# Global Expansion in Carbon Fiber Manufacturing: Strategic Considerations for Energy Utilization

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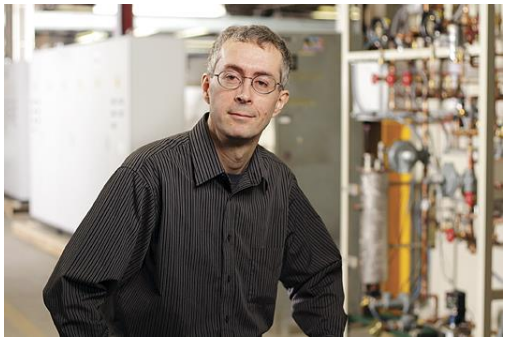
Composites World Carbon Fiber 2015

# About Harper

- Headquartered in Buffalo, NY
- An Employee-Owned Company
- State-of-the-art Technology Center
- Multi-disciplined engineering talent
  - Chemical
  - Ceramic
  - Mechanical
  - Electrical
  - Industrial
  - Process & Integration



# Carbon Fiber Carbonization Process – Scales of Operation

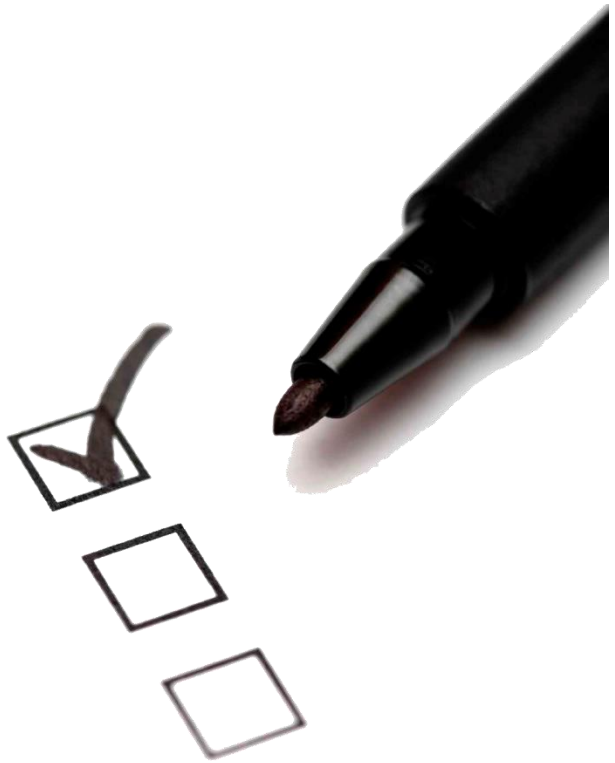
| Scale | Size Range (Tow-Band Width) | Capacity |
|---|---|---|
| Commercial Production Line | 1000 – 4200 mm | 500 - 4000 ton/year |
| Pilot Line | 300 -1000 mm | 20 - 100 ton/year |
| Microline | ≤100 mm | Less than 10 ton/year |
| Scientific Line | Fractional tows (<1k or less than 1,000 filaments) | Less than 1 ton/year |

Courtesy of Oak Ridge National Laboratory

Courtesy of Georgia Institute of Technology

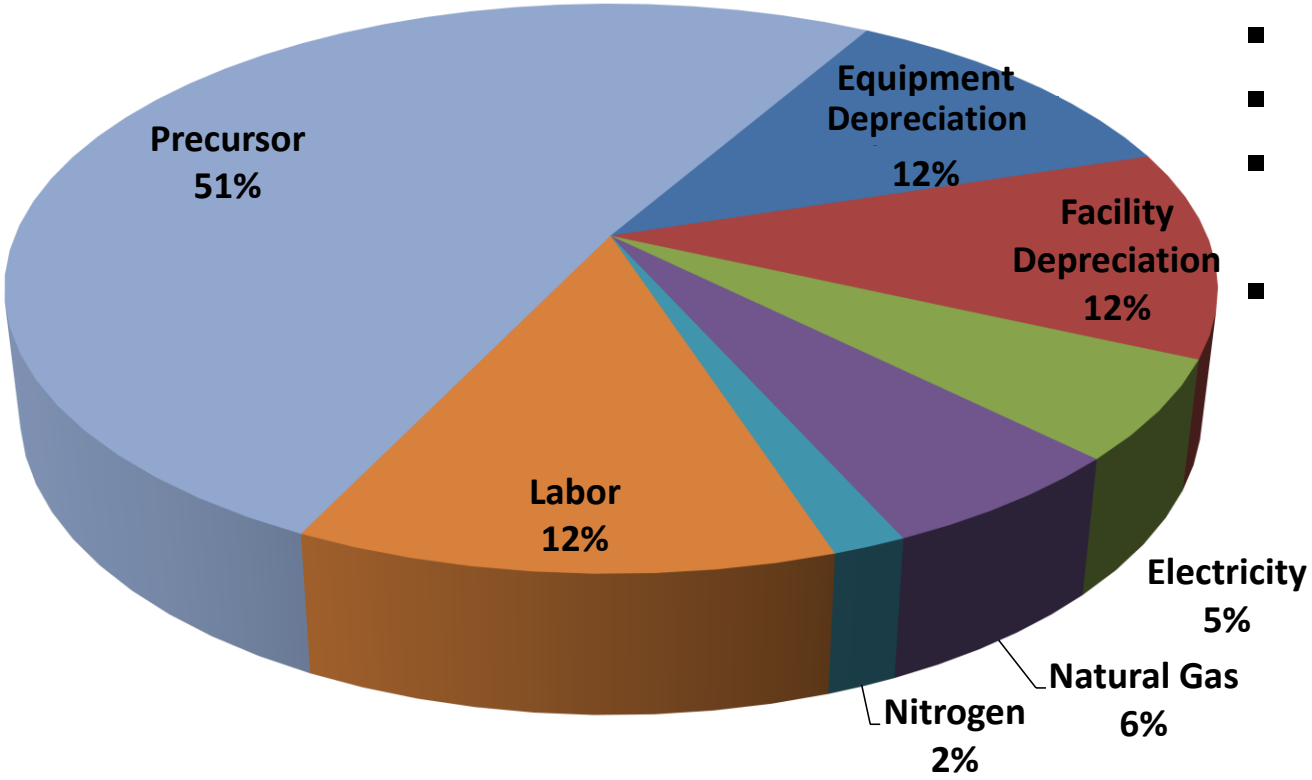
# Agenda

- **Economics Framework**
- Energy Markets Review
- Case  Example
- Wrap Up



# Harper Estimated Cost Structure Carbon Fiber Manufacturing

Cost of Manufacturing (CF) Based on 1500 TPY 12k (90min, 90s, 90s RT)




- Energy ~10% of total
- Oxidation = 30-40%
- ~8 MW total consumption
- $4MM USD per year (energy)

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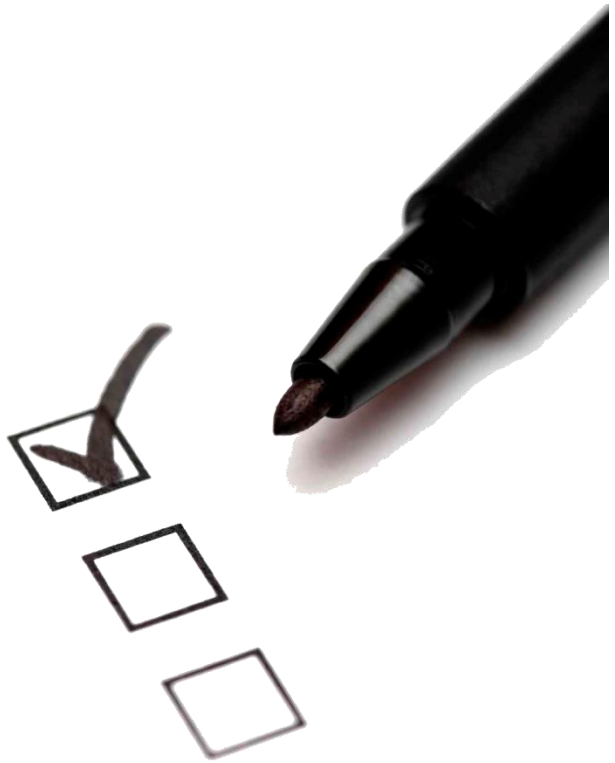
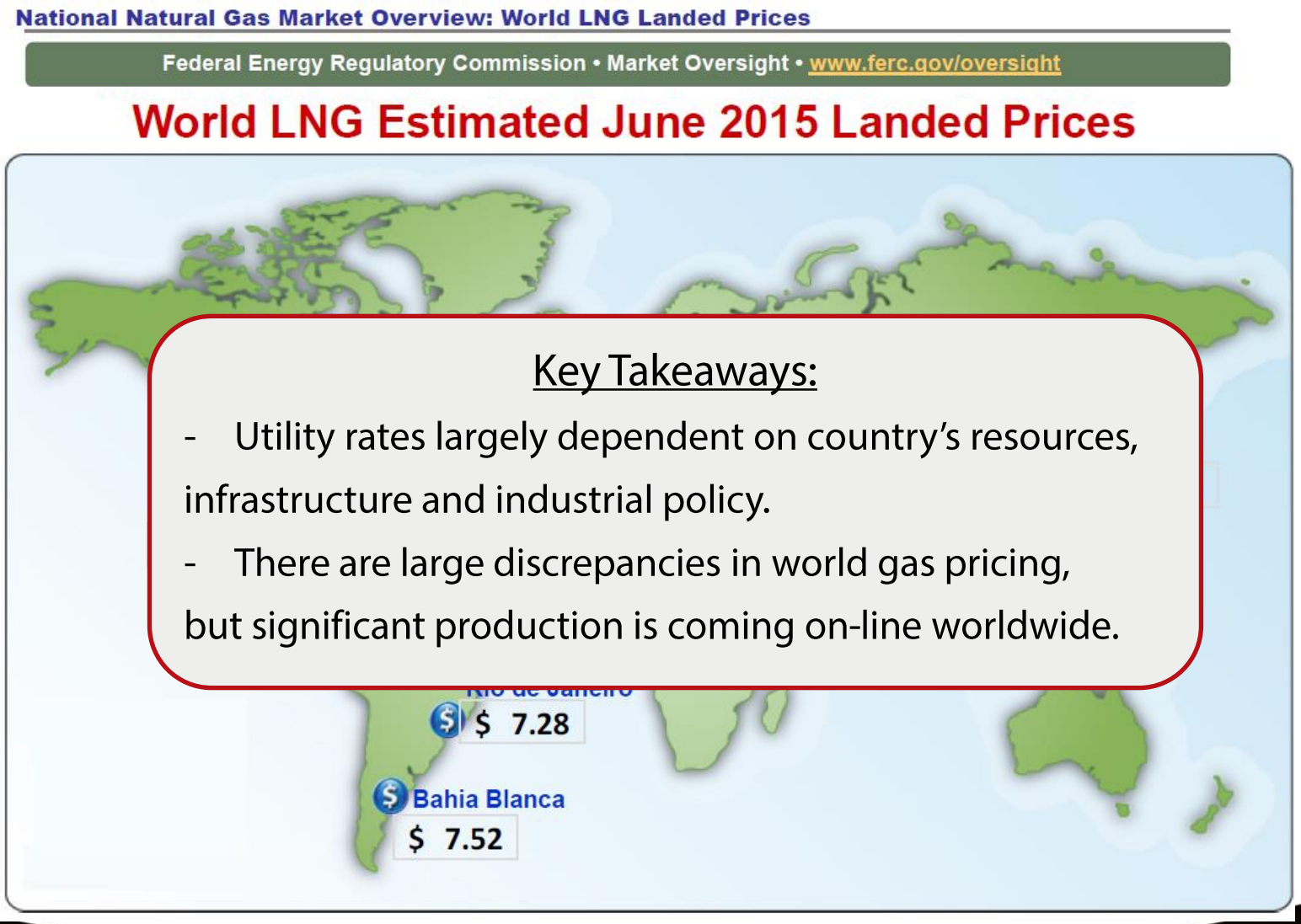


# Global Electric Prices

Estimated 2014 Industrial Electric Prices (Cents/Kwh)


Sources: IEA, EIA, OANDA

# Global Gas Markets

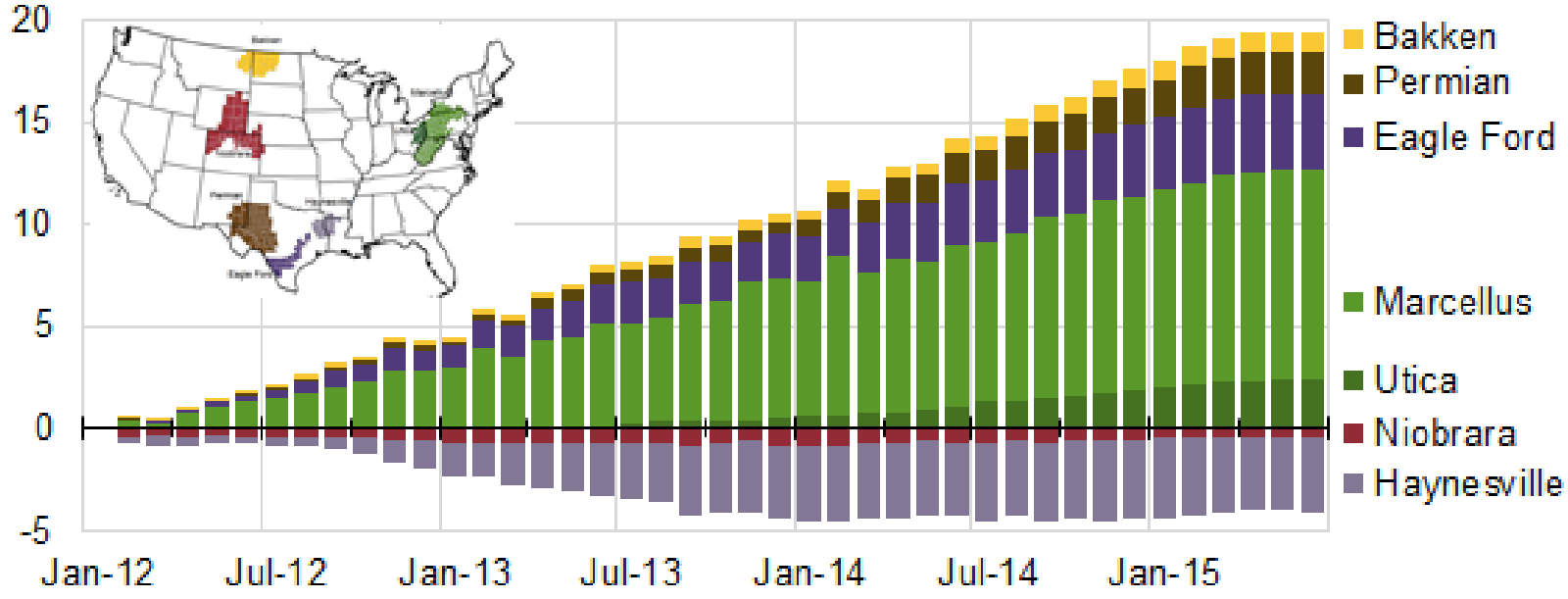



Source: IEA, FERC

# Shale Natural Gas Development

## Marcellus, Utica provide 85% of U.S. shale gas production growth since start of 2012

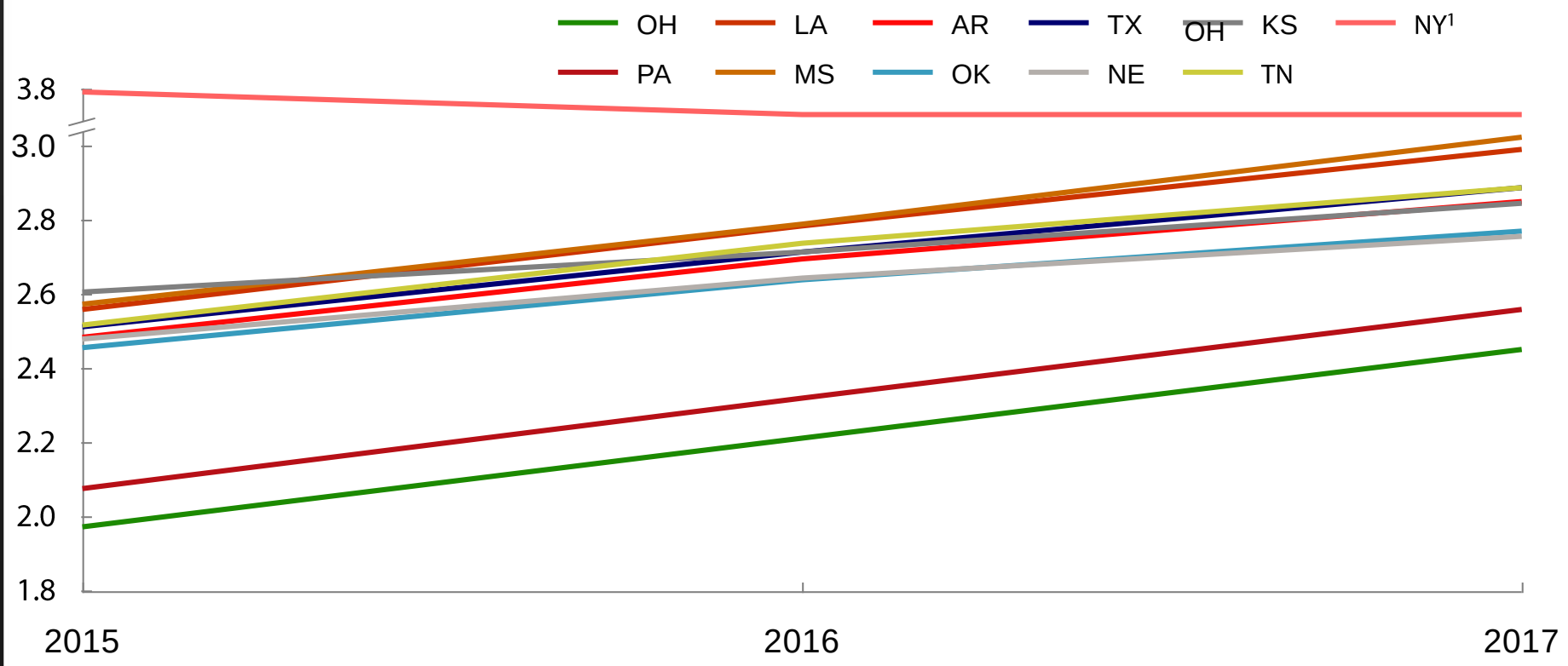
**Natural gas production in selected regions (Jan 2012 - June 2015)**
cumulative change since January 2012, billion cubic feet per day (Bcf/d)




Source: Jobs Ohio

# Prices Differential Exist Between The Major Gas Hubs

**Average natural gas price at major natural gas hubs,** dollars per MMBtu




1: 2017 data for NY largely unavailable, so price show as equal to 2016

SOURCE: ABB Energy Velocity; NYMEX

Harper International

# Specific Case Examples

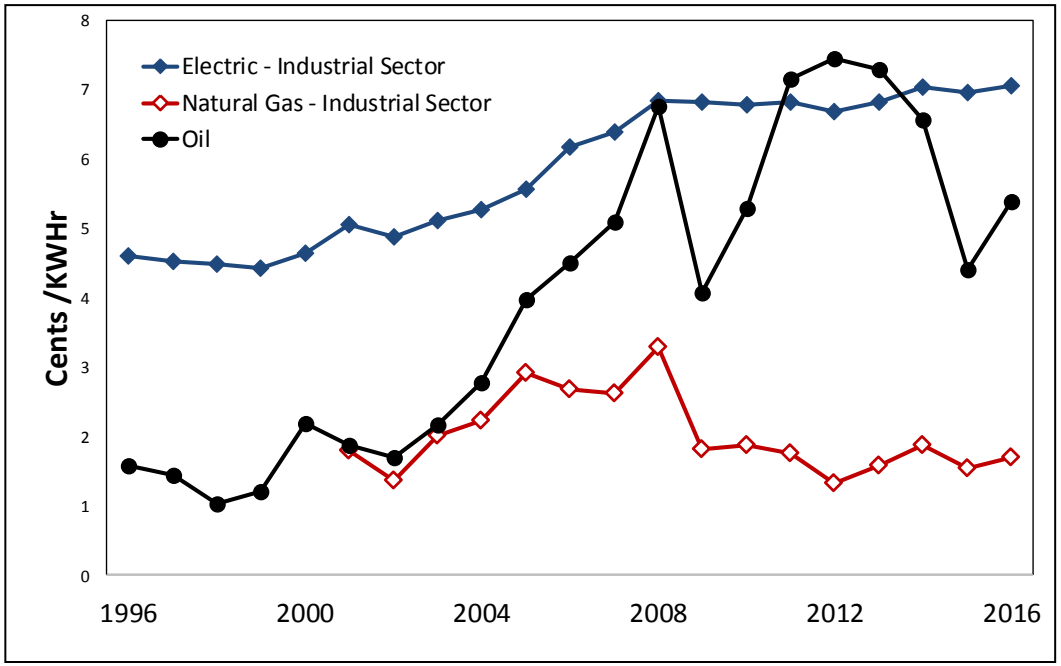
A select set of locations where considered for example comparative calculations.

- USA – Average Industrial
- Europe
- China
- Japan

*USA Regions: Ohio, New York, Tennessee

# North America Natural Gas & Electric Prices

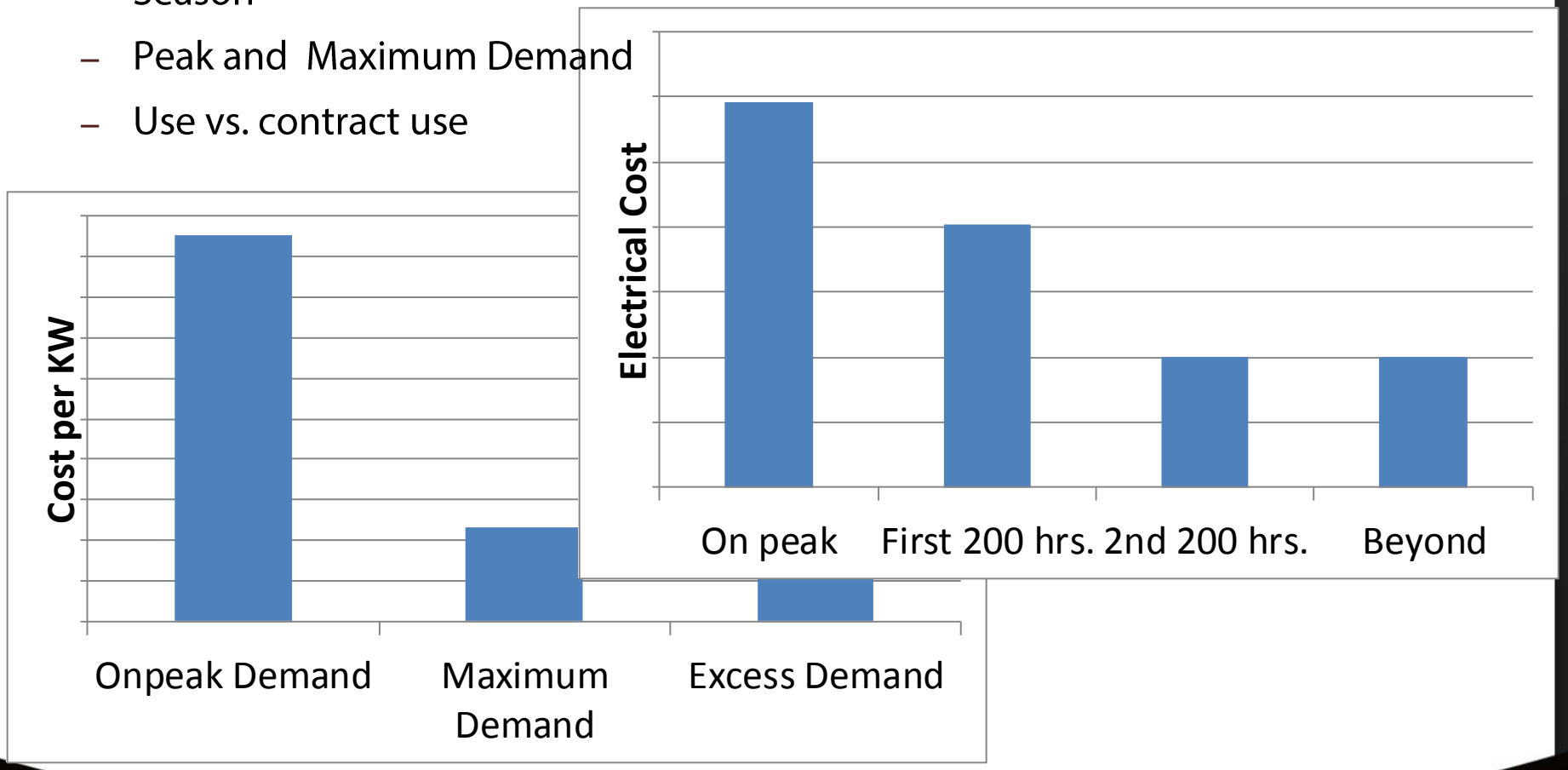
- Natural gas prices (relatively) stable
- Electric prices rising
- Oil unstable




Source: www.eia.gov/forecasts

# Electrical Cost Fluctuations

- Electrical costs vary by
  - Season
  - Peak and Maximum Demand
  - Use vs. contract use



## Observations

- Energy is a major cost in Carbon Fiber production
- Energy prices vary by:
  - Region
  - Current Economic Conditions
  - Season and even time of day
- There is great opportunity in flexible energy sources

## Conclusions

- Minimizing risk through equipment design and pricing strategy are critical
- Pressure persists for cost savings to support further adoption in automotive and aerospace applications
- Location Location Location

**How do we address these challenges?**

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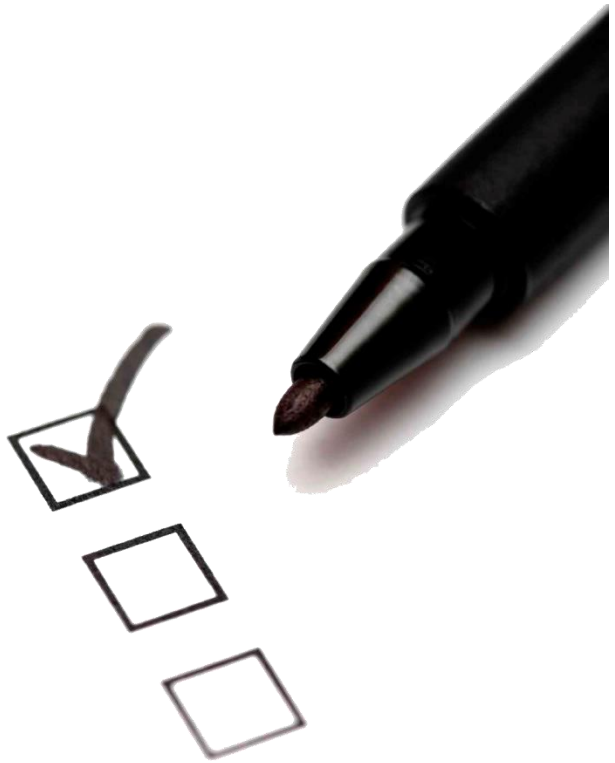


# Case Study: Natural Gas vs Electric Heating

3 meter – Current industry standard production scale

| Line Size | Filaments /mm | Line Speed | Production Capacity (Tons/Year) |
|---|---|---|---|
| **3 Meter** | 2050 | 10 m/min | 2007 |

# Discussion of Major Factors in Calculation of Consumed Energy


Carbon Fiber Basis

- Small Tow / Large Tow

Flow sheet dependency

- Heat recovery from abatement system
- Oven make-up air: amount and incoming temperature
- Number of ovens, oven passes, etc.
- Oven infiltration flow rate

# Oxidation Ovens

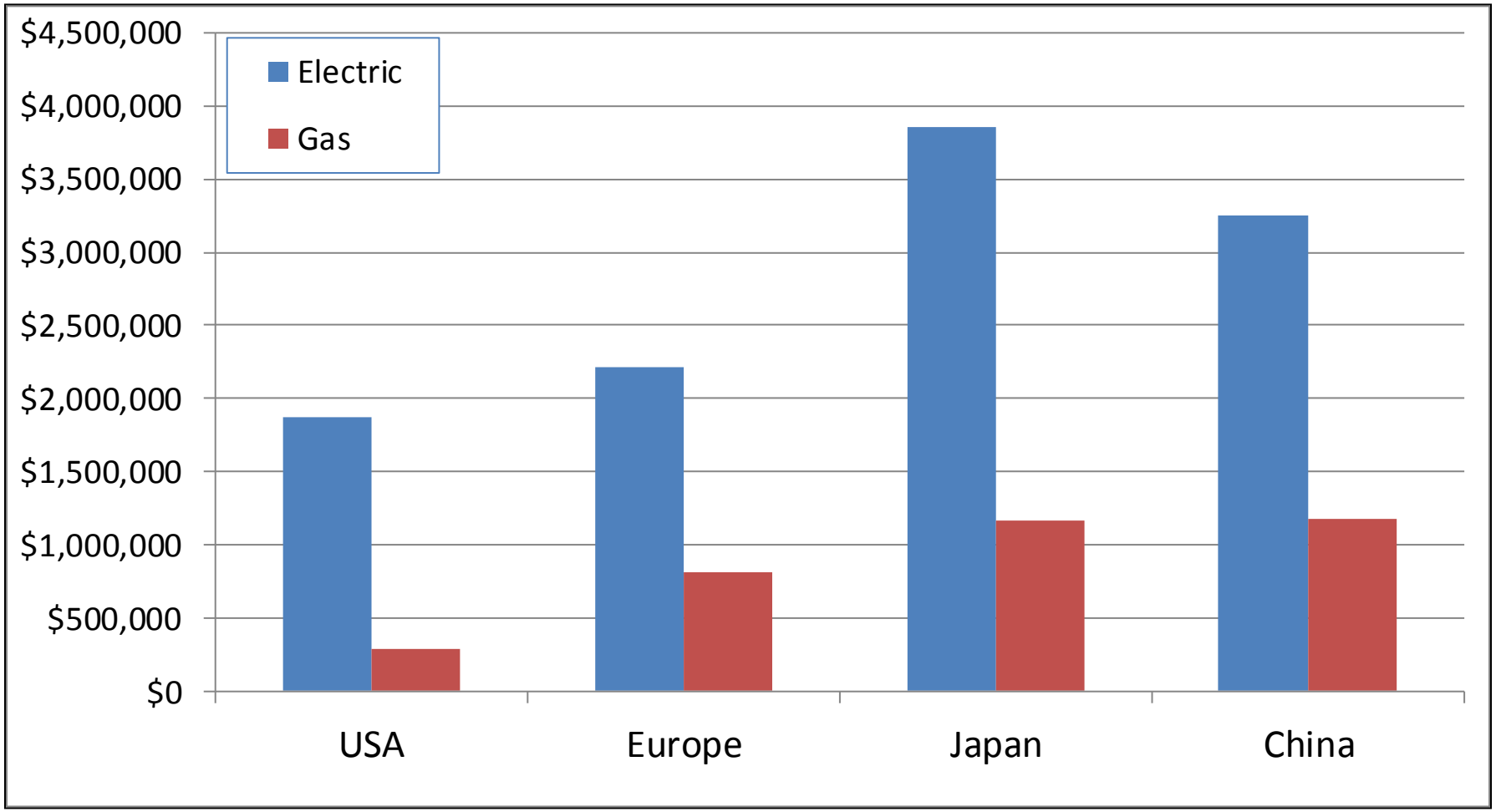
# Ovens Overview

Ovens are largest consumers of energy in carbon fiber line

- 30-40%
- Oven energy consumption tied to overall process flow diagram
  - Preheated makeup air

3M Oxidation Oven Section

# Annual Cost of Oxidation – 2015
# Gas Heating – Huge advantage over electric




Utility Rate Sources: EIA, World Bank,
MIT Joint Program Report 282; Natural Gas Pricing Reform in China

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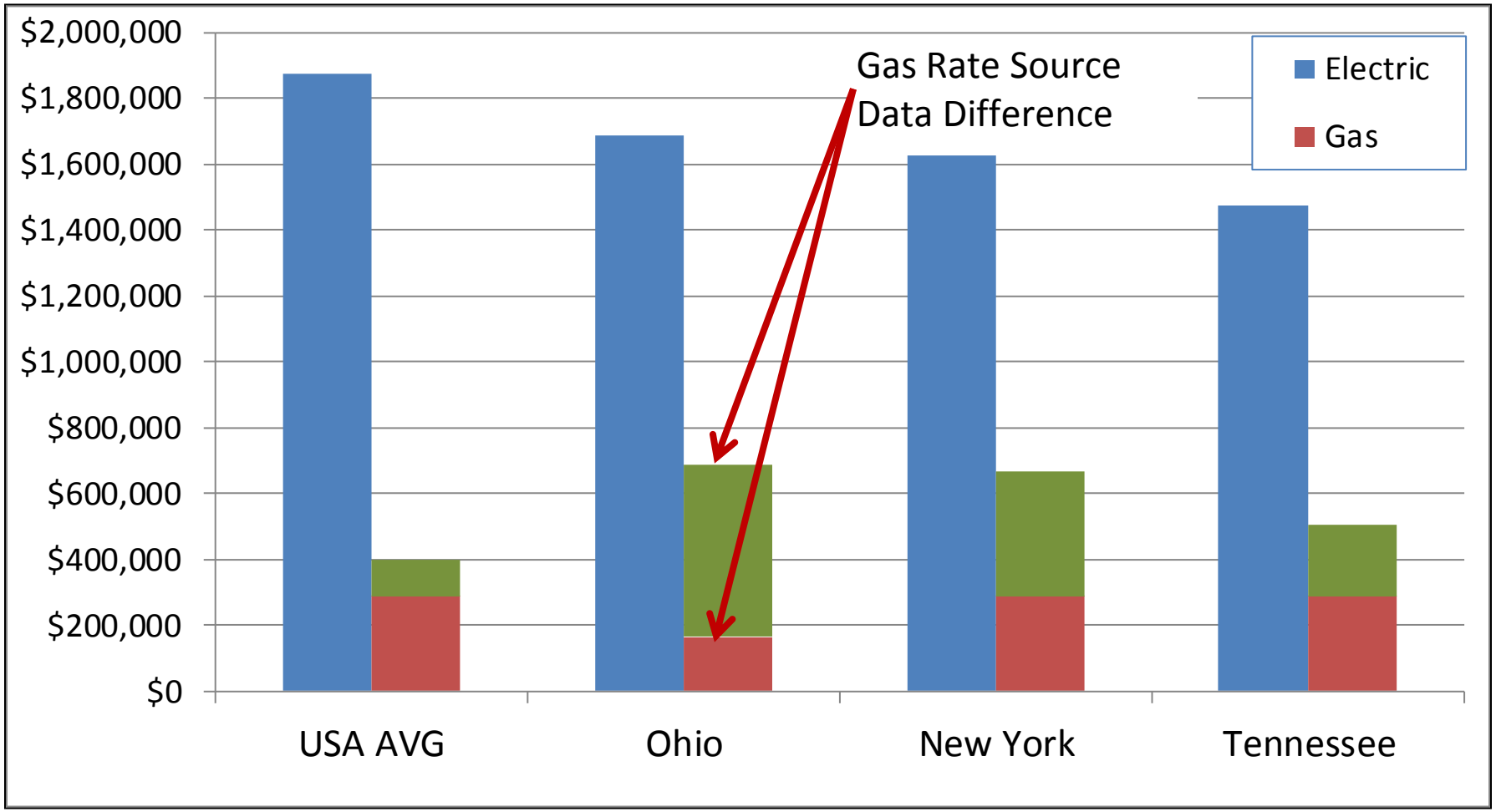
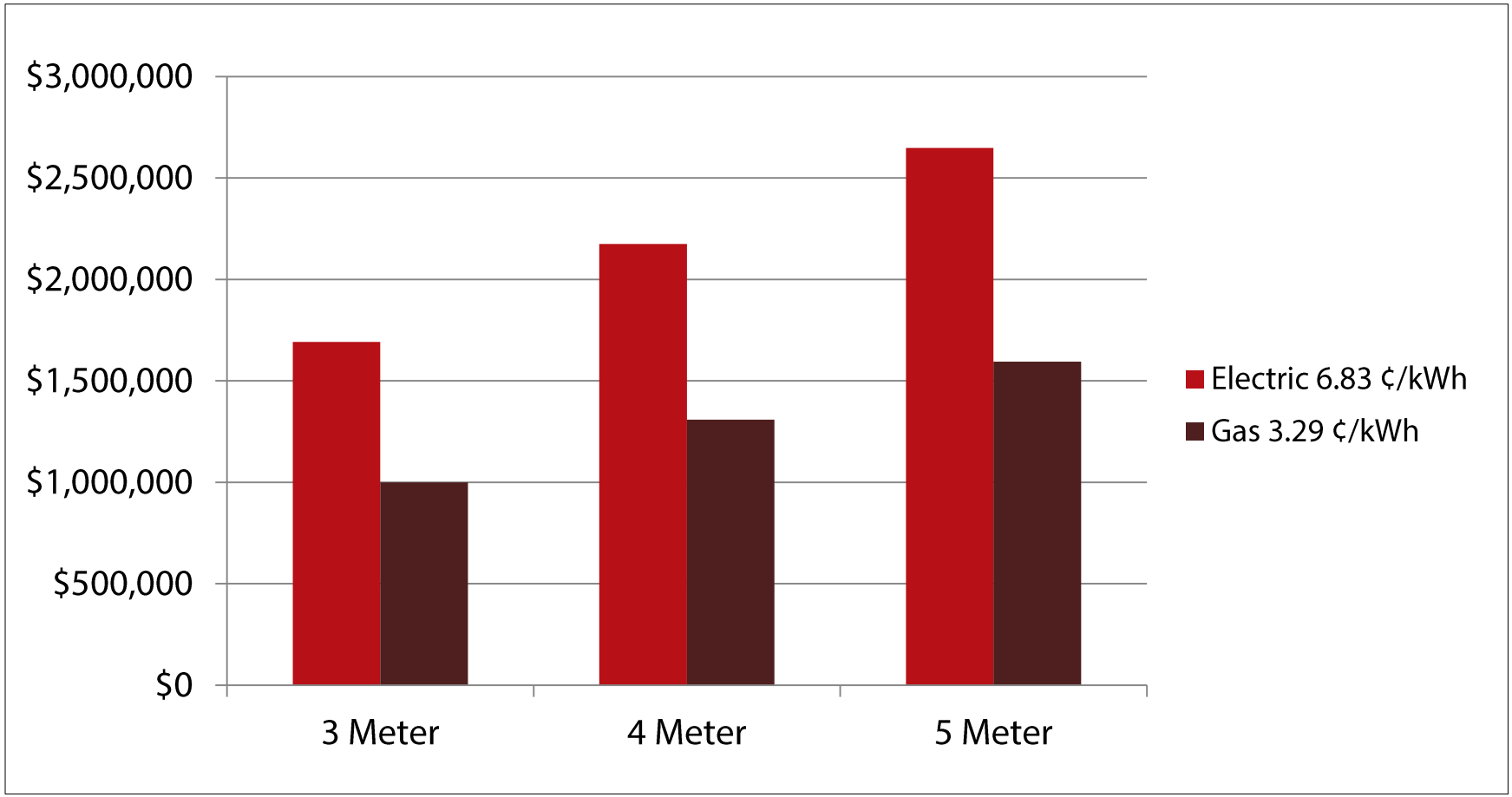



Utility Rate Sources: EIA, World Bank, Jobs Ohio

# Annual Cost of Oxidation - USA 2008
# Gas Heating – Much smaller advantage over electric



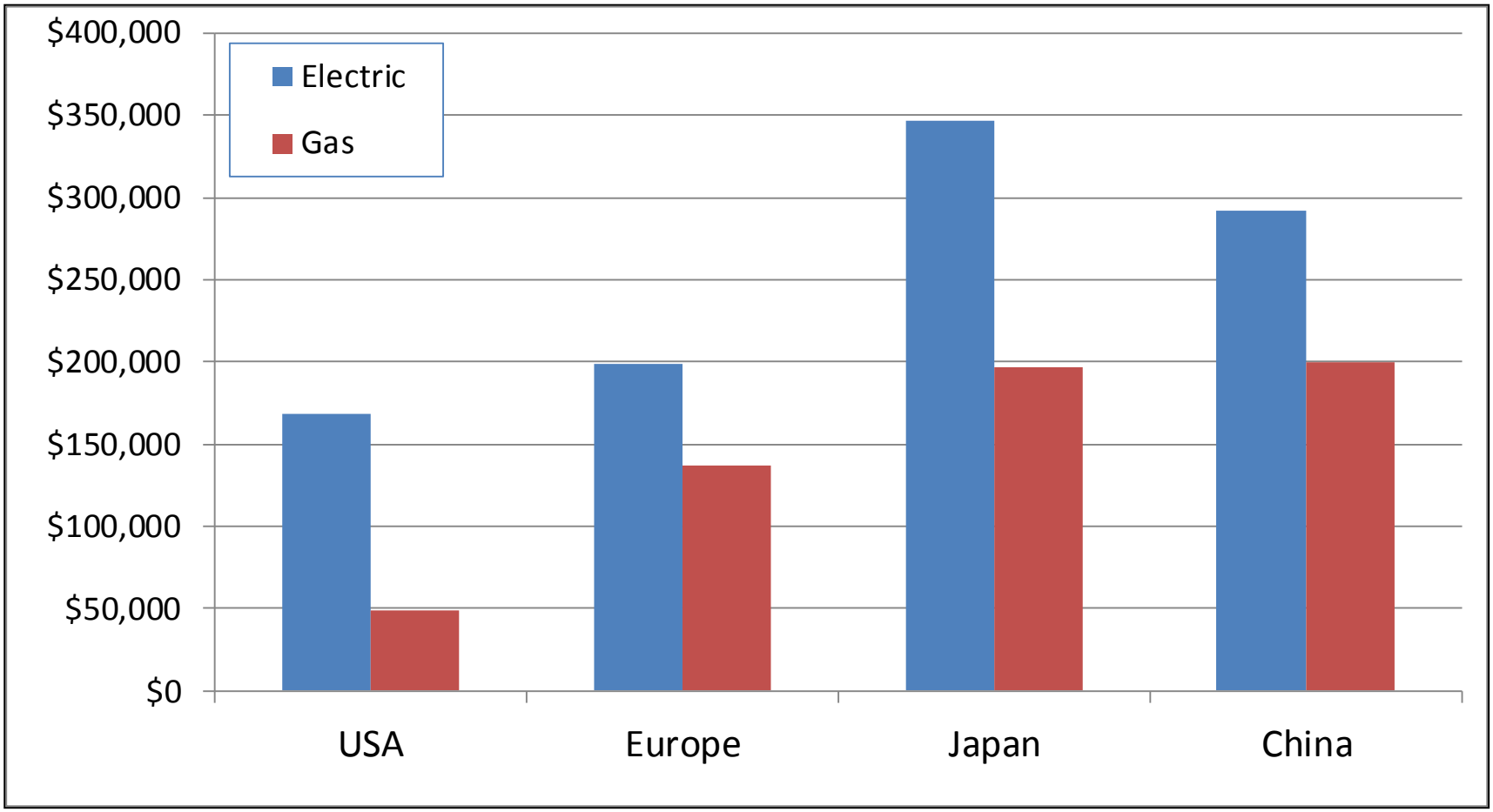
# Ovens Summary

- Ovens are largest consumers of energy in carbon fiber line
  - 30-40%
- Globally, gas fired ovens make the most sense

- Dual-fuel ovens could leverage low-cost gas to drive down cost

# LT Furnace

# Annual Cost of LT– 2015
# Gas Heating – advantage over electric

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# Annual Cost of LT– USA 2015
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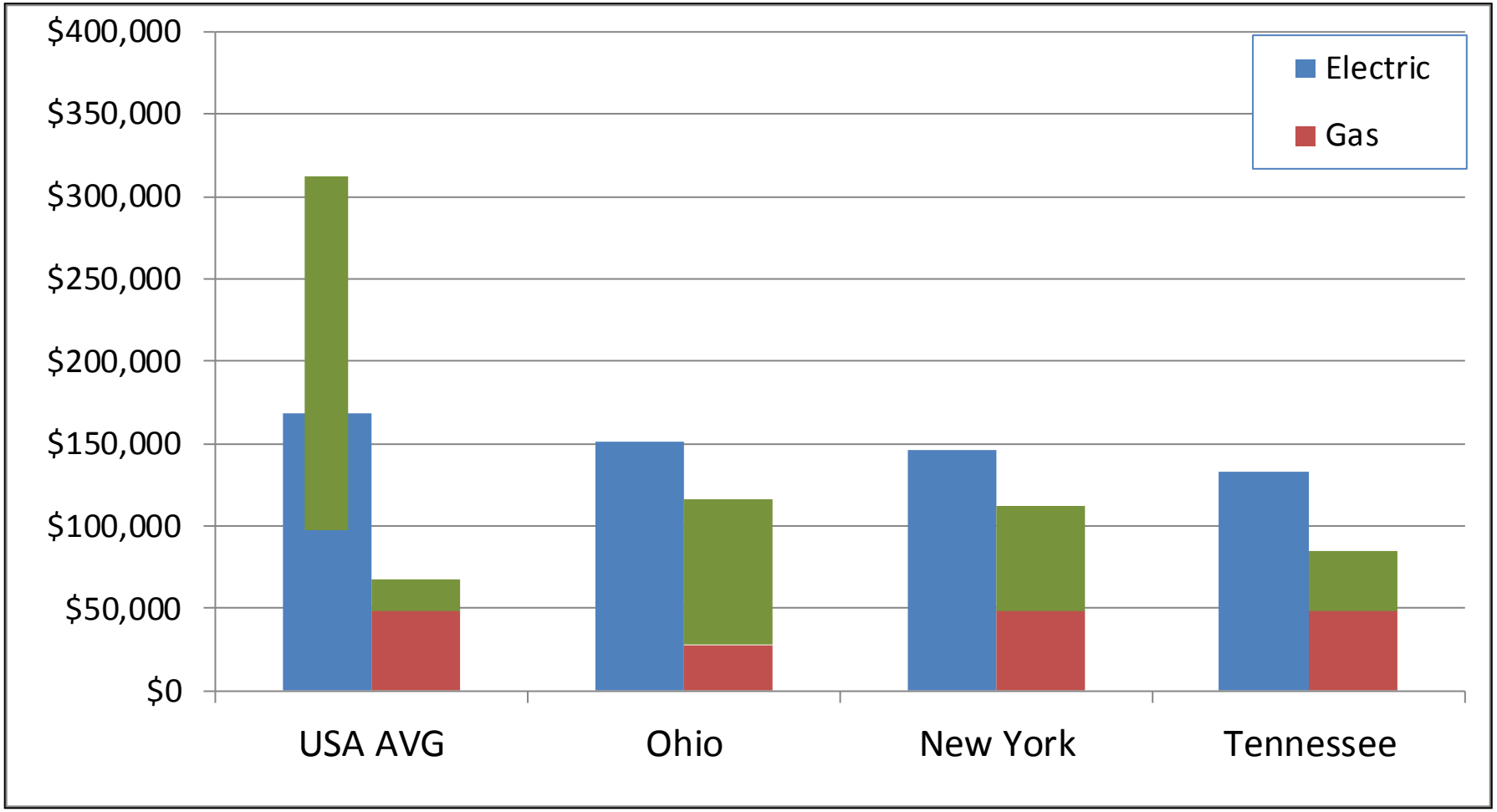
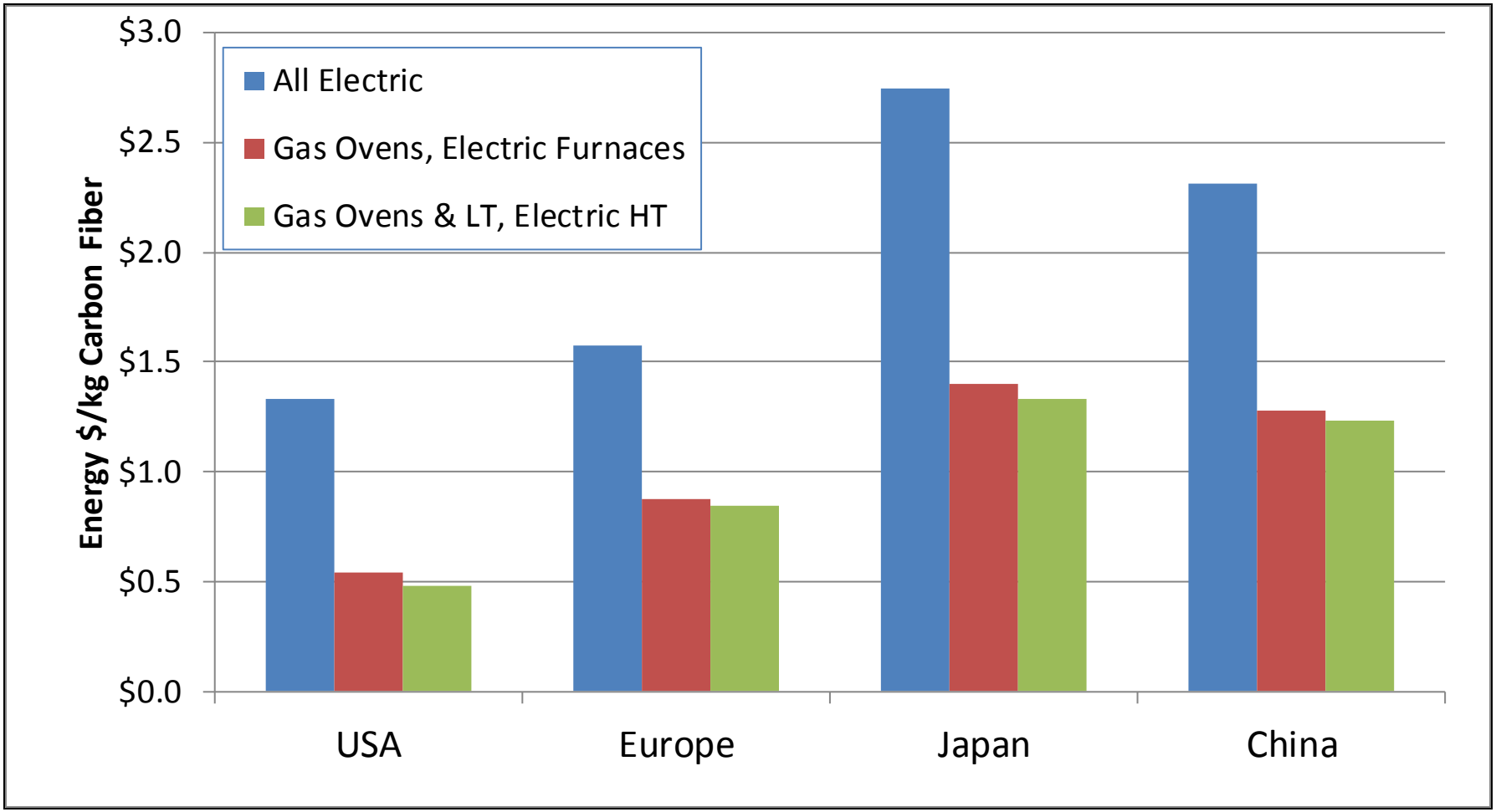



Utility Rate Sources: EIA, World Bank, Jobs Ohio

# LT Furnace Summary

- Gas heating less efficient at higher temps
  - So cheap gas offers less of an advantage
- Even in USA, heating source not obvious
- LT is small power consumer, so choice not so critical

# Gas Ovens Have Big Impact on Overall Energy Cost per kg Carbon Fiber

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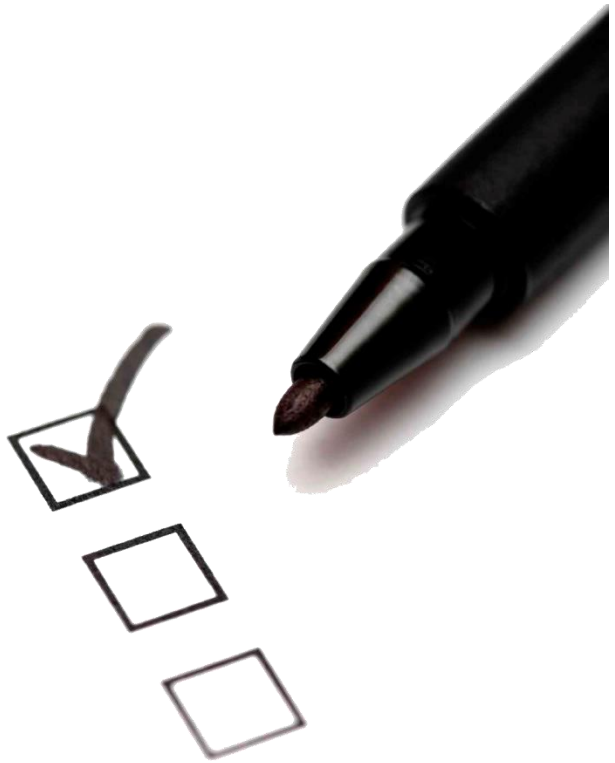
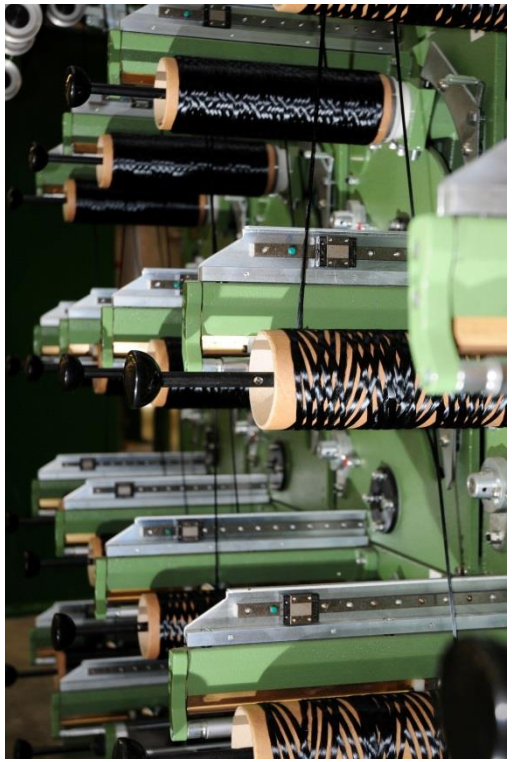


# Putting It All Together

- Understand the energy price structure
- Sustainable energy
- Flexibility is key to optimization
- Hybrid plant – dual fuel oxidation
  - Ovens – large zones and low temp
  - Possible to incorporate dual heating methods
  - Huge opportunity for cost savings
- Select LT carefully
  - Higher temp, many zones in one box
  - Dual heating impractical
  - Low power consumption, less opportunity for savings
- HT, UHT
  - High Temps – Gas impractical



# Hybrid Powered Ovens Utilize Gas AND Electric Heating

- Oven has both gas fired heaters and electric heaters
- Can use both at once for fast heat up
- Can use either / or at steady operation

Indirect Gas Fired Heater

Electric Heater

# Why a Hybrid Oven?

1. Increased availability with dual utility option
2. Faster to start-up / reduced down time
3. Flexibility of selecting fuel based on current cost
4. It's a universal plant (installable anywhere in the world)

# Final Thoughts

- Increasing availability of natural gas worldwide
- Energy cost reduction potential for gas fired system
- Proven experience in gas and electric fired systems

# Thank you for your time!
# We welcome any questions…

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