# Value Analysis of Alternative Diesel Particulate Filter (DPF) Substrates for Future Diesel Aftertreatment Systems

DEER Conference
August 4, 2009

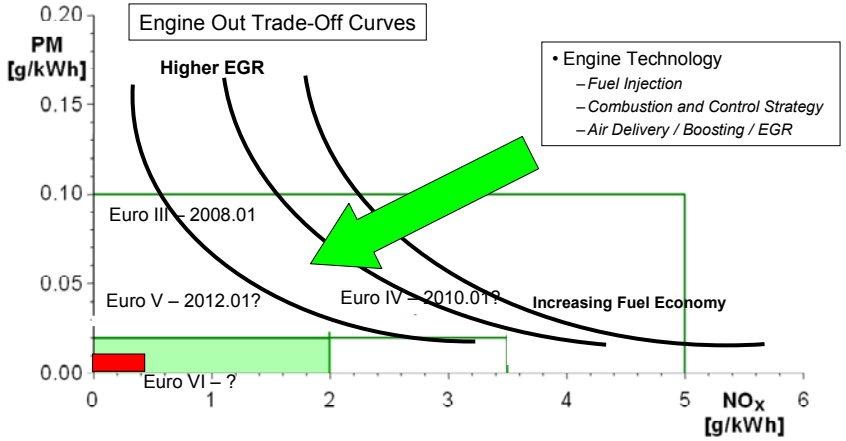
**Steve Majkowski**
**Global Marketing Director - Powertrain and Emissions**

# Outline

- Regulations Driving New and Optimized Systems Architectures
- Aerify™ Acicular Mullite Diesel Particulate Filter
- Case 1 – Heavy-Duty Engine
- Case 2 – Light-Duty Engine

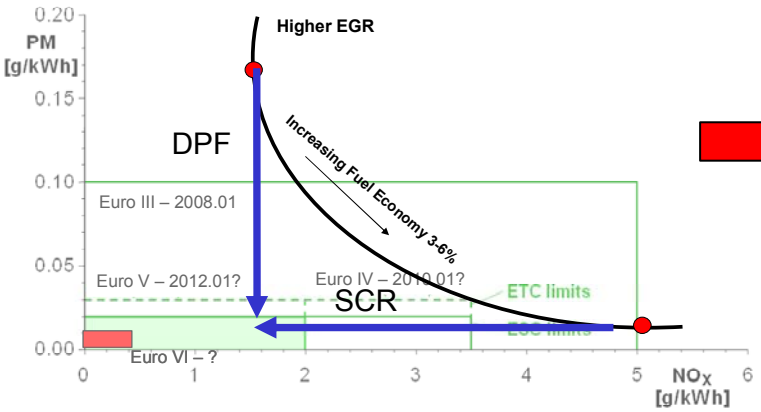
# Tightening Emissions Regulations Drive Engine Management and Aftertreatment

## Engine Controls Move the Trade-Off Curve

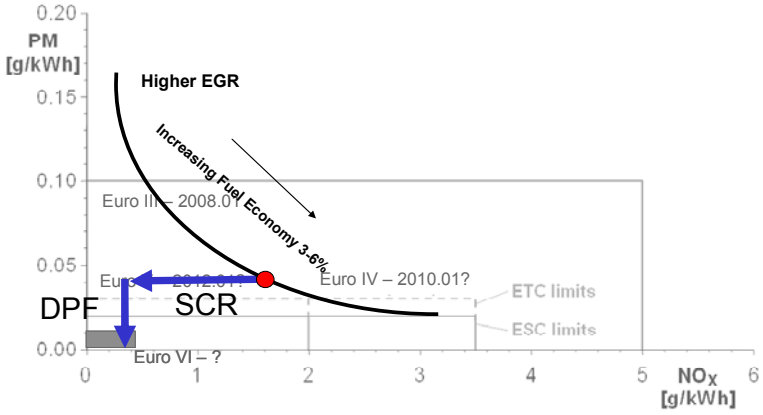



## But Lower Standards Push Strategies From

**PM *or* NOx**

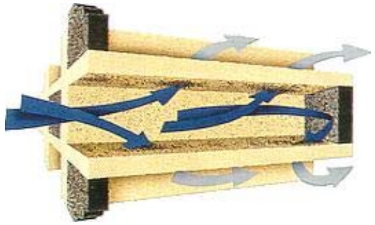


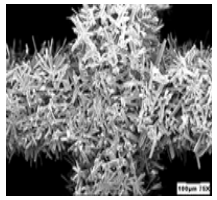

**PM *and* NOx**

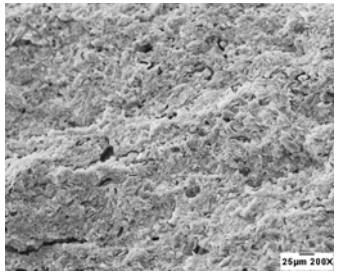


# Aerify™ Diesel Particulate Filter (DPF)

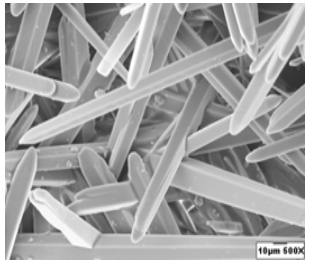
- Wall Flow Ceramic Filter - High porosity substrate with excellent strength
- Mass production begins 2011
- Additional chemical process performed in manufacturing to create the acicular mullite unique microstructure
- Product families include monolith and segmented parts, depending on customer requirement
- Enables flexible value proposition
  - High Filtration Efficiency – Both mass and particle number
  - Reduced fuel consumption
  - Reduced package size
  - Reduction of total systems cost
  - Improved systems integration
    - i.e. SCR on filter





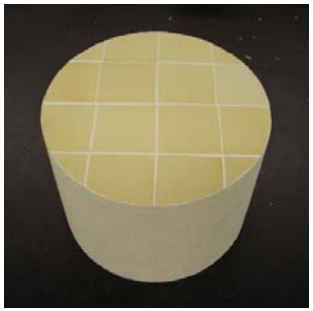


Before Mullite Process



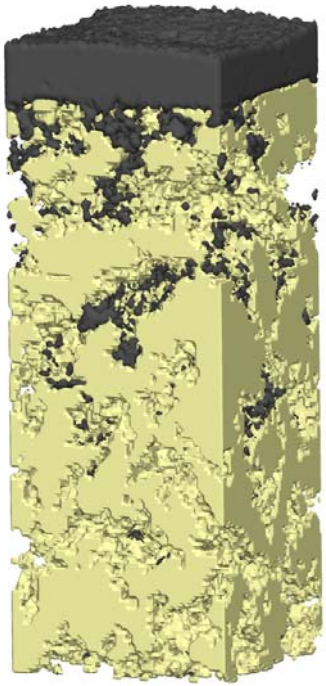
After Mullite Process

Acicular Mullite - Unique High porosity microstructure

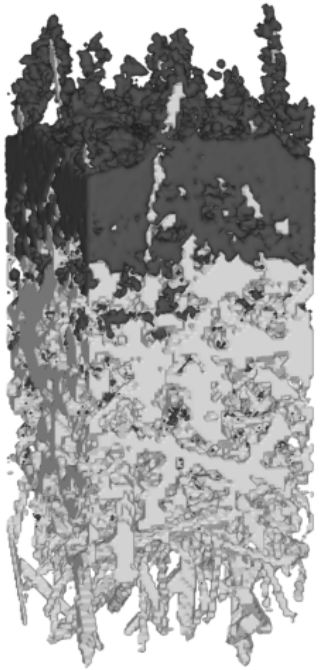


Monolith & Segmented Constructions

# Soot Deposition In AERIFY DPF



Cordierite



AERIFY

- “Soot-in-the-wall” is the cause for pressure drop hysteresis
- The high porosity and permeability protects AERIFY DPF from being vulnerable in regards to “soot-in-the-wall”
- Soot lay down on unique needle structure provides high contact area between soot and needle structure

# Case 1 – Heavy – Duty Diesel

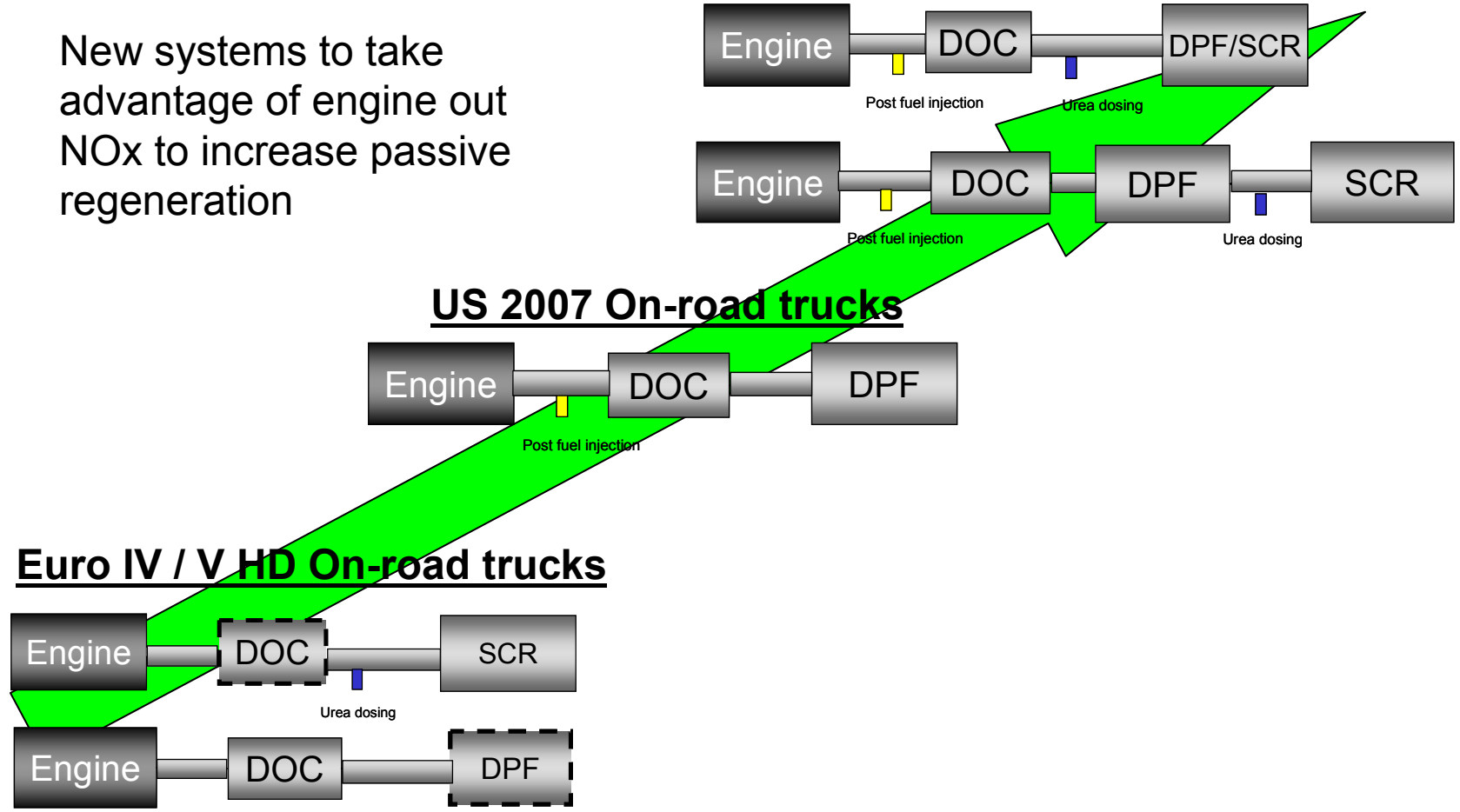
# Heavy Duty Needs

| HD Market Attribute | Engine Design Goals | Ways to Improve |
|---|---|---|
| • Fuel is a large variable cost for the end user | • Reduced fuel consumption | • Reduce post injection occurrences<br>• More passive regeneration<br>• Reduced DPF backpressure for lower pumping losses |
| • Aftertreatment is a large system expense | • Reduced system cost | • Downsize the aftertreatment system<br>• Reduce PGM usage<br>• Integrated solutions |
| • Long life – minimize downtime due to reliability | • Reduce in-field warranty | • Reduce post injection occurrences – less chance of uncontrolled regeneration<br>• Improve control system and soot mass measurement<br>• Improve DPF material robustness |

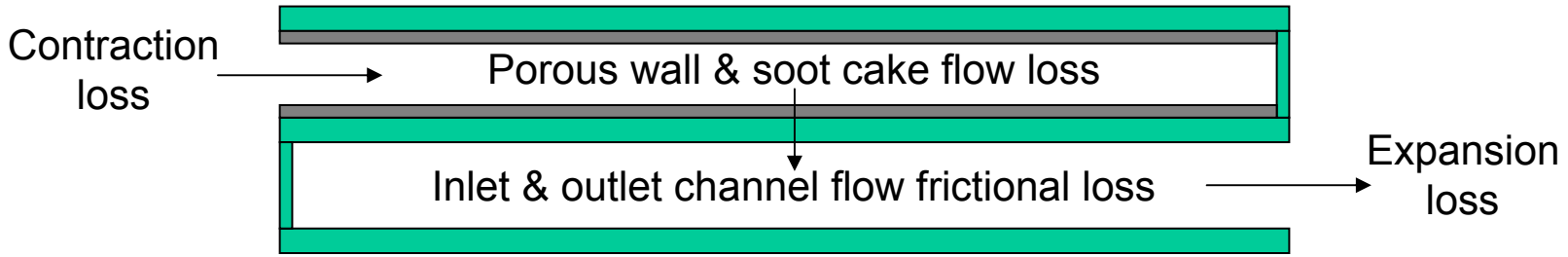
# HD Diesel Aftertreatment

## - System Architecture Trends

New systems to take advantage of engine out NOx to increase passive regeneration



# AERIFY DPF Can Be Downsized!




$$\Delta P_{total} = \Delta P_{wall} + \Delta P_{soot} + \Delta P_{channel\ \ flow} + \Delta P_{entrance\ \ / exit}$$

**small** **strong**

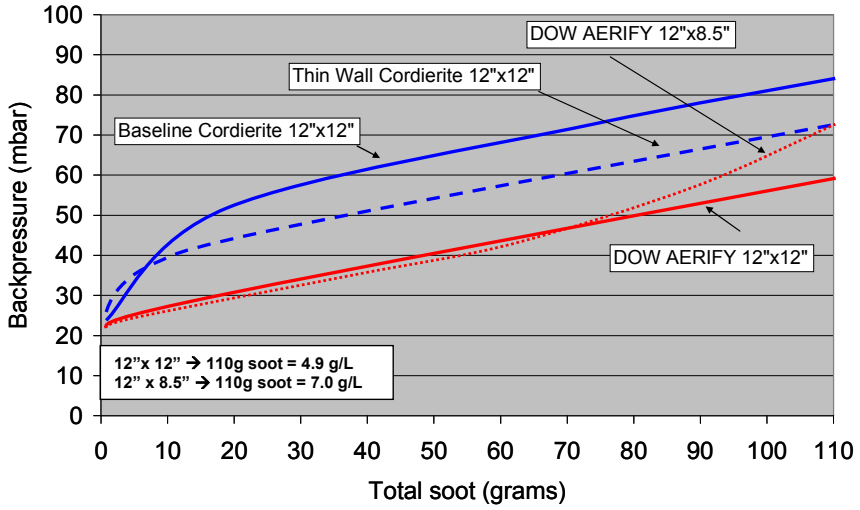
- High porosity and permeability of AERIFY DPF makes the wall contribution small compared to the channel contribution

- Optimal filter length is shorter for AERIFY DPF than for other commercially available DPF

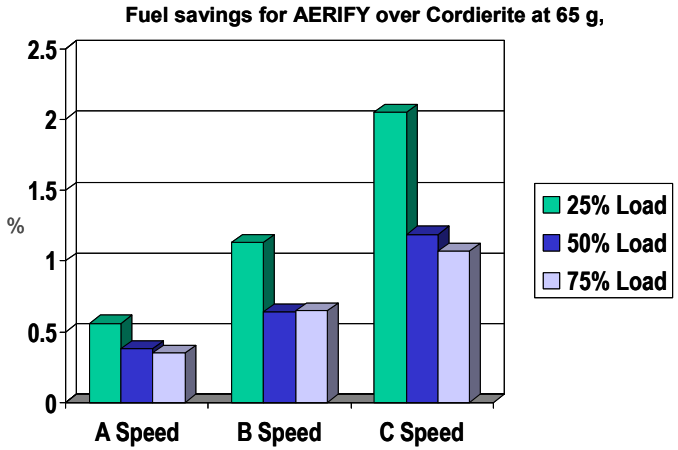
# Back Pressure Advantage - CDPF

## - Significant Length Downsizing (>25%)

- Low back pressure compared to competitive materials
  - Segmented Acicular Mullite filter versus Monolith cordierite
- Linear backpressure profile for improved soot load predictions and OBD control

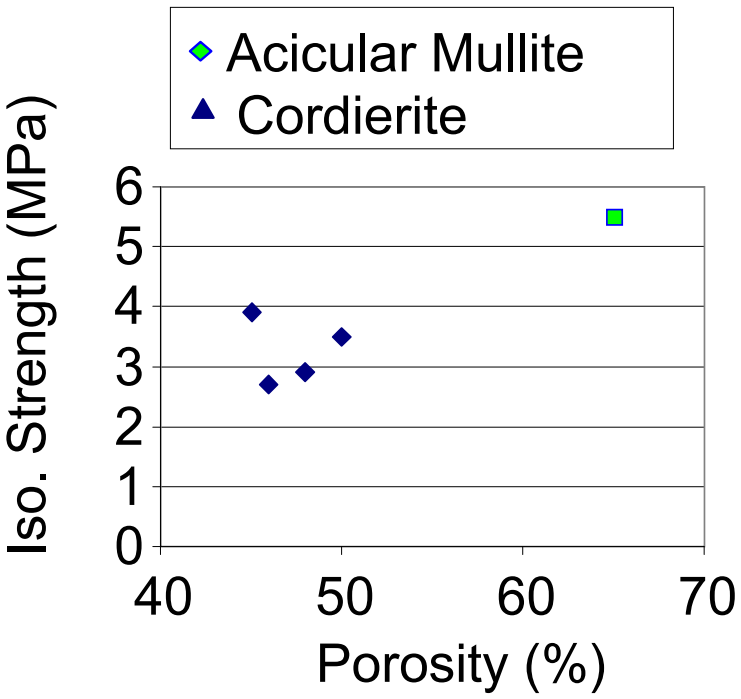


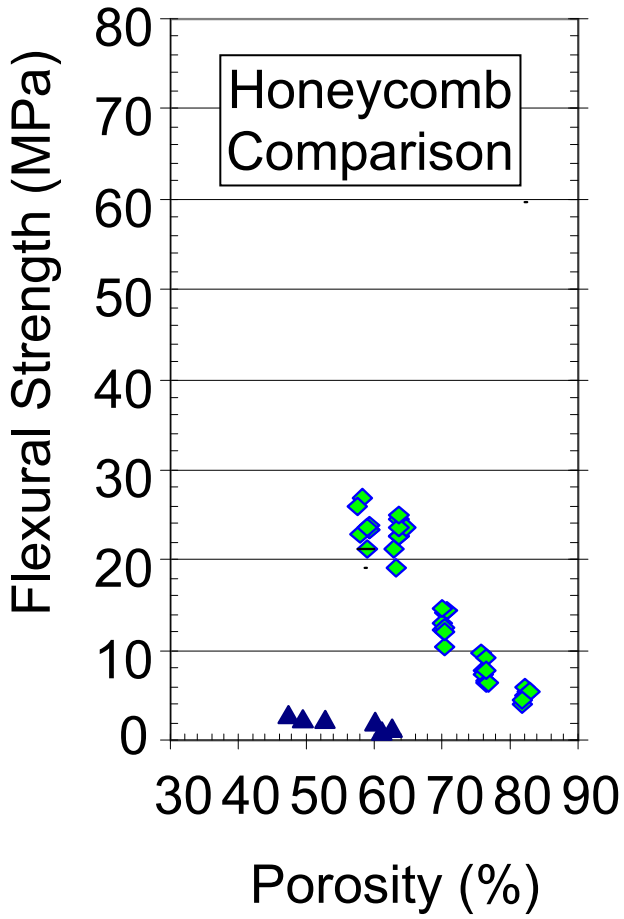

-Results in improved fuel economy on the engine dyno



# Improved Strength Of High-Porosity Mullite DPF

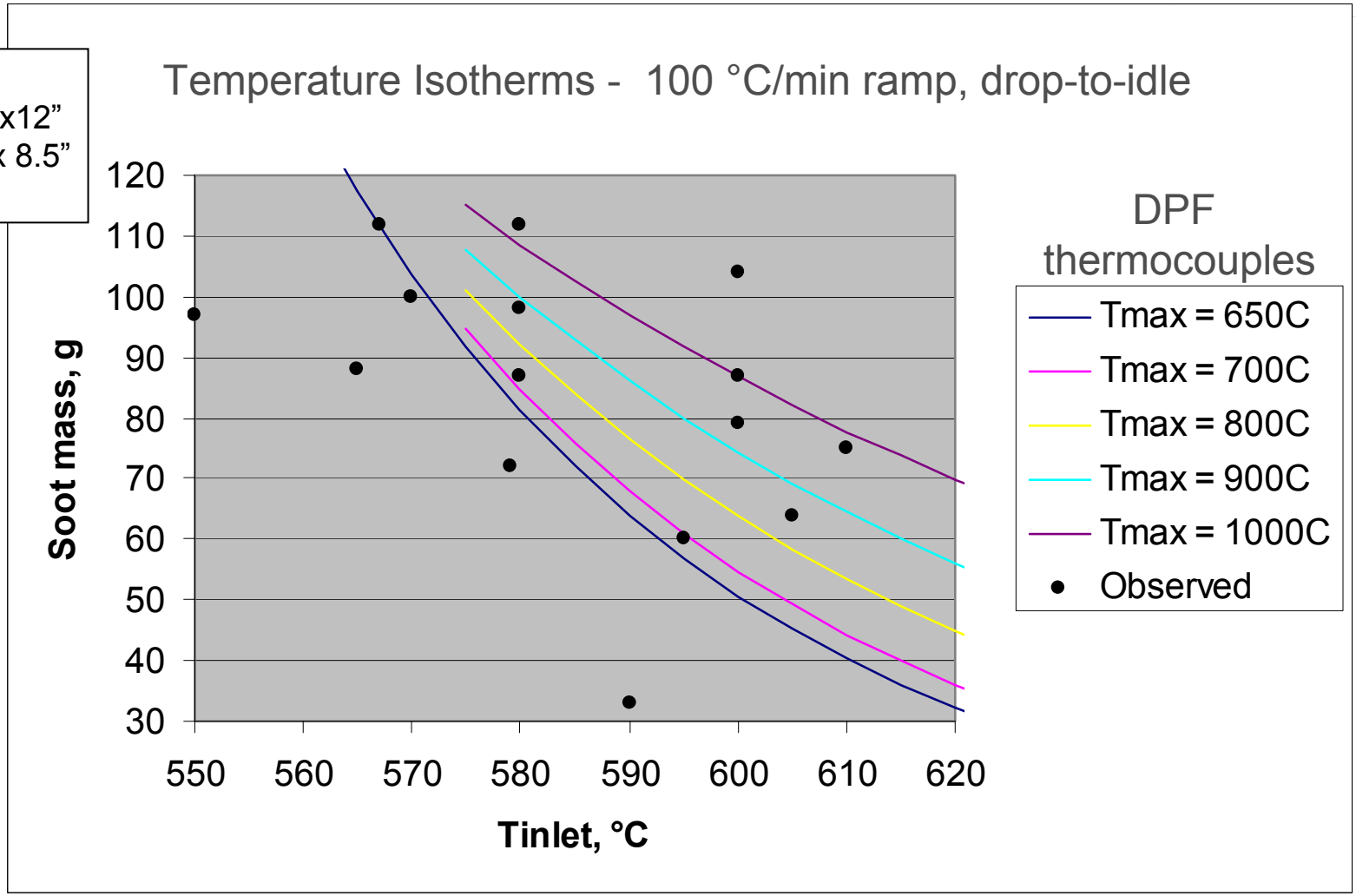
High-porosity Mullite exhibits higher flexural and isostatic strength compared to Cordierite



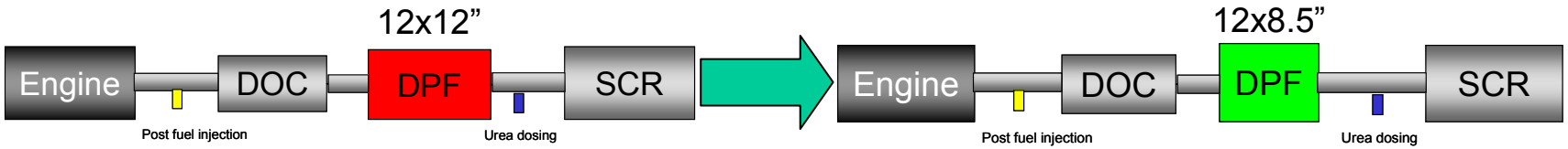
# Excellent Soot Mass Limit
# DTI Tests For Coated 12x8.5 Mullite DPF

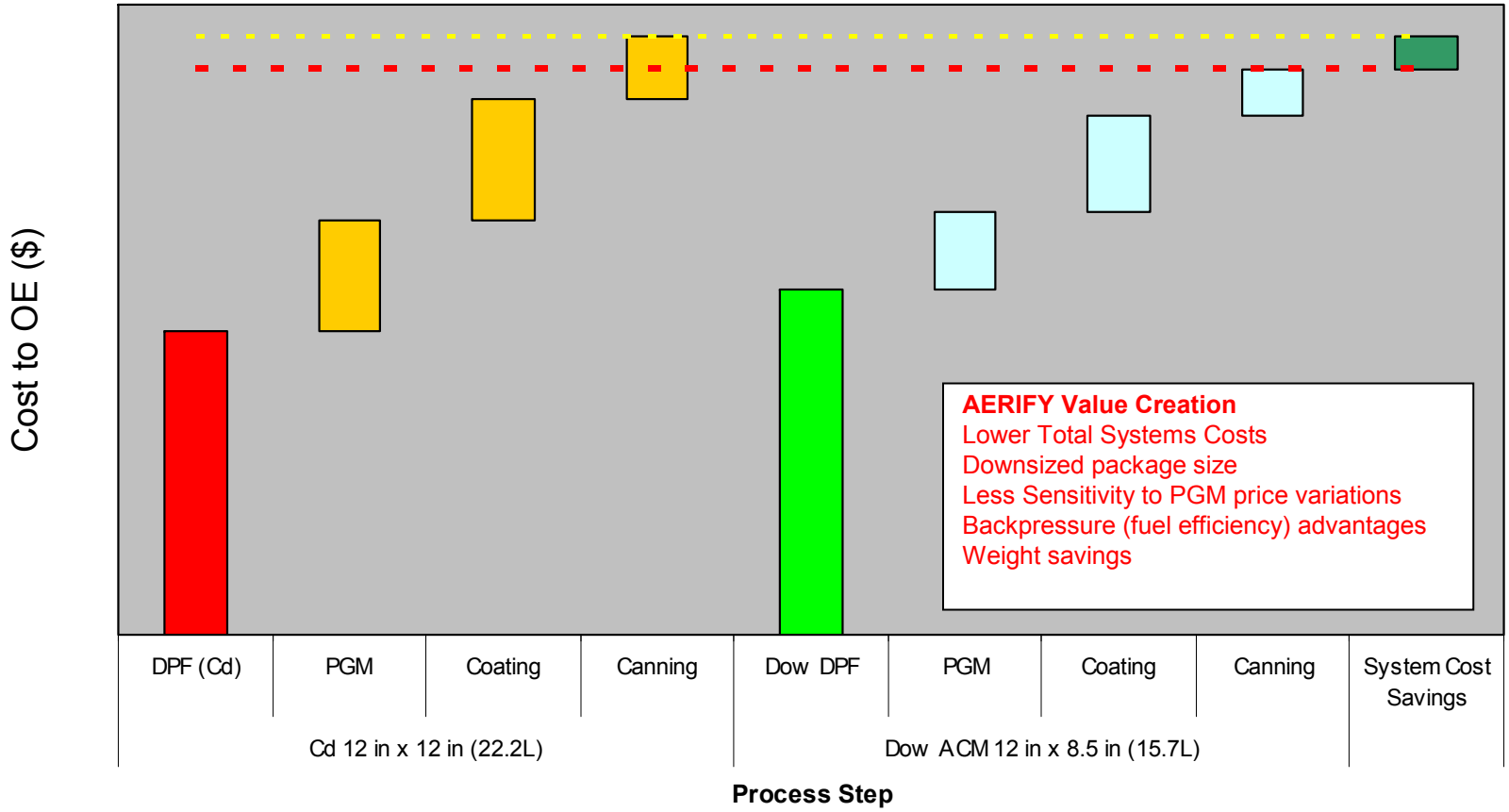
120 grams
~ 5.5 g/L 12x12”
~7.5 g/L 12x 8.5”




- High robustness by segmentation and downsizing

# Value Analysis – HD (Downsized DPF)



# Heavy-Duty System

- Conclusions
  - *Heavy duty trucks have some unmet needs*
    - *Reduced fuel consumption*
    - *Reduced the system cost*
    - *Improved the system reliability*
  - *System architectures are evolving to help meet those needs*
    - *Aftertreatment design*
    - *More passive regeneration*
    - *Improved controls*
  - *New DPF products like Acicular Mullite offer multiple improvements*
    - *Have a higher SML and strength than cordierite – improved robustness*
    - *Enable system downsizing*
      - *Lower system cost*
      - *Less exposure to PGM pricing*
      - *Smaller package*
    - *Reduced system backpressure for reduced fuel consumption*

# Case 2 – Light-Duty Vehicle

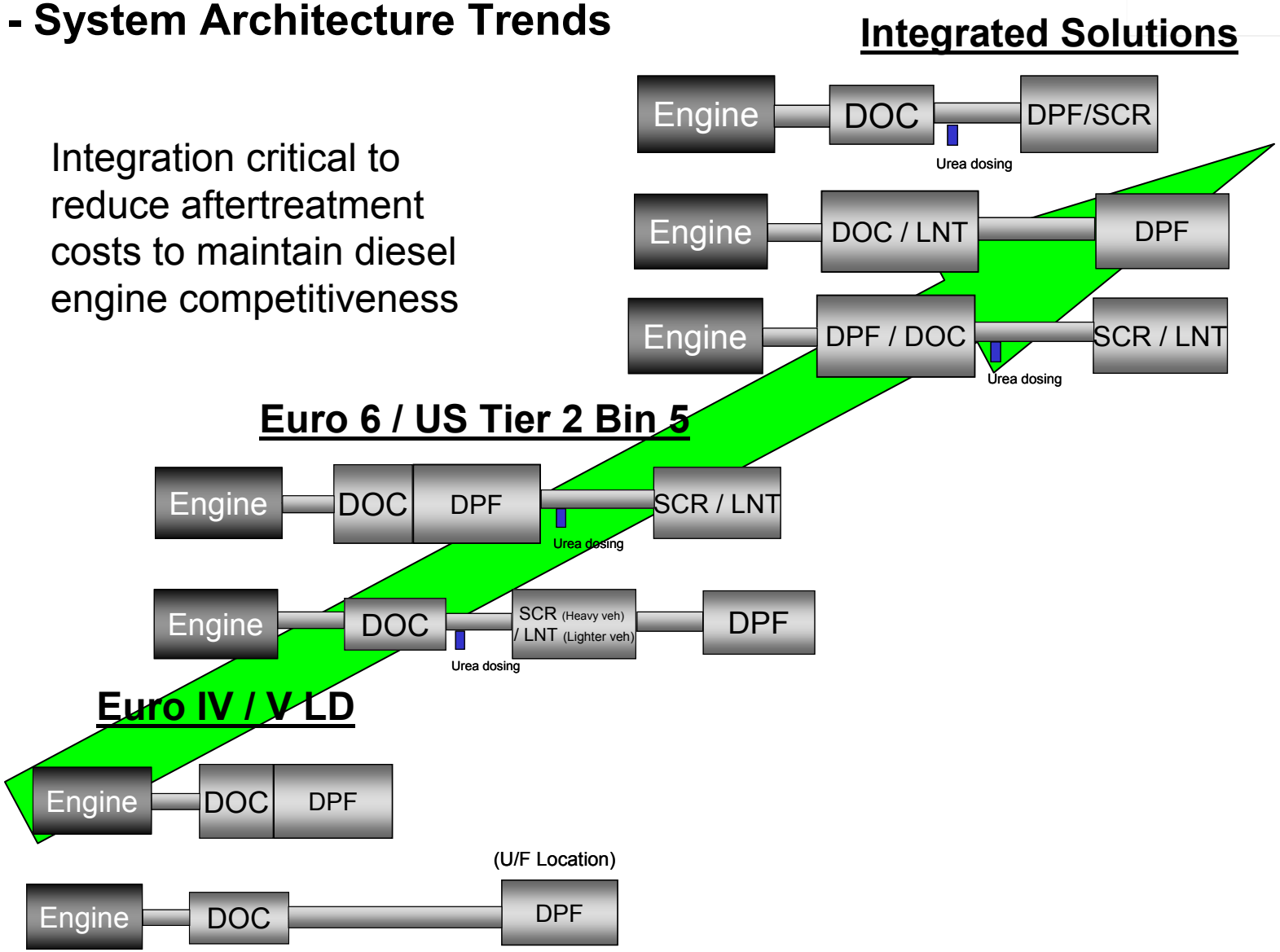
# Light Duty Needs

| LD Market Attribute | Engine Design Goals | Ways to Improve |
|---|---|---|
| • Aftertreatment is a large system expense for diesel – competing against gasoline engines | • Reduced system cost | • Reduce PGM usage<br>• Downsize the aftertreatment system<br>• Integration of aftertreatment |
| • Emission regulation | • Improved efficiency<br>• Reduce light-off time | • Improved catalyst technology<br>• Lower thermal mass substrates |
| • CO2 regulation | • Reduced fuel consumption | • Reduce post injection occurrences – more passive regeneration<br>•Reduced DPF backpressure for lower pumping losses |
| • Customer satisfaction | • Maintain / reduce warranty while implementing new substrate materials | • Find appropriate high porosity substrate materials |

# LD Diesel Aftertreatment

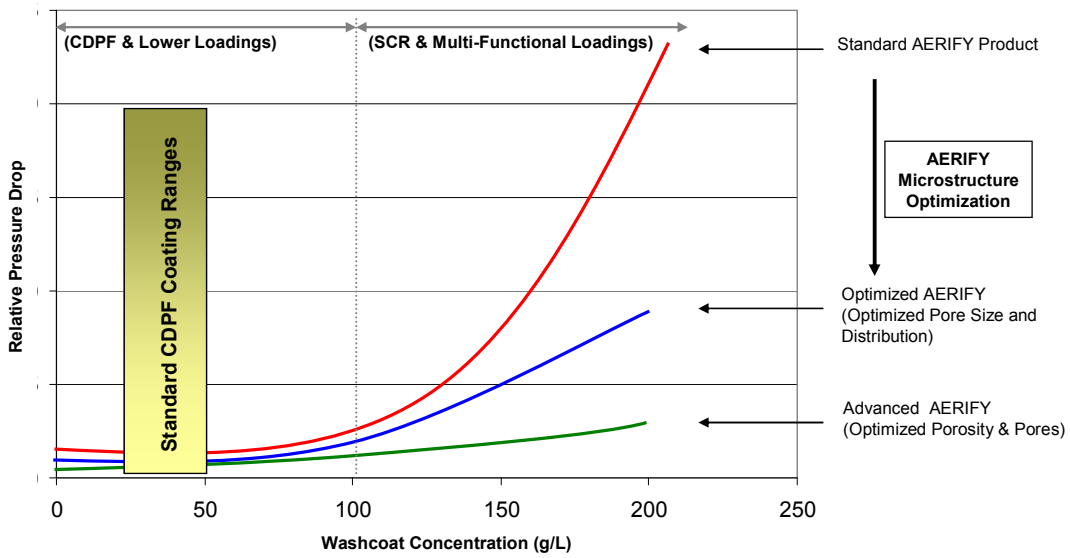
## - System Architecture Trends

Integration critical to reduce aftertreatment costs to maintain diesel engine competitiveness



# Superior Coatability and Strength at High Porosity-
## Enables Multi-function Substrates without FE penalty

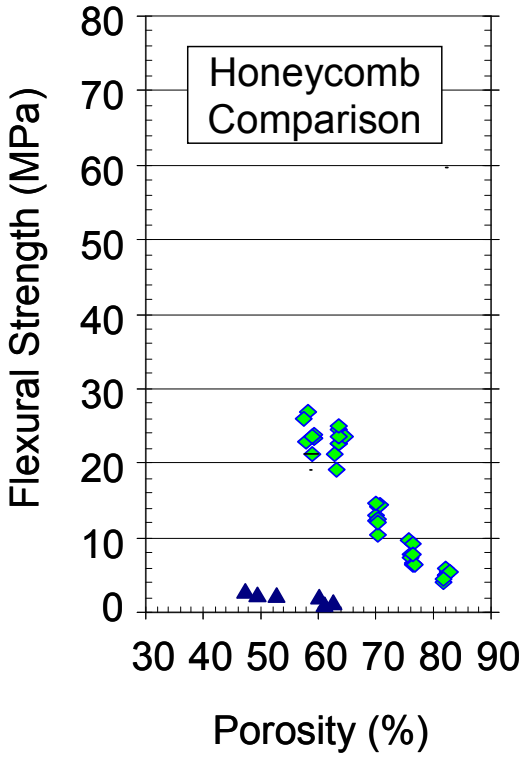
### Coatability



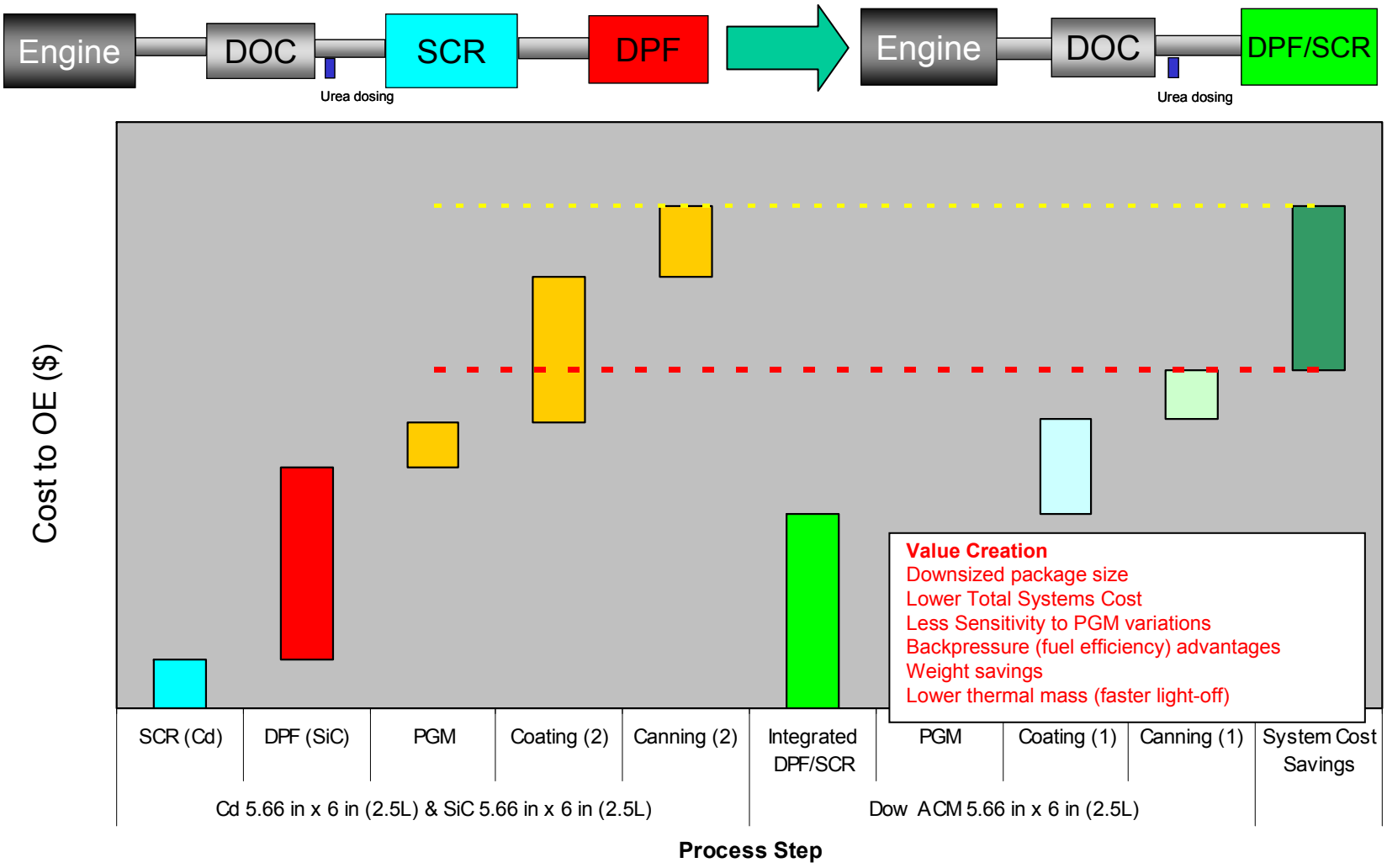

**Standard AERIFY : Low backpressure at low & moderate coating concentrations**
**Adv AERIFY: Add'l backpressure advantages at high coating concentrations**

Curves are a combination of modeling and test data

### Strength



# Value Analysis – LD (Integrated DPF/SCR)



# Light-Duty System

- Conclusions
  - *Light-duty vehicles have some unmet needs*
    - *Reducing the system cost*
    - *Reducing CO2 / fuel consumption due to regulation*
    - *Maintain durability performance*
  - *System architectures are evolving to help meet those needs*
    - *Integrated solutions are the trend*
    - *Improved controls enable high porosity solutions*
  - *New DPF products like Acicular Mullite meet multiple needs*
    - *Enable high washcoat loadings while minimizing backpressure on DPF*
    - *Eliminate separate substrates and cans to enable system cost savings*
    - *Provide higher soot mass limits and durability than other materials at the same porosity*


Thank You