



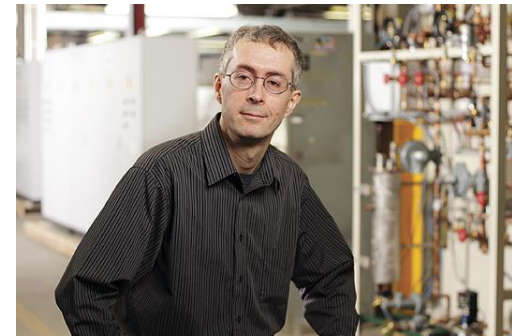
Global Expansion in Carbon Fiber Manufacturing: Strategic Considerations for Energy Utilization

Peter Witting, PhD

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

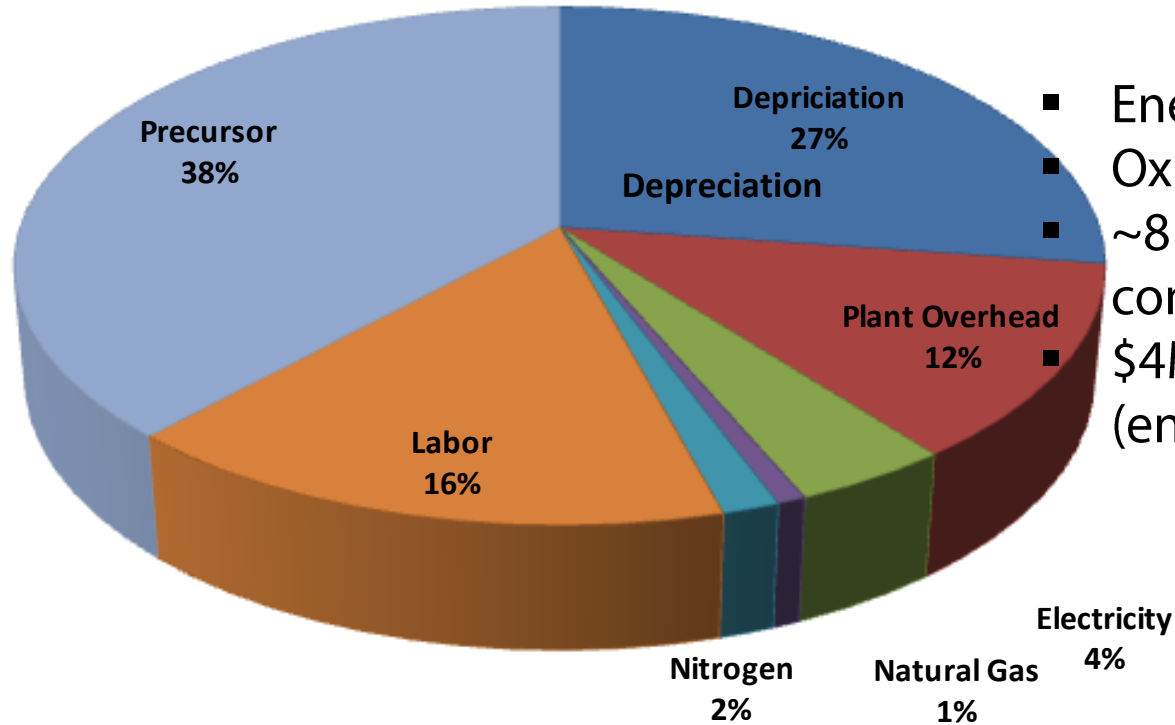
Agenda

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



Harper Estimated Cost Structure

NEXANT Cost of Manufacturing (CF) Based on 3000 TPY



- 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)



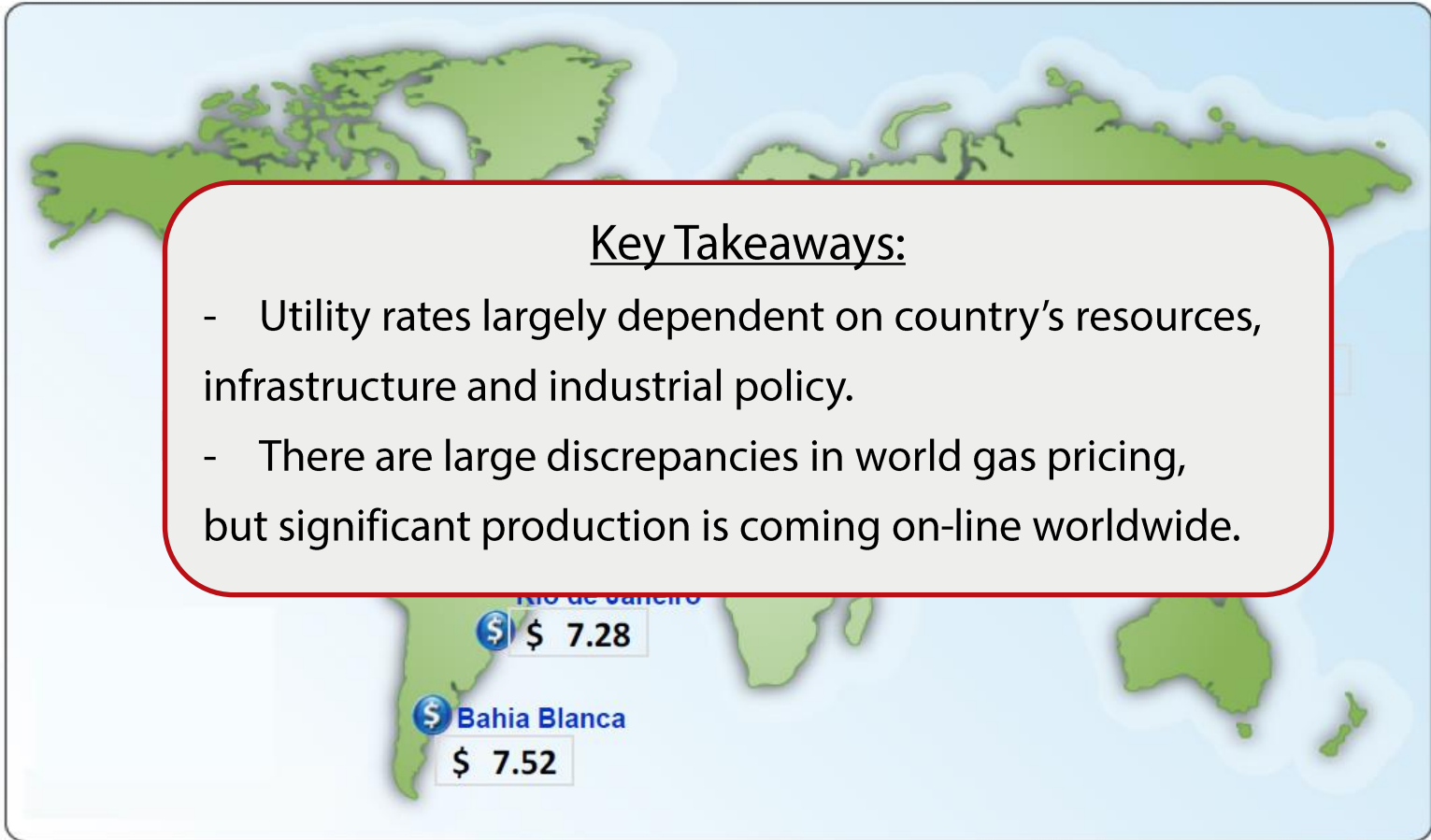
Sources: IEA, EIA, OANDA

Global Gas Markets

National Natural Gas Market Overview: World LNG Landed Prices

Federal Energy Regulatory Commission • Market Oversight • www.ferc.gov/oversight

World LNG Estimated June 2015 Landed Prices

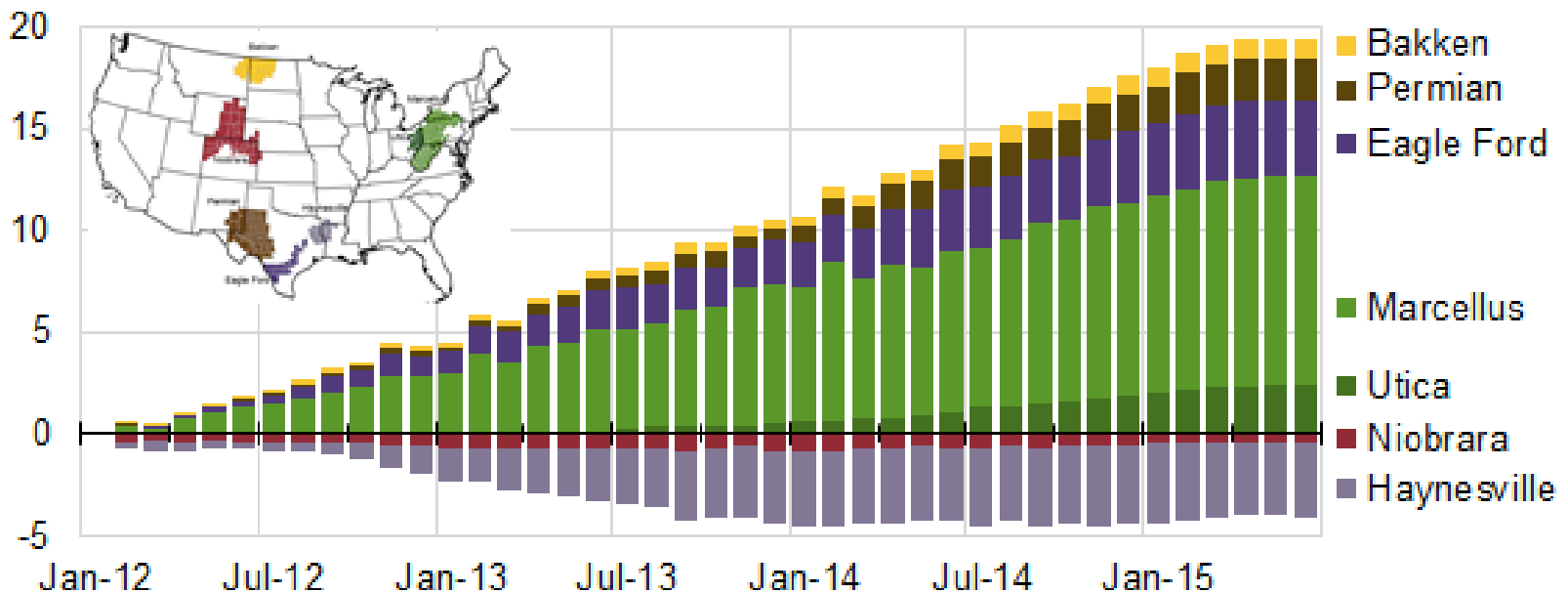


Source: IEA, FERC

Shale Natural Gas Development

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

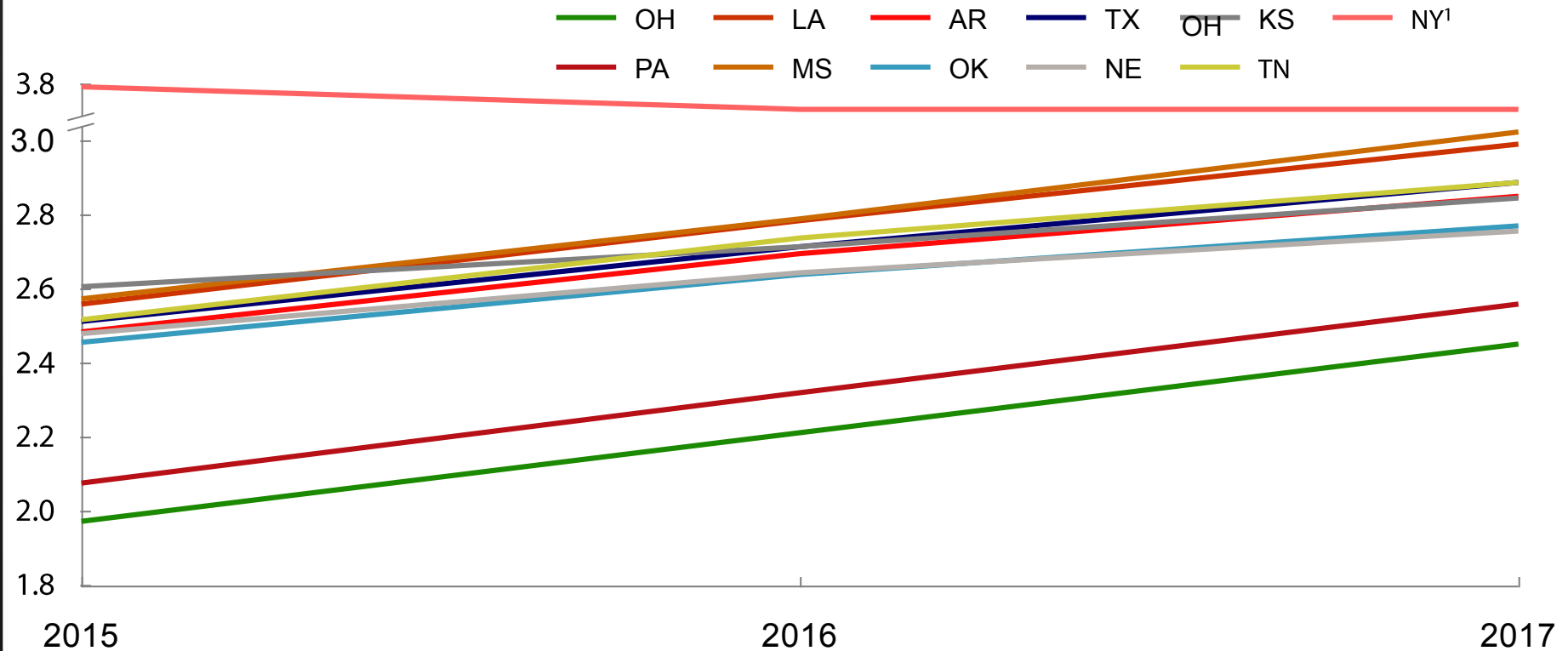
Natural gas production in selected regions (Jan 2012 - June 2015)
cumulative change since January 2012, billion cubic feet per day (Bcf/d)



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

Specific Case Examples

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

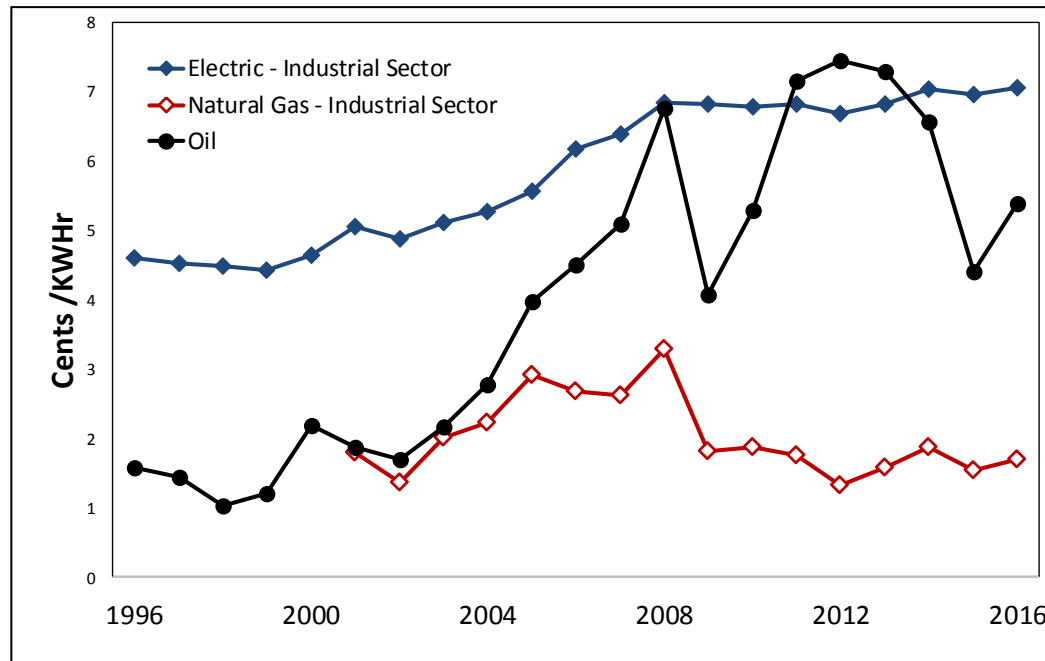
- USA – Average Industrial
- Europe
- China
- Japan

*USA Regions: Ohio,
New York, Tennessee



North America Natural Gas & Electric Prices

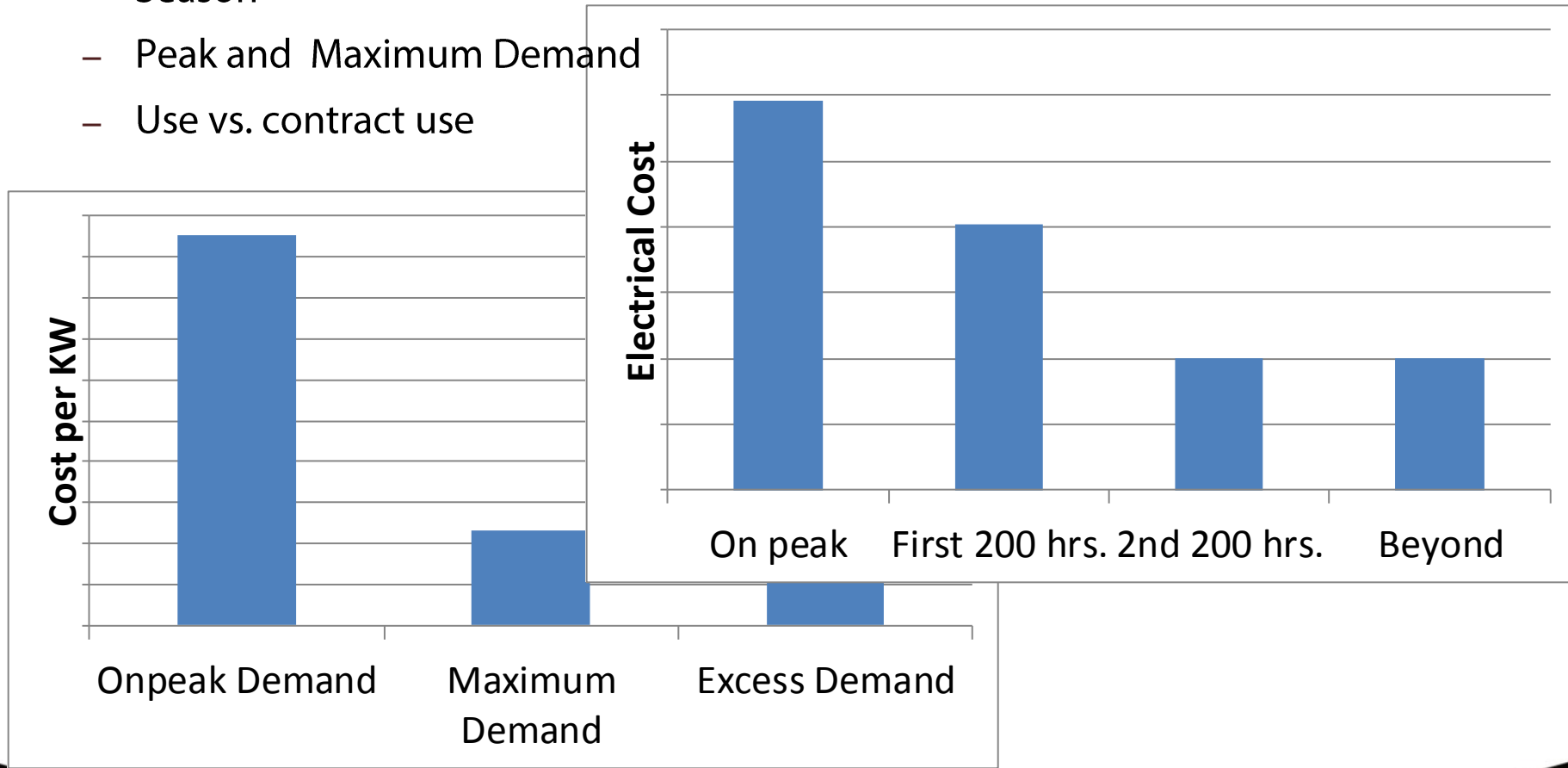
- Natural gas prices (relatively) stable
- Electric prices rising
- Oil unstable



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

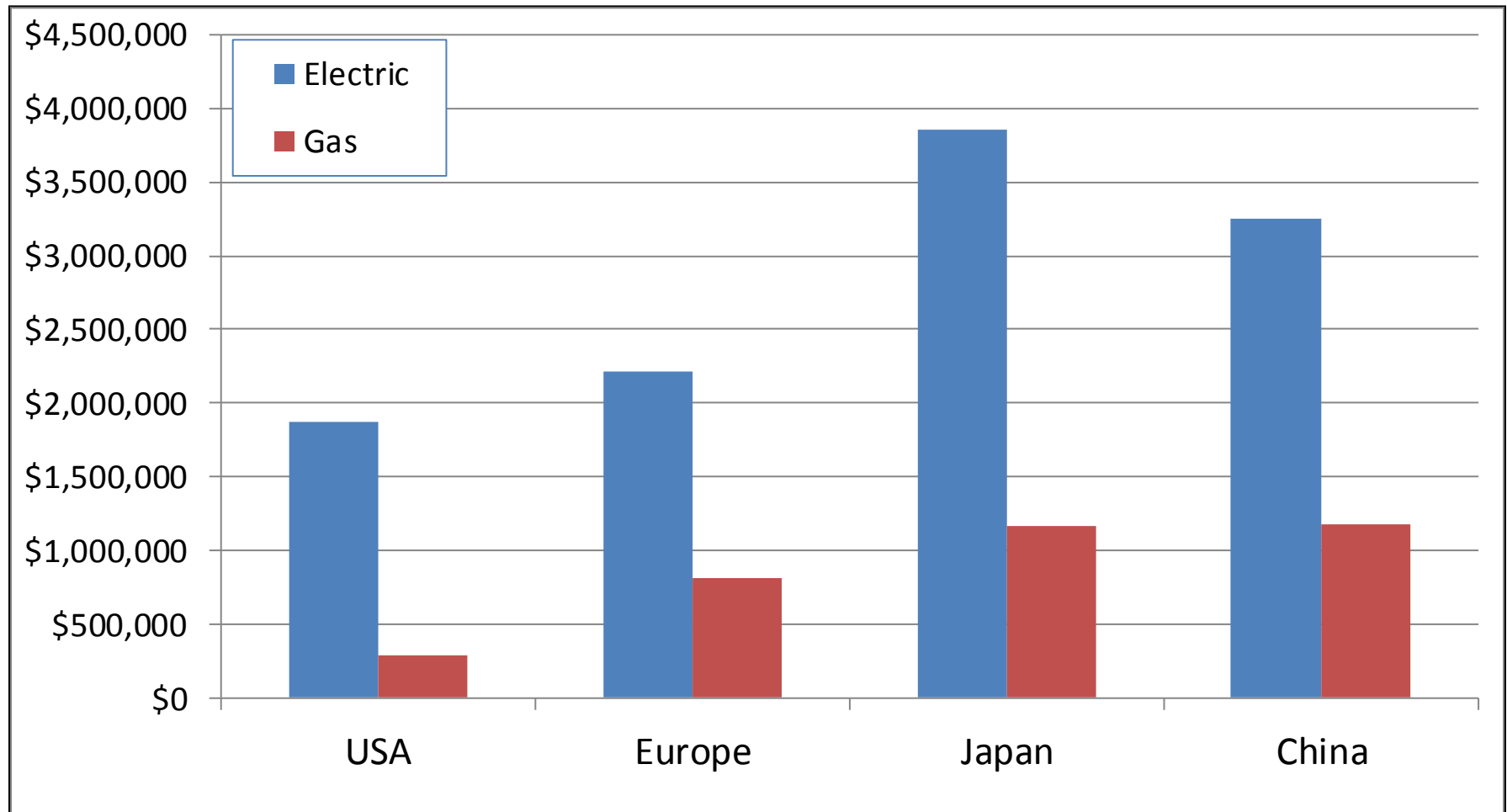
- 30-40%
- Oven energy consumption tied to overall process flow diagram
 - Preheated makeup air



3M Oxidation Oven Section

Annual Cost of Oxidation – 2015

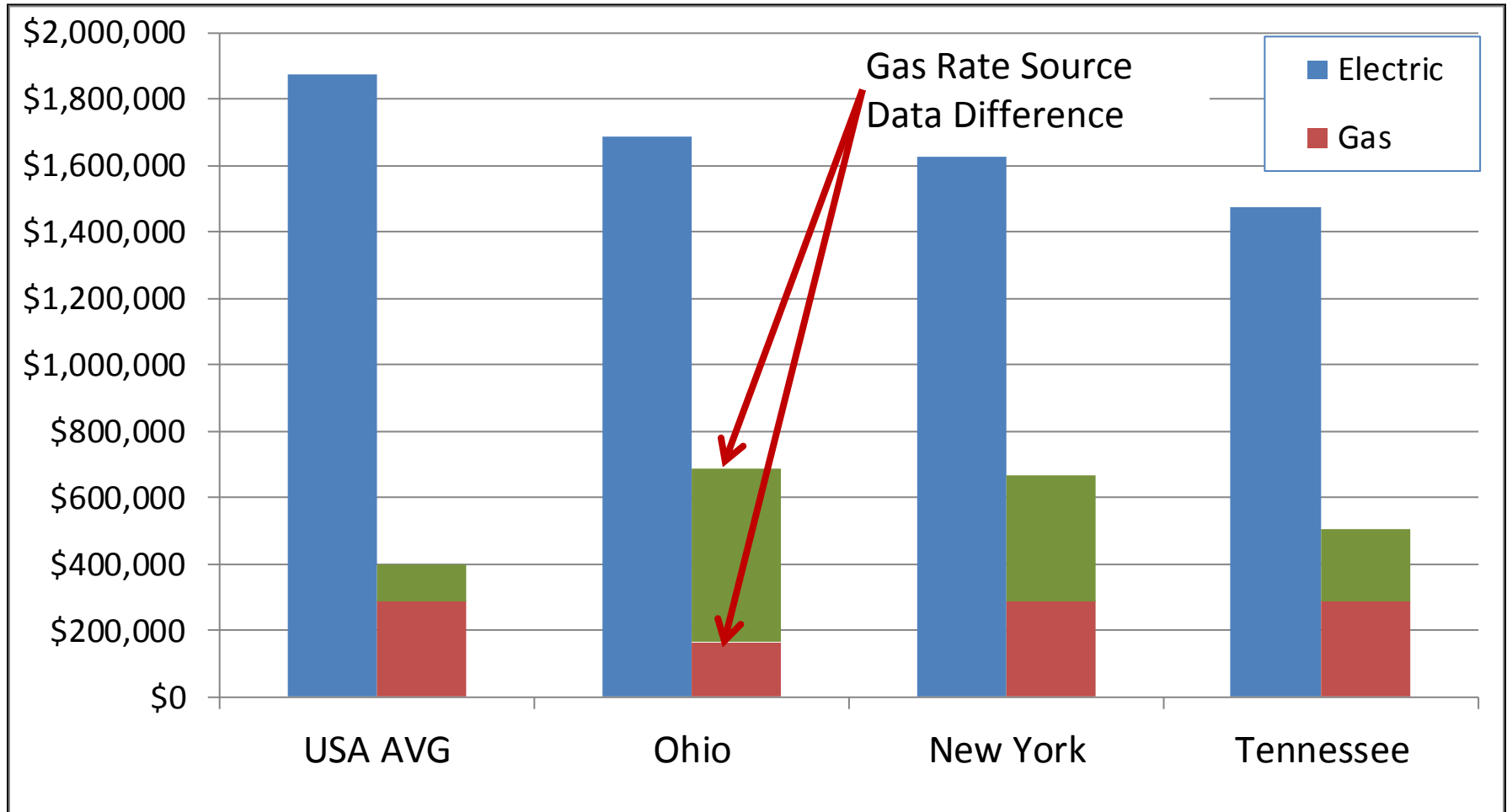
Gas Heating – Huge advantage over electric



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

Annual Cost of Oxidation – 2015

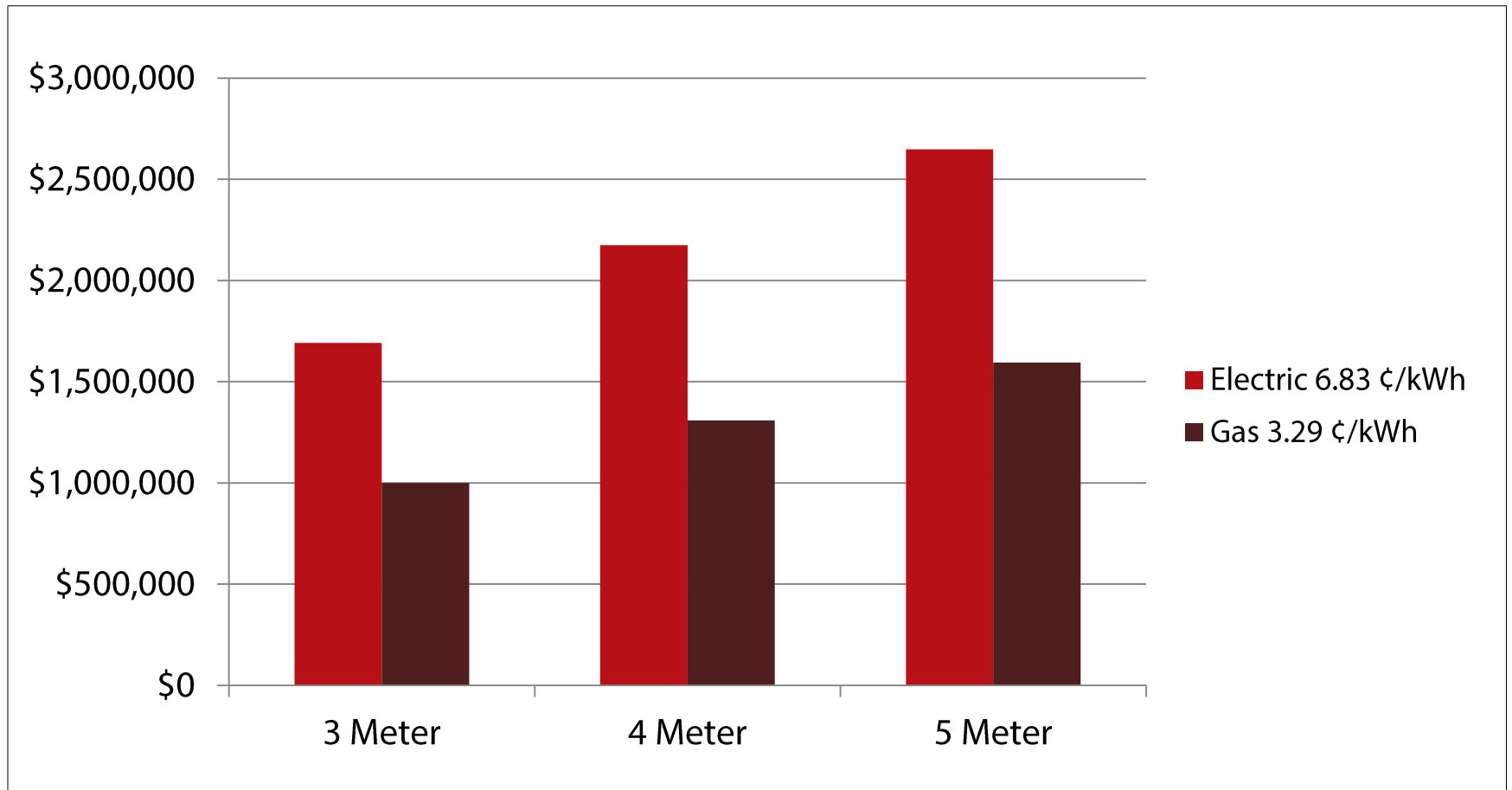
Gas Heating – Huge advantage over electric



Utility Rate Sources: EIA, World Bank, Jobs Ohio

Annual Cost of Oxidation - USA 2008

Gas Heating – Much smaller advantage over electric



Ovens Summary

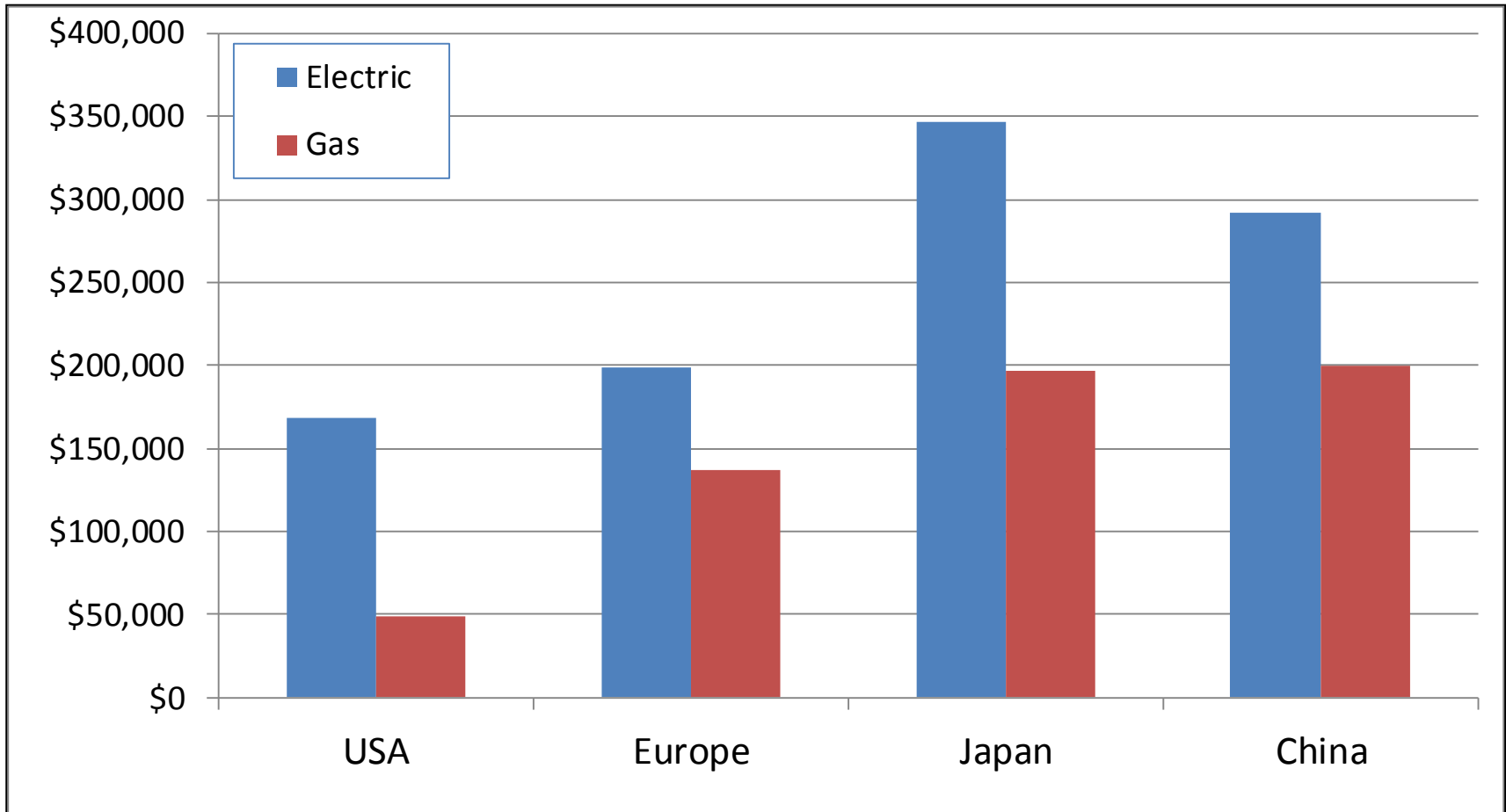
- Ovens are largest consumers of energy in carbon fiber line
 - 30-40%
- Globally, gas fired ovens make the most sense
- Dual-fuel ovens could leverage low-cost gas to drive down cost



LT Furnace

Annual Cost of LT– 2015

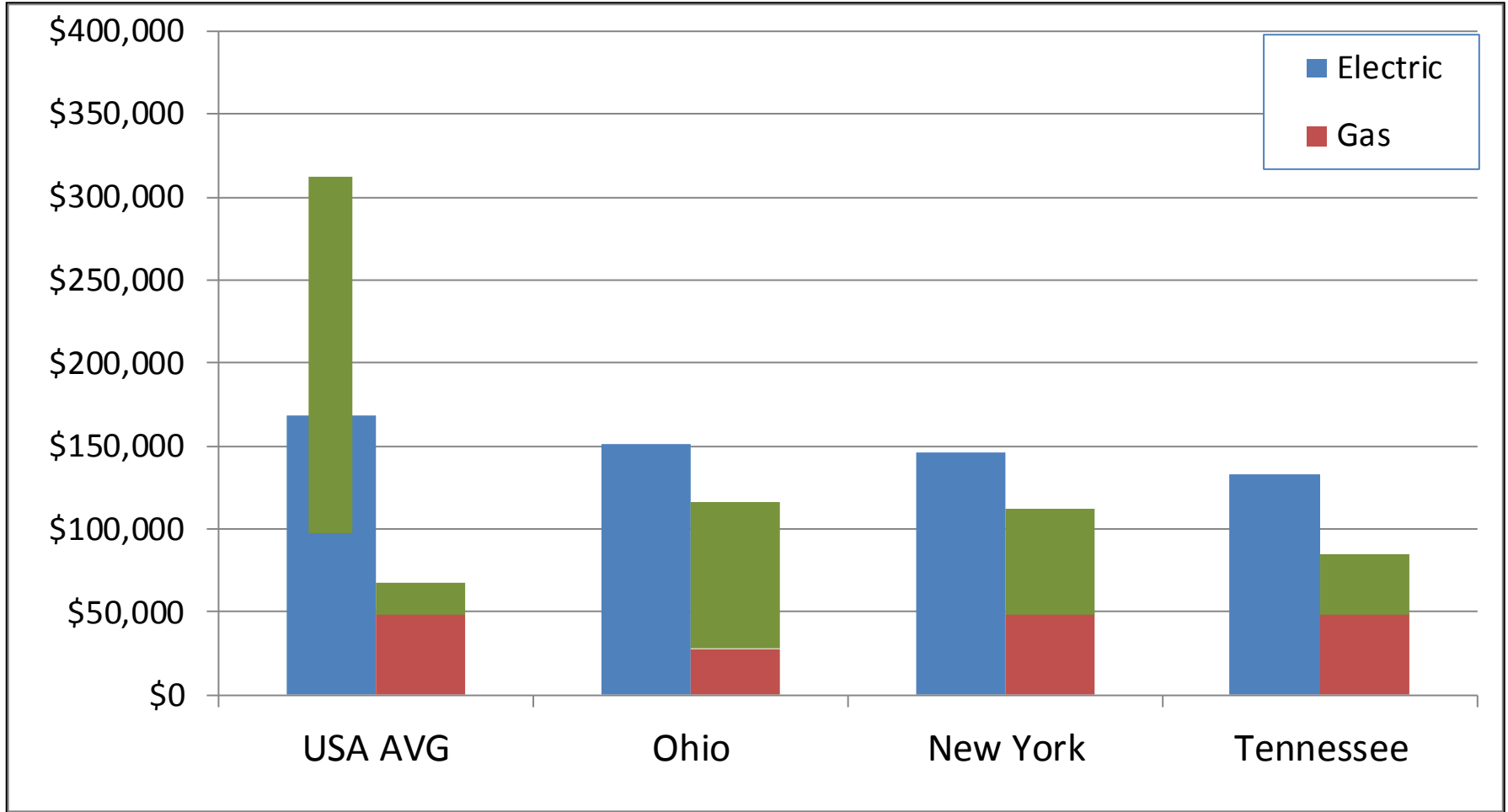
Gas Heating – advantage over electric



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

Annual Cost of LT- USA 2015

Gas Heating – advantage over electric



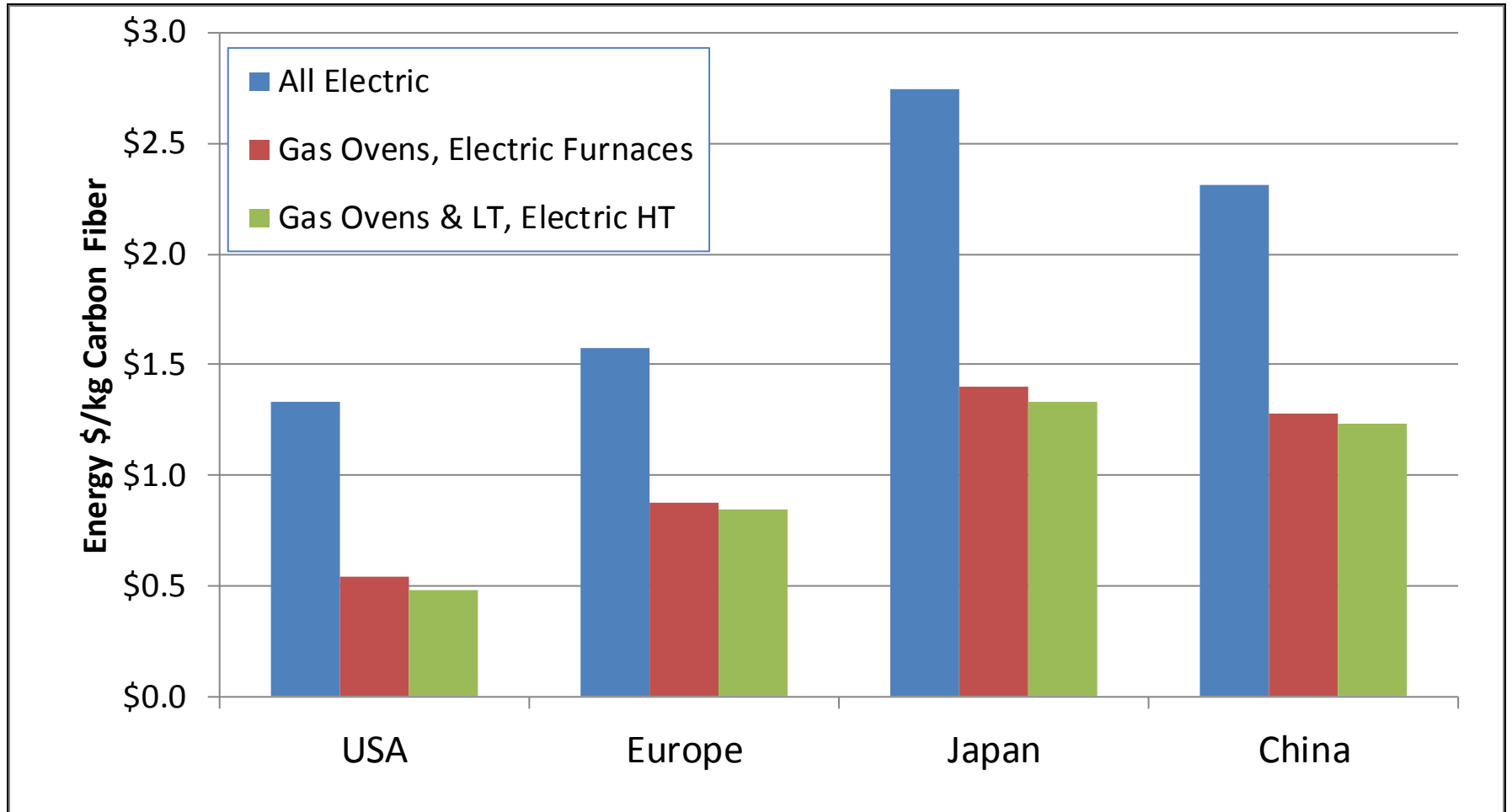
Utility Rate Sources: EIA, World Bank, Jobs Ohio

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



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

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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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