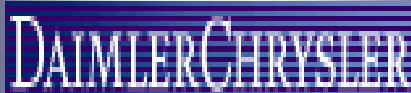




# FreedomCAR and Vehicle Technology Program

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U.S. Department of Energy

Society of Plastics Engineers  
Automotive Composites  
Conference and Exhibition  
September 12 - 14, 2006

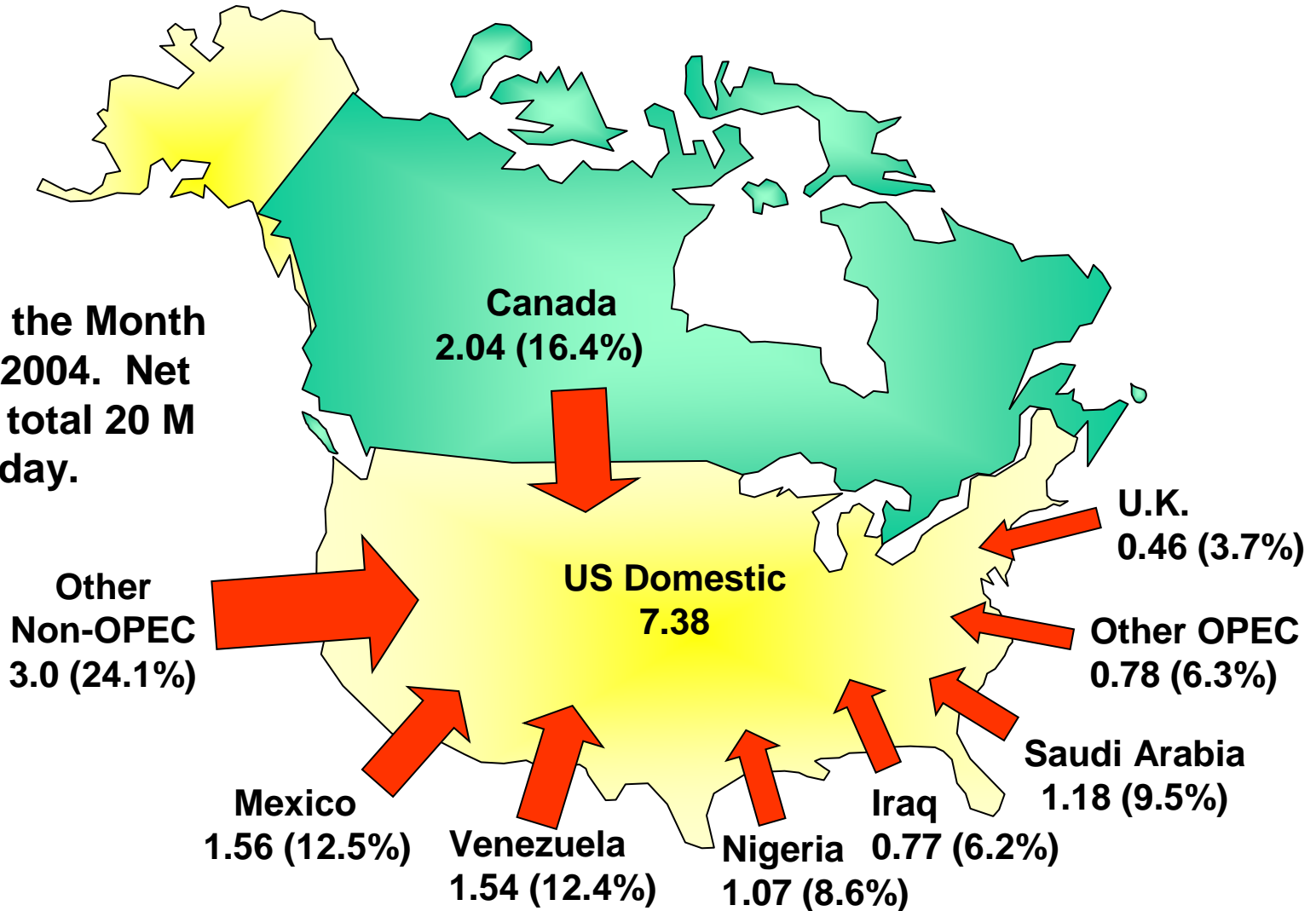




# Our Oil Situation

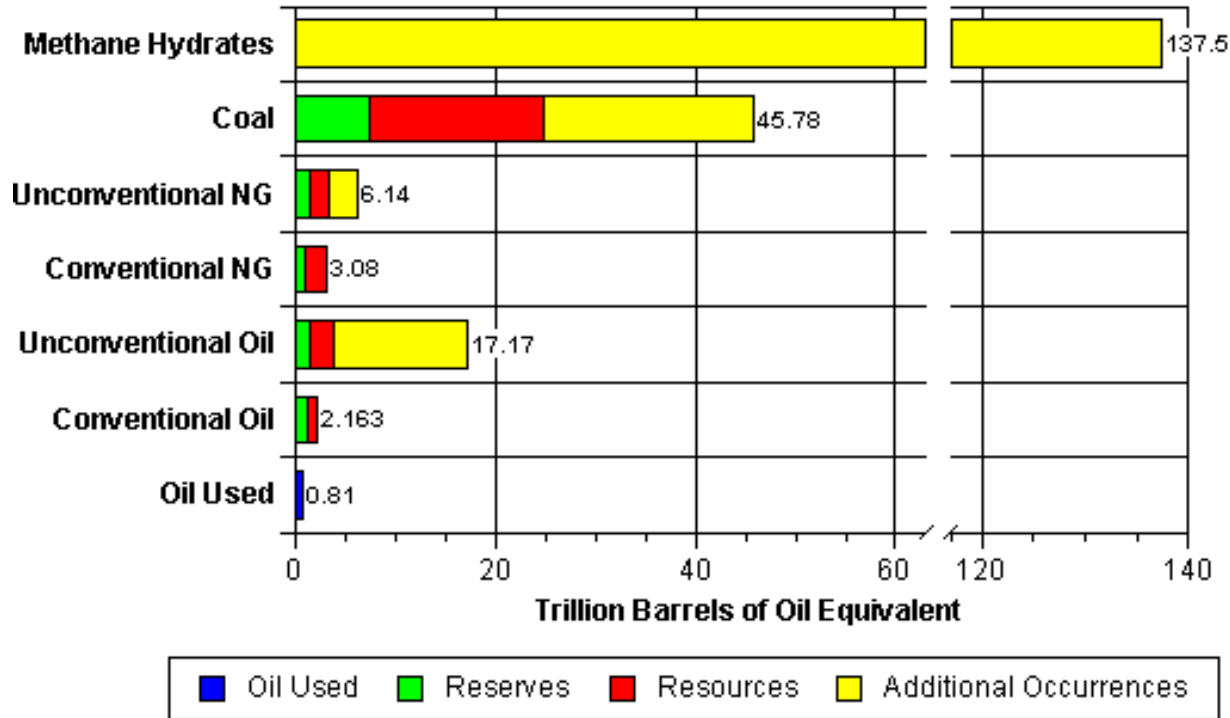
Millions of barrels per day (% of imports)

Data for the Month of April 2004. Net Imports total 20 M Barrels/day.





# World Fossil Fuel Potential



Source: H. H. Rogner, "An Assessment of World Hydrocarbon Resources," Annual Review of Energy and Environment, 1997.

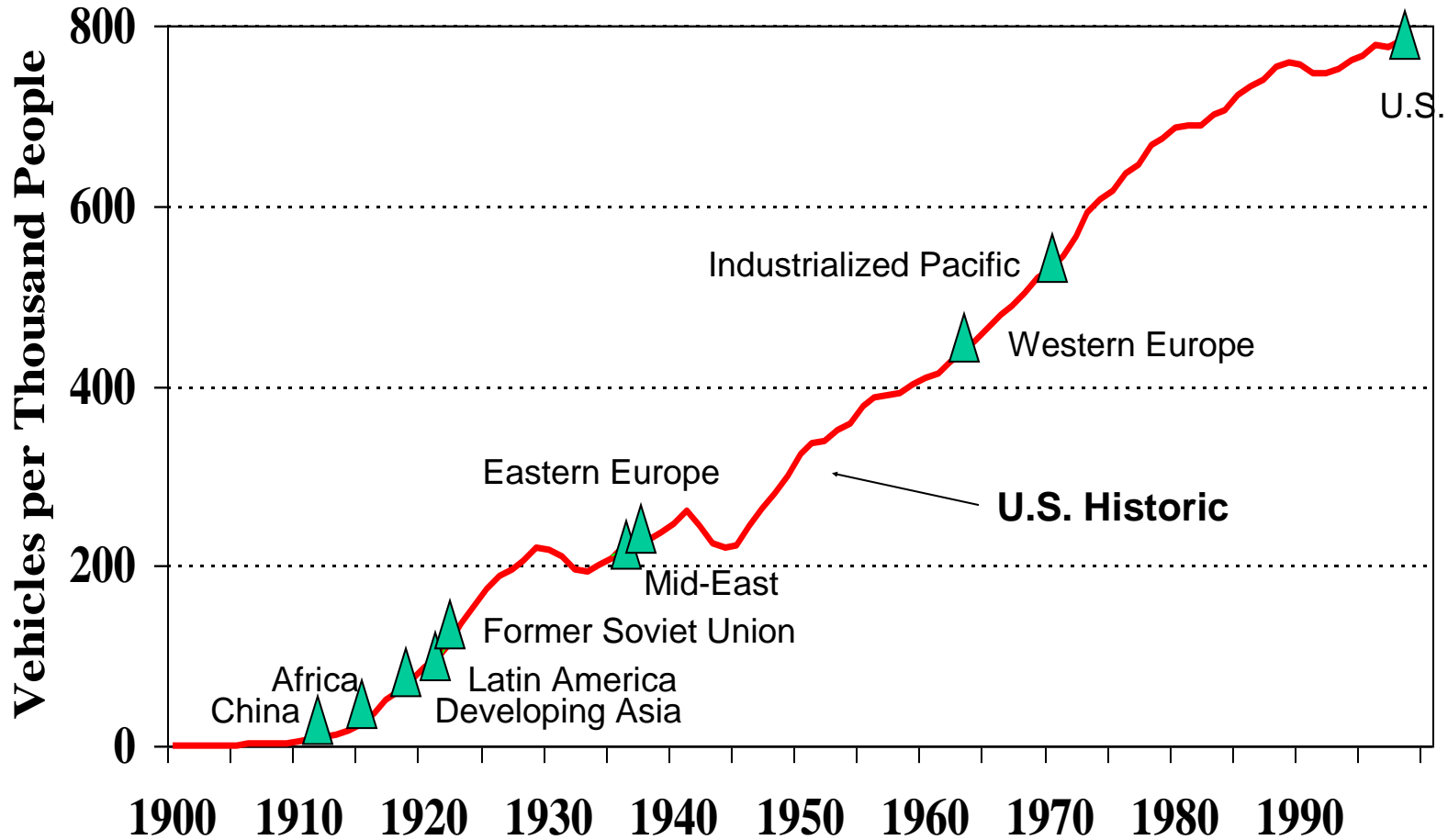


# Liquid Fossil Fuel Resources





# Global Growth in Transportation Accelerating the Demand for Oil



**China, with 13 vehicles per 1000 people, is where the U.S. was in 1913**



- US energy security requires reduced dependence on imported petroleum
- Lighter vehicles consume less fuel
  - Rule of thumb: 10% less mass reduces fuel consumption by 5% - 7%
  - Mass reduction is a critical component in all rational energy efficiency strategies, irrespective of power plant and energy source
- Carbon fiber reinforced composites appear to be the best materials for significantly reducing vehicle mass, thereby reducing US petroleum demand

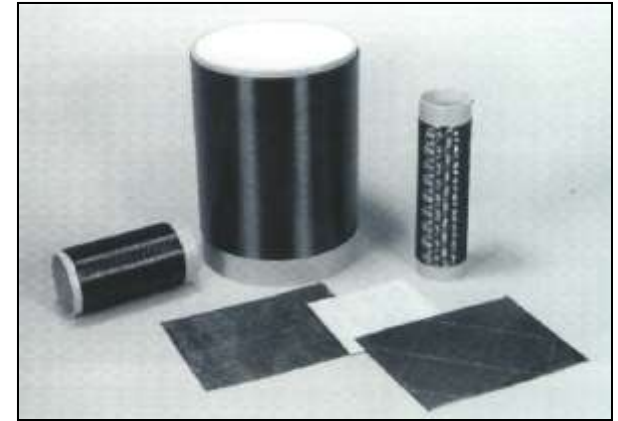


# Carbon Fiber s Appeal

- Very high stiffness and strength per unit mass
  - Better fuel economy
  - Increased payload
  - Better dynamics
- Excellent fatigue endurance
- Corrosion resistant
- Excellent dimensional stability
  - Near-zero CTE minimizes thermal expansion/contraction over a wide range of service temperatures (maintains good trim/fit)
- Tailorable/directional properties
- Good electrical, magnetic, thermal response
  - Nonmagnetic
  - Electrically conductive
  - Pitch fibers can have thermal conductivity and thermal diffusion coefficient  $\gg$  copper
    - Very fast thermal response
    - Conducts axially, insulates radially (thermal analog of optical fibers)
- High elastic energy storage capacity
- “Sex appeal”



# #1 Priority



## \$3 - \$5 Per Pound

Program Goals:

Strength:  $\geq 250$  Ksi

Modulus:  $\geq 25$  Msi

Strain:  $\geq 1\%$



# Tough Issues for Automotive Composites

1. Auto designers are not comfortable with composites in crash critical applications. Full vehicle & subsystem demonstration needed.
2. Many composite processing methods are optimized for performance, not production rate efficiency. Cost optimization of production methods needed.
3. Size of the carbon fiber industry cannot support large scale utilization. Must choose applications and ramp up capacity.
4. Boom or bust nature of the market. Automotive industry needs long term pricing and

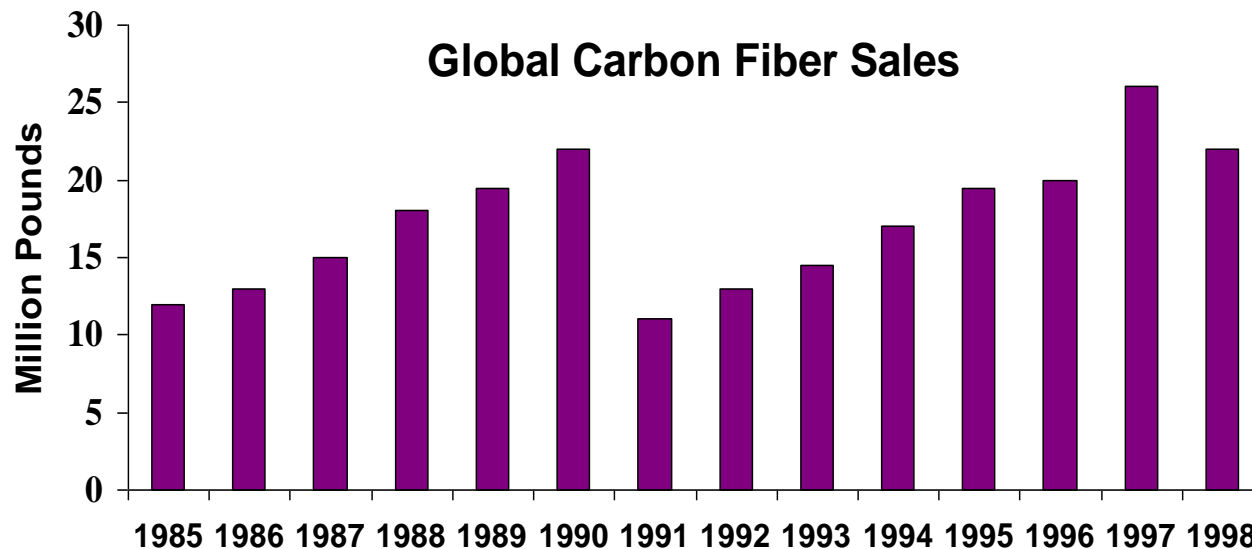




North American Vehicle Production  
> 18M / year

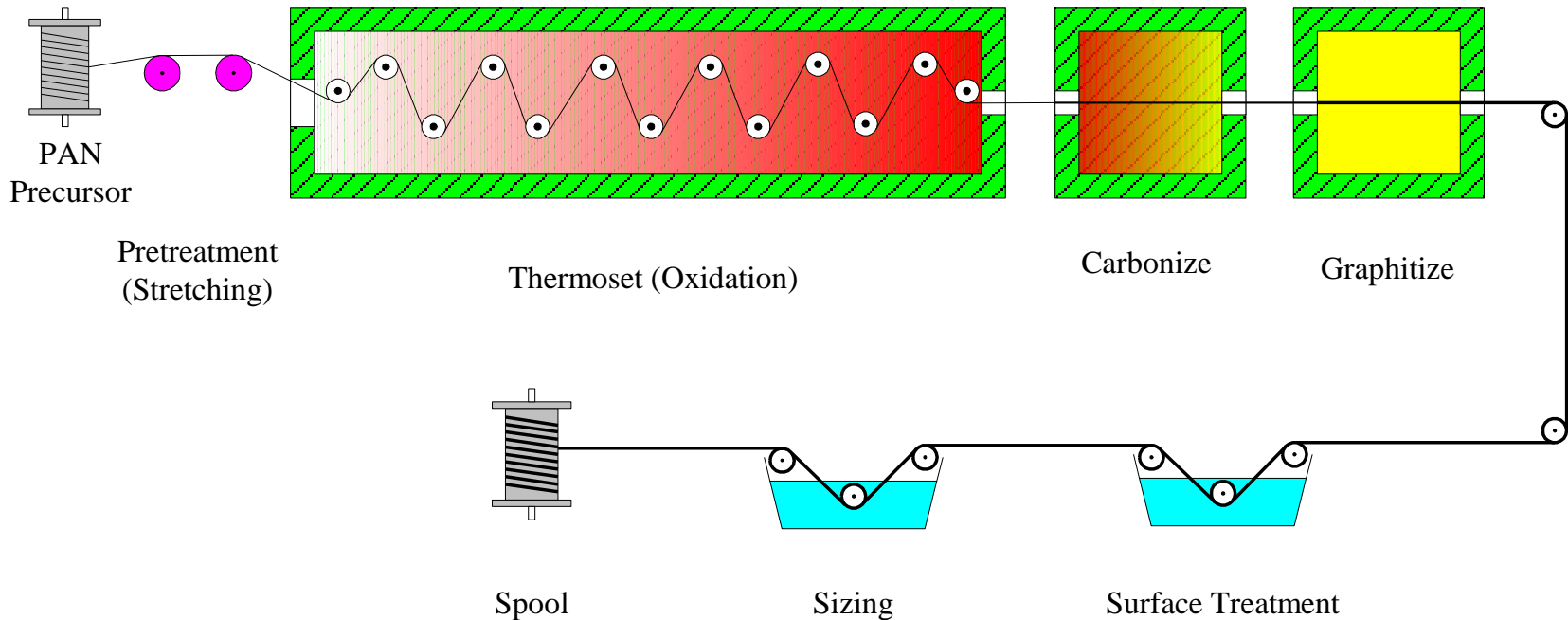
**Nearly  
4X  
World  
Capacity**

10 pounds of Carbon Fiber per Vehicle:  
180M lb/year





# Low Cost Carbon Fiber



**Typical processing sequence for PAN and pitch –based carbon fibers**

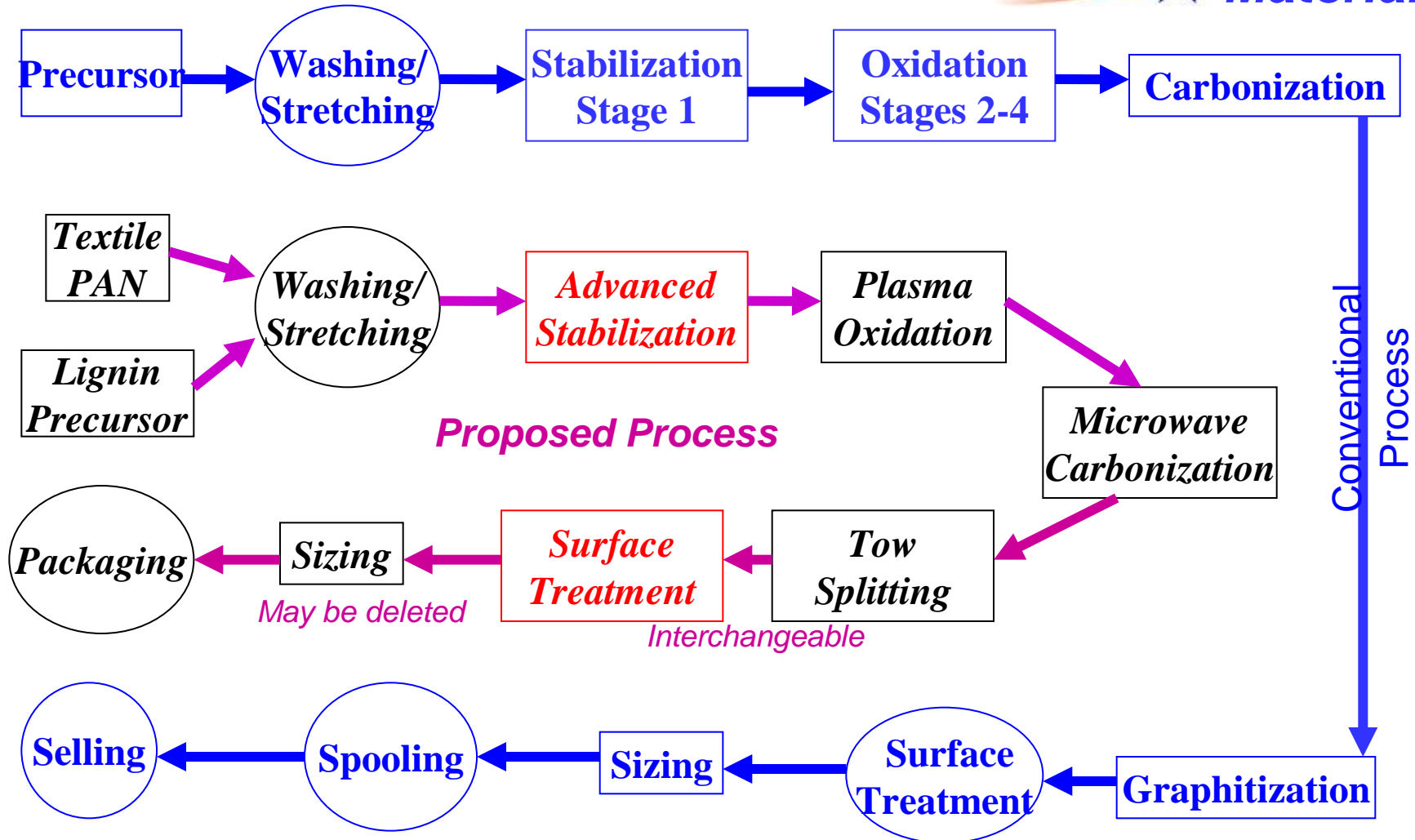
## Major Cost Elements

Precursor	43%
Oxidative stabilization	18%
Carbonization	13%
Graphitization	15%
Other	11%

- Automotive cost target is \$3 - \$5/lb  
Tensile 250 ksi, 25 Msi, 1% ultimate strain
- ORNL is attempting major technological breakthroughs for major cost elements



# Carbon Fiber Integration





# Lignin Based Precursors

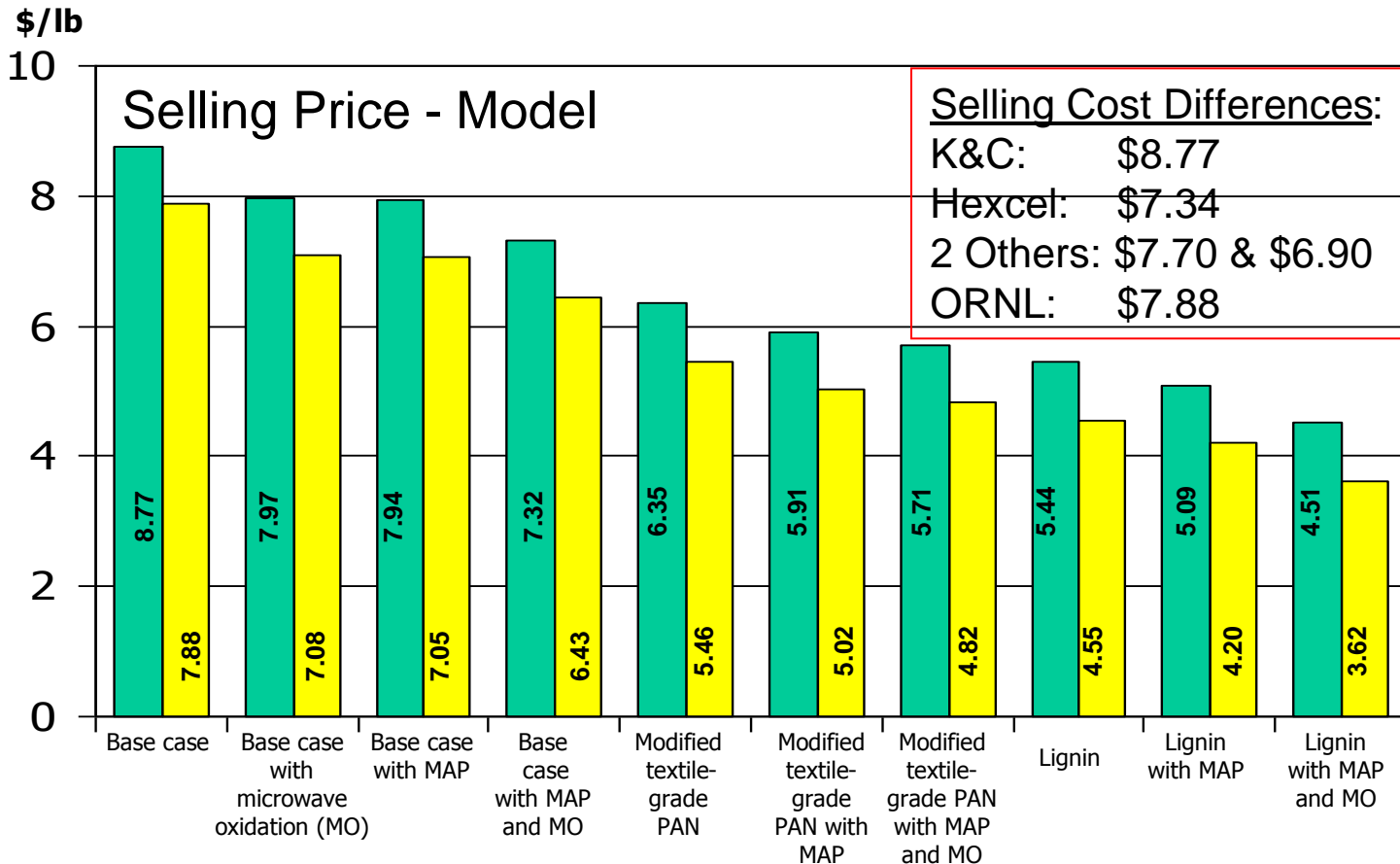
- Low-cost, high-volume carbon fibers precursor sources:
  - Regenerated cellulosics, Recycled Polymers, Lignin, Fiber Blends (alloys)
- Materials evaluated available in quantities sufficient to support the passenger transport.



- 10% of U.S. Kraft lignin would make enough carbon fiber to replace 50% of the steel in light transport.
- Environmentally-friendly melt spun fiber
- Oxygenated polymer minimizes stabilization
- Lower emissions in carbonization
- May be integrated into pulp mill
- Melt-spinning is a simple, inexpensive process costing \$0.05-\$0.10/lb

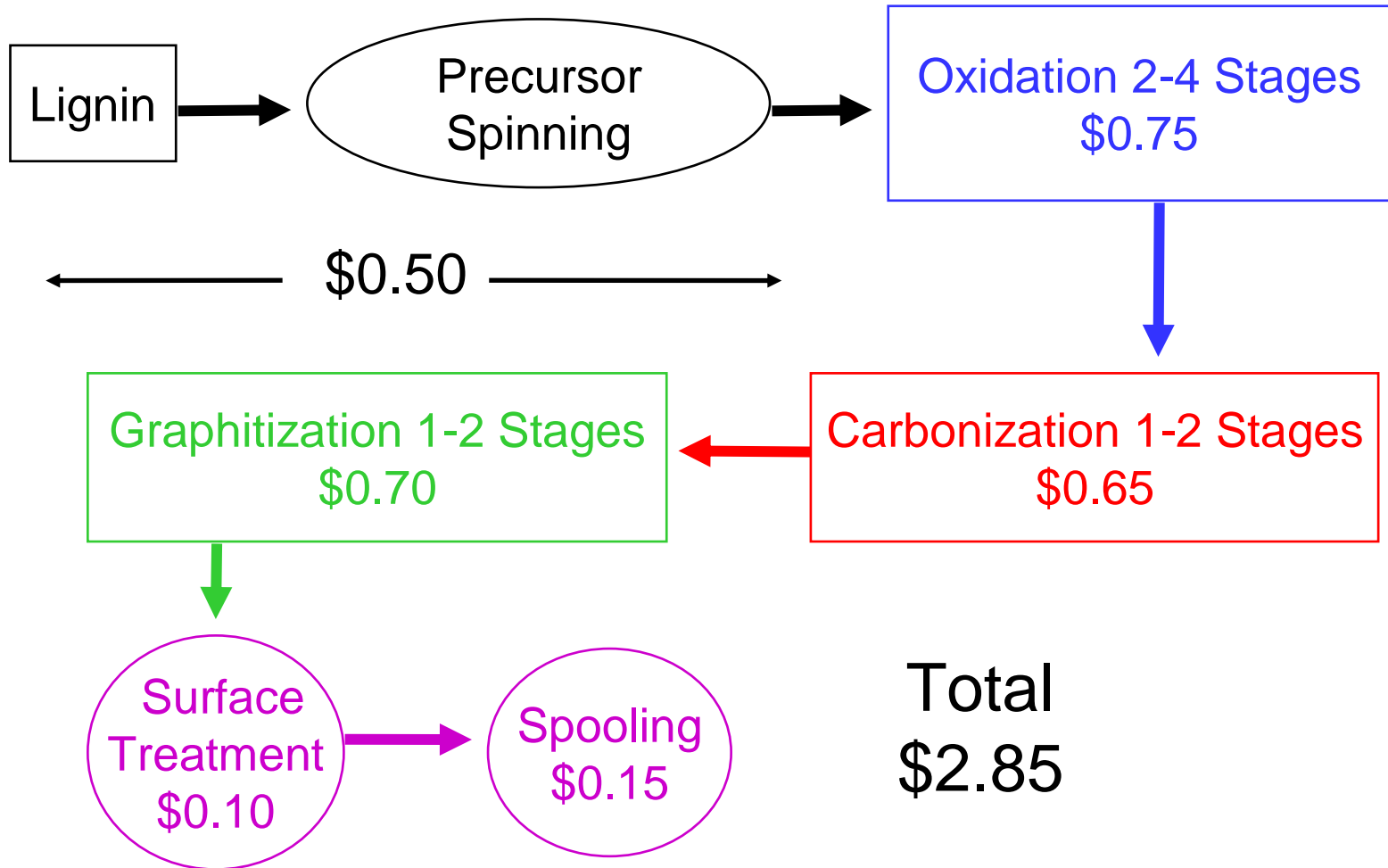


## Preliminary Data - Estimated Selling Prices



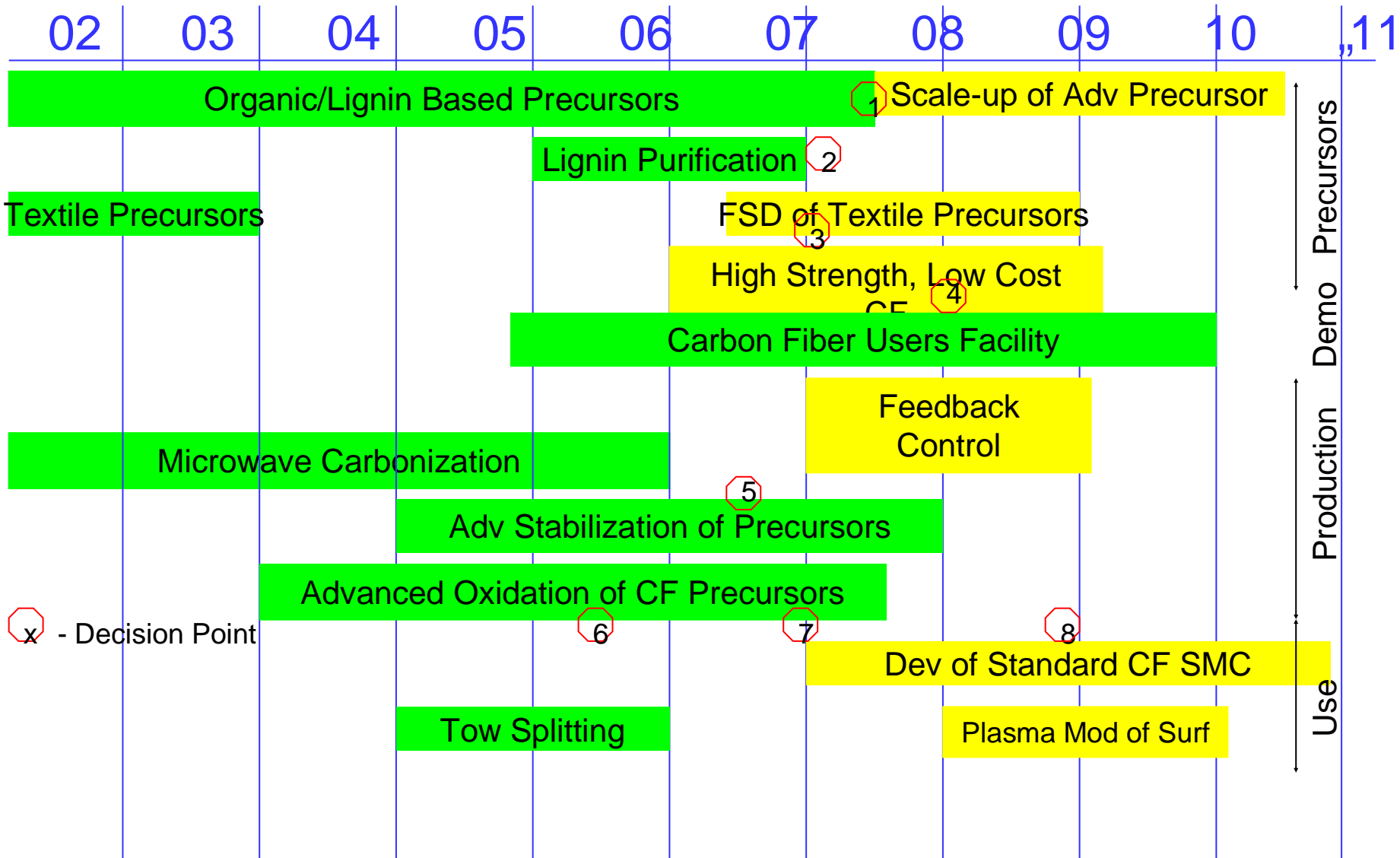


# Estimated Costs for Lignin-Based Carbon Fiber



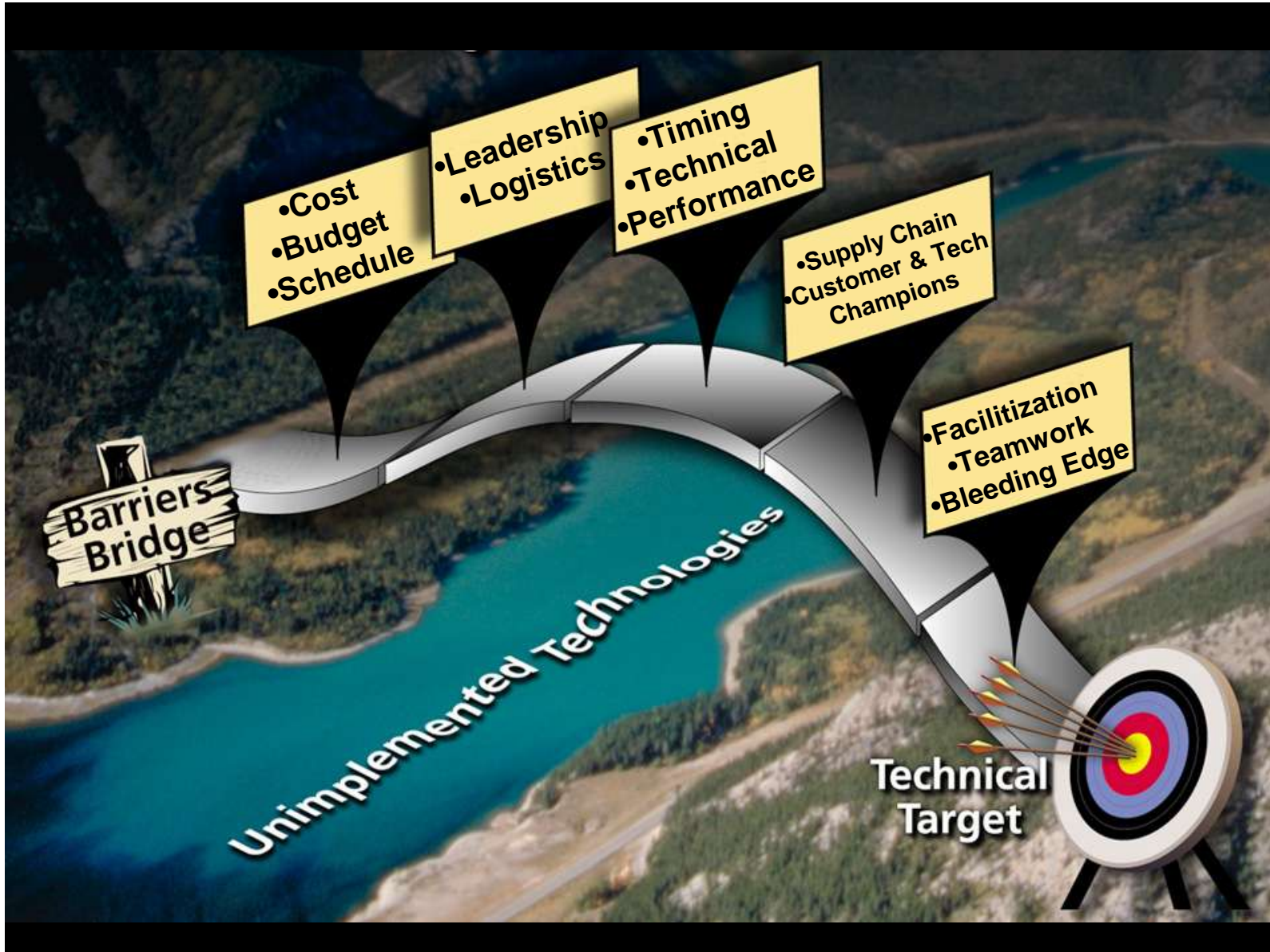


# Low Cost Carbon Fiber Plan





# Pathway to Technology Commercialization





# Successful Implementation Characteristics

- Technical performance
- Cost targets satisfied
- Budget
- Strong committed leadership
- Timing
- Supply chain
- Committed customer (champion)
- Technical champions
- Logistics/teamwork



## FreedomCAR Materials

