

John Deere's Approach to Reducing Diesel Engine Emissions

The EGR Route

May 10, 2011

JOHN DEERE

Reducing Diesel Engine Emissions

John Radke

Manager, Worldwide Customer Support

John Deere Power Systems

- Emissions Regulations
- John Deere Solutions
- John Deere Value Proposition

The Right Technology. Right Now.

Interim Tier 4 Technology
PM & NOx Emissions Reduction Alternatives

Particulate Matter (PM) Reduction

1) Combustion Process In Cylinder
   - High Pressure Fuel System
   - Multiple Injection
   - Engine Timing
   - Power Cylinder Optimization
2) Exhaust Filter with DOC/DPF
3) Combination Solution
   - In-Cylinder Solution
   - Exhaust Filter



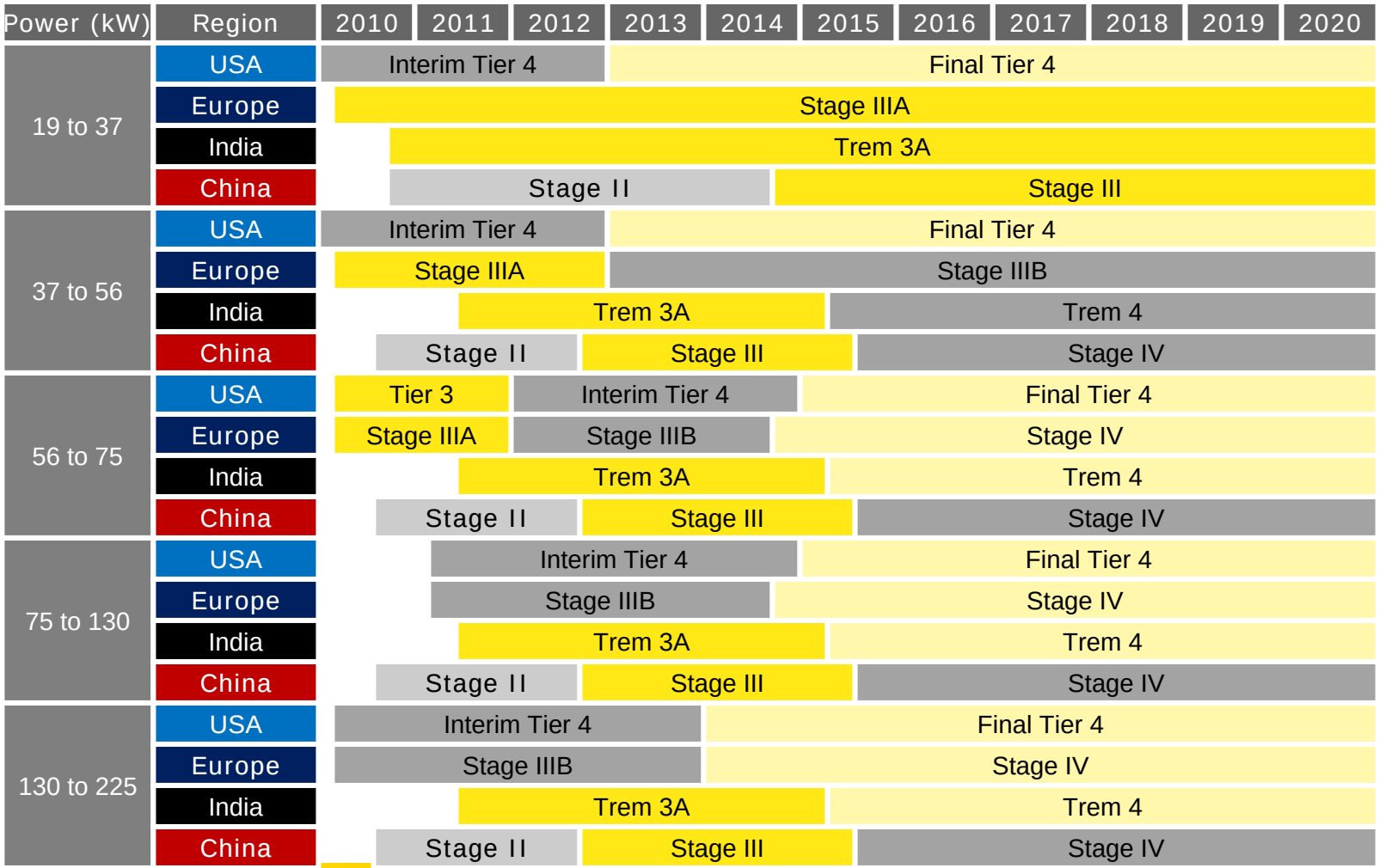
Oxides of Nitrogen (NOx) Reduction

1) Cooled EGR
2) Selective Catalytic Reduction (SCR)



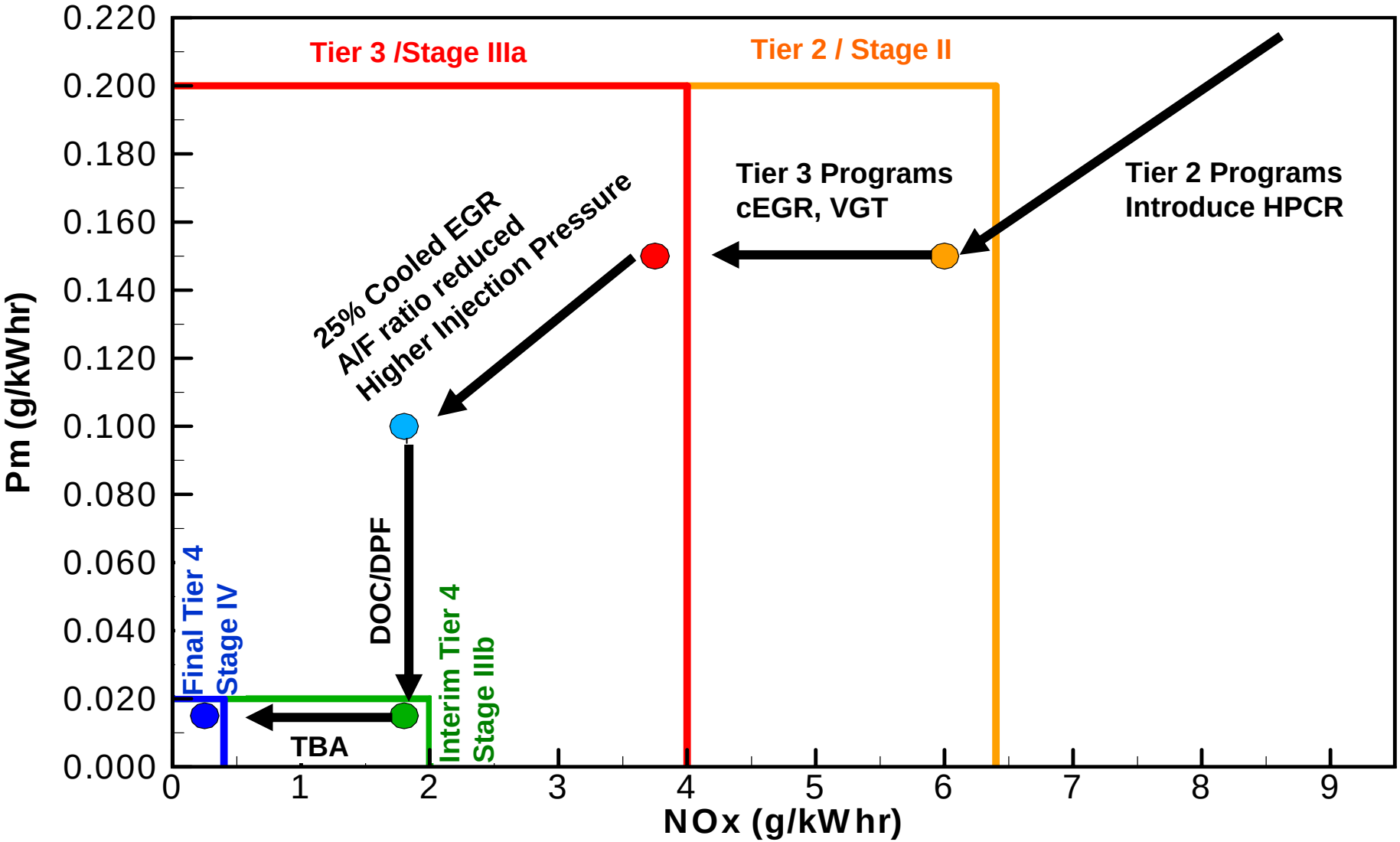
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The world is moving towards higher emissions standards (Some future dates are estimates)



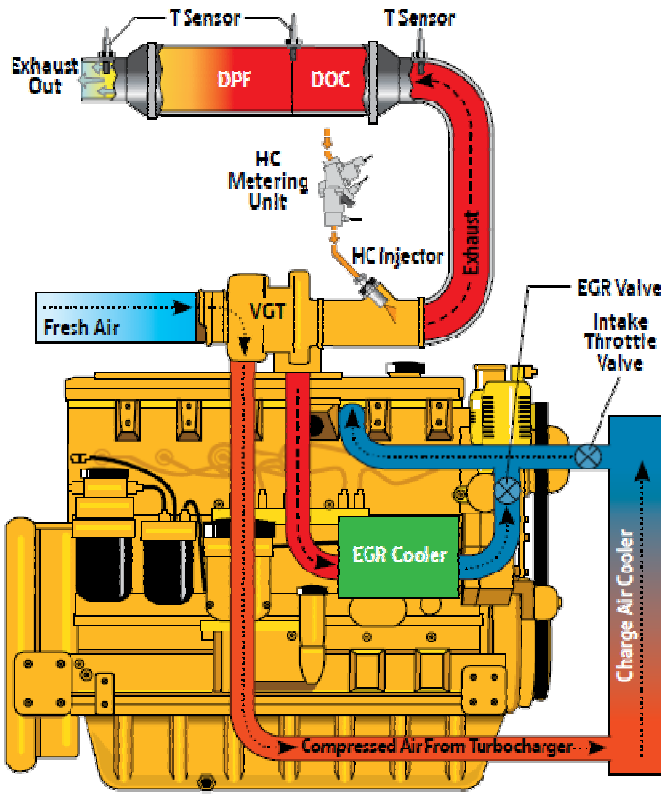
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Deere Engine Technology Roadmap

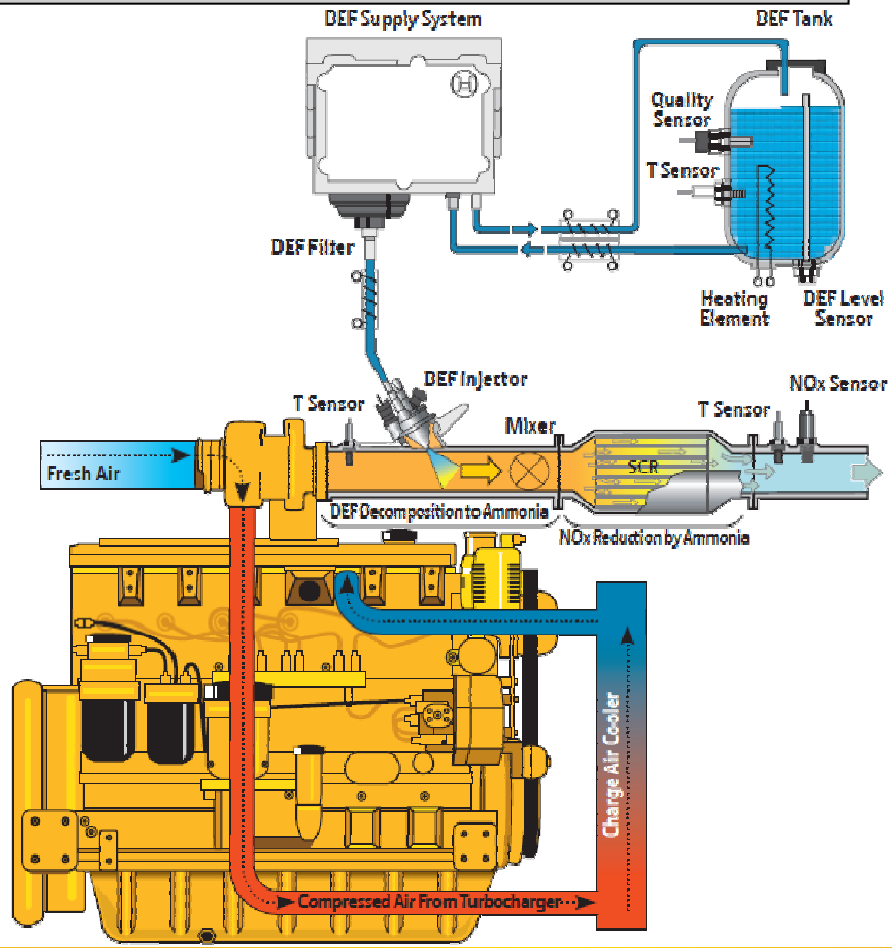


Interim Tier 4 Technology
PM & NOx Emissions Reduction Alternatives

Cooled EGR and Exhaust Filter

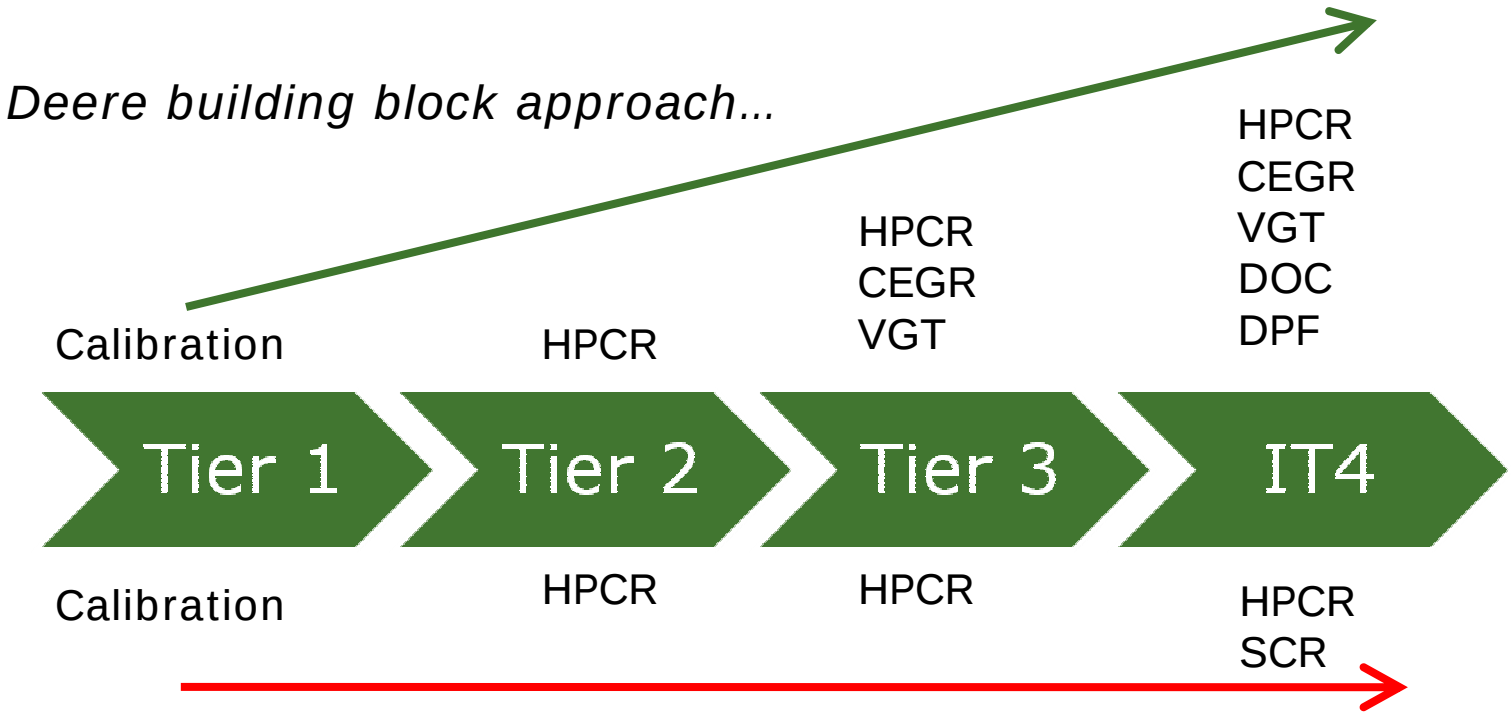


Selective Catalytic Reduction (SCR)



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Technology Progression



Interim Tier 4 Technology
PM & NOx Emissions Reduction Alternatives

Cooled EGR and Exhaust Filter		Selective Catalytic Reduction (SCR)

• **Cooled EGR system**
  • EGR cooler
  • EGR valve
	⟷	• **SCR system**
		  • SCR catalyst
		  • DEF tank
		  • DEF filter
		  • DEF sensors that monitor tank temperature and measure tank level
		  • Urea heating elements
		  • NOx sensor

• **Variable Geometry Turbocharger (VGT) or Series Turbochargers (VGT & Fixed)**	⟷	• **Fixed geometry turbocharger**
• **Exhaust filter (DOC & DPF)** • **Intake throttle valve**	⟷	• **In-cylinder solution**
• **Single fluid (diesel)** Key Adv.	⟷	• **Two fluids (diesel fuel & DEF)**

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Interim Tier 4 Technology
PM & NOx Emissions Reduction Alternatives

Cooled EGR and Exhaust Filter		Selective Catalytic Reduction (SCR)

• **Cooled EGR system**
  • EGR cooler
  • EGR valve
 	
More convenient
	⟷	• **SCR system**
		  • SCR catalyst
		  • DEF tank
		  • DEF filter
		  • DEF sensors that monitor tank temperature and measure tank [illegible]
		  • Urea heating elements
		  • NOx sensor
		
		More complex

• **Variable Geometry Turbocharger (VGT) or Series Turbochargers (VGT & Fixed)**	⟷	• **Fixed geometry turbocharger**
• **Exhaust filter (DOC & DPF)** • **Intake throttle valve**	⟷	• **In-cylinder solution**
• **Single fluid (diesel)** Key Adv.	⟷	• **Two fluids (diesel fuel & DEF)**

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Interim Tier 4 Engine Technology
The PowerTech™ Interim Tier 4 Solution

Cooled EGR for NOx Reduction – <u>The Simple Solution</u>

Cooled EGR provides customers with a simple solution for IT4

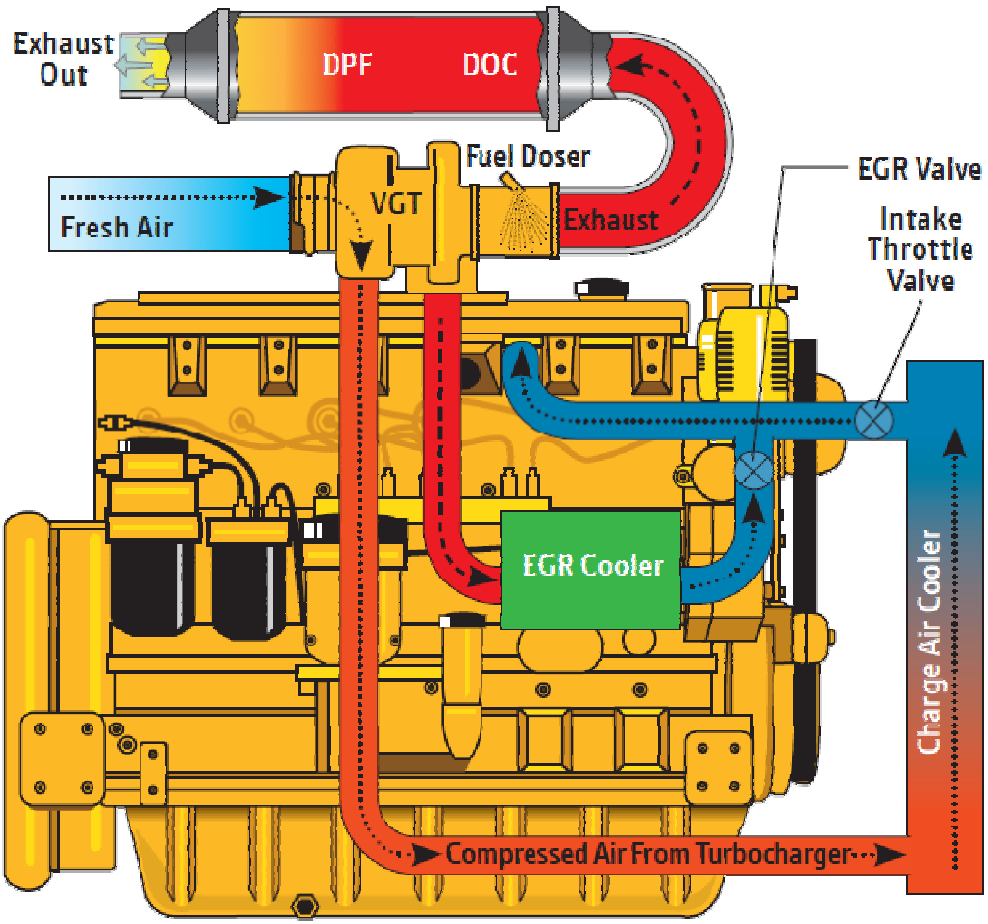
- Single fluid solution simplifies operator involvement
- Monitor and fill only one tank with diesel fuel
- Eliminates all DEF availability and storage concerns
- No DEF freezing or degradation concerns
- No de-rate issues associated with SCR

Cooled EGR First

- PowerTech Plus™ engines adopted cooled EGR technology for T3/Stage IIIA
- Cooled EGR technology is the foundation for Interim and Final Tier 4 emissions regulation requirements

Interim Tier 4 Engine Technology

The PowerTech™ Interim Tier 4 Solution



qPM Reduction (90%) with Exhaust Filter

qNOx Reduction (45%) with Cooled EGR

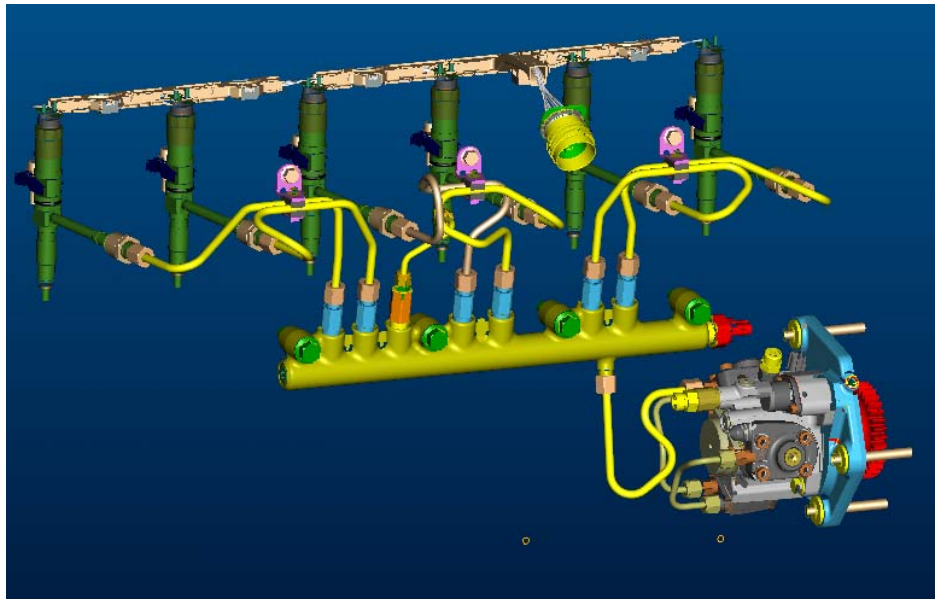
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Advanced Control System - ECU

- ECU Controls all Engine *and* Exhaust Filter Systems
- Increased Input/Output Capability (40%) Over Tier 3
  - Faster Response To Engine Sensor Inputs
  - Faster Reprogramming of ECU
- Next Generation Processor (faster)
- Internal Processor Memory Increased By Four Times
- RAM (random access memory) Doubled

Deere's ECU is fast and fully integrated

Interim Tier 4
High Pressure Fuel Systems



q Background

- Electronic - multiple fuel injections
- High pressure injection atomizes fuel into finer particles which burn more completely and reduce PM
- Deere fuel systems are the first step in equipment integrated for fuel economy

q Interim Tier 4

- Increase HPCR injection pressures up to 2000 bar (29,000 psi)
  - Ø 6.8L, & 9.0LEngines
- Increase EUI injection pressures up to 2275 bar (33,000 psi)
  - Ø 13.5L engine

Deere fuel systems optimize fuel economy, reducing operating costs

Interim Tier 4
Cooled EGR System

q Background

- Tier3 Platform use 10-15% EGR flow rates
- NOx formation occurs during high combustion temperatures
- EGR lowers oxygen levels during combustion, lowering combustion temps
- Cooling of EGR flow also helps to lower combustion temps

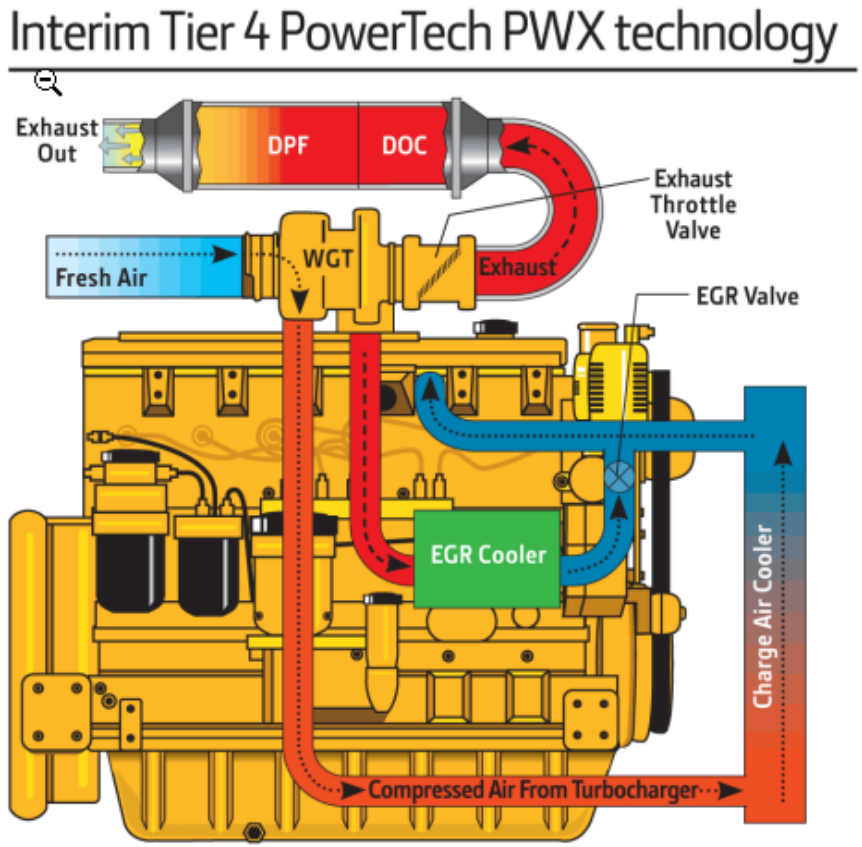
q Interim Tier 4

- Increasing EGR flow rates to 20-30% to further reduce NOx levels
- Optimized combustion from precise measurement of EGR flow rates
- The ECU is a key enabler of accurate EGR valve actuation, measurement and emissions control

Deere's EGR systems enable a single fluid IT4/S3B solution

Interim Tier 4 Technology
PowerTech™ PWX

- **Advanced Cooled EGR w/ Venturi Flow Measurement**
- **Exhaust Filter with DOC/DPF**
  - § Passive & Active Filter Cleaning
  - § In-Cylinder Hydrocarbon Dosing System
  - § Exhaust Temperature Management
- **Wastegated Turbocharger (WGT)**
- **High Pressure Fuel Systems**
- **Four-Valve Cylinder Head**
- **Full Authority Electronic Engine & <u>Aftertreatment</u> Controls**

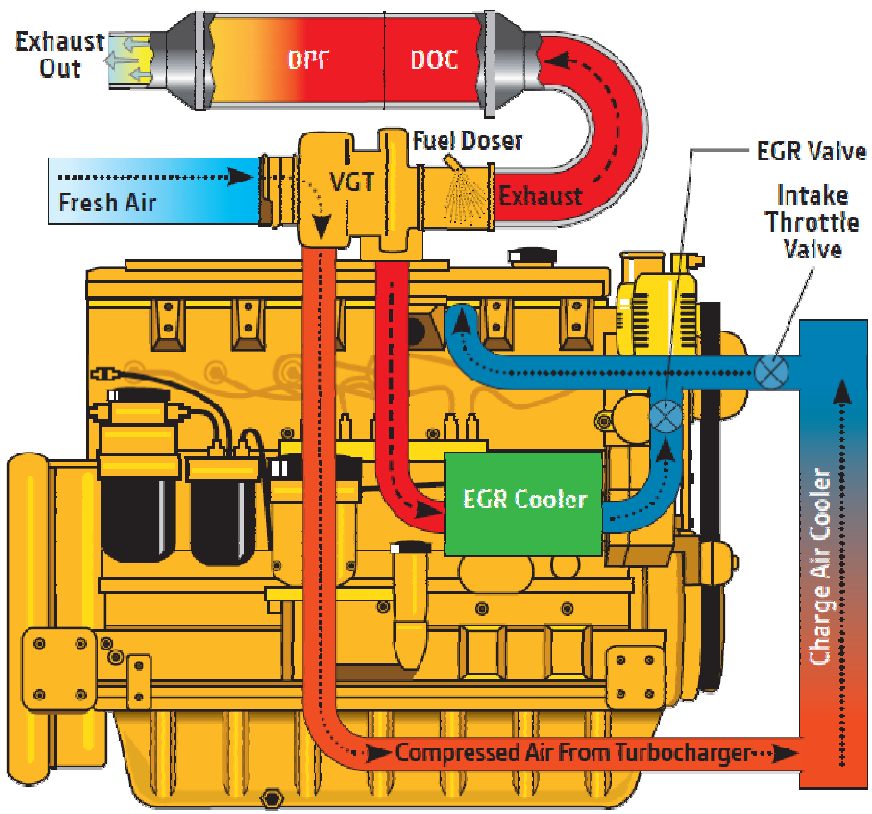


Deere designed a simpler, more convenient IT4/S3B solution

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Interim Tier 4 Technology
PowerTech™ PVX

- **Cooled EGR optimized flow measurement**
- **Exhaust Filter with DOC / DPF**
  - § Passive & Active filter cleaning
  - § External Hydrocarbon Dosing System
  - § Exhaust Temperature Management
- **PVX Variable Geometry Turbocharger (VGT)**
- **High Pressure Fuel Systems**
- **Four-Valve Cylinder Head**
- **Electronic Control Unit (ECU) with Aftertreatment Controls**

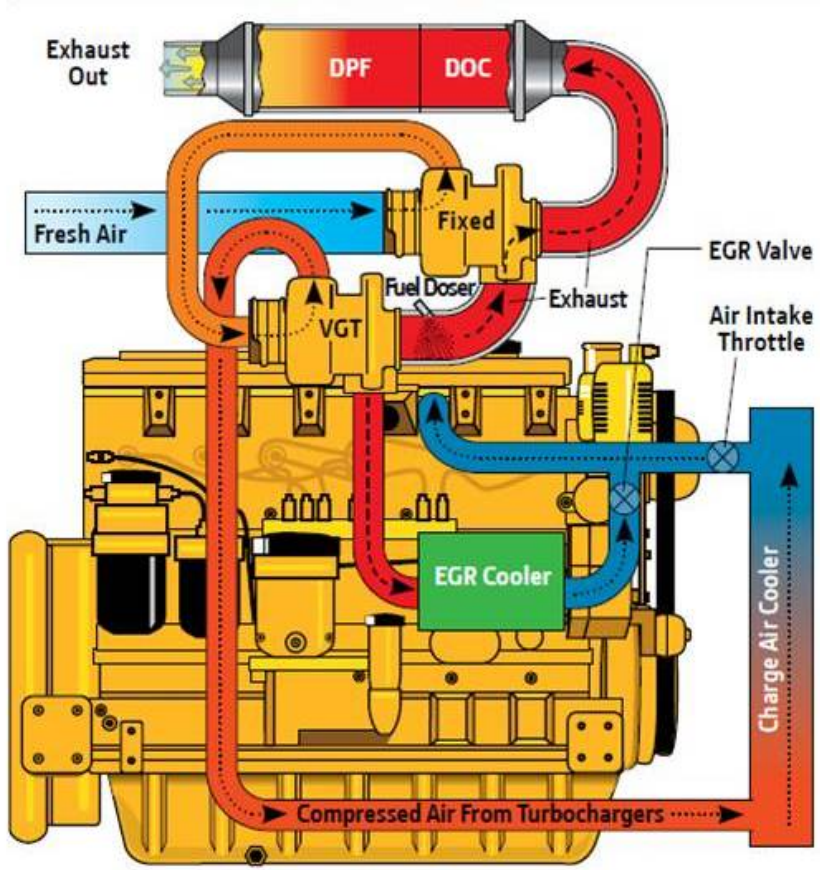


Deere designed a simpler, more convenient IT4/S3B solution

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Interim Tier 4 Technology
PowerTech™ PSX

- **Cooled EGR optimized flow measurement**
- **Exhaust Filter with DOC / DPF**
  - § Passive & Active filter cleaning
  - § External Hydrocarbon Dosing System
  - § Exhaust Temperature Management
- § **PSX - Series Turbocharging**
  - § Variable Geometry Turbocharger (high pressure)
  - § Fixed Geometry Turbocharger (low pressure)
- **High Pressure Fuel Systems**
- **Four-Valve Cylinder Head**
- **Electronic Control Unit (ECU) with Aftertreatment Controls**



Deere designed a simpler, more convenient IT4/S3B solution

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Interim Tier 4 Experience



- Fully meets emission standards
- Strong engine performance and uptime
- Operator recognition of improvements over Tier 3



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The Right Technology. Right Now.

The John Deere Stage IIIB/IT4 advantage is clear:

- **A simple solution**
- **A field proven solution**
- **An integrated equipment solution**
- **A fuel efficient solution**
- **A fully supported solution**

Deere 9.0L was the first engine to be IT4/Stage 3B Certified

Customer Preferred Technology – Fully Validated

(>174hp)

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108,000 Vehicle



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