Maximizing the Competitive Benefits of Low Cost Natural Gas in the Manufacturing of Carbon Fiber

JEC Europe, March 2015

Presented by: Dr. Peter Witting

Presentation Summary

How do the market dynamics and fluctuations of electric and natural gas prices affect Carbon Fiber carbonization lines now, and in the next 10 years?

Agenda

- Economics Framework
- Energy Markets Review
- Impact on Carbon Fiber Production
- Wrap Up

About Harper

-> Established Leader in Thermal Processing Systems

-> Key Partner in Carbon Fiber Scale Up

Primary Technical Focus:

- New / Challenging / Advanced Material Processing
  - 200°C – 3000°C
  - Batch and Continuous processing
  - Precise atmospheric controls
  - High purity requirements
  - Complex gas-solid interactions

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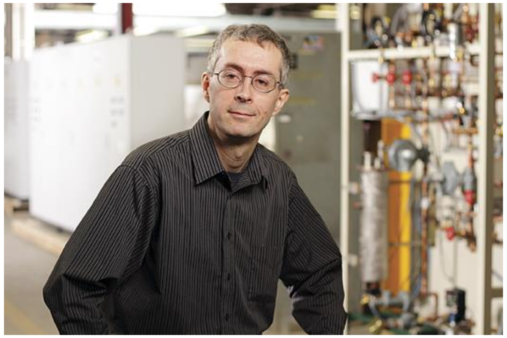
About Harper

- Headquartered in Buffalo, NY
- An Employee-Owned Company
- 5,800 sq ft Technology Center, 30,000 sq ft Office Space
- Multi-Disciplined Engineering Talent
  - Chemical
  - Ceramic
  - Mechanical
  - Electrical
  - Industrial
  - Process & Integration



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Presentation Overview

Volatility in global utility prices can create **commercial risk** and drive **unexpected costs** in production.

⇨

Reducing uncertainty can be achieved through **well planned, multi-functional plant equipment,** creating Carbon Fiber plants that can be installed anywhere in the world.

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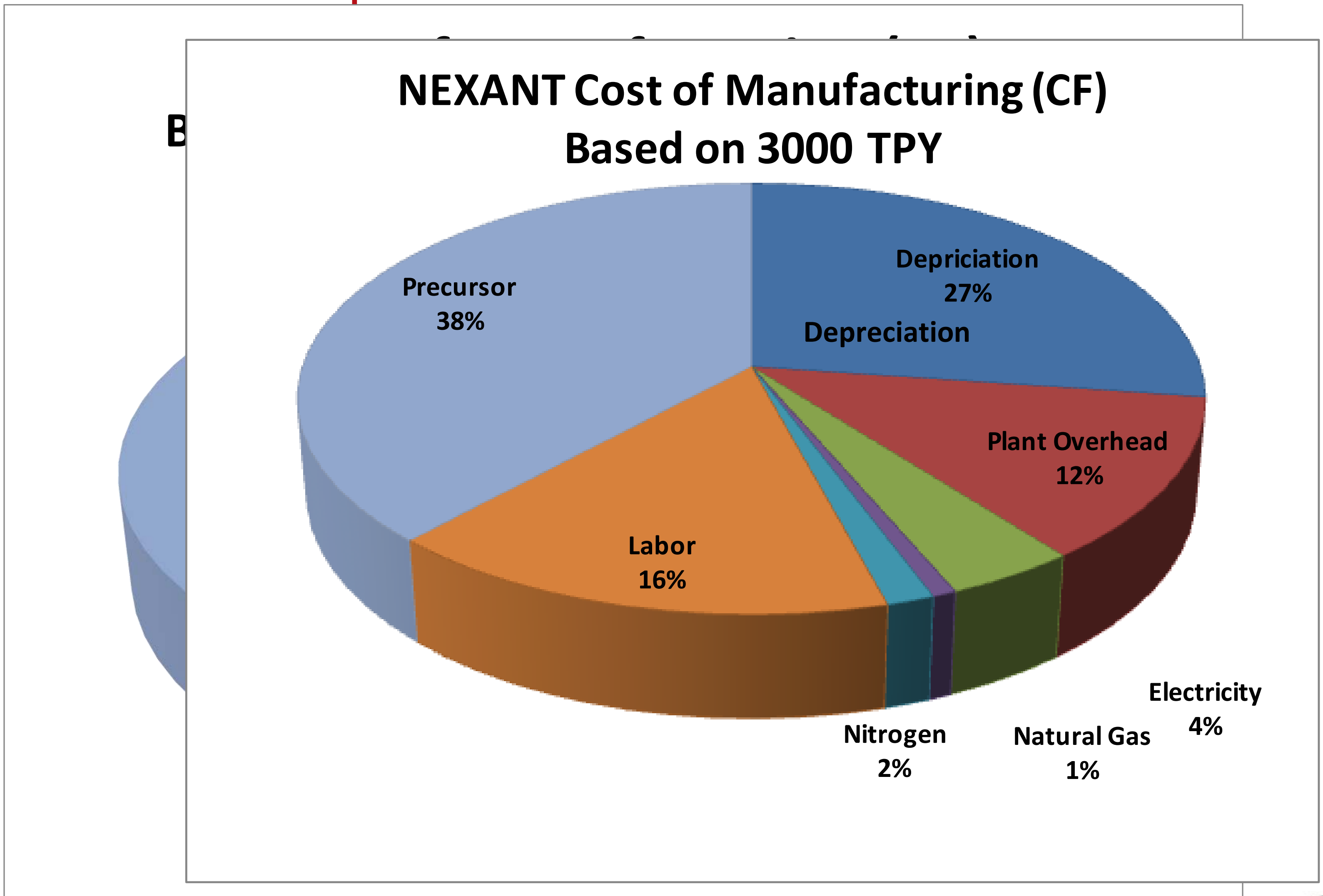
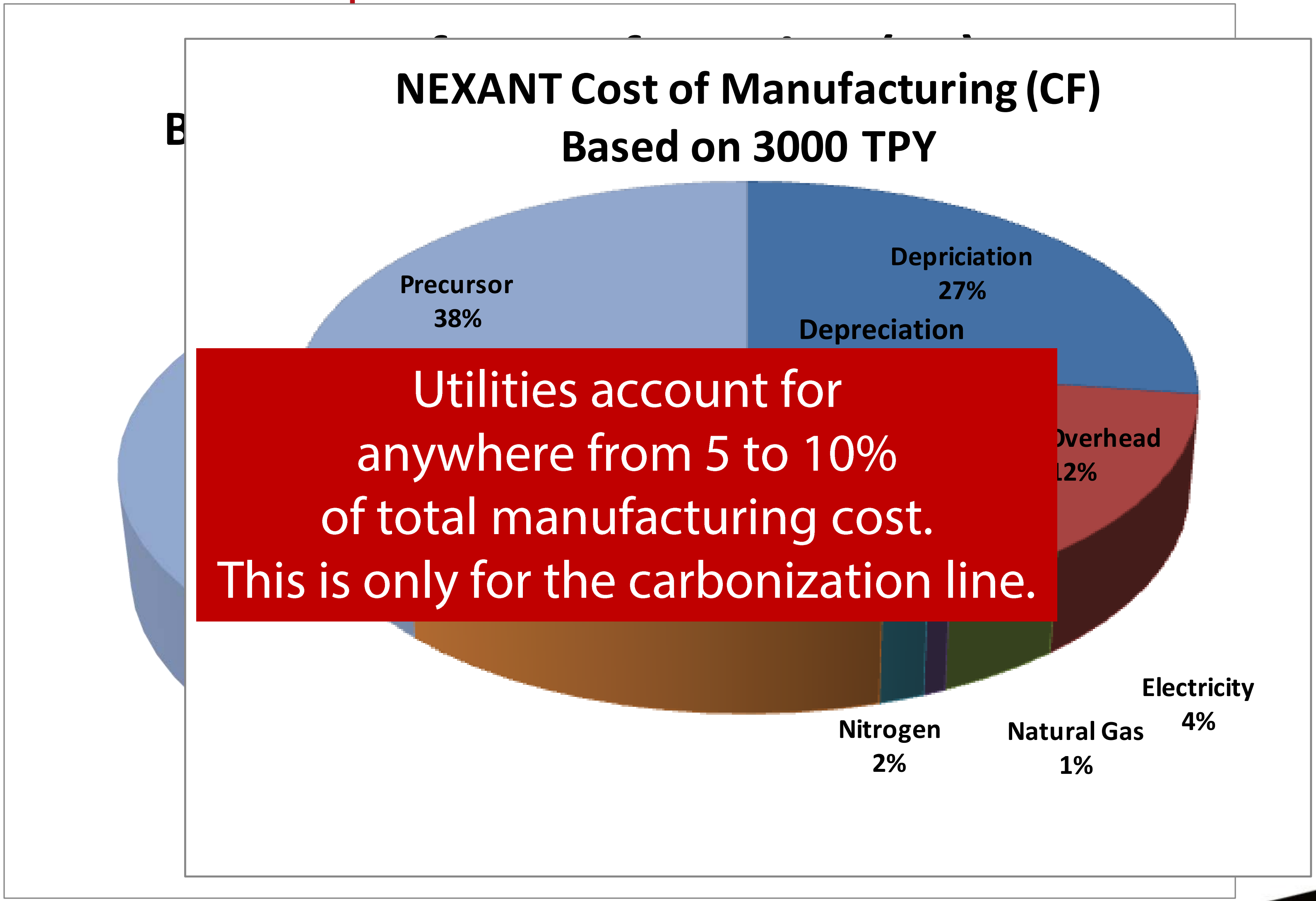
Example Model :
Harper Estimated Cost Structure



Example Model :
Harper Estimated Cost Structure



Utilities account for anywhere from 5 to 10% of total manufacturing cost.
This is only for the carbonization line.

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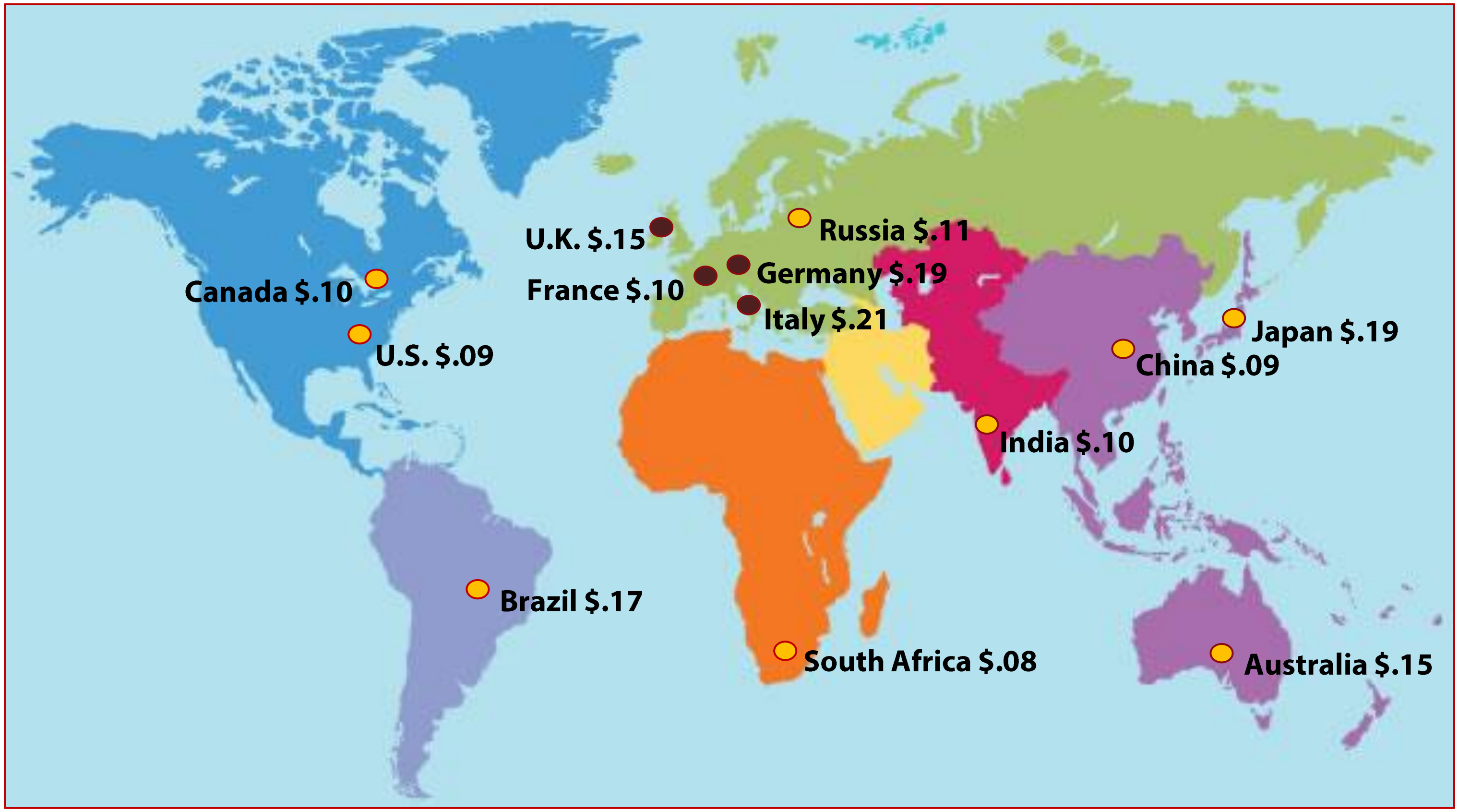
Global Electric Prices

Estimated 2014 Industrial Electric Prices (Cents/Kwh)



Sources: IEA, EIA, OANDA

Global Electric Prices

Estimated 2014 Industrial Electric Prices (Cents/Kwh)

Key Takeaways:

- Price varies by locality due to availability of energy, infrastructure, pricing regulations and corporate structure.
- Price often varies within each country. For example, industrial electric rates range between $.03 to $.15 by state in the U.S.
- Worldwide trends in adopting new environmental standards and changing of input (i.e. moving from coal to natural gas).

Sources: IEA, EIA, OANDA

Global Gas Markets

World LNG Estimated November 2013 Landed and Hub Prices ($US/mmbtu)

	Production (bcm)	
	2008	2035
Russia	662	881
Iran	130	279
Turkmenistan	71	136
Canada	175	192
United States	575	779
Norway	102	127
Australia	45	155
Qatar	78	260
Indonesia	74	119
Nigeria	32	119
Algeria	82	168
Latin America Total	148	292

	Reserves (bcm)
Mozambique	2825
Tanzania	565
Israel	407

Source: IEA, FERC

Global Gas Markets

World LNG Estimated November 2013 Landed and Hub Prices ($US/mmbtu)

	Production	
Russia	[illegible]	[illegible]
Iran	[illegible]	[illegible]
Turkmen[illegible]	[illegible]	[illegible]
Canada	[illegible]	[illegible]
United S[illegible]	[illegible]	[illegible]
Norway	[illegible]	[illegible]
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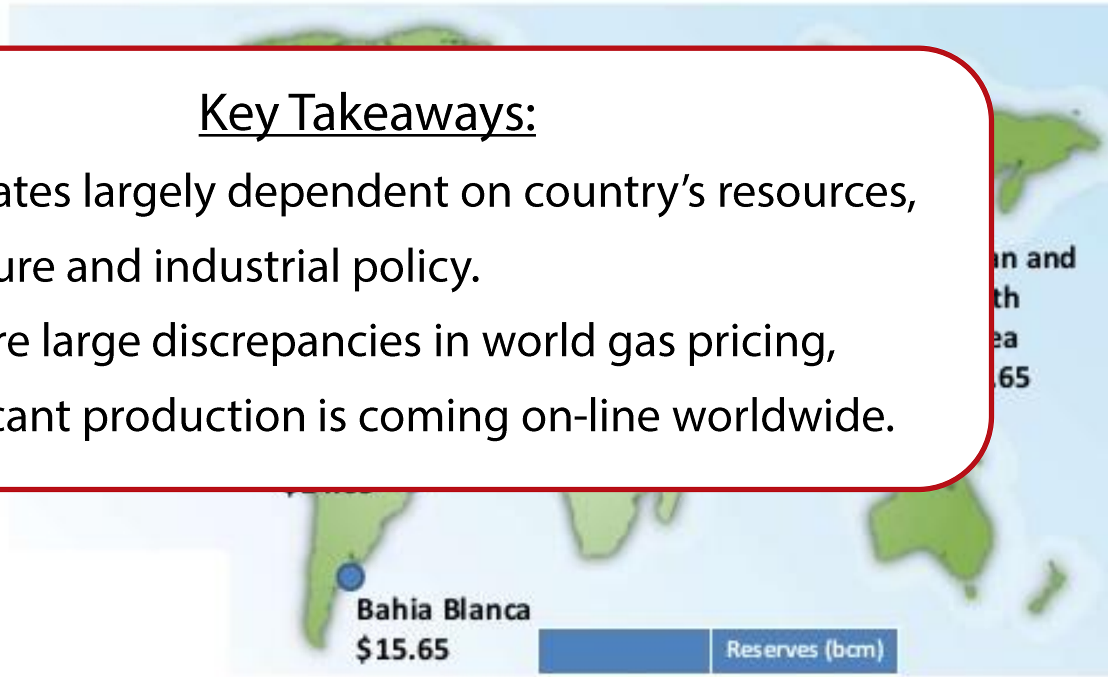

	Reserves (bcm)
Mozambique	2825
Tanzania	565
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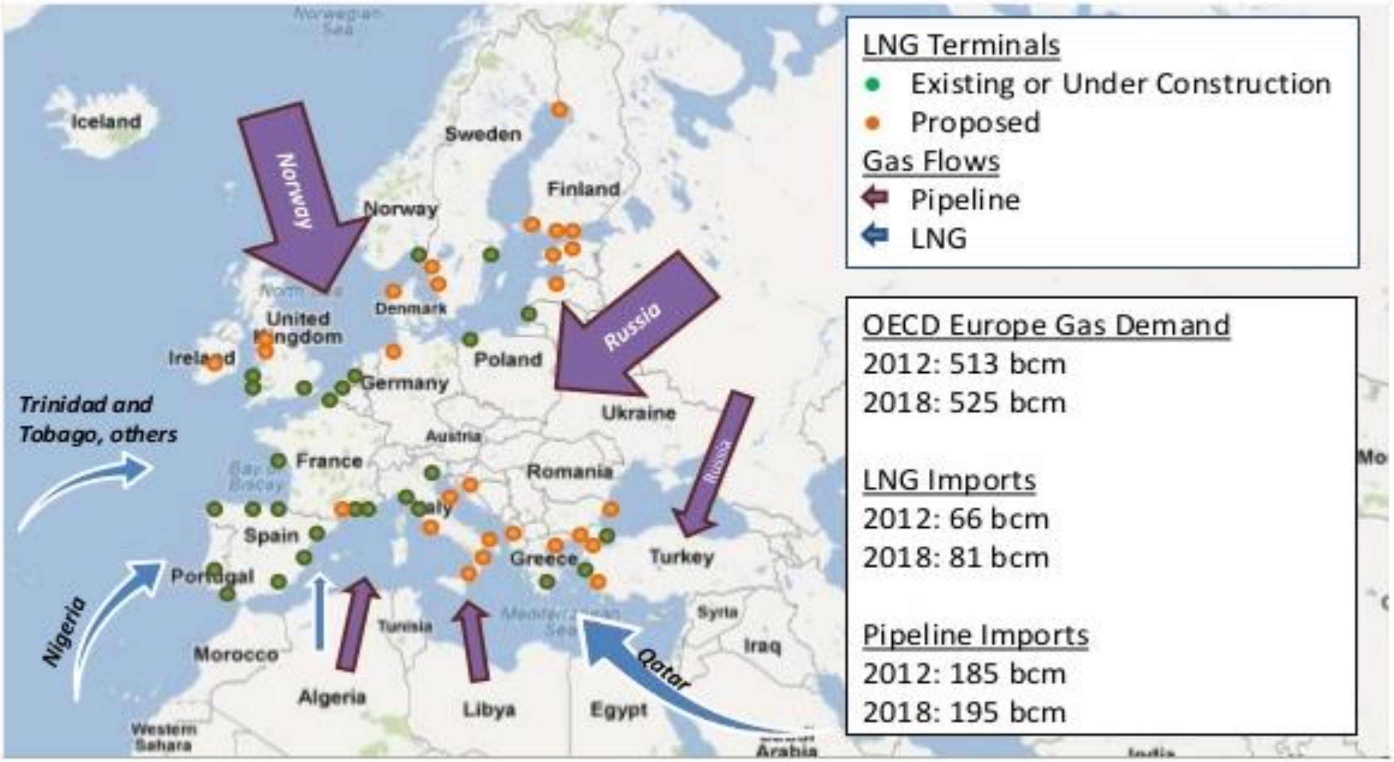
Key Takeaways:

- Utility rates largely dependent on country's resources, infrastructure and industrial policy.
- There are large discrepancies in world gas pricing, but significant production is coming on-line worldwide.

Source: IEA, FERC

Europe Gas Trade: 2012-2018

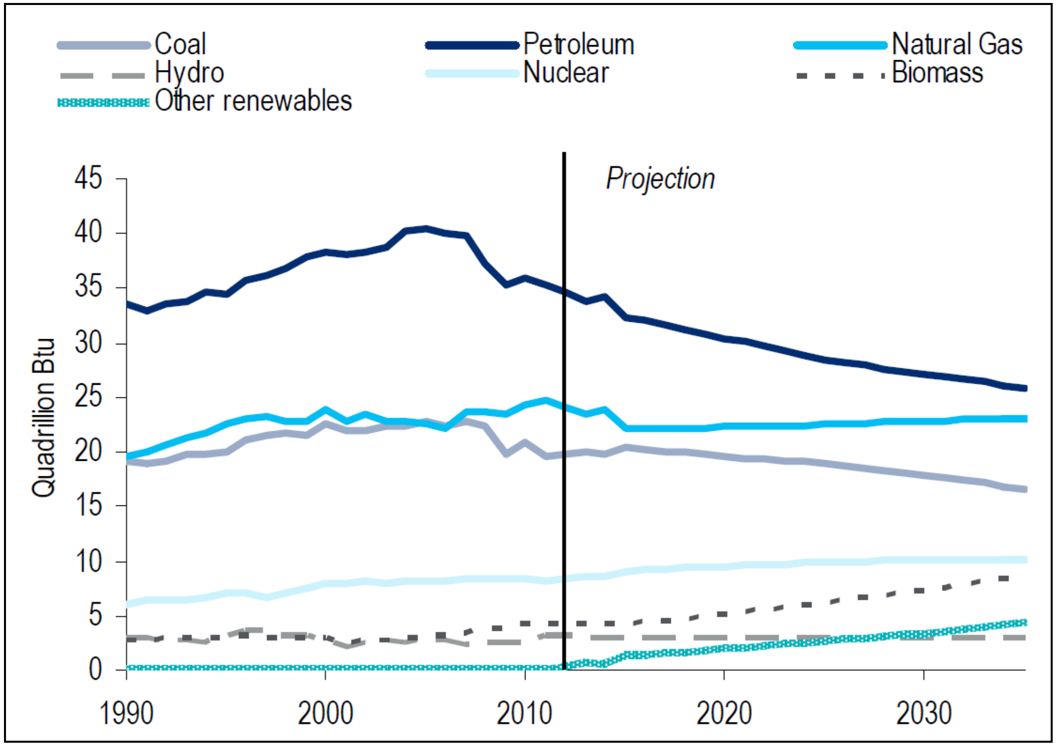
- One example of the planned infrastructure for natural gas is in Europe.
- There are many transport systems under construction or planned which would increase the availability of natural gas throughout Europe.



Source: Gas Infrastructure Europe & IEA Market Report 2013

Primary Energy Mix by Country: United States

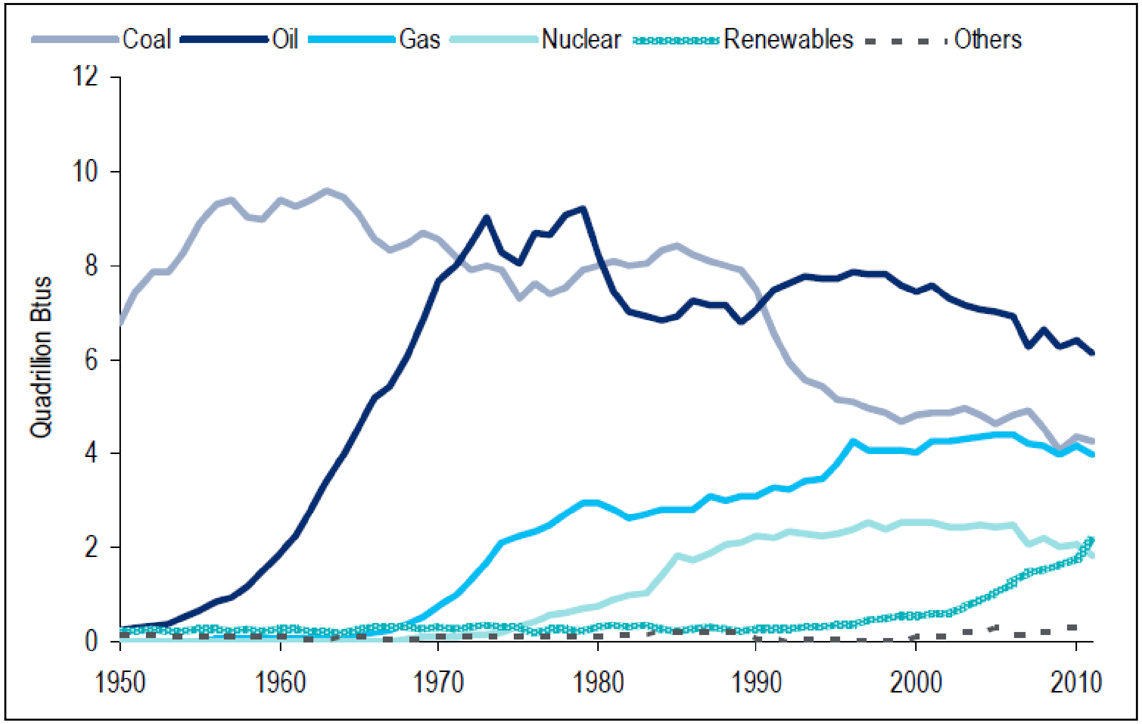
- Since the 1950s, the US energy mix has been dominated by petroleum, although percentage contribution to the mix has been gradually declining since the late 1970s. A story similar applies to coal.
- Natural gas, on the other hand, is enjoying a steady rise to prominence in both energy and electricity generation, and by 2015 is projected to contribute 26.5% to the energy mix.



Source: IEA, EIA, Citi Research

Primary Energy Mix by Country: Germany

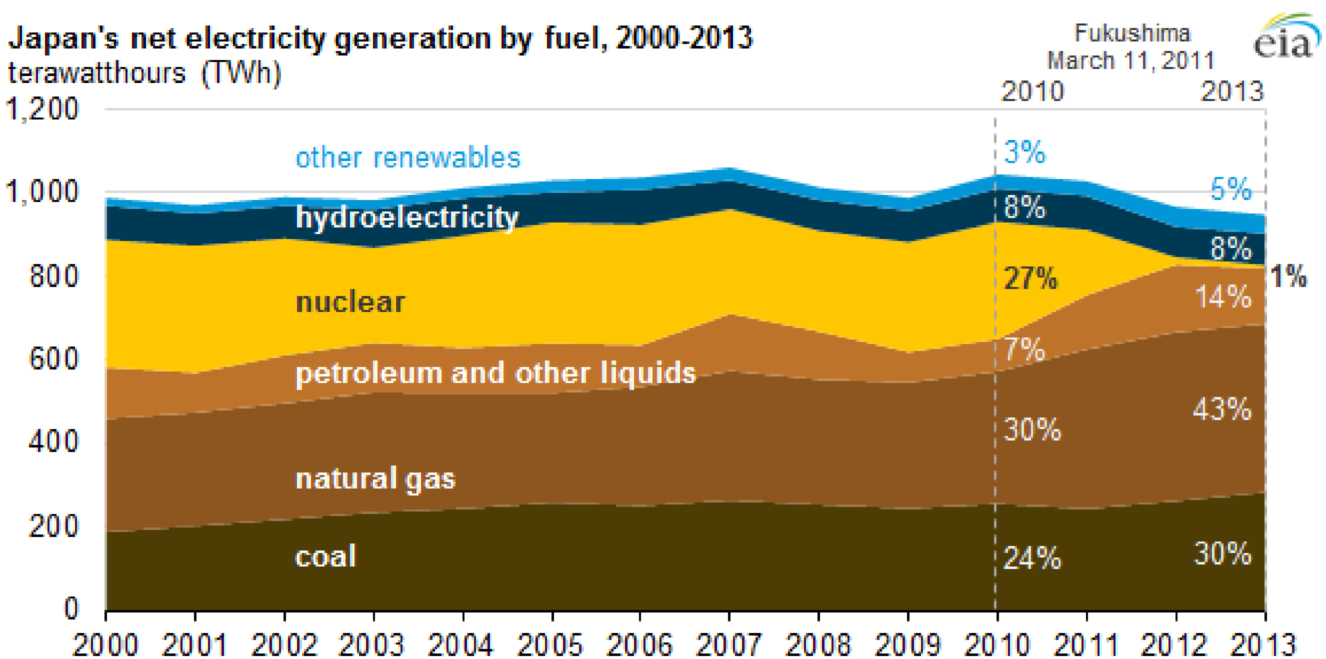
- Germany is still dependent on petroleum and coal for its energy and electricity; natural gas and renewables are well placed to usurp these fuels in the medium future.
- Environmental concerns will continue to lead to a reduction of reliance on coal.



Source: GE, AG Energiebilanzen, Citi Research

Primary Energy Mix by Country: Japan

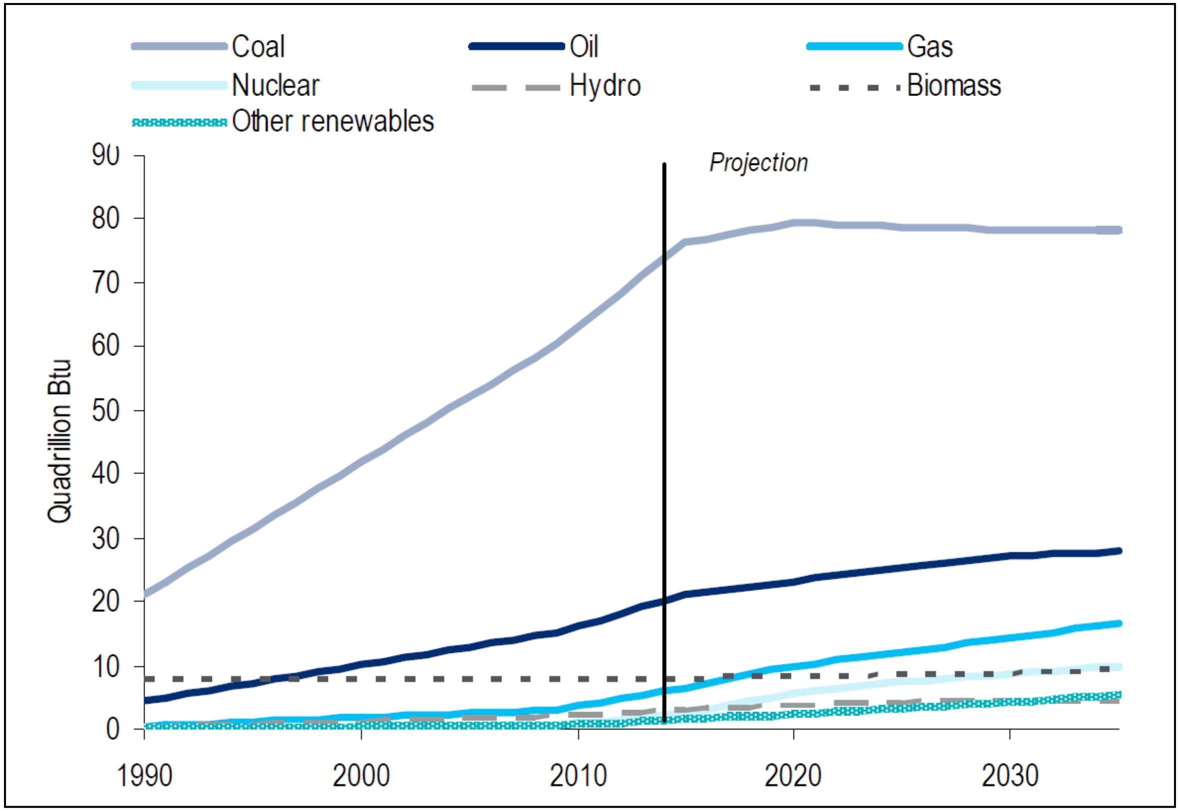
- After Fukushima, natural gas largely replaced the nuclear energy displaced. When Japan reenergizes the nuclear sector, it will be interesting to see what happens to the coal and petroleum sectors.
- The use of natural gas for temporary replacement energy may result in future increased availability and decreased costs – a changing energy market.



Source: EIA

Primary Energy Mix by Country: China

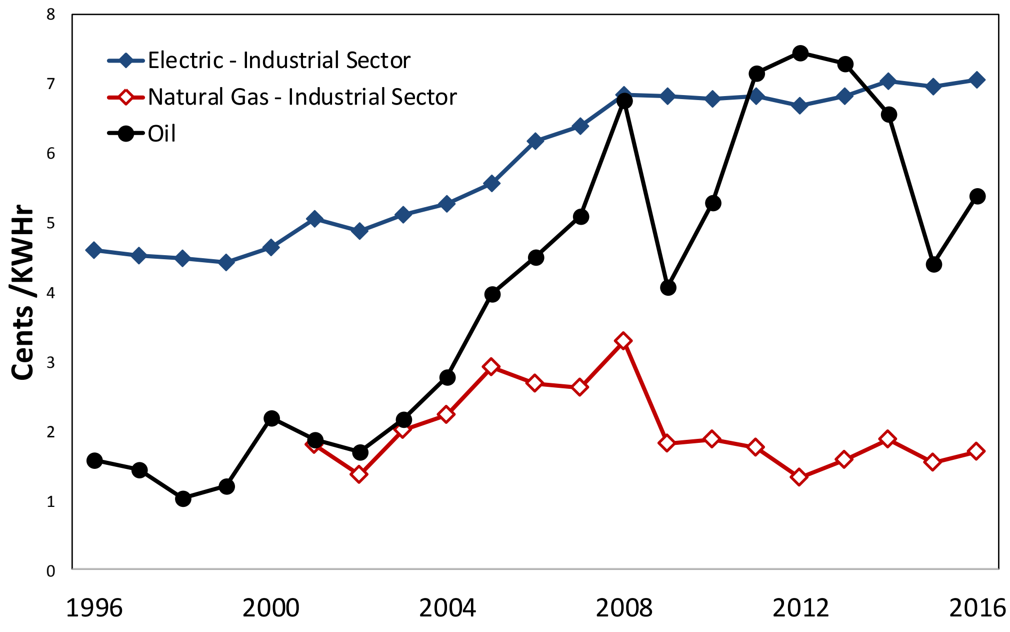
- The use of Coal (dominant energy source) is expect to level off, while increased development and usage of oil, natural gas, and renewables will increase.



Source: IEA, Citi Research

North America Natural Gas & Electric Prices

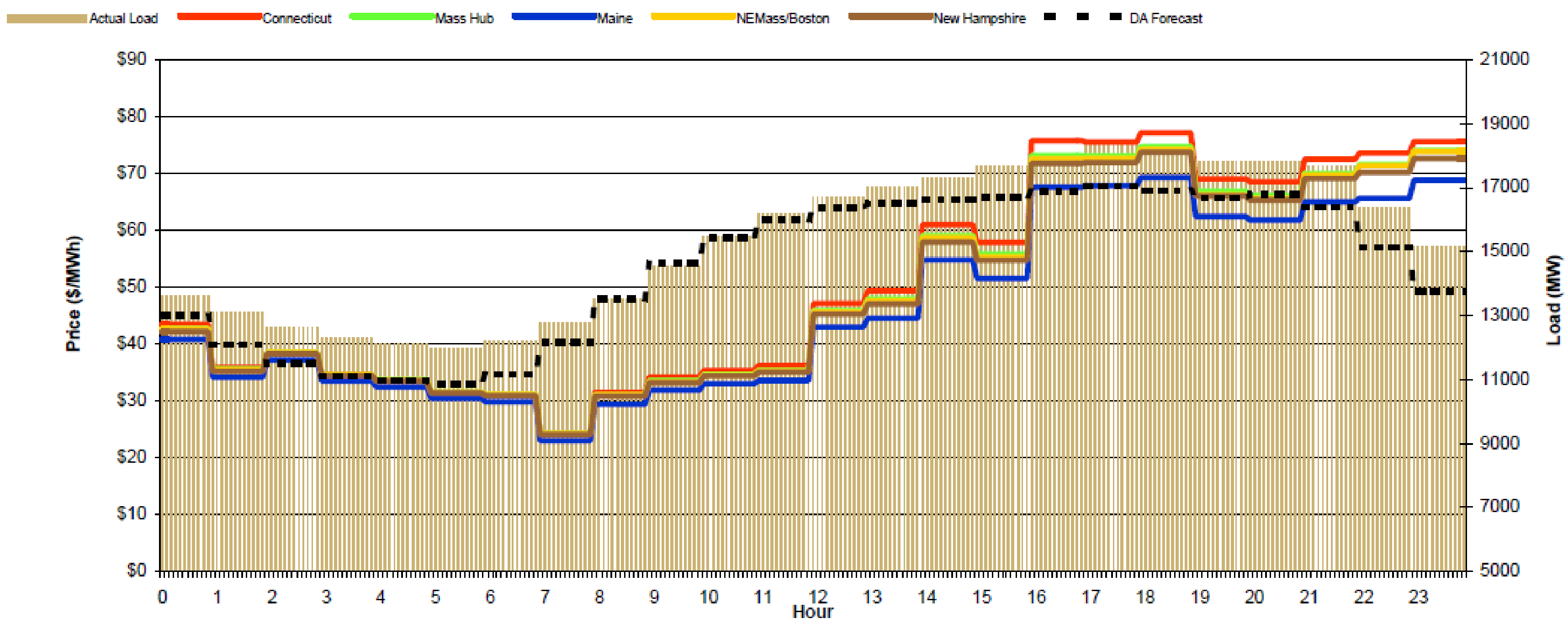
- Natural gas prices have been relatively stable in comparison with petroleum and oil.
- Improvements in the transport system and new sources have resulted in a increased capacity and continued stabilization of prices.
- Electric prices have continued to rise but at a modest rate. On average the cost of electrical is significantly higher than gas – but there is considerable price differences between regions.



Source: www.eia.gov/forecasts

Electrical Fluctuations

Utility costs fluctuates during the day and throughout the year



Source: http://www.ferc.gov/market-oversight/mkt-electric/isone/isone-iso-archives.asp

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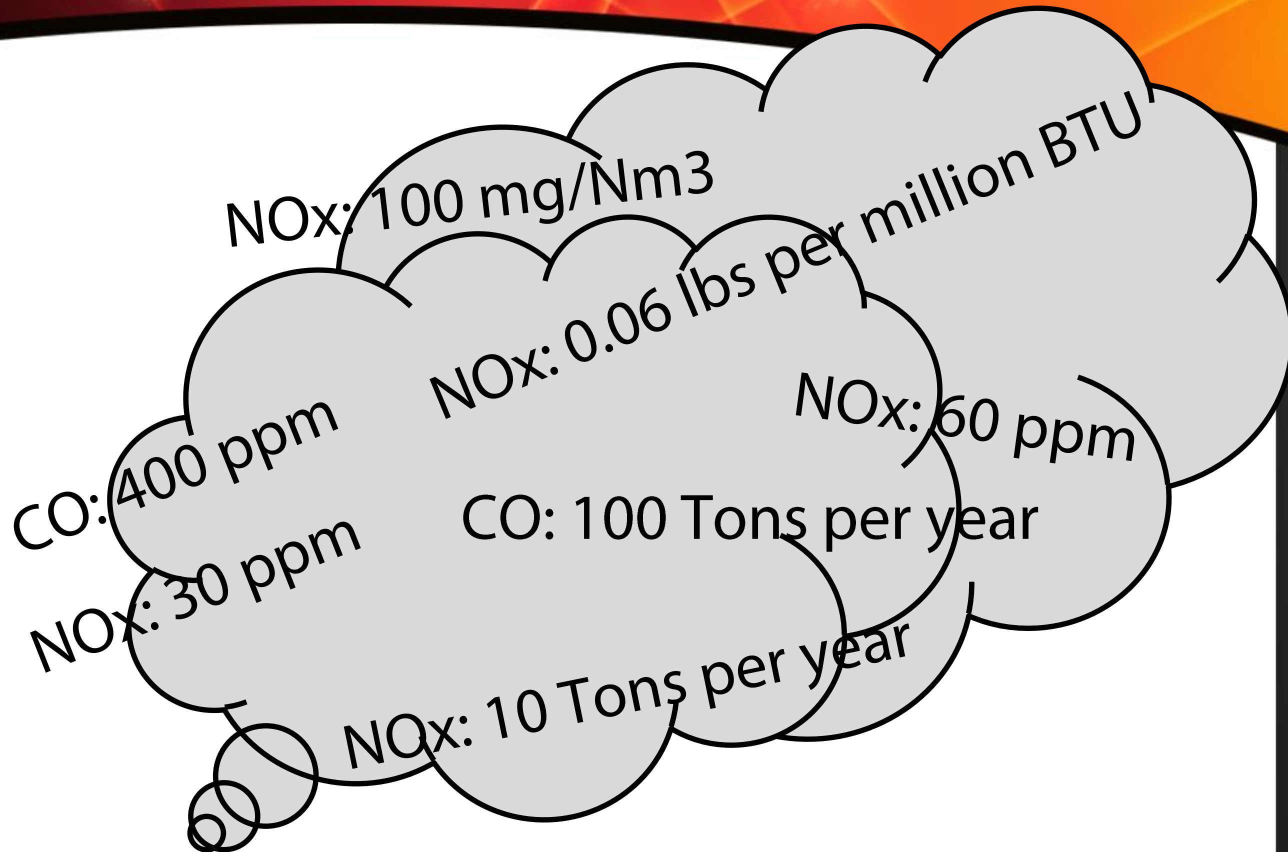
Emissions :

NOx and CO emissions are not uniform across the globe, or even within the same country



**In choosing a gas fired system, the specific emission requirements must be understood upfront for design of the proper burner system with optimized efficiency and uniformity.

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Observations

- Utilities are a major cost factor in Carbon Fiber production
- Global utility prices are highly unpredictable and demand changing
- Volatility evident on all major continents

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

How do we address these challenges?

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- Economics Framework
- Energy Markets Review
- **Impact on Carbon Fiber Production**
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Gas-Fired Carbon Fiber Production Systems

How can gas-fired systems play a role
in Carbon Fiber production
to maximize the changing dynamics
of the energy market?

LT Furnace – Gas Burner Combustion System Design Options

Burner Types

- Cold Air
- Hot Air
- Self Recuperative

Flue Arrangement

- Charge End
- Discharge End
- Individual Zone

Heat Recovery

- Preheat Combustion Air
- Preheat Atmosphere Gases

There are many choices for flue arrangement, heat recovery, and burner style influencing efficiency that can be configured for a specific line.

LT Furnace
Gas vs. Electric Operational Cost

	Unit Cost	Consumption / Year	Yearly Cost
Natural Gas	0.02 $/kWh	2,300,000 kWh	$46,000
Electric	0.07 $/kWh	1,700,000 kWh	$119,000
	Savings per LT Furnace with Natural Gas		$73,000

*Assumes 7200 hrs/year operation, typical US prices for calculation for a 1500 TPY line.

LT Furnace
Gas vs. Electric Operational Cost

	Unit Cost	Consumption	Yearly Cost
Natural			,000
Electric			,000
			,000

Key Takeaways:

- There is reward in terms of utility cost savings which can be significant.
- Energy consumption for natural gas is higher than electric which is due to the flue loss of gas fired systems. These flue losses can be minimized with various heat recovery options.
- Savings for a ~1500 TPY LT system are significant. These, of course, need to be evaluated at the prevailing rates of the installation location and in consideration of future trends in utility pricing.

*Assumes 7200 hrs/year operation, typical US prices for calculation for a 1500 TPY line.

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Gas-Fired LT Furnaces

- Harper has produced gas-fired systems for decades. Our gas-fired LT furnaces have proven uniformity to meet the most demanding requirements of our customers.

- Harper has measured thermal uniformity for 3m wide systems with excellent results. These results are due to the thoughtful consideration of the burner selection, arrangement, flue gas management, and setup. These play a critical roll in determining the performance of the system.

Oxidation Ovens – Gas or Electric

Ovens require approximately 8 to 15 times the energy of a LT system - it is the energy hog of the carburization line. Therefore…

Selecting the best value in energy is critical for long term success.

Potential Utility Saves with Gas Fired Oven

Per Oven zone potential savings with Natural Gas

	Unit Cost	Consumption / Year	Yearly Cost
Natural Gas	0.02 $/kWh	3,800,000 kWh	$81,000
Electric	0.07 $/kWh	3,200,000 kWh	$227,000
	Savings per Oven with Natural Gas		$146,000
	Savings with six Ovens zones		$876,000

*Assumes 7200 hrs/year operation,
US Prices for calculation

Potential Utility Saves with Gas Fired Oven

Per Oven zone potential savings with Natural Gas

	Unit Cost	Consumption	Yearly Cost
Natural Gas			$81,000
Electric			$227,000
			$146,000
			$876,000

<u>Key Takeaways:</u>

Savings for a ~1500 TPY LT system are even more dramatic for an Oxidation Oven.

These, of course, need to be evaluated at the prevailing rates of the installation location and in consideration of future trends in utility pricing.

*Assumes 7200 hrs/year operation,
US Prices for calculation

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)

Hybrid Plant Design
Universal Plant

Flexibility….Efficiency….Optimization

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Final Thoughts

- Higher 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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