

# 2020 JISEA Presenter Profile: Samantha Bench Reese



Samantha is a senior analyst at the National Renewable Energy Lab (NREL). She puts research problems in context of economic tradeoffs and analytically shows technology potential through supply-chain analysis, trade-flow mapping, market research, and building bottom-up cost models. Before NREL, she transitioned products from R&D to volume manufacturing. Her background is in mechanical and electrical engineering. She has an M.S. (Yale) and B.S. (Caltech) in Engineering & Applied Science.



## 2020 Virtual JISEA Meeting on Power Systems and Industry & Agriculture

April 9, 2020

**LED Lighting: A Global Enterprise**

Samantha Reese

# Project Goal

- Focused on integrated luminaires using a 2x2 troffer as example:
  - Understand manufacturing costs and value-add along the supply chain
  - Investigate trade flows
- How can R&D investments in a product manufactured not domestically benefit a domestic economy

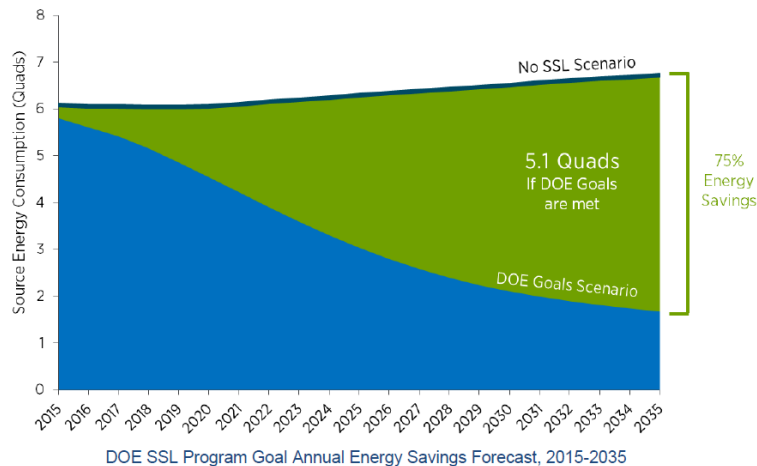


“Columbia Lighting : Products : Lensed Troffers : LJT.” Accessed March 24, 2016. <http://www.columbialighting.com/products/ljt>.

# Motivation for Analysis: Energy Savings



- The DOE SSL program conservatively forecasts that LED lighting sales (based on lumen-hours) will increase from approximately 3% in 2013 to about 48% in 2020, and 88% in 2035
- This results in 261 terawatt-hours (TWh) in site electricity savings annually, a 40% reduction
- If SSL Program's R&D priorities and milestones are achieved, the total 2035 annual energy savings would increase to 75%,



Source:

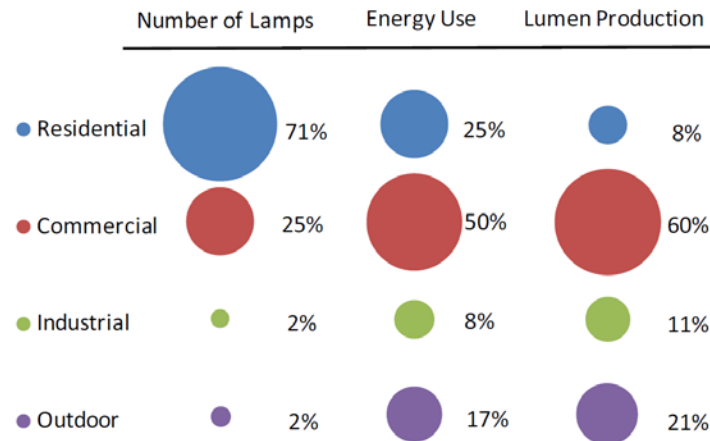
DOE SSL Program, "Energy Savings Forecast of Solid-State Lighting in General Applications September 2016 - energysavingsforecast16\_0.pdf." Accessed November 7, 2016. [http://energy.gov/sites/prod/files/2016/10/f33/energysavingsforecast16\\_0.pdf](http://energy.gov/sites/prod/files/2016/10/f33/energysavingsforecast16_0.pdf).

Bardsley, Norman, Stephen Bland, Monica Hansen, Lisa Pattison, Morgan Pattison, Kelsey Stober, and Mary Yamada. May 2015. *Solid-State Lighting R&D Plan*. DOE/EE-1228. DOE Solid-State Lighting Program, Building Technologies Office, Office of Energy Efficiency and Renewable Energy U.S. Department of Energy, Washington, D. C., 2015. [http://energy.gov/sites/prod/files/2015/06/f22/ssl\\_rd\\_plan\\_may2015\\_0.pdf](http://energy.gov/sites/prod/files/2015/06/f22/ssl_rd_plan_may2015_0.pdf)

# Project Goal: Importance of LED die/packages

- 2014 was the year general lighting accounted for over 50% LED revenue
  - Lighting needs will drive future growth and innovation
- Commercial lights account for greatest energy use

	2014	2020	Growth
General Lighting	52%	70%	17%
LCD TVs and Monitors	17%	7%	-10%
Signs and Large Displays	8%	7%	-2%
Cell Phones	9%	6%	-3%
Automotive Lighting	3%	3%	0%
Projectors	1%	3%	2%
Notebooks & Tablets	7%	3%	-4%
Personal Lighting	1%	1%	0%
Other Displays	2%	1%	-1%



Sources:

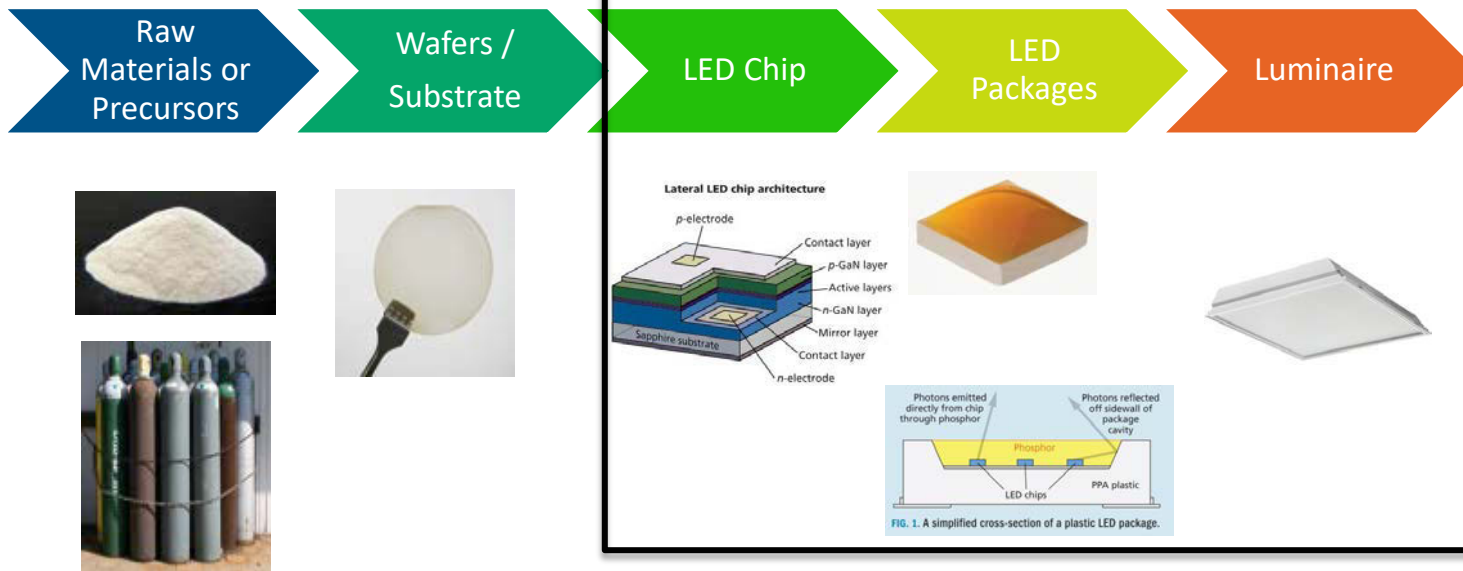
Mukish, Pars, and Eric Virey. 2014. *LED Packaging Technology and Market Trends 2014*. Lyon, France: Yole Développement

Popping the Charts: Strategies Unlimited Unveils SSL Market Data (MAGAZINE) - LEDs." Accessed May 11, 2016. <http://www.ledsmagazine.com/articles/print/volume-13/issue-4/features/markets/popping-the-charts-strategies-unlimited-unveils-ssl-market-data.html>.

DOE Solid-State Lighting Program "2010 U.S. Lighting Market Characterization" (January 2012)

# Simplified Luminaire Value Chain

Simplified to illustrate components directly related to the luminaire. Many other components of the value chain also exist. These will be accounted for as high level cost inputs, but their manufacturing costs will not be modeled in detail.

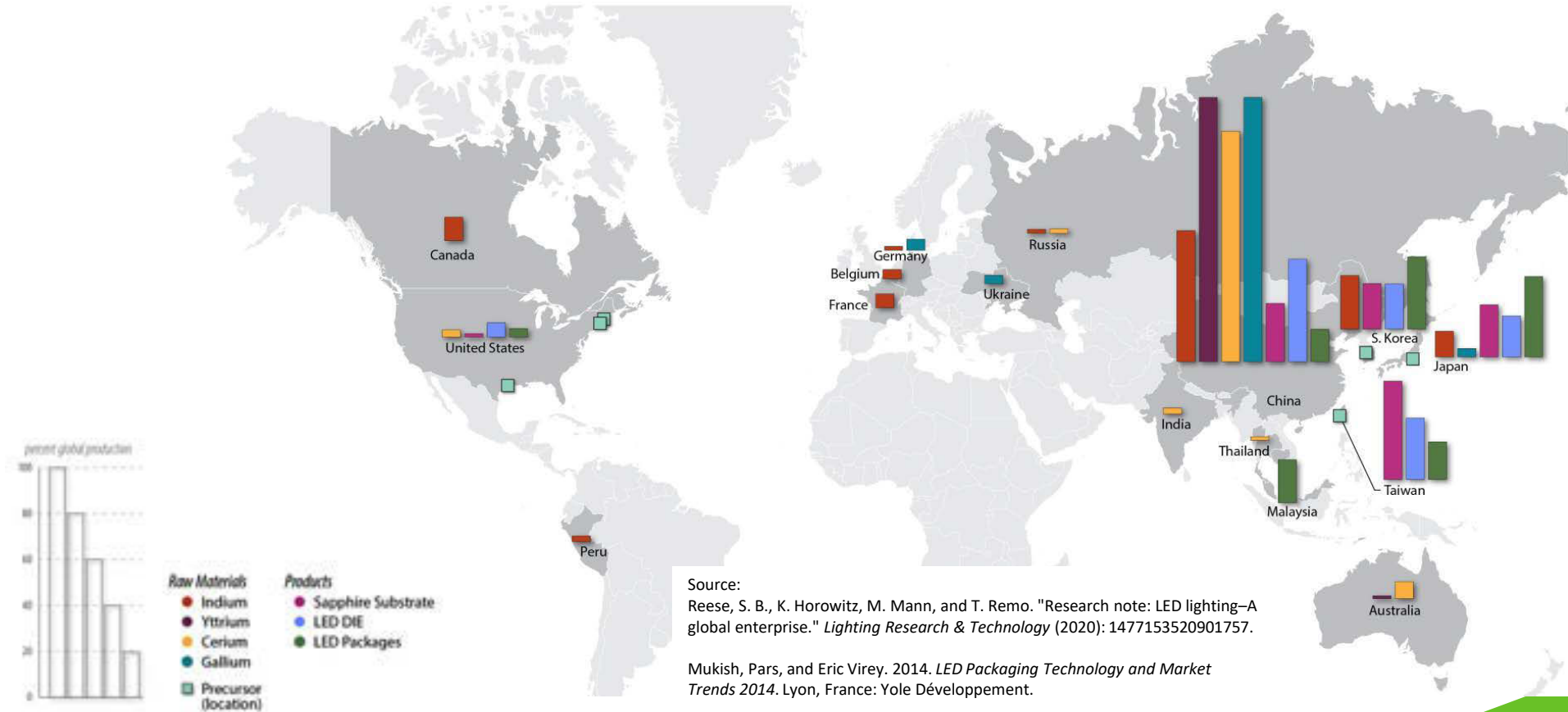




# Global Supply Chain

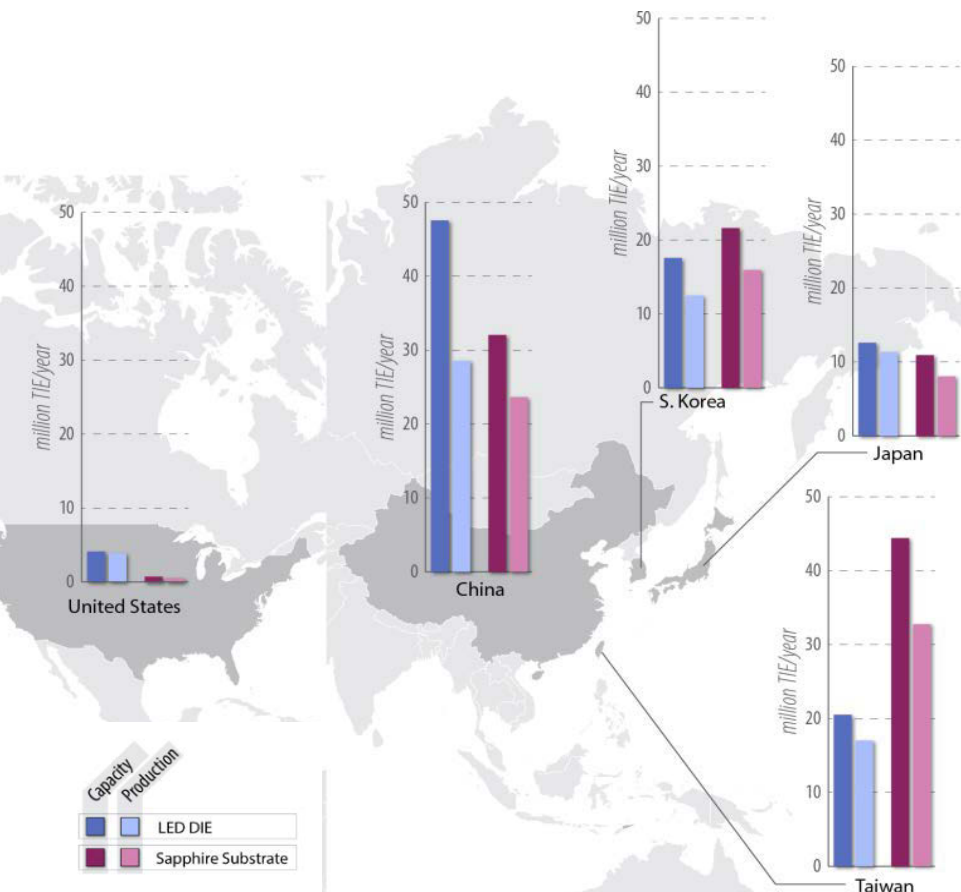
# Manufacturing and Capacity (2015)

## Raw Material, Substrate, Die, & Package





# Die and Substrate: Capacity & Production (2015)



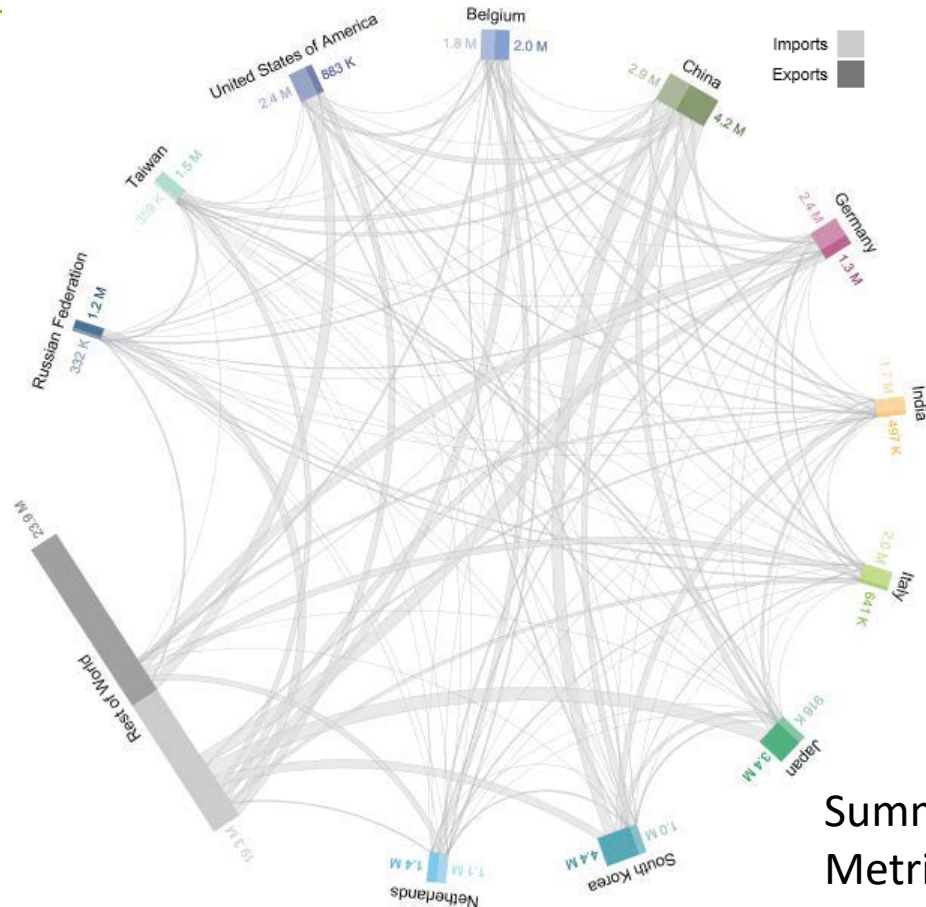
	% 2015 Substrate Market (based on revenue)	% 2015 World Die Market	2015 Die Capacity Utilization
China	22%	38.3%	60%
Japan	19%	15.2%	90%
South Korea	17%	16.8%	71%
Taiwan	37%	22.9%	83%
United States	1%	5.2%	94%
ROW	4%	1.6%	77%

Source: Mukish, Pars, and Eric Virey. 2014. *LED Packaging Technology and Market Trends 2014*. Lyon, France: Yole Développement.

# Trade Flow- Cold Roll Coil Steel Trade (2015)

[Interactive Chart](#)

- Cold Roll Coil Steel is globally traded without any single dominate source



Summary in  
Metric Tons

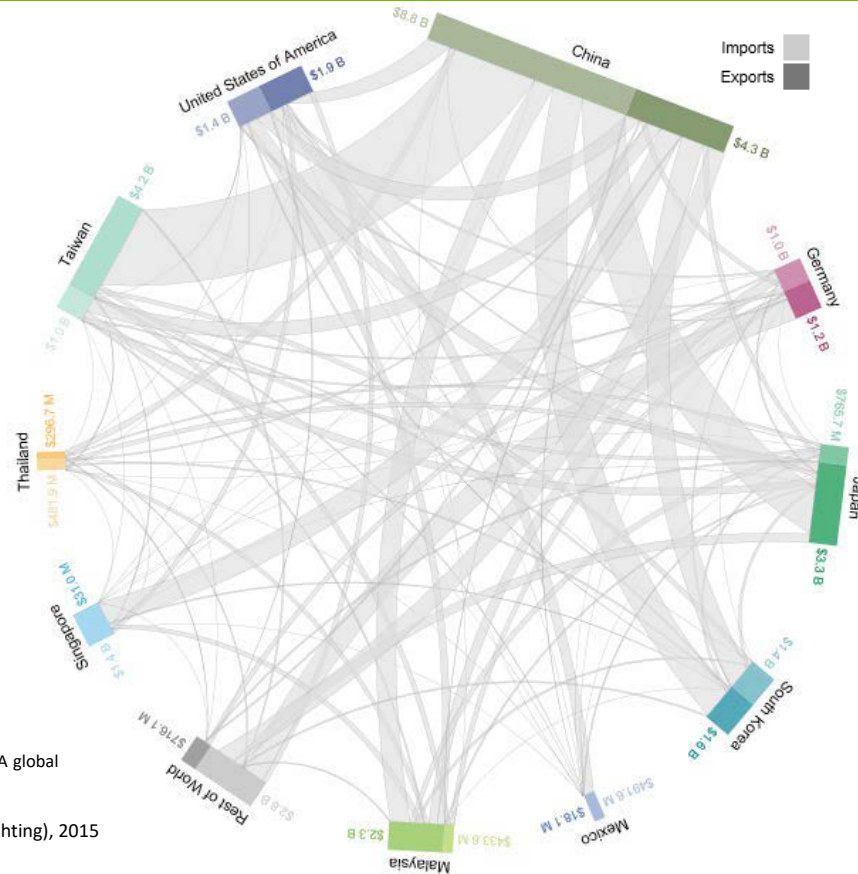
Source:

Reese, S. B., K. Horowitz, M. Mann, and T. Remo. "Research note: LED lighting—A global enterprise." *Lighting Research & Technology* (2020): 1477153520901757.

World Steel Dynamics

# Trade Flow- Die/Packages (2015)

- Considerable trade between countries that don't actually produce either die or packages
  - Skews the trade data to make it appear more product is produced that actually occurs



Country	Imports	Exports
LED die/package trade flow		
United States	\$1.4B	\$1.9B
China	\$8.8B	\$4.3B
Germany	\$1.0B	\$1.2B
Japan	\$766M	\$3.3B
Malaysia	\$434M	\$2.3B
Mexico	\$492M	\$18M
Rest of World	\$2.8B	\$716M
Singapore	\$1.4B	\$31M
South Korea	\$1.4B	\$1.6B
Taiwan	\$1.0B	\$4.3B
Thailand	\$482M	\$296M

Source:  
 Reese, S. B., K. Horowitz, M. Mann, and T. Remo. "Research note: LED lighting—A global enterprise." *Lighting Research & Technology* (2020): 1477153520901757.

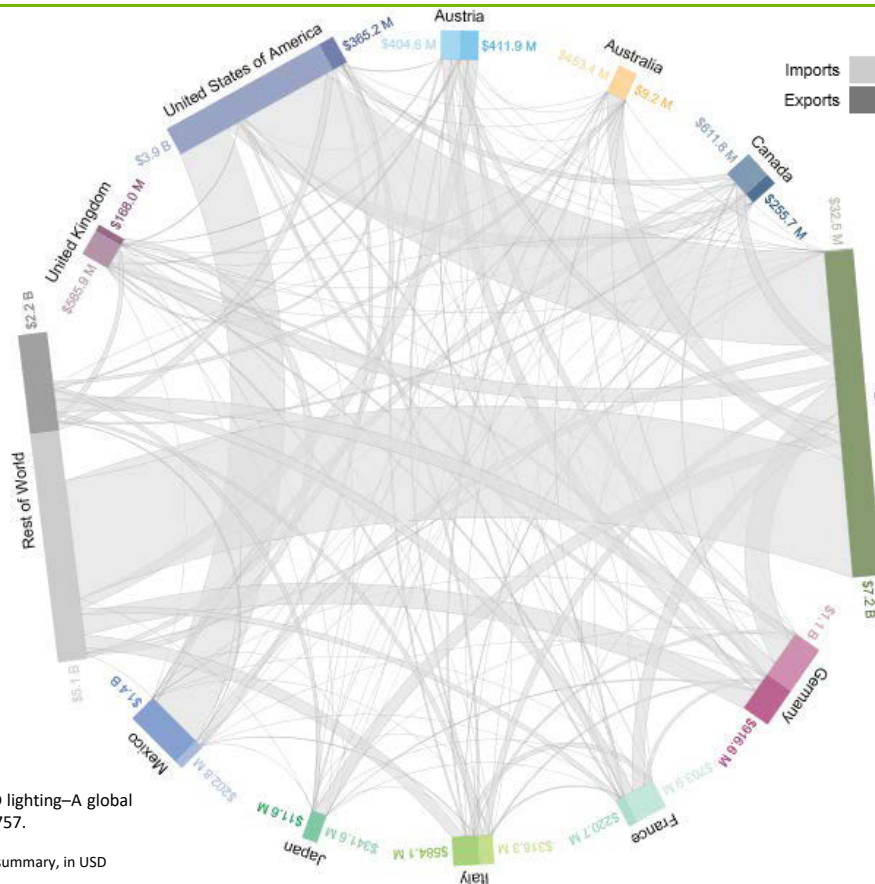
Die/Package trade flow (includes all LEDs, not limited to those used for lighting), 2015 global summary, in USD  
[www.trademap.org](http://www.trademap.org)

# Trade Flow- All Luminaires (2015)

(Both LED and Traditional)

[Interactive Chart](#)

- Trade codes are not yet sophisticated enough to differentiate whether they are integrated LED lights or traditional light housings
- China dominates the trade of luminaires



Country	Imports	Exports
Luminaires trade flow		
United States	\$3.9B	\$365M
Australia	\$453M	\$9M
Austria	\$405M	\$412M
Canada	\$611M	\$256M
China	\$33M	\$7.2B
France	\$704M	\$221M
Germany	\$1.1B	\$917M
Italy	\$318M	\$584M
Japan	\$342M	\$11M
Mexico	\$203M	\$1.4B
Rest of World	\$5.1B	\$2.1B

Source:  
Reese, S. B., K. Horowitz, M. Mann, and T. Remo. "Research note: LED lighting—A global enterprise." *Lighting Research & Technology* (2020): 1477153520901757.

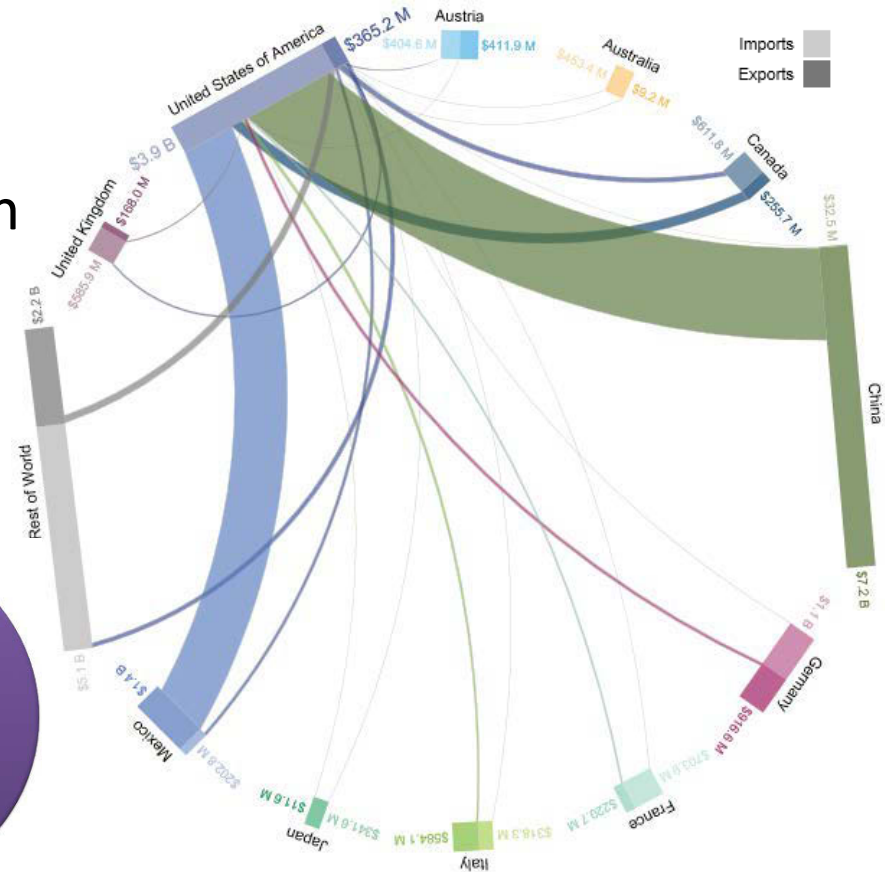
Luminaire trade flow (including both LED and traditional luminaires, 2015 global summary, in USD  
Data from: [www.trademap.org](http://www.trademap.org)

# Trade Flow- U.S. Luminaires (2015)

[Interactive Chart](#)



- According to Navigant Research the luminaire market was \$17.3 billion
- United States **imported** \$3.9 billion in luminaires
- The United States therefore **manufactured** domestically ~\$13 billion in lighting products  
 – **77%** of total revenue sold



Source:  
 Reese, S. B., K. Horowitz, M. Mann, and T. Remo. "Research note: LED lighting—A global enterprise." *Lighting Research & Technology* (2020): 1477153520901757.

Luminaire trade flow (including both LED and traditional luminaires, 2015 global summary, in USD)

Navigant Research Market Data: Residential Energy Efficient Lighting and Lighting Controls Incandescent, Halogen, Fluorescent, and LED Luminaires and Lamps and Intelligent Lighting Controls: Global Market Analysis and Forecasts Published 3 Q 2016



# Bottom-Up Cost Modeling

# Regional Manufacturing Costs



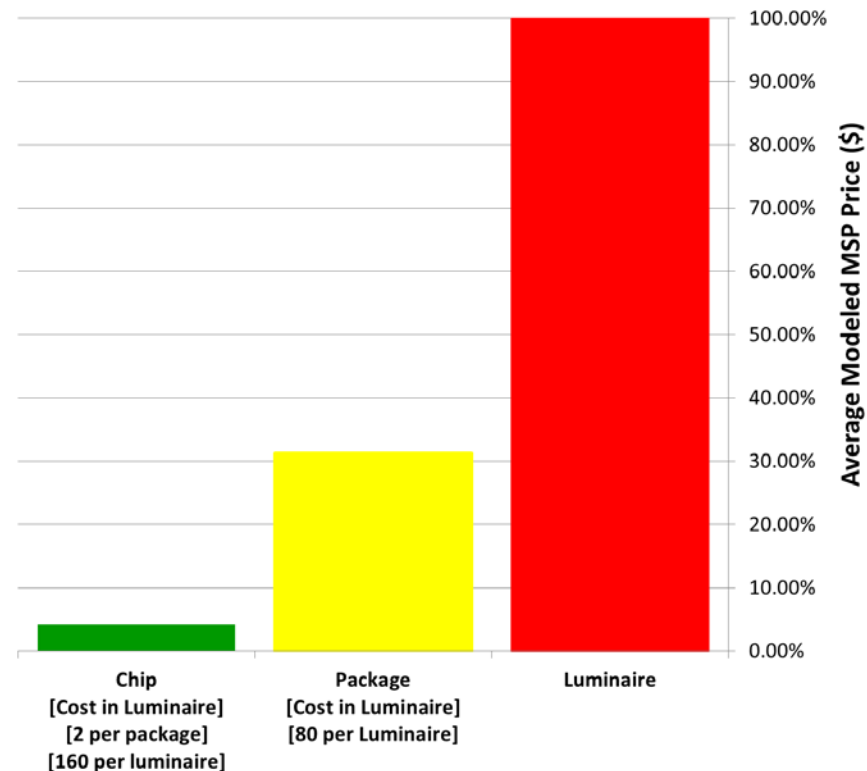
- Bottom-up modeling
  - Models the effect of core country factors:
    - Labor rates
    - Electricity prices
    - Effective corporate tax rates
  - Assumes the same knowledge/capability of firms in each country, and the same risk associated with firms in each country
  - Assumes all equipment is fully purchased new
  - Same cost of debt and equity, D/E ratio
  - Same production volumes, yields, and wafer diameter
    - Wafer model assumes 100% capacity utilization
  - No subsidies
- MSP is the minimum sustainable price that a company must sell its product for in order to pay back the capital and operating expenses during the plant lifetime

# Value Add Comparison-Modeled MSP Prices



- Navigant Research indicates the 2015 luminaire market was \$17.3 billion
- 2015 trade data shows the United States **imported** \$3.9 billion in luminaires
- The United States therefore **manufactured** domestically ~\$13 billion in lighting products
- The high value piece of the chain is dominated by domestic production
  - 77% of total revenue sold

Value Add along 2x2 Troffer Supply Chain



Source:  
Reese, S. B., K. Horowitz, M. Mann, and T. Remo. "Research note: LED lighting—A global enterprise."  
*Lighting Research & Technology* (2020): 1477153520901757.

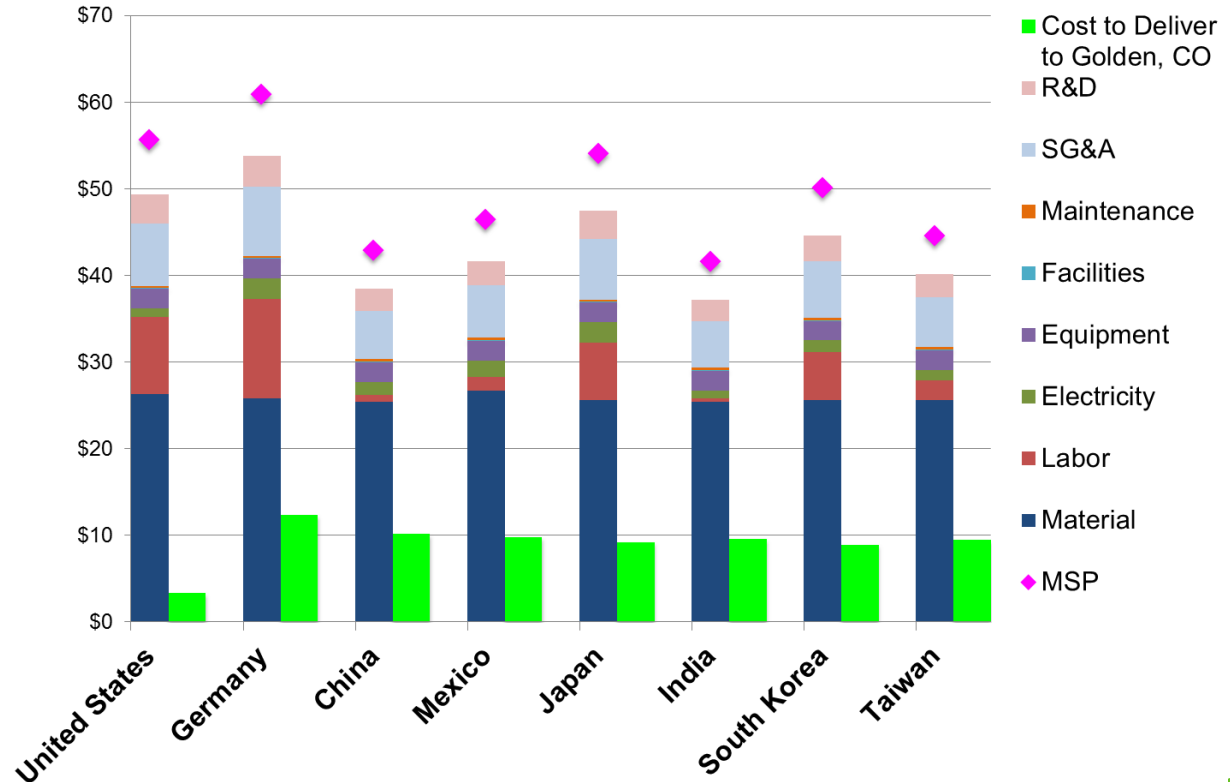


# LED Luminaire Cost and Time to reach Golden, CO



- Assumes 40ft container
- #408 2'x2' troffers per container
- Ship reaches closest U.S. port
  - Truck shipping from the port

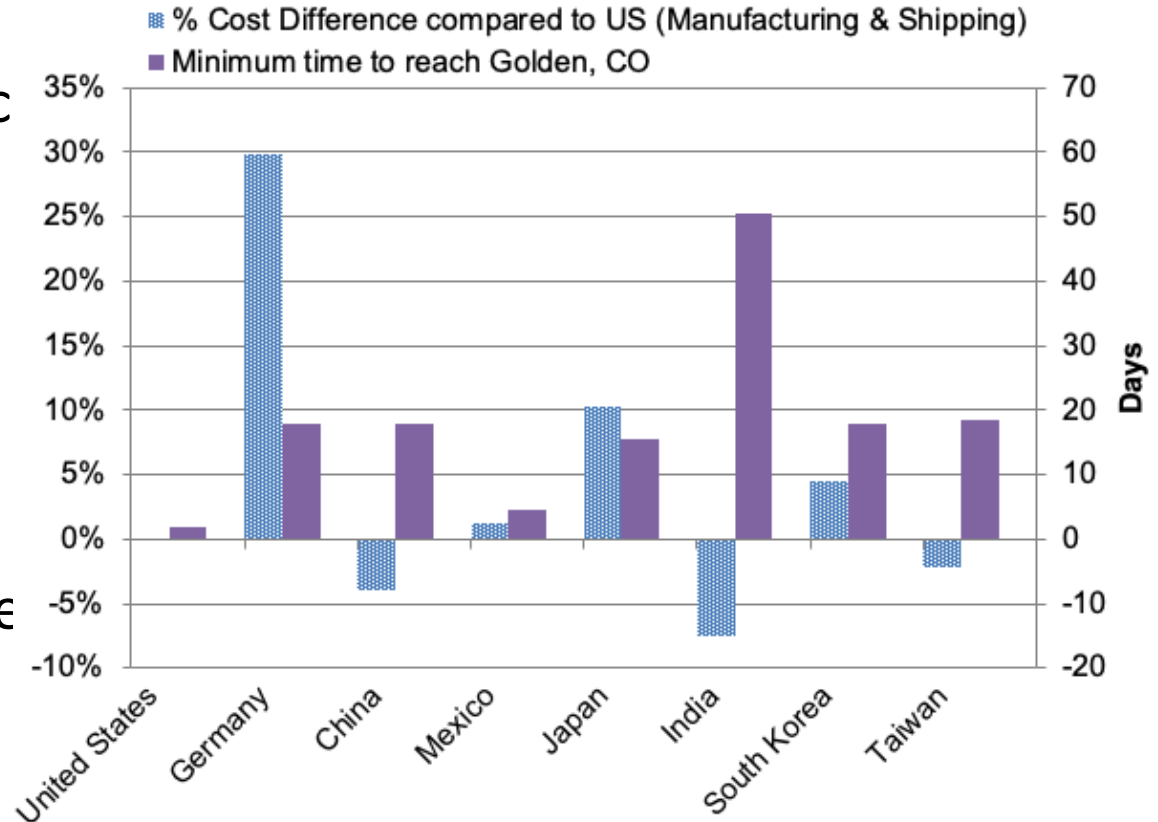
2x2 Troffer Modeled MSP (2000 lm, 30W, 4000K)



# Cost/Time Tradeoff



- Once shipping is accounted for
  - China
  - India
  - Taiwanstill cheaper
- Still significant time



# Conclusion



- General lighting is projected to consume 70% of packaged LEDs in 2020
- Advances in LED technology incentivize luminaire updates
- LED technology is rapidly evolving thus long shipping times are undesirable
- The cumulative result is that LED integrated luminaires reduce the energy needed for lighting and currently have a value chain that allows for domestic manufacturing benefiting the domestic economy

# Thank you

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