HOW MASS AUTOMOTIVE USE WILL AFFECT THE WAY CARBON FIBER PRODUCERS MUST THINK ABOUT THEIR FACILITY'S CARBON FOOTPRINT

Bill Stry

Senior Process Technology Engineer

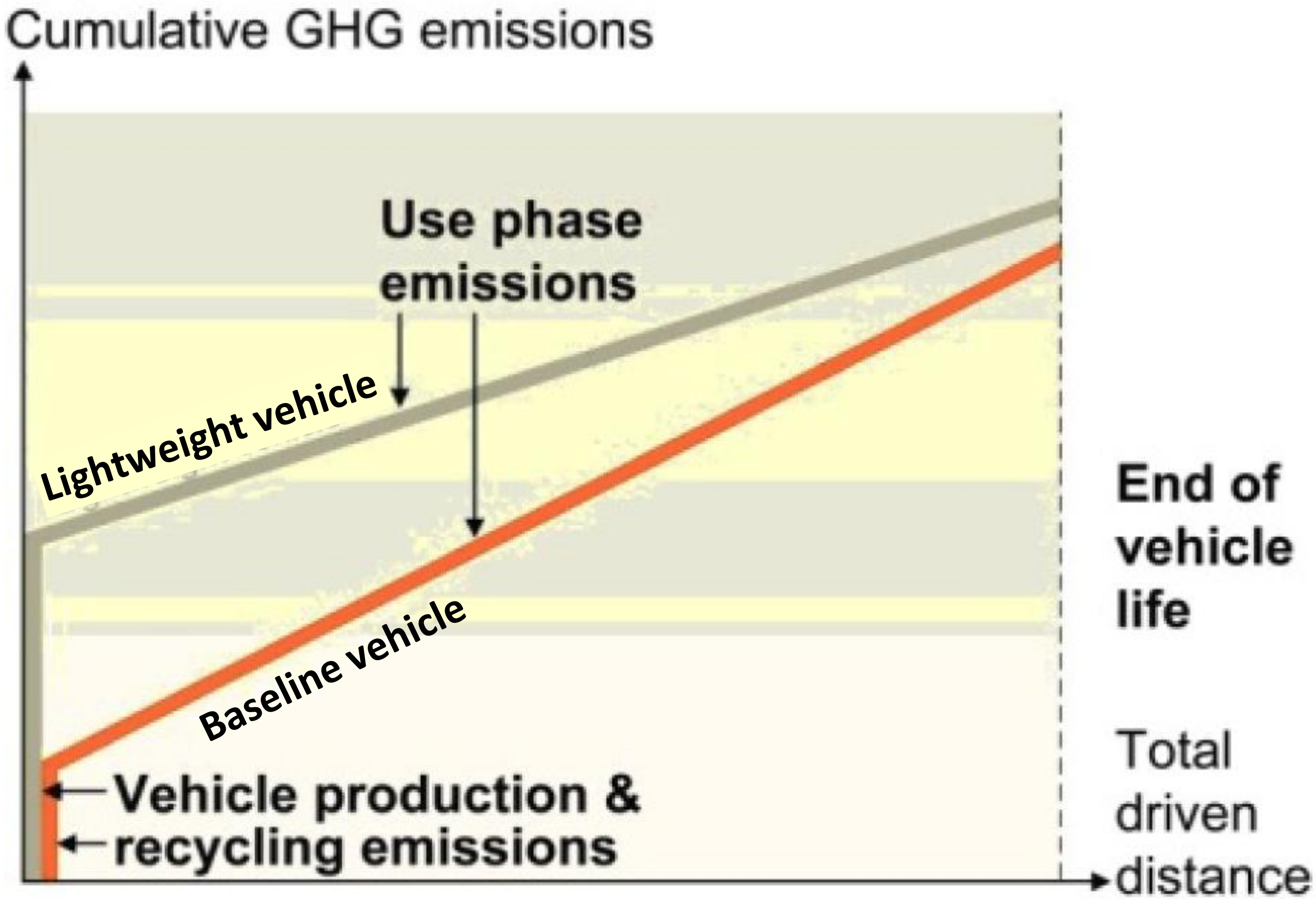
GOCarbonFiber 2013
October 9th, Seattle WA

Agenda

- Automotive life cycle analysis challenges CFRP producers to reduce their facility's carbon footprint
- The opportunity and challenge for alternate CF precursors
- The affect of increased scale of operation on safety and environmental practices

Harper International

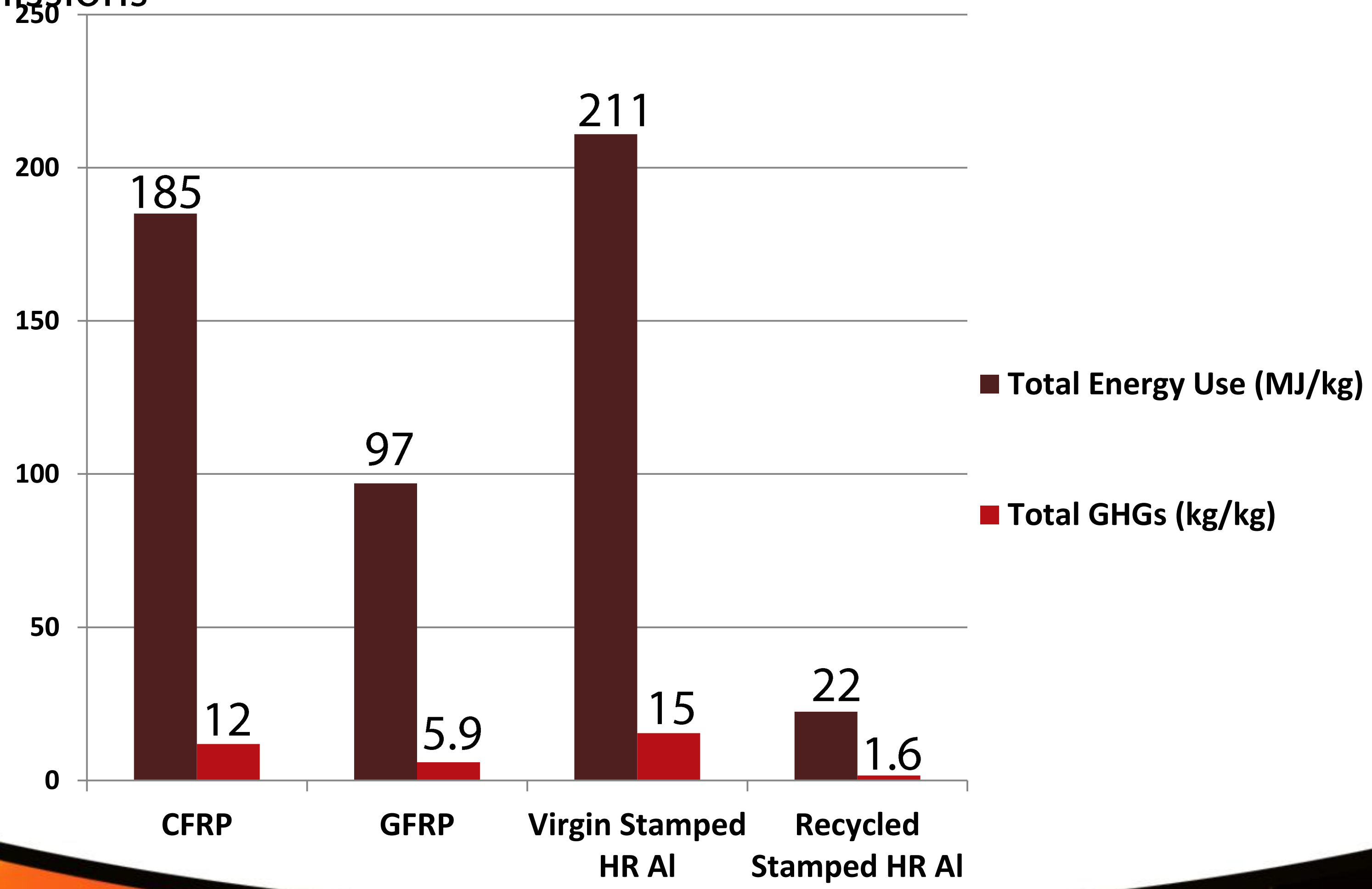
Sample Automotive LCA



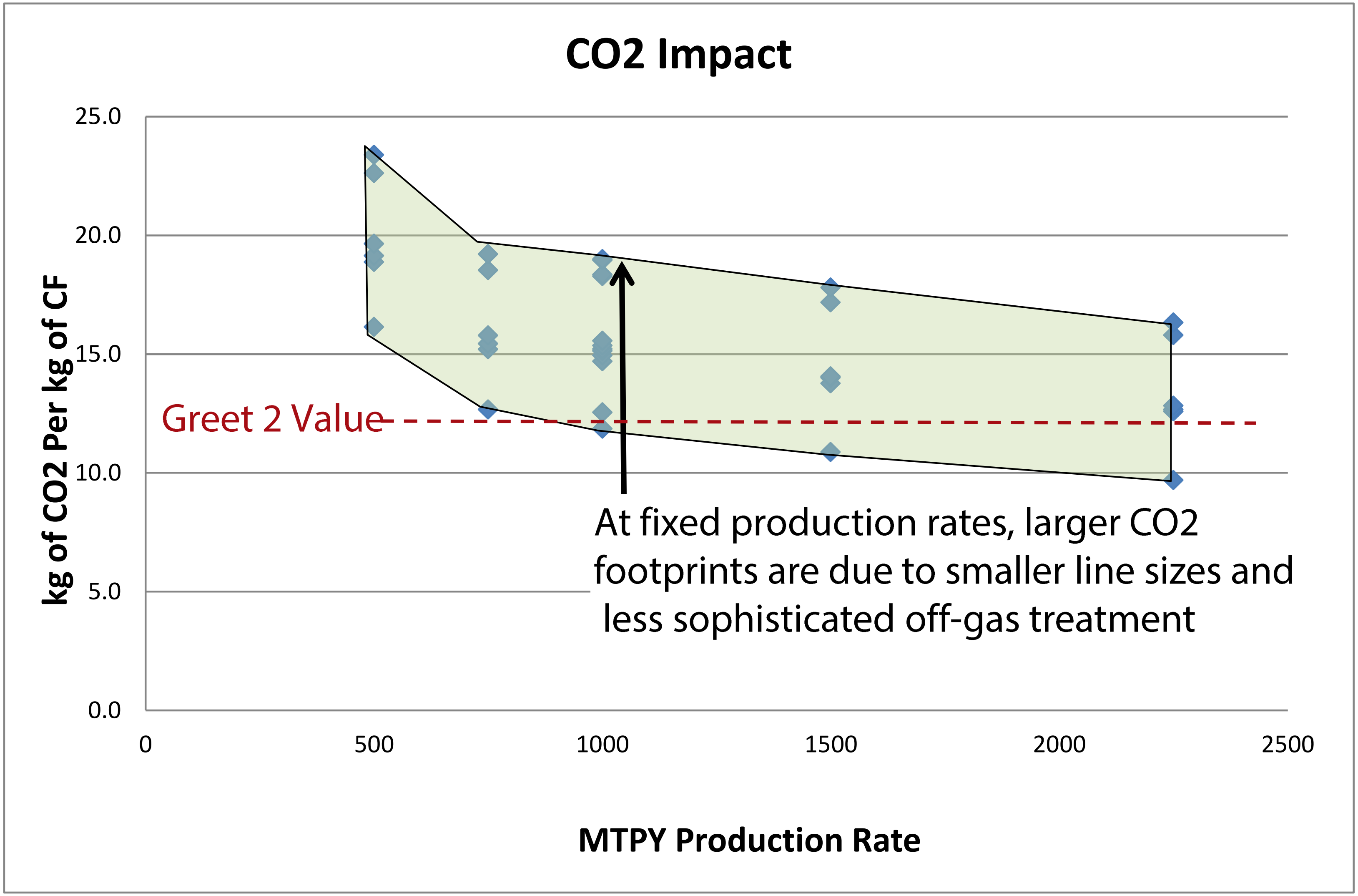
Harper International

Review of Base Data

- The GREET2 Vehicle-Cycle Model (Argonne National Laboratory, 2012) provides a database of material production energies and associated emissions



Review of Base Data



Data from www.harperbeacon.com

Carbon Fiber Embodied Energy

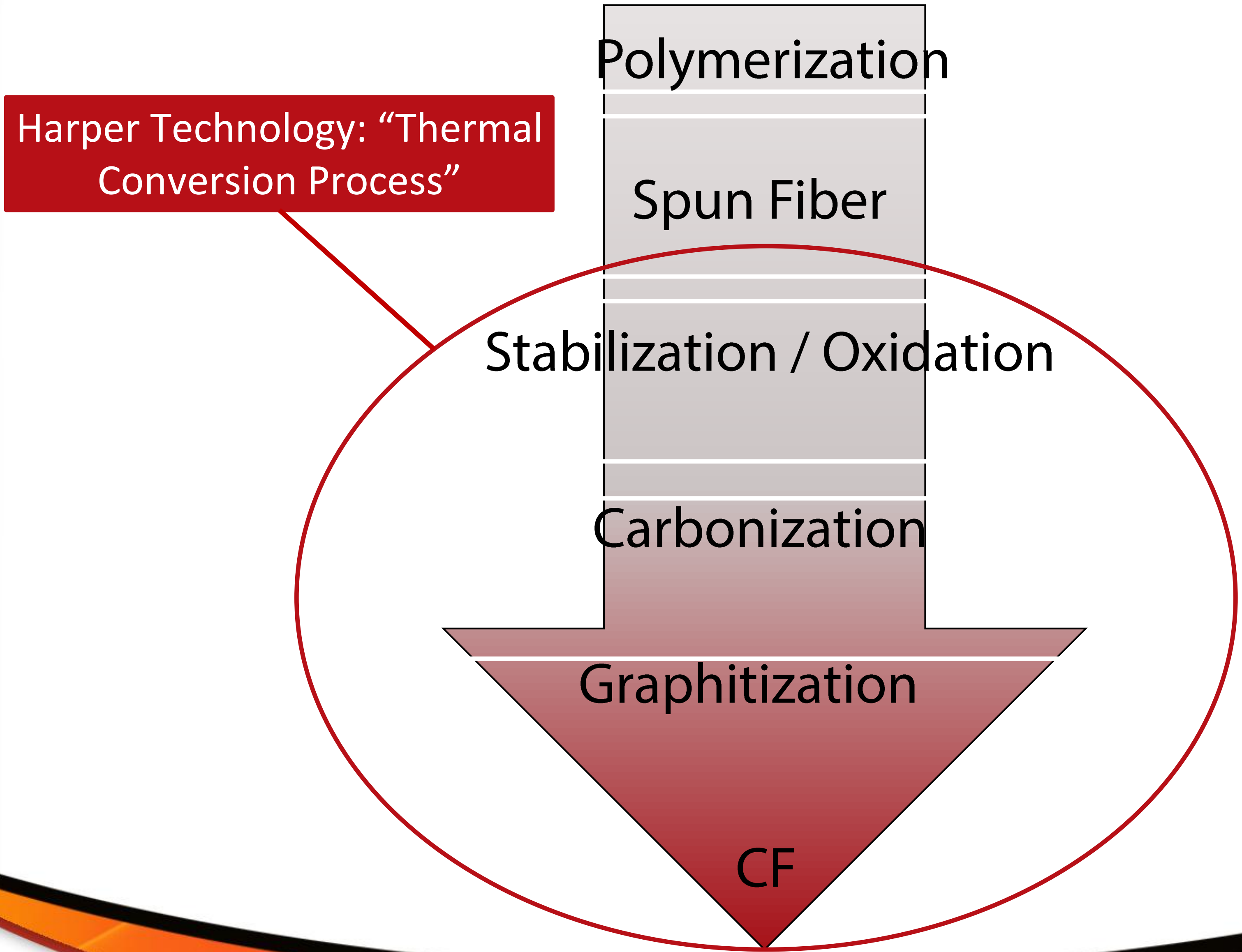
- The GREET2 value for CFRP (MJ/kg) comes from…

$$E_{CFRP} = (E_{epoxy} X_{epoxy} + E_{CF} X_{CF}) \text{ x Waste Factor} + \text{Fabrication E}$$

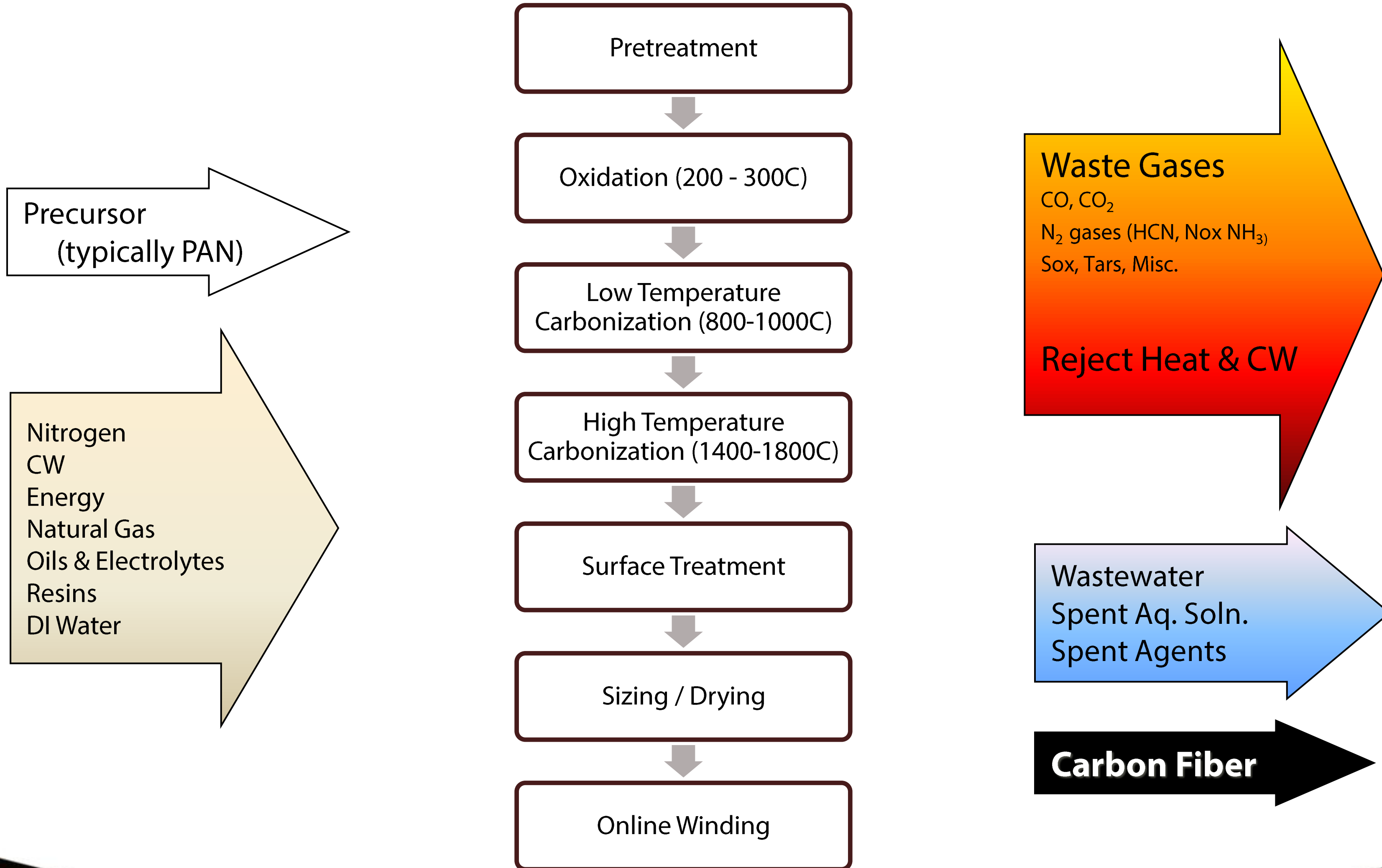
E_{CFRP}	$E_{epoxy} X_{epoxy}$	$E_{CF} X_{CF}$	Waste Factor	Fabrication E
185	128 x0.7	207 x0.3	1.14	12

- Carbon fiber 207 MJ/kg is 10X glass fiber and near virgin aluminum

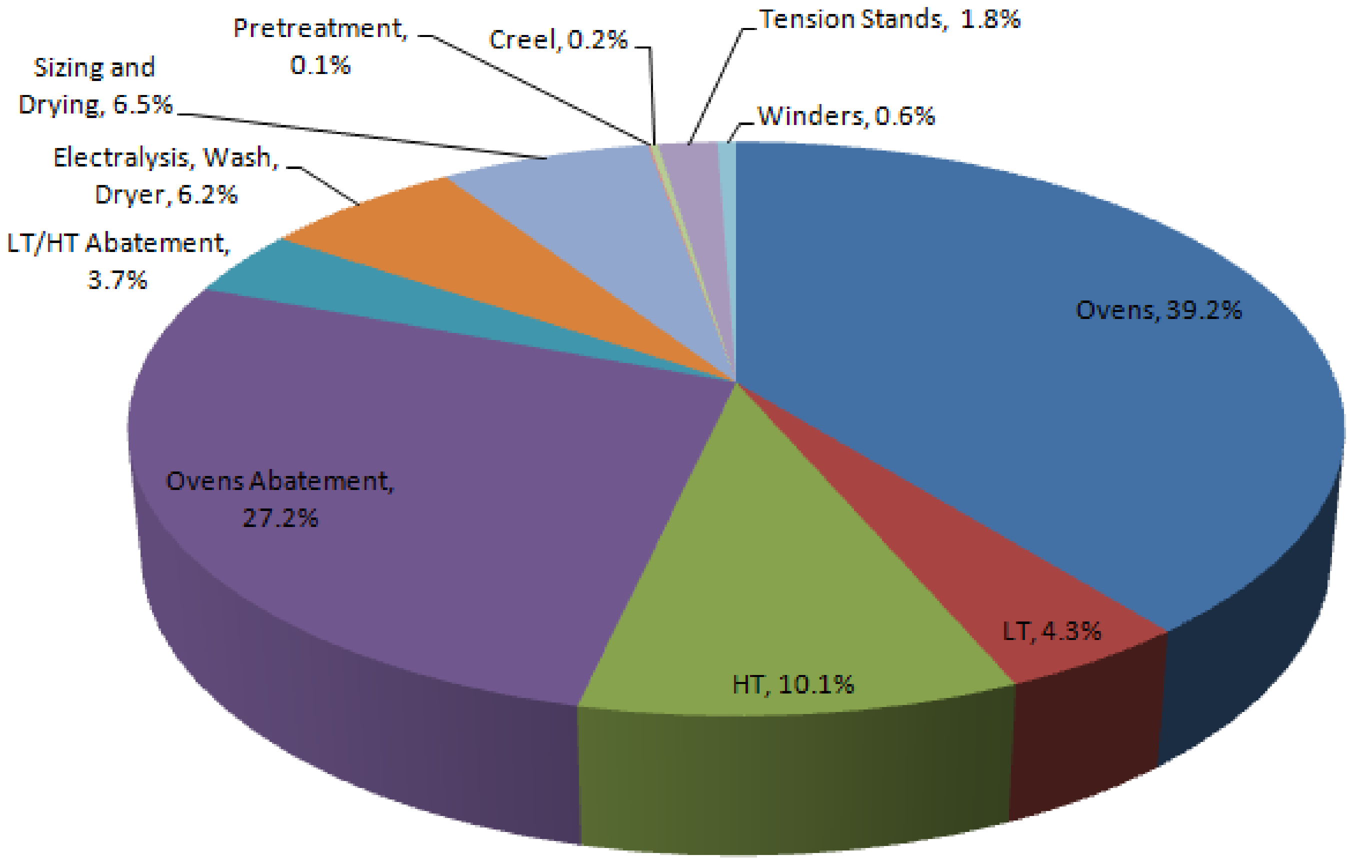
Carbon Fiber Process Overview



Carbon Fiber Thermal Conversion Process



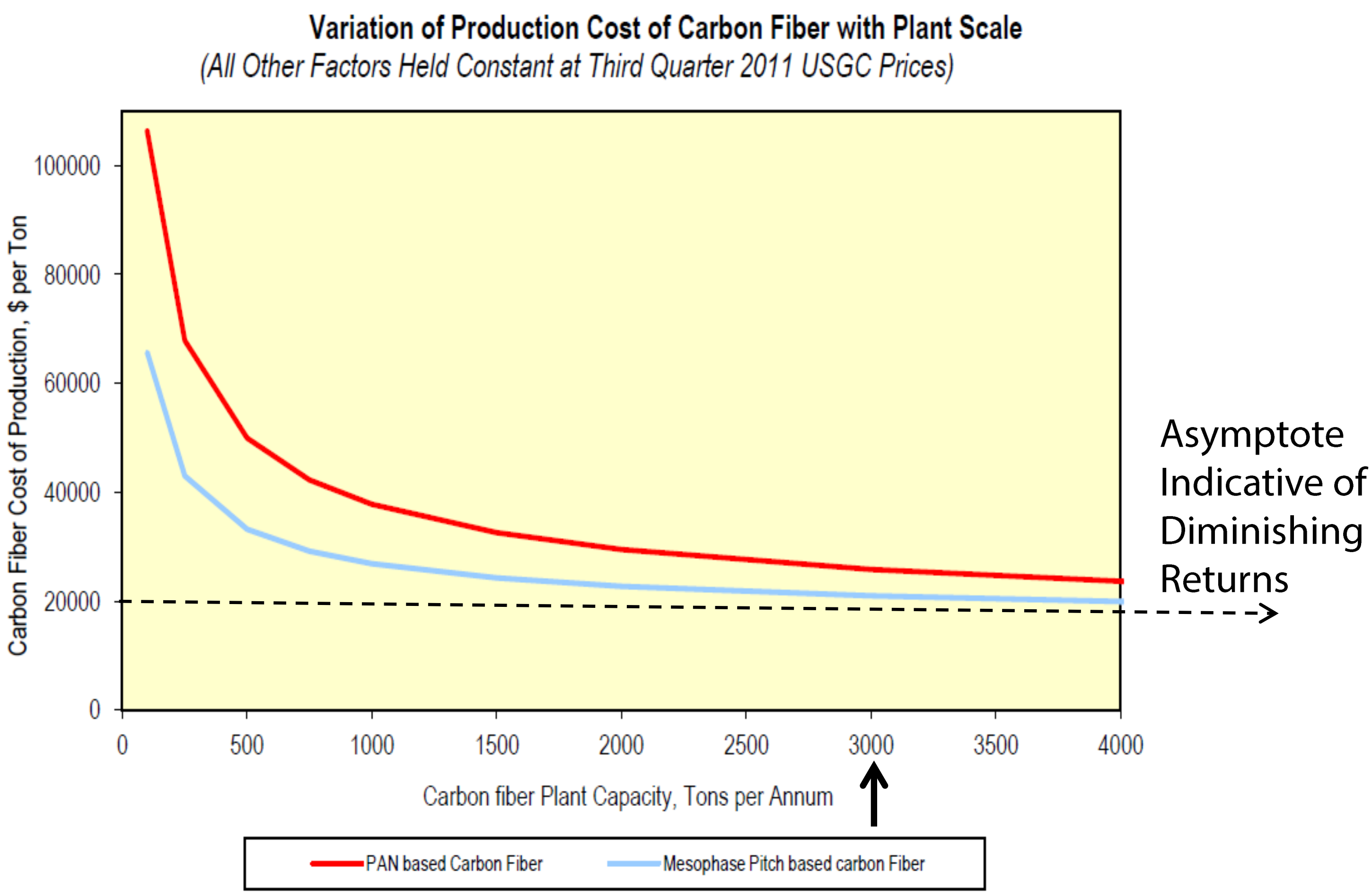
PAN Precursor Thermal Conversion Energy Use



Example: Capacity = 3000 TPY Carbon Fiber

Total Energy Consumption = 11.2 MW = 97 MJ/kg-CF

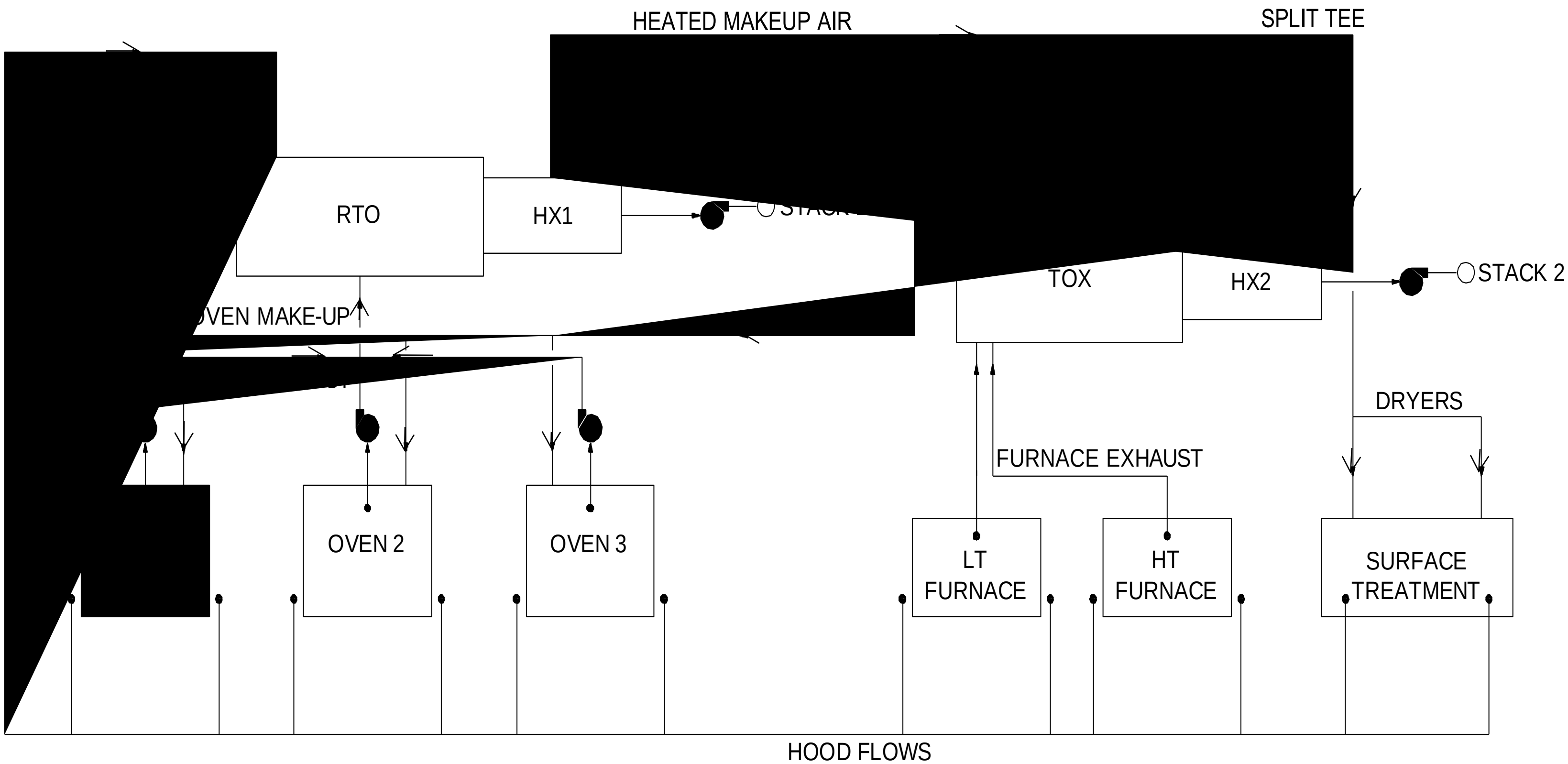
Economies of Scale



Carbon Fiber Production Cost by Plant Capacity
(Cost Per Ton Carbon Fiber)

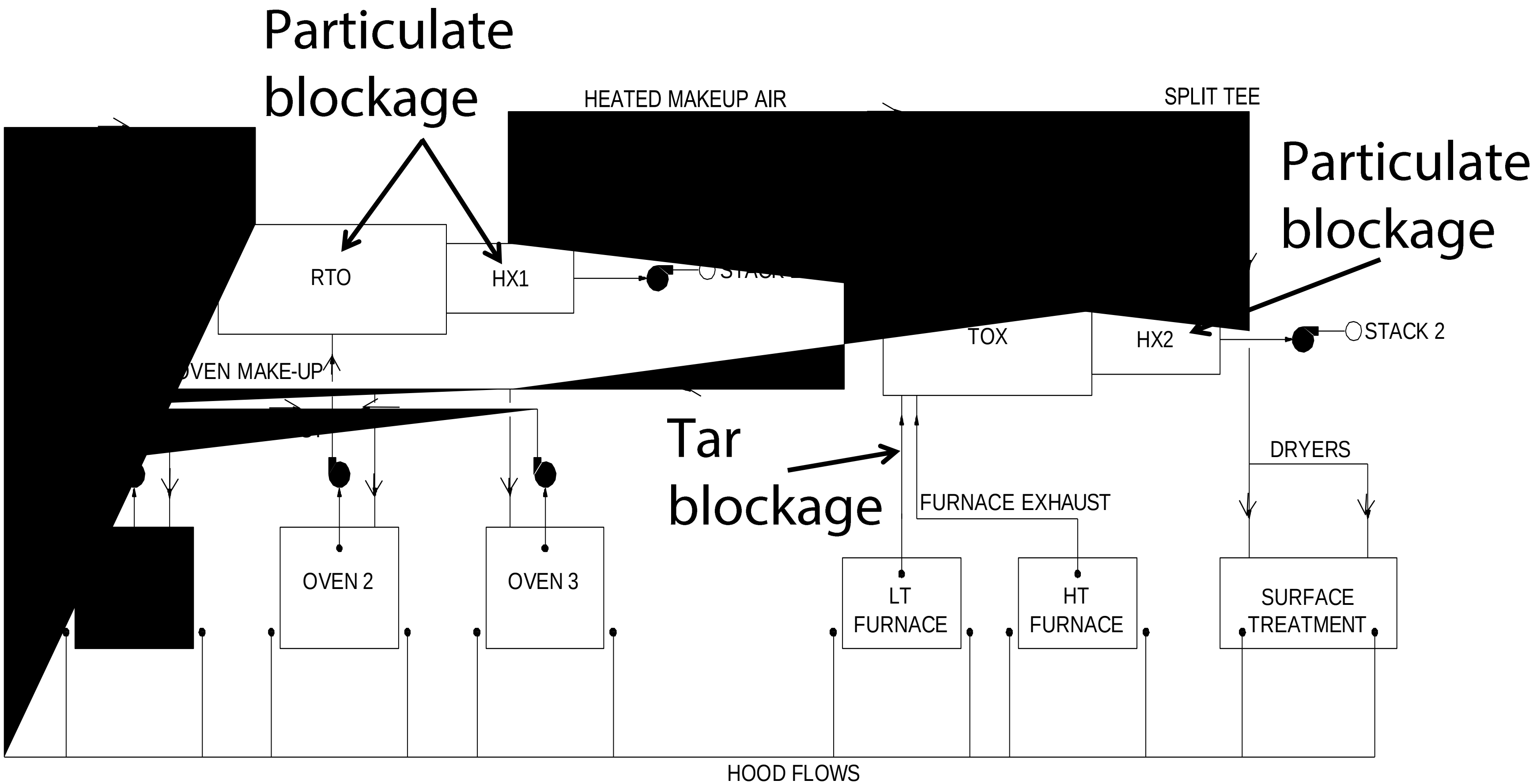
Courtesy of A. Coker; J. Goh; K. Patel, "Carbon Fiber", Nexant, Process Evaluation Research Planning

Energy Focus
– Advanced, Integrated Flowsheets



- Lowers energy use
- Ties together multiple unit operations

Abatement Energy Focus – Operational Issues



- Particulate origin is Si in finish oils of precursor
- SiOx particulate not destroyed by thermal abatement

Waste Gas Abatement Energy Use (31% of total conversion energy)

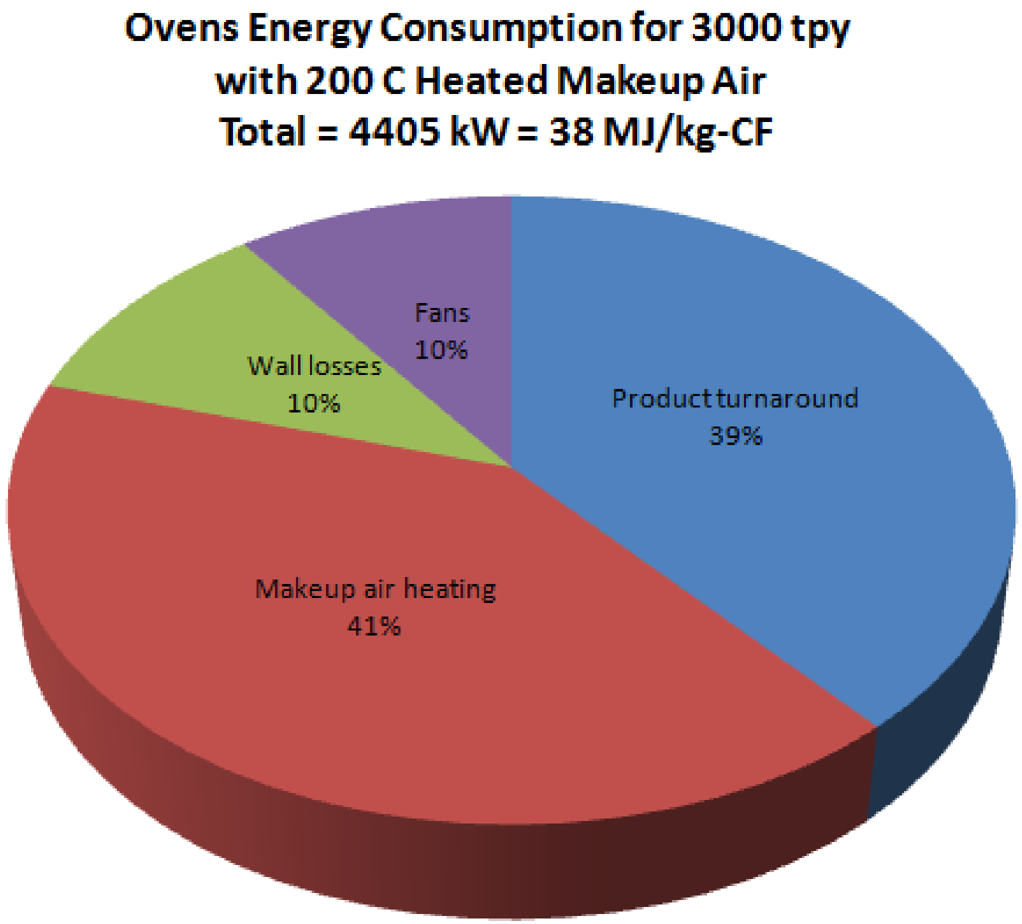
- Abatement energy use (and CAPEX) driven by amount of gas flow
- Amount of gas flow is driven by process chemistry and equipment
- PAN typically requires 160 - 200 kg of exhaust per 1 kg carbon fiber produced
- This amount necessary for…
  - Minimizing particulate and condensates getting on the fiber
  - Keeping down HCN levels in the work area (NIOSH REL = 4.7 ppm)
  - Keeping down particulate and condensation buildup on oven surfaces

Image courtesy of Anguil Environmental

Waste Gas Abatement Energy Use (31% of total conversion energy)

- PAN typically requires 160 - 200 kg of exhaust per 1 kg carbon fiber
- Alternate precursors are likely to lower this ratio
- Some, such as polyolefins, may use wet process stabilization
- Some, such as refined lignin, may use scrubbers in lieu of incineration
- Some, such as mesophase pitch, may use solvent recovery
- What will be the particulate generation of alternate precursors?

Ovens Energy Use – 39% of Total



Ovens power consumption can vary +/- 30%

due to variances in recipe and line configuration

Oxidation Ovens Energy Use
(39% of total conversion energy)

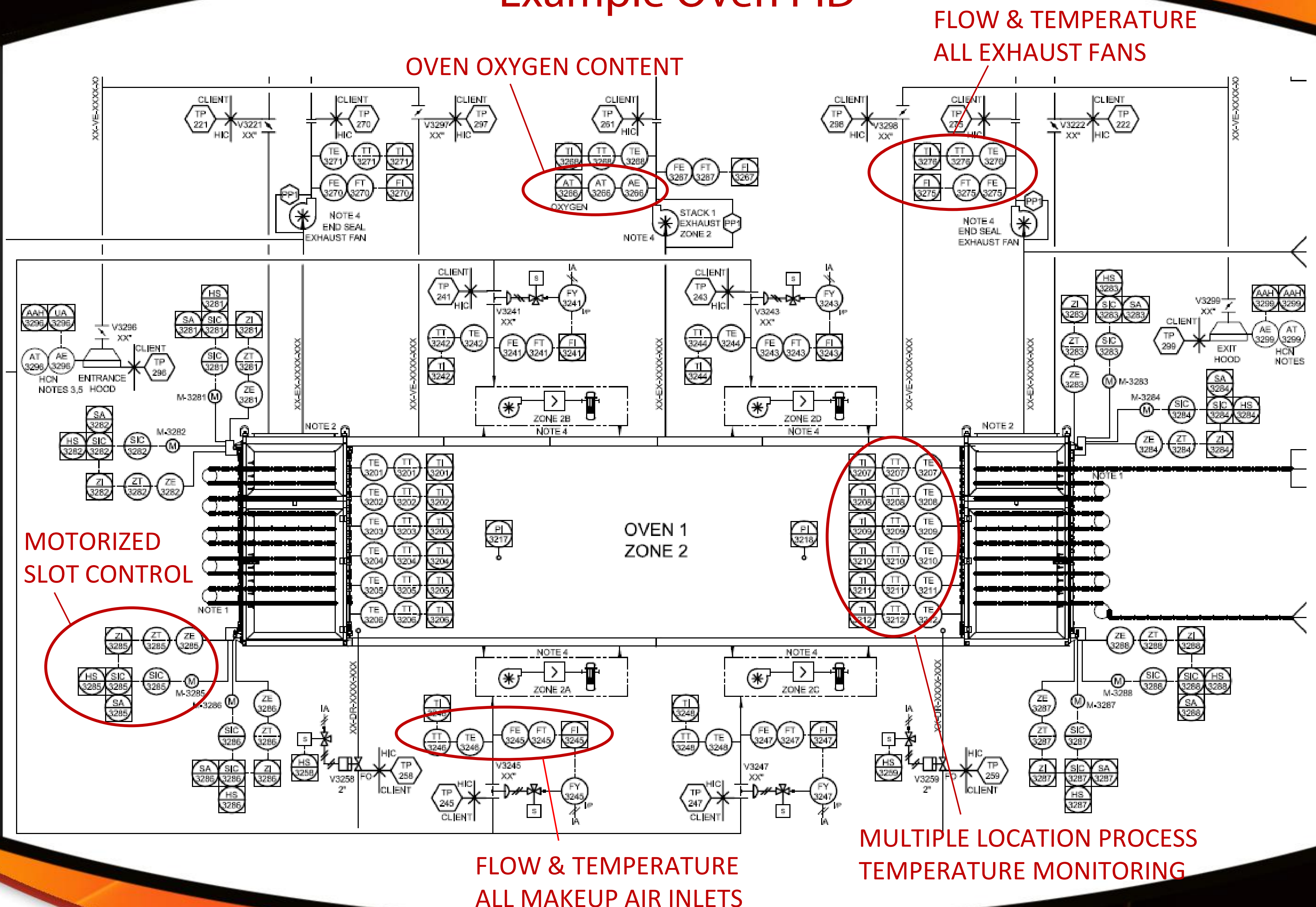
- Today PAN typically requires 60 – 90 minutes of residence time
- Technology improvements may greatly reduce the required time
- Finer filaments - roughly, ½ the diameter needs ¼ the residence time
- Atmosphere pressure plasma (RMX, ORNL) may require only 1/3 of the conventional residence time
- If these technologies combined, PAN oxidation times < 10 minutes look feasible




Oven Instrumentation Can Benefit Energy Use and Product Quality

- Measured flow rates at all exhausts and makeup air locations provides real-time knowledge of:
  - Rate of make-up air use and cold air infiltration
  - Total flow and temperature of oven exhaust sent to abatement system
- Measured oven oxygen and /or VOC content provides information for setting optimum exhaust flow rates
- Slot height controls can lower cold air infiltration and escape of oven gas
- Array monitoring of temperature can increase processing speed and product quality

Example Oven PID

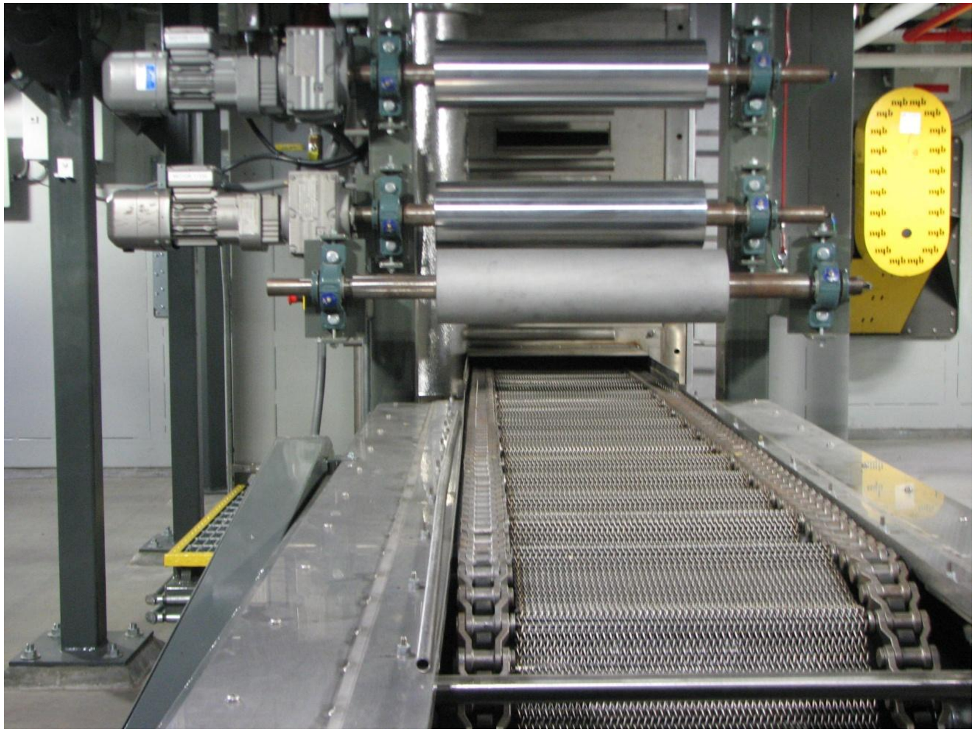


Safety Aspects for Alternate Precursors

- PAN risks include exposure to HCN and chance of fire from exothermic runaway

- Alternate precursors present different challenges
- Polyolefins may use sulfuric acid bath for stabilization

- Lignin or cellulosic materials may be processed as mats with greater risk of exothermic runaway



This content presented in partnership with Oak Ridge National Laboratory

Summary:
Increasing attractiveness of CF for automotive

- Decrease energy required in the CF process
  - Integrated energy recovery technology (and further optimization)
  - Lower energy thermal processes
  - Cleaner precursors and/or more VOC tolerant processes
- Use low GHG energy source for CF production (i.e. Moses Lake
-

  GHG
- CF composites made with thermoplastic resins

Thank you for your time!

Visit us at harperintl.com and harperbeacon.com