x 20"

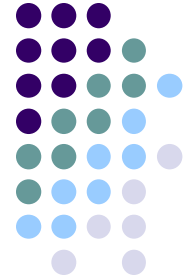


30 ton, 30" x 40"

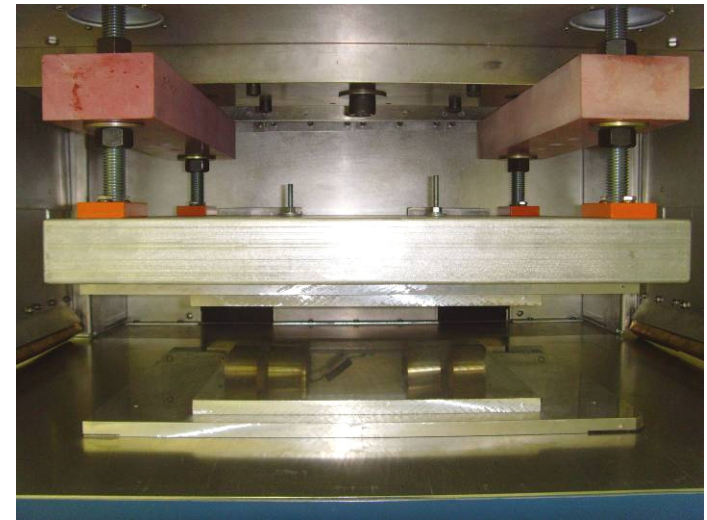
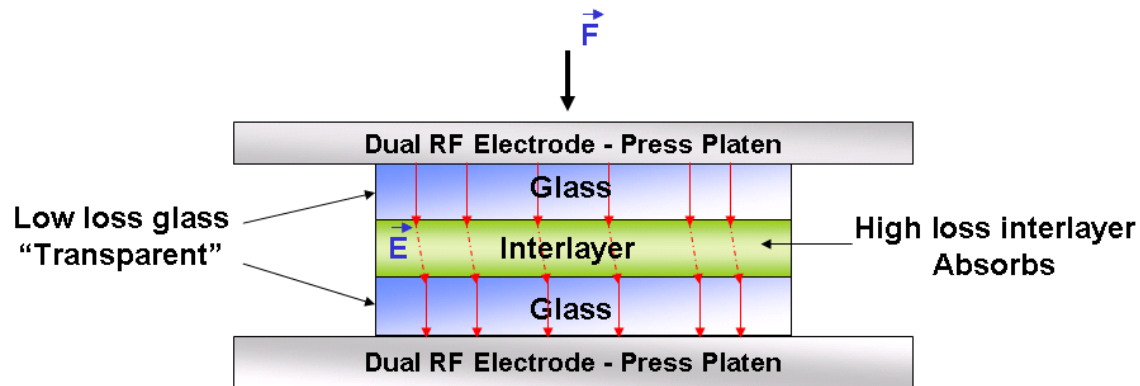


700 ton, 48" x 120"





RF Heating & Press



Rapidly alternating electric field creates friction – *Dielectric Heating*

Polar “lossy” materials heat

Vinyls, polyurethanes,
epoxies, phenolics

Intermediate materials

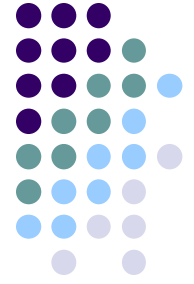
Acrylics, polycarbonate,
glass, nylons, polyesters

Non polar materials don't heat

polyethylene, polypropylene,
PTFE, ETFE

Conductive materials transmit RF
Capacitive Coupling





FastFuse Quality Testing

RF Laminated Glass → Comparable to Autoclave

ISO 12543 Accelerated environmental testing

Boil, 100 °C, 2 h

Bake, 100 °C, 2 h

- EVA, Sekisui S-LEC EN
- EVA, Bridgestone EVASAFE
- TPU, Deerfield A4700
- PVB, Sekisui EZCOOL

ASTM C1172 – Visual inspection

ATPD 2352 – Optical Specs

JIS-R-3211 – Impact test

V-50 ballistic performance

Passed
Passed
Passed
Passed

Passed

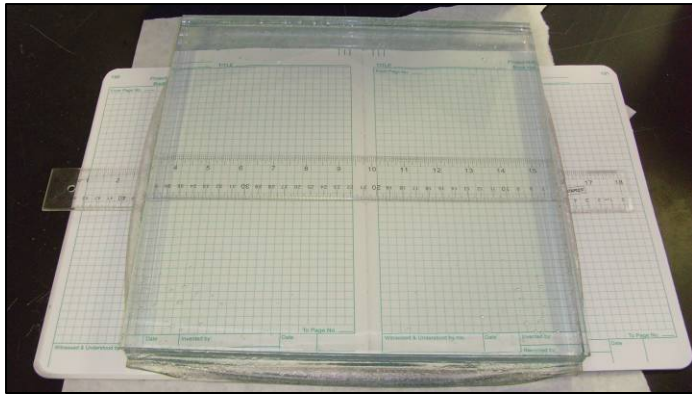
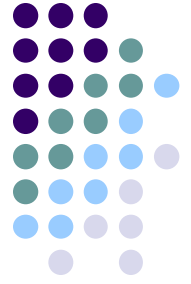
Passed

Equivalent to autoclave

Equivalent to autoclave



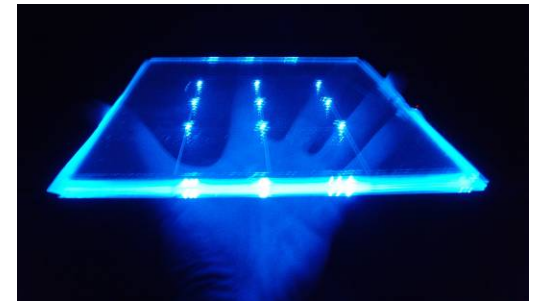
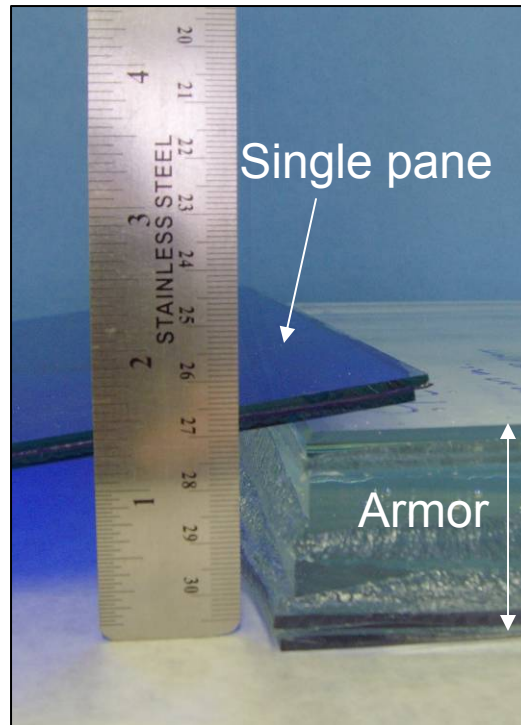
Other Products: Transparent Armor, Solar Panels, Lighting

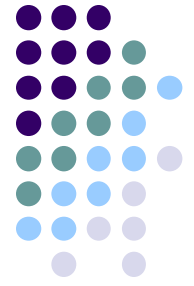


5 minutes in RF press

18 hours in Autoclave

Armor thickness compared to single-pane "windshield" laminate

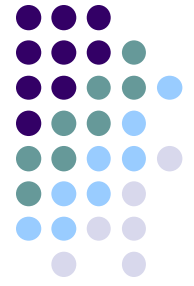




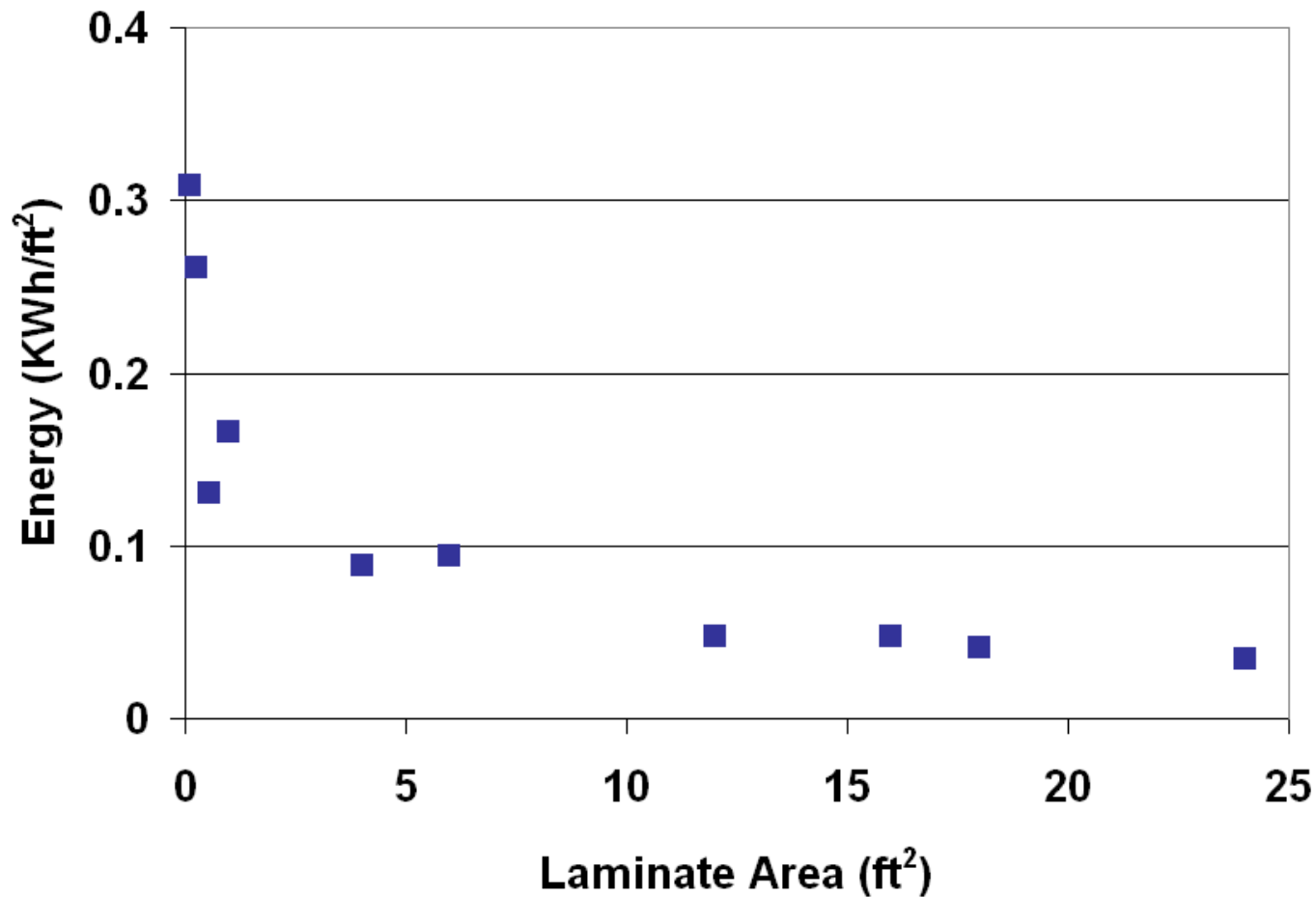
FastFuse Scale-up Study

36" x 24"	6 ft²
24" x 24"	4 ft²
18" x 16"	2 ft²
12" x 12"	1 ft²
9" x 9"	0.56 ft²
6" x 6"	0.25 ft²
4" x 4"	0.11 ft²

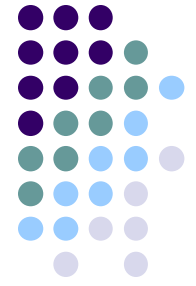




FastFuse Energy Scale-up



FastFuse Scale-up vs. Industry Energy Use



Industry Average

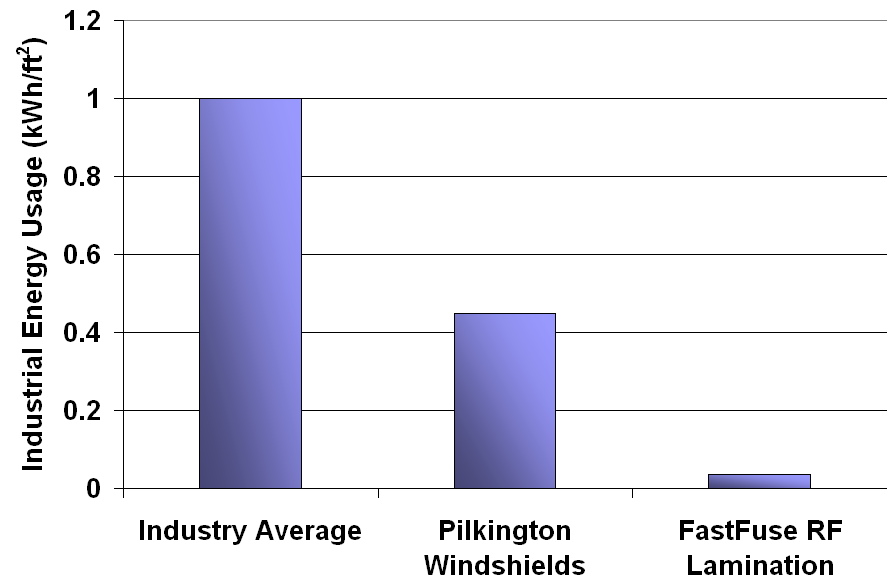
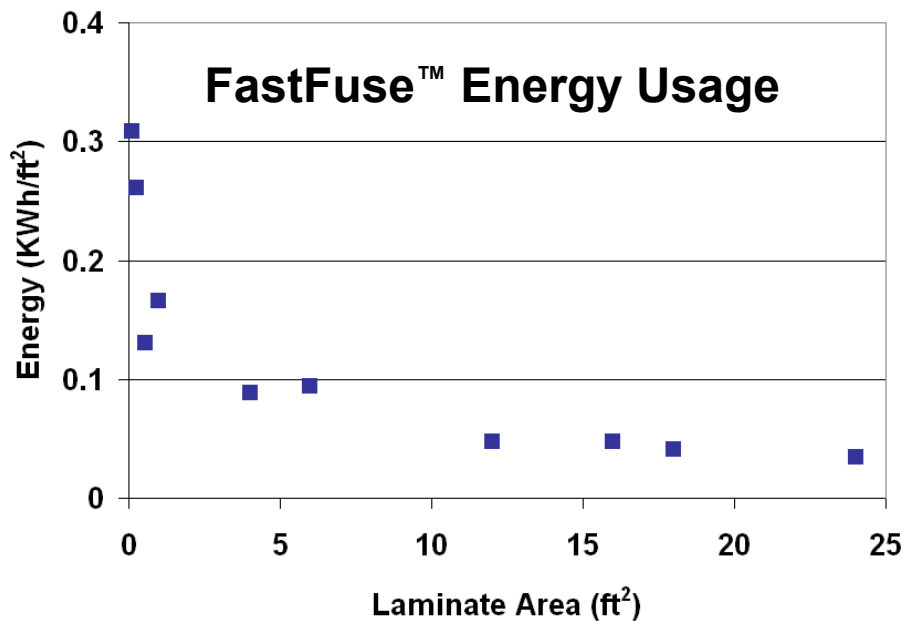
1 kWh/ft² (DOE MECS)

Windshields

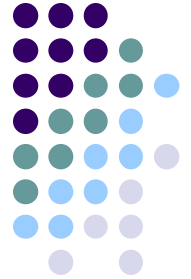
0.45 kWh/ft² (Pilkington estimate)

FastFuse™

0.036 kWh/ft²



Pilkington Autoglass Production



Pilkington North America

Ceralink's industrial demonstration partner

2 major North American laminating plants

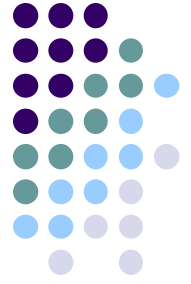
- Versailles, Kentucky
- Collingwood, Ontario



Typical industry data

- Production capacity – 240 windshields/batch
- Production time – 90 minutes
- Energy per sq ft. – 0.45 kWh
- Window size ~16 ft²

Autoclave Energy Projections



Key data

- Production capacity – 240 windshields/batch
- Production time – 90 minutes
- Energy per sq ft. – 0.45 kWh
- Window size ~16 ft²

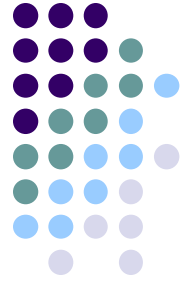


Maximum Autoclave capacity (nonstop annual)

- Annual production – **22,400,000 ft²**
- Annual energy – **10,100,000 kWh**
- Annual energy cost @ \$0.15/kWh – **\$1,510,000**

- Energy per batch – **1,729 kWh**
- Energy demand per batch ~**1700 kW**

FastFuse™ Energy Projections



Key data

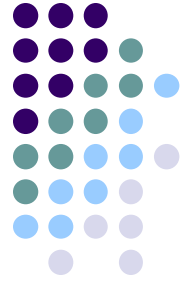
- Production capacity – 1 windshields/press
- Production time – 1 minute
- Energy per sq ft. – 0.04 kWh
- 3 presses – Equivalent throughput to autoclave



Maximum RF capacity (nonstop annual)

- Annual production – **22,400,000 ft²**
- Annual energy – **896,000 kWh**
- Annual energy cost @ \$0.15/kWh – **\$134,000**

- Energy per 240 windows (3 presses) – **154 kWh**
- Energy demand average (3 presses) ~**150 kW**



Side Window Scale up (1)

- Approximately 3 times more glass to be laminated
- Need 3 times more lamination capacity



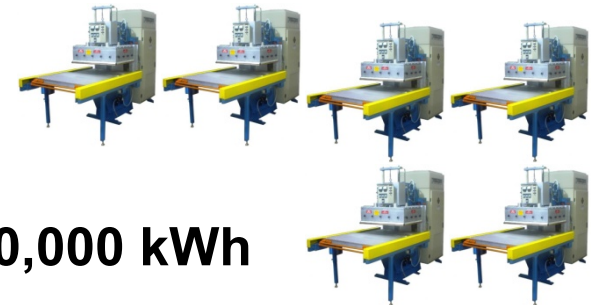
Option 1 – Install 3 new autoclaves

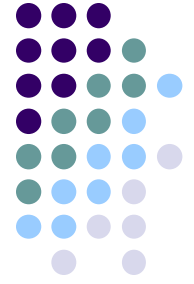
- Additional demand – **5100 kW**
- Additional annual energy consumption – **30,300,000 kWh**
- **Additional energy cost – \$4,540,000**



Option 2 – Install 9 RF Presses

- Additional demand – **450 kW**
- Additional annual energy consumption – **2,690,000 kWh**
- **Additional energy cost - \$404,000**



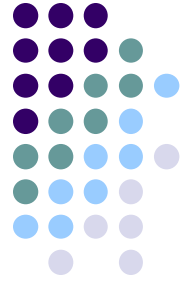


Side Window Scale up (2)

- 9 new presses at \$500,000
 - \$4,500,000 investment
- 3 new autoclaves at \$500,000
 - \$1,500,000 investment
- First year FastFuse™ energy
 - \$404,000
- First year autoclave energy
 - \$4,540,000



- First year energy savings
 - \$4,130,000
- Additional Capital Investment for FastFuse™
 - \$3,000,000
- Total First Year FastFuse™ Savings
 - **\$1,130,000**

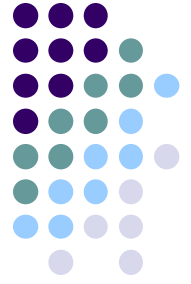


FastFuse™ 2011 Roadmap

- Curved side window lamination
 - In progress with Pilkington Automotive & Thermex Thermatron
 - Curved tooling in development
- Non-destructive ultrasonic adhesion testing
 - Dr. Henrique Reis, UIUC
 - Correlating NDE results to measured adhesion levels



FastFuse™ Summary



- 90% lamination energy reduction possible
- Opportunities in manufacturing growth areas
 - Laminated side windows
 - Solar panels
- Energy & cost analysis support RF implementation
- Quality verifications are key to acceptance
- FastFuse™ is energy efficient, flexible, green alternative for armor & other laminated products
- Ceralink established an on-site laboratory for FastFuse™ R&D, projects, and demonstrations



Acknowledgements

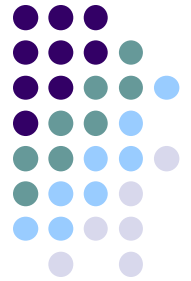
U.S. Department of Energy, Industrial Grand Challenge
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New York State Energy Research & Development Authority

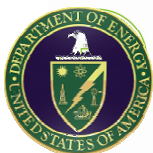
Pilkington North America

Dr. Henrique Reis,
University of Illinois at Urbana Champaign

Thermex-Thermatron



PILKINGTON
NSG Group Flat Glass Business

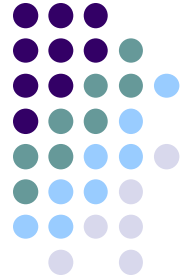


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Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable

nyszerda
Energy. Innovation. Solutions.

Ceralink inc



Thank you! Questions?

Ceralink Inc. develops advanced materials,
green processes, and new products for industry.



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**2007 U.S. patent applied for
RF Press Lamination Technology**

