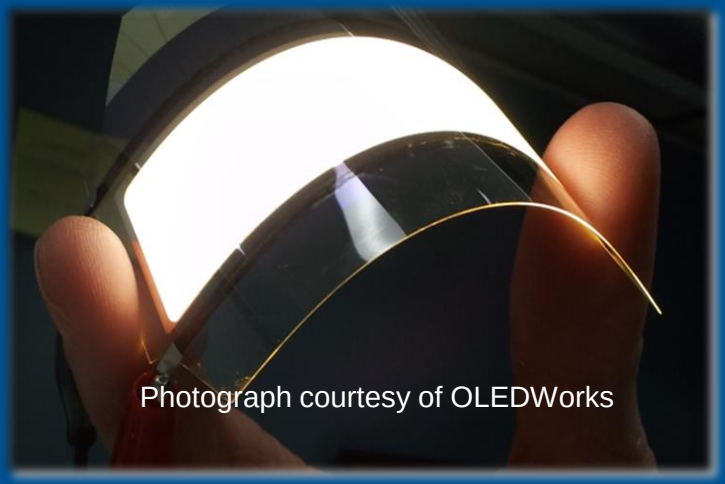
CORNING

Integrated substates for OLED lighting

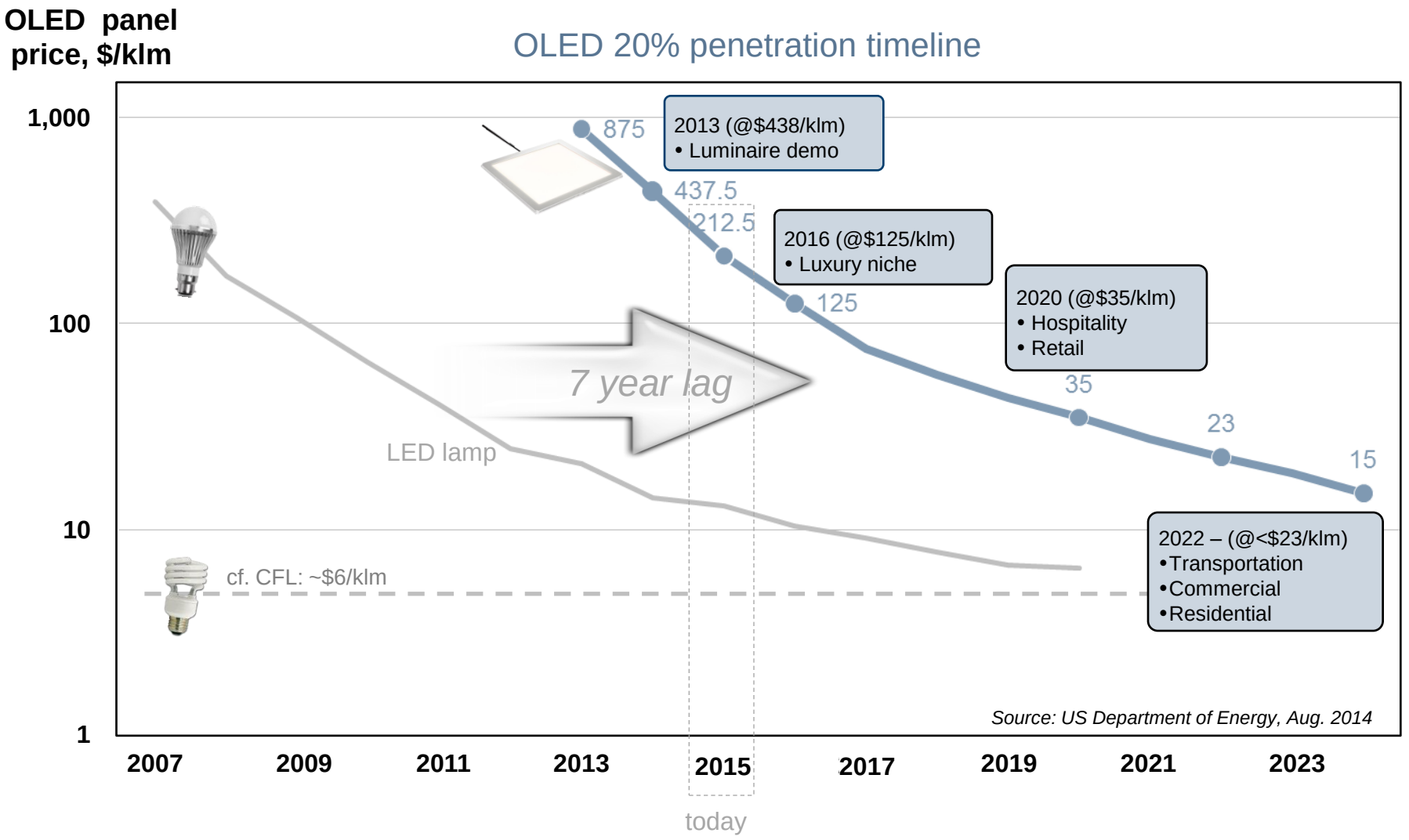
Mark Taylor

February 4, 2016



Photograph courtesy of OLEDWorks

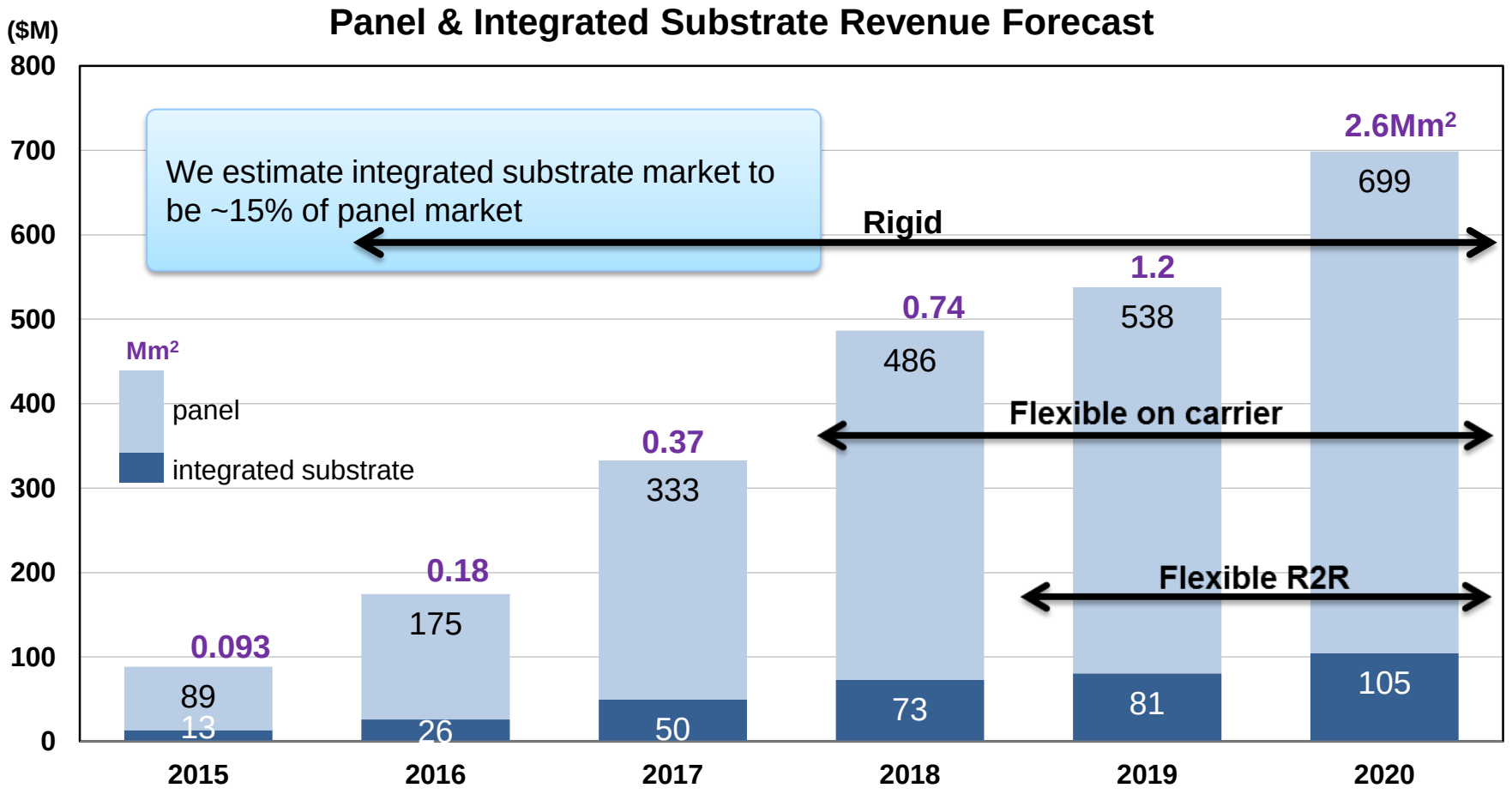
OLED adoption follows LED adoption curve with a seven year lag



Integrated substrate producer update

- Nippon Electric Glass / Saint-Gobain joint venture
  - 60/40 joint venture “OLED Materials Solutions”
  - Based in Higashiomi, Shiga, Japan
  - Glass frit-based light extraction technology
- PPG
  - Completing DoE project on light extraction
  - Incorporating light extraction into float technology
- NSG/Pilkington – no news
- Asahi
  - Appears to have shelved KIWI light extraction technology
  - Patents are for sale
- Corning
  - Demonstrated 2x light extraction on rigid glass
  - Developing flexible glass integrated substrate

Integrated substrate roadmap will help drive market growth



Source: n-tech Research (formerly NanoMarkets) 2015, Corning analysis

Corning's integrated substrate value proposition

1. Integrated substrate
   - Internal light extraction layer (ILEL) currently delivers 40% (2x)
   - Need to achieve **2.5x** ILEL by 2016 to keep moving down $/klm curve
   - Reduces cost and complexity for panel makers by providing a deposition-ready substrate

2. Flexible glass unlocks the conformability value element for OLED lighting
   - Conformable products are important to applications such as hospitality and transportation
   - Corning® Willow® Glass-on-carrier technology allows panel makers to deposit OLEDs without R2R technology

3. Roll-to-roll process capability provides a path to >30% cost reduction vs. current sheet-to-sheet process
   - Drives faster market adoption through lowering cost
   - Provides substrate with highest barrier property in a R2R format

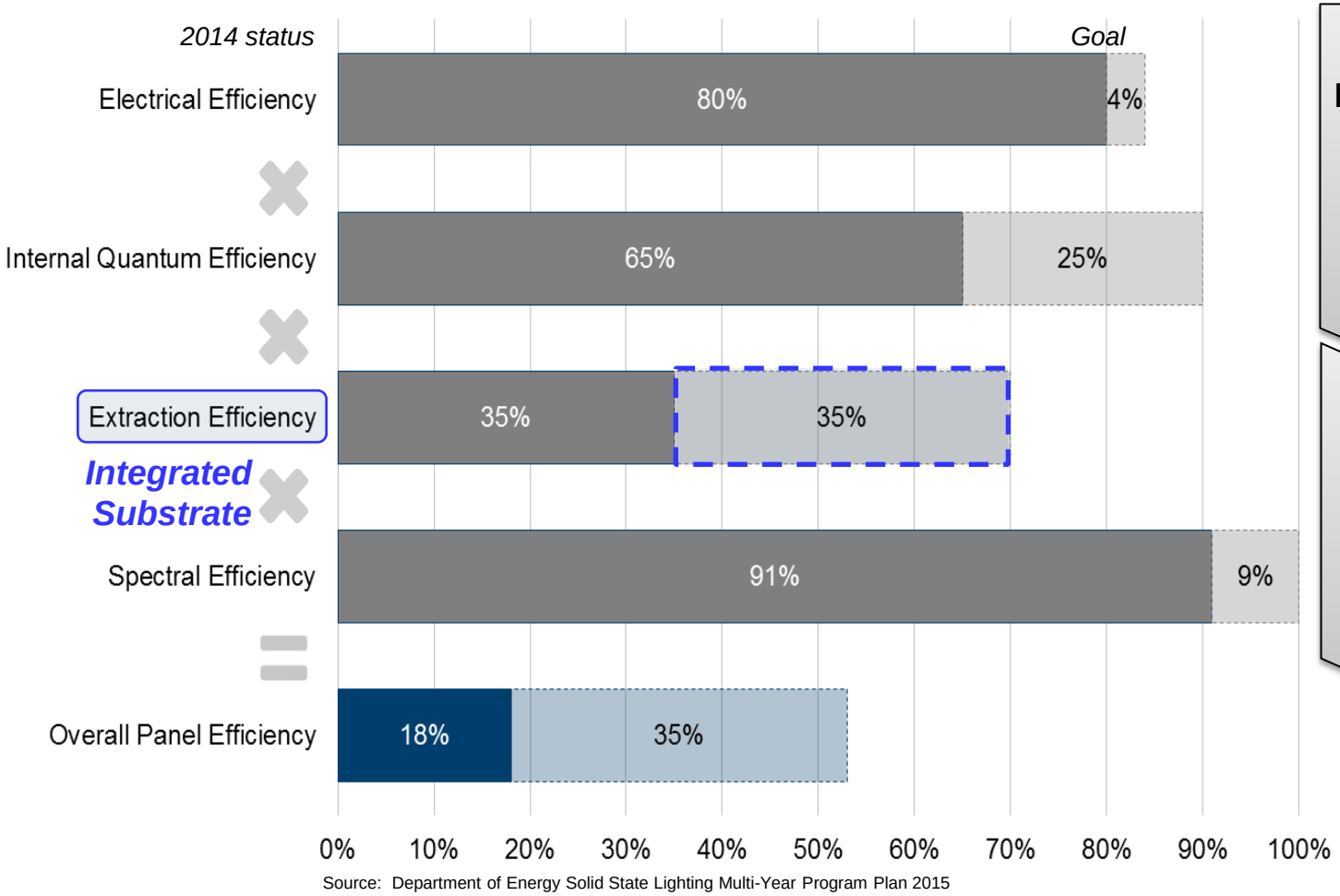
Corning milestones in 2015

- Completed initial screening of ILEL technologies on full OLED devices
- Demonstrated initial roll-to-roll capability for ILEL
- Demonstrated feasibility of flexible glass substrate on carrier through full OLED process

Concept	Light extraction		Material cost	Willow R2R Compatibility
	ILEL	ILEL+ELEL		
Tech 1	1.92	2.05	Medium	Fair
Tech 2	**1.95**	**2.17**	**Low**	**Excellent**
Tech 3	1.96	2.21	High	Fair

Extraction efficiency has greatest impact on panel efficiency

Panel Efficiency Improvement Opportunities

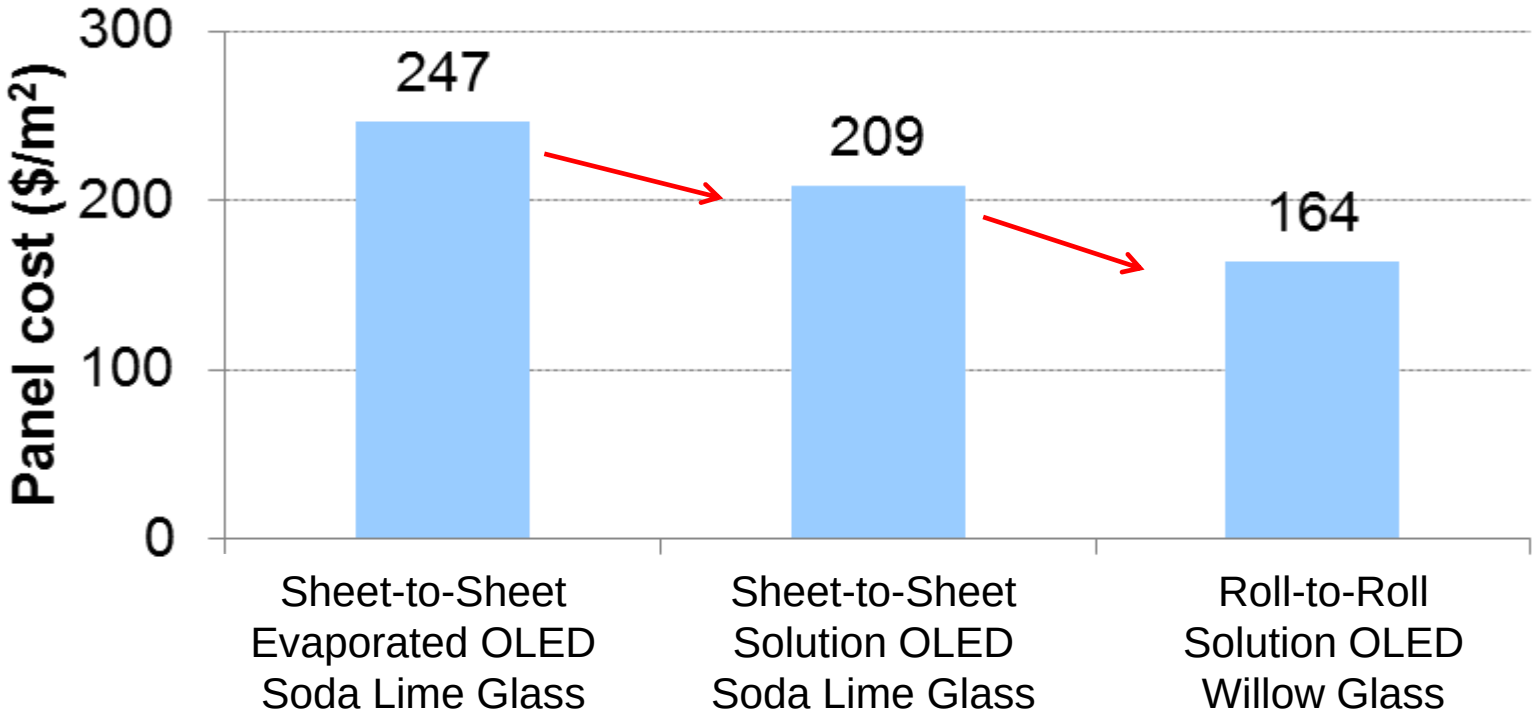


Source: Department of Energy Solid State Lighting Multi-Year Program Plan 2015

Current Extraction Efficiency → 2x (40%)

2016 Extraction Efficiency Target
2.5x (50%)
(best in industry)

Moving to roll-to-roll processing can reduce panel costs by 35%

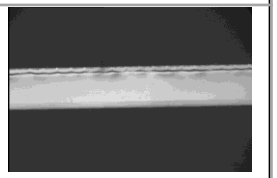


- Simpler OLED layer
- Lower investment cost
- Better materials utilization
- 15% cost reduction

- Willow Glass-based integrated substrate
  - 15% cost reduction
- Higher throughput speed
  - 7% cost reduction
- Reduced materials cost
  - 3% cost reduction

Getting ready for roll-to-roll processing

- Cleaning (TFT grade)
  - Sheet cleaning on cassettes
  - R2R cleaning
- Cutting

Method	Strength (Mpa)	Edge finish
CO_2 Laser	350	
Mechanical (MDI-Schott)	220	

- Handling
  - Non contact wands
  - Suction cup and air table

ITRI
Industrial Technology Research Institute

Corning will share handling and roll-to-roll know-how with its partners

Technical challenges for 2016-2017

- Manufacturing readiness for rigid sheet integrated substrate
- Push light extraction beyond 2x with a manufacturable process
- Transfer integrated substrate processes to roll-to-roll
  - Flexible sheet handling
  - ILEL deposition
  - Conductor deposition
  - Patterning
- Packaging and luminaire design for flexible glass
- Roll-to-roll OLED processing