

## The FEV GT<sup>2</sup> Engine

A Downsized & Sequentially Boosted Engine  
Concept for Fuel Economy

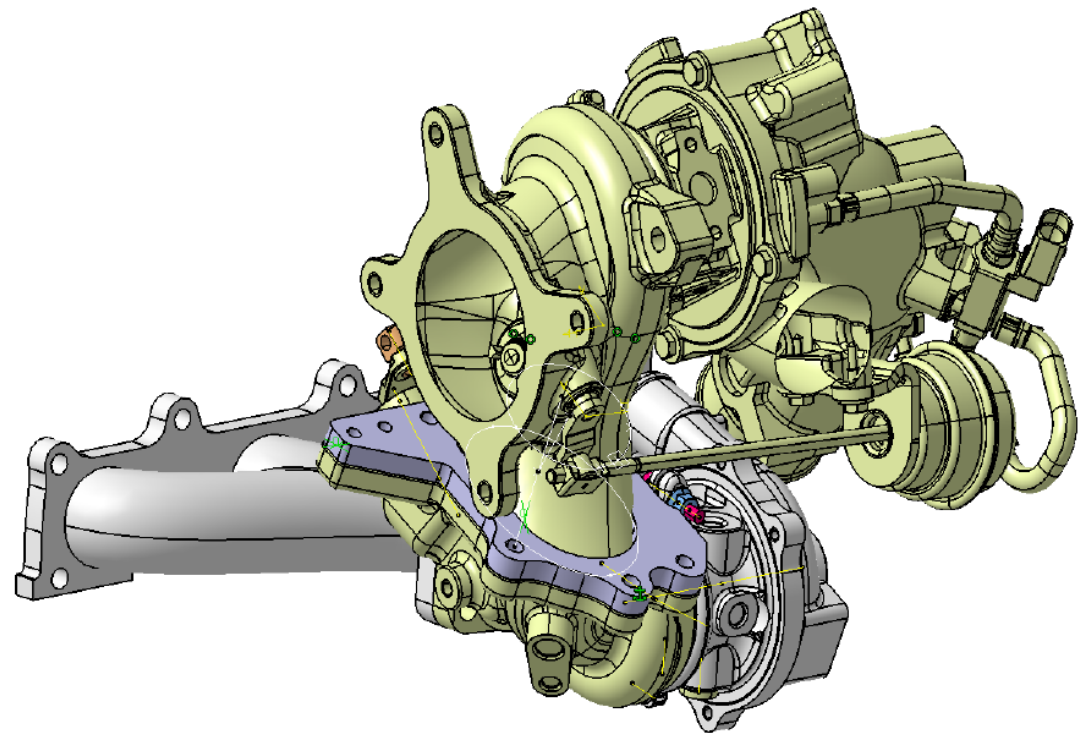
prepared for: *ENGINE EXPO 2012*

Tuesday, October 23<sup>rd</sup>, 2012



## Agenda

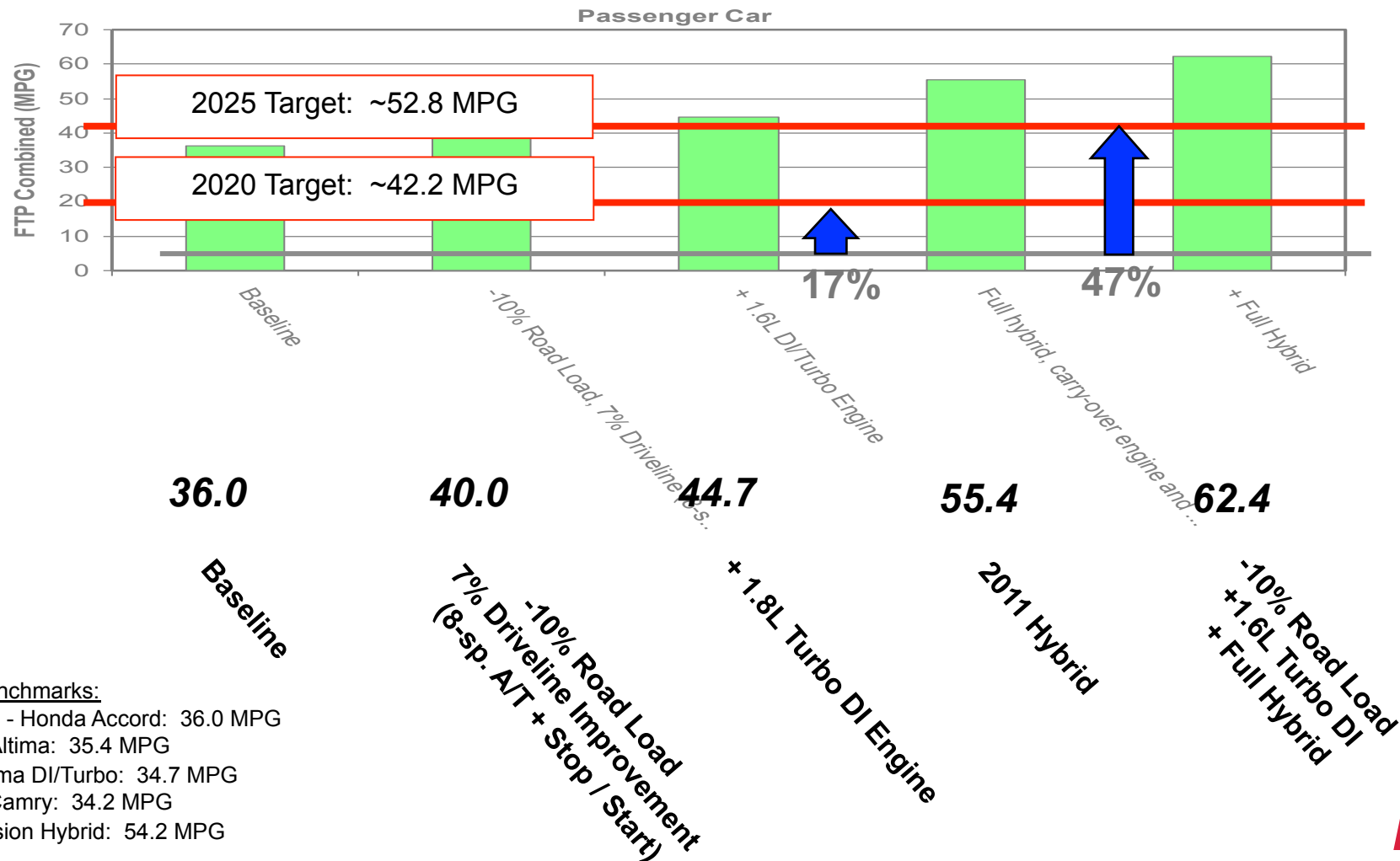
- 2025 Café Requirements
- Demonstrator Development
  - Reason for the FEV GT<sup>2</sup> engine
  - Engine Concept Selection
  - Engine Development
  - Vehicle Build
  - Achievements
- Meeting Future Café Standards
- Conclusions



# The FEV GT<sup>2</sup> Engine 2025 Café Requirement

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## The Challenge: Mid-Size Passenger Car



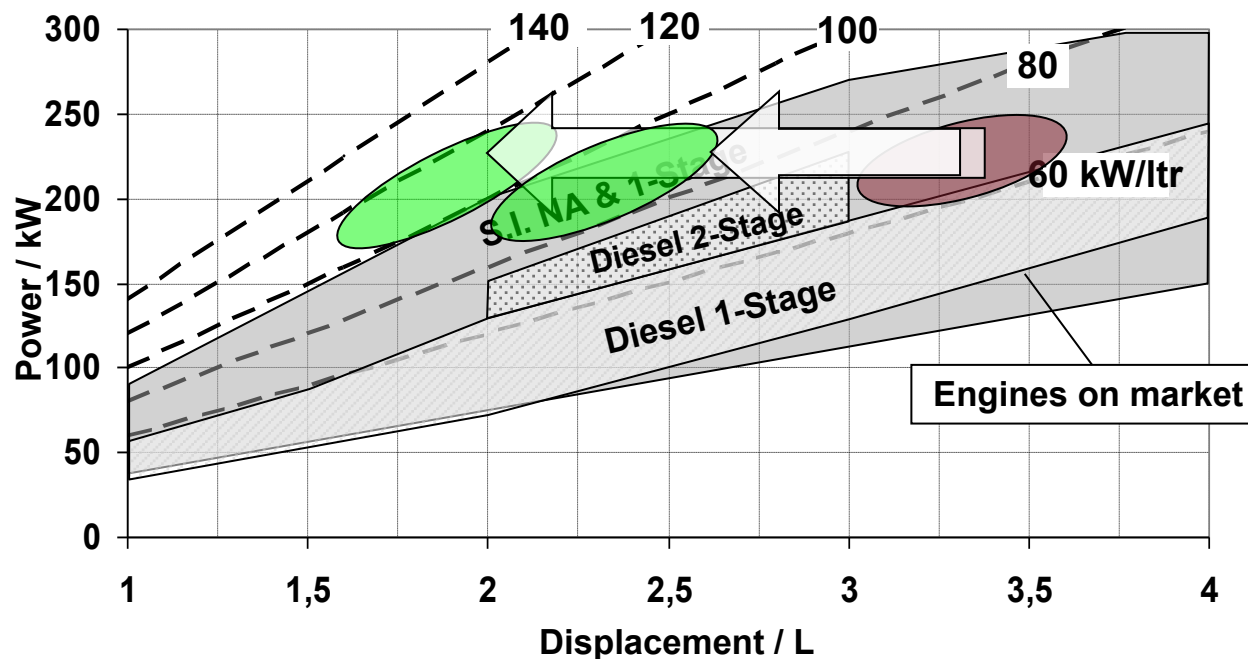
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# The FEV GT<sup>2</sup> Engine Demonstrator Development



## Reason for the FEV GT<sup>2</sup> Engine

- Maximize the fuel consumption benefits from downsizing
- Expand beyond current downsizing limits
  - Power density limited to 90~100kW/L → limited downsizing capability
  - High power density translates to poor transient response
  - Minimizes benefits of 7/8/9 speed transmissions

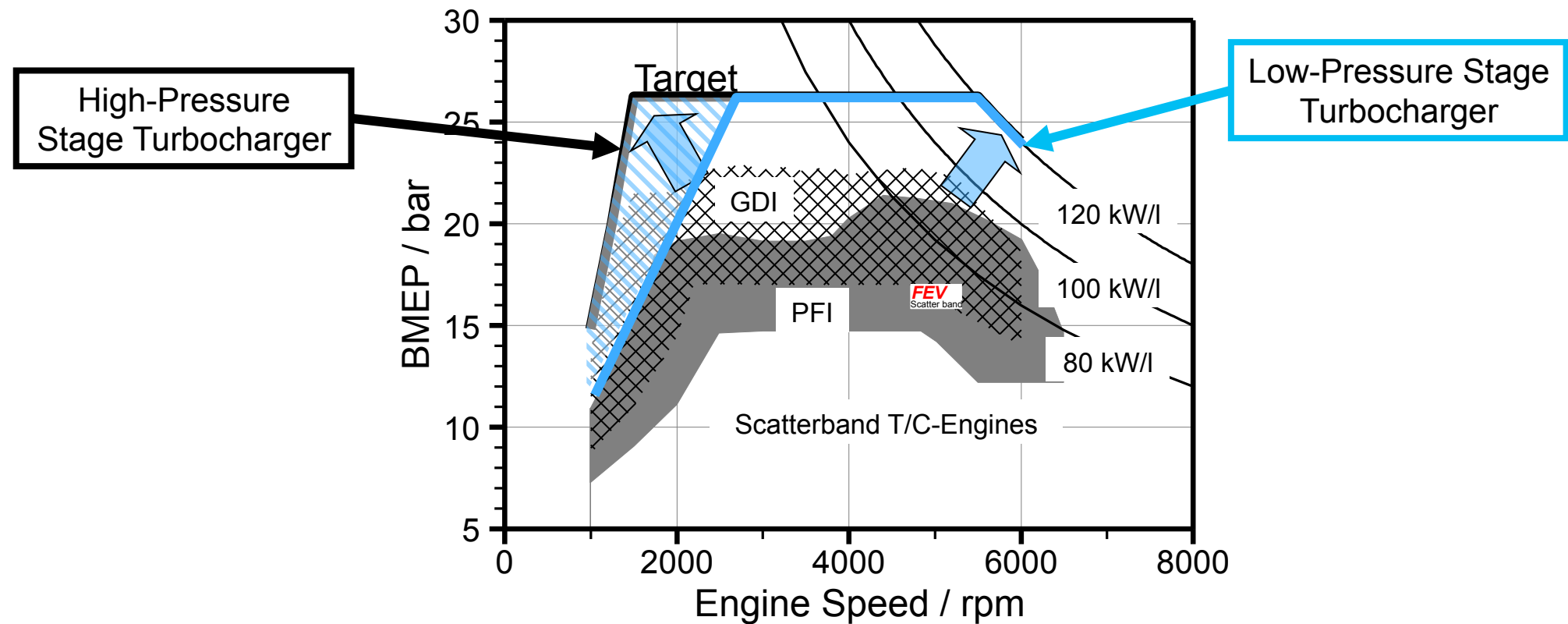


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## Engine Concept Selection

- Torque curve for maximum downsizing
  - Replace a 3.5L V6 NA engine with no degradation in performance



**Sequential Boosting System Required**

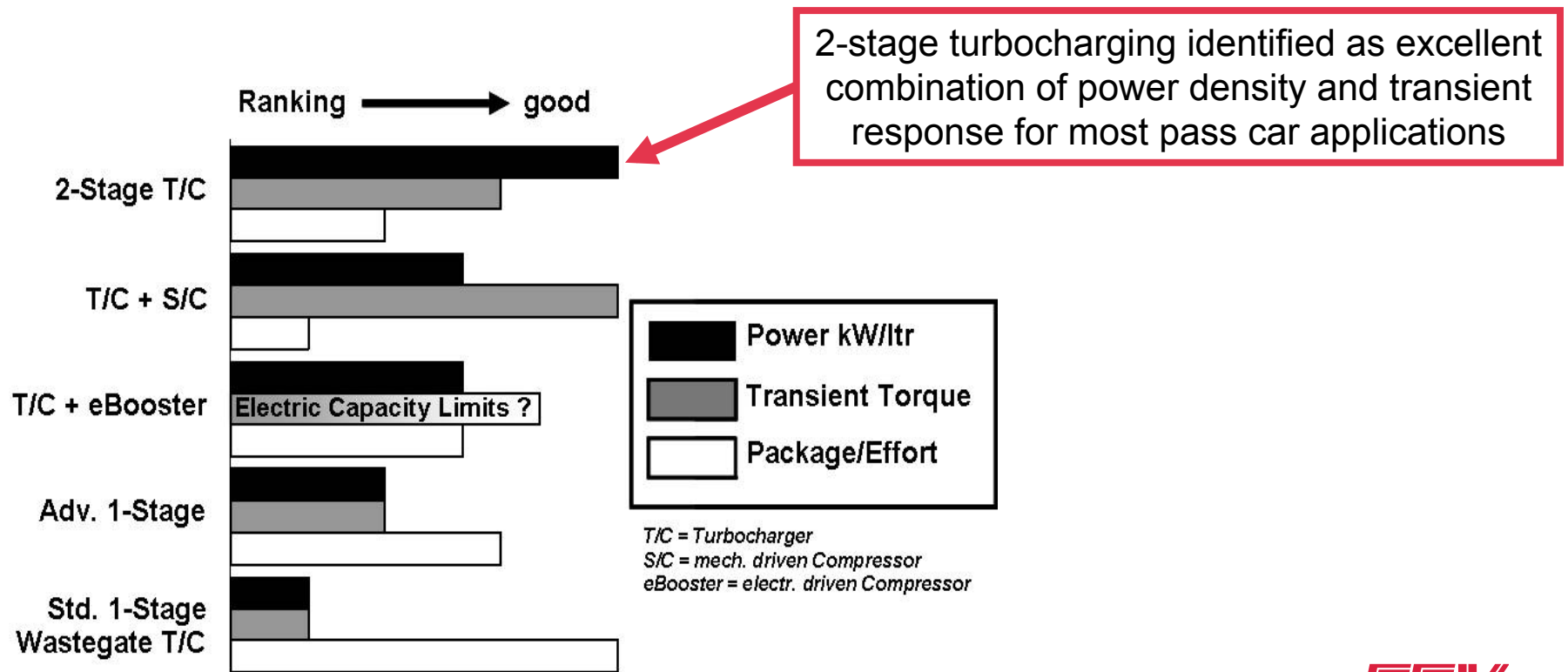
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## Engine Concept Selection

- Several concepts evaluated w/ respect to power, transient response, and packaging
  - Transient torque → maximize for downsizing capability
  - Power density → maximize for performance

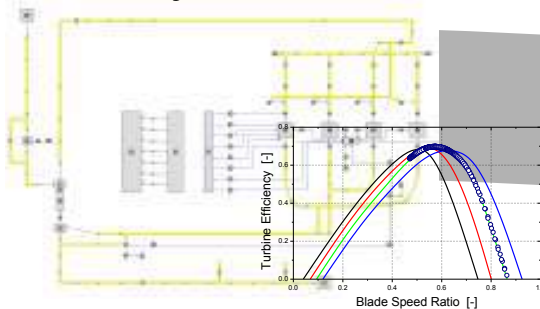




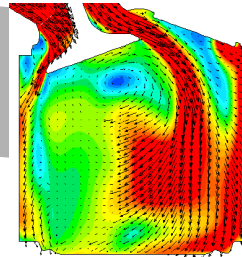
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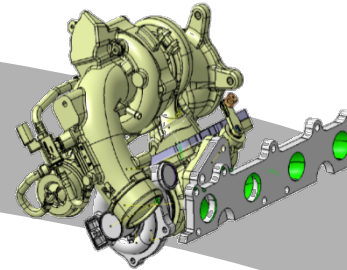
1D System Simulation



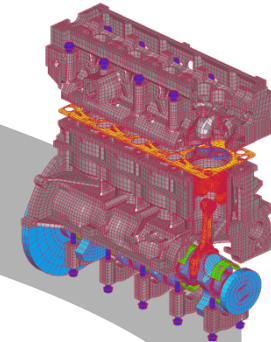
*CMD* Combustion  
Development



Design



CAE



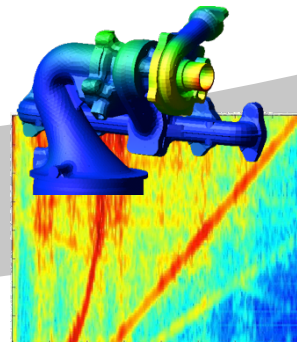
## Engine Development Using FEV's Toolchain



Vehicle Integration



Engine Testing



Acoustics



Turbocharger  
Bench Testing



Inspection  
&  
Assembly

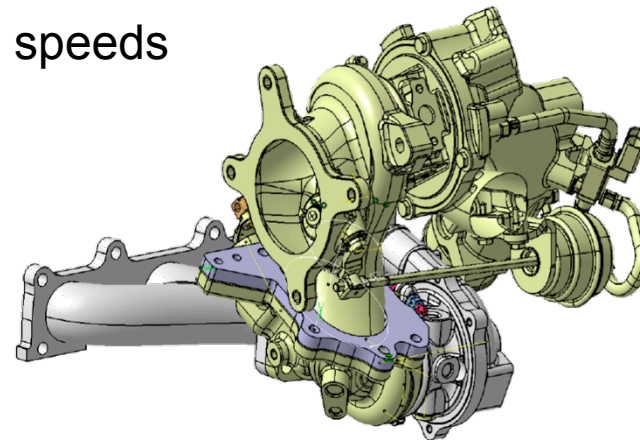
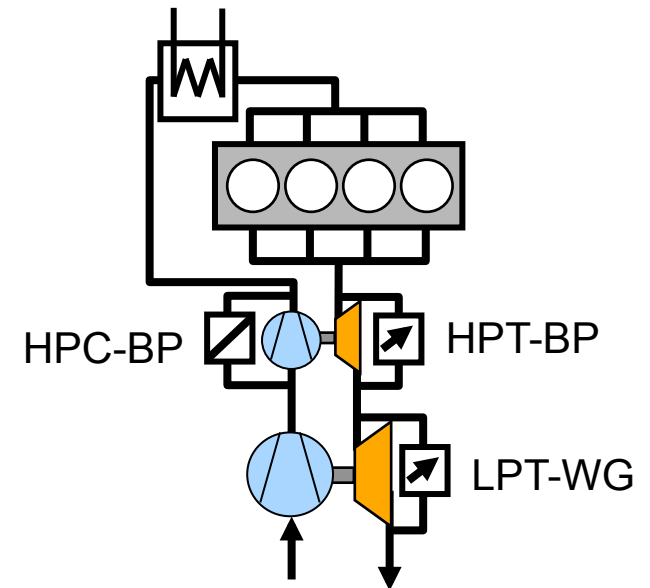
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# The FEV GT<sup>2</sup> Engine Demonstrator Development

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## Engine Development – Boosting System

- High-pressure turbine bypass (HPT-BP)
  - Vacuum actuated
  - Bypass valve acts as wastegate at low engine speeds
  - Fully bypassed at high engine speeds
- High-pressure compressor bypass (HPC-BP)
  - Vacuum actuated
  - on/off bypass (active)
  - complete mass flow bypassed at high engine speeds
- Low-pressure turbine (LPT-WG)
  - Positive pressure actuated
  - Conventional wastegate function



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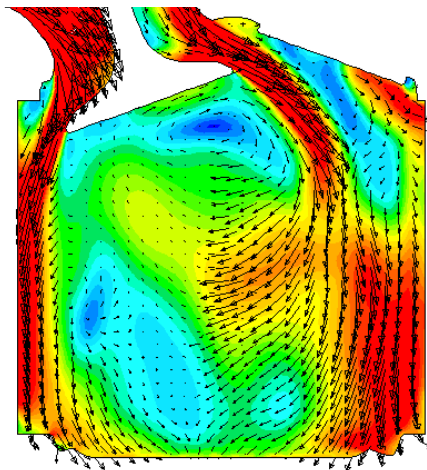


# The FEV GT<sup>2</sup> Engine Demonstrator Development

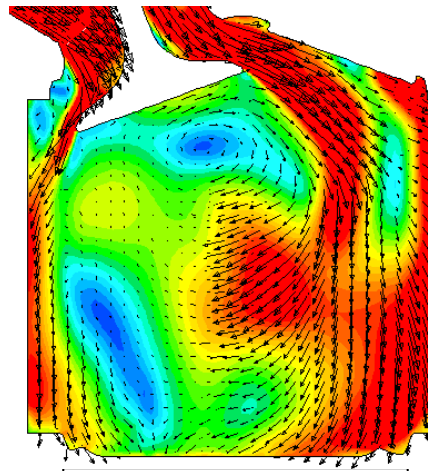
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## Engine Development – Combustion System

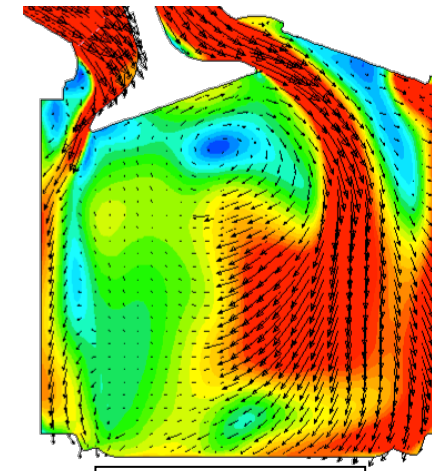
### ■ CMD Results



Base System

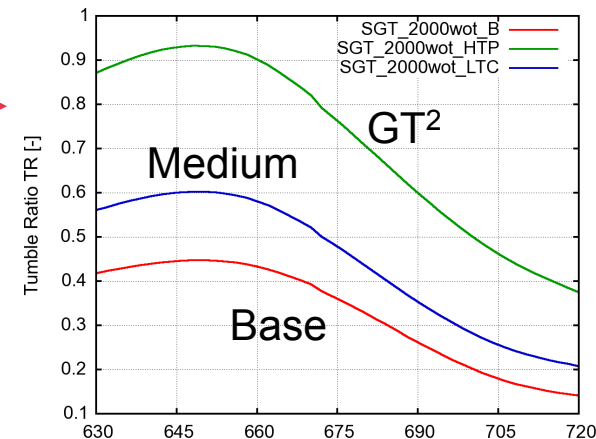
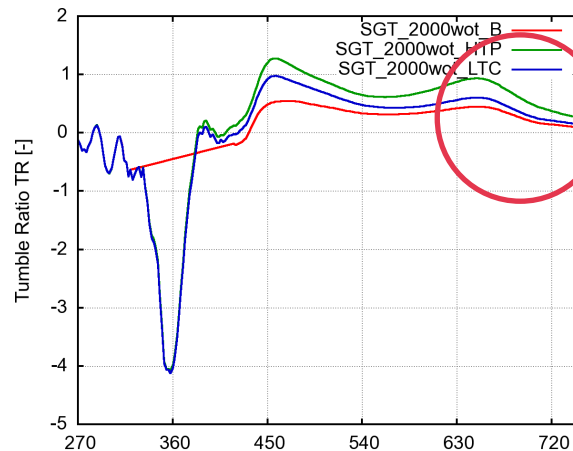


Medium Tumble



GT<sup>2</sup> System

Flow Velocities  
@ 460°



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# The FEV GT<sup>2</sup> Engine Demonstrator Development

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## Vehicle Build

- 2005 Ford Focus ST
  - Minimal base engine integration effort
- Production transmission
- Production style charge air cooler
- Production style catalyst



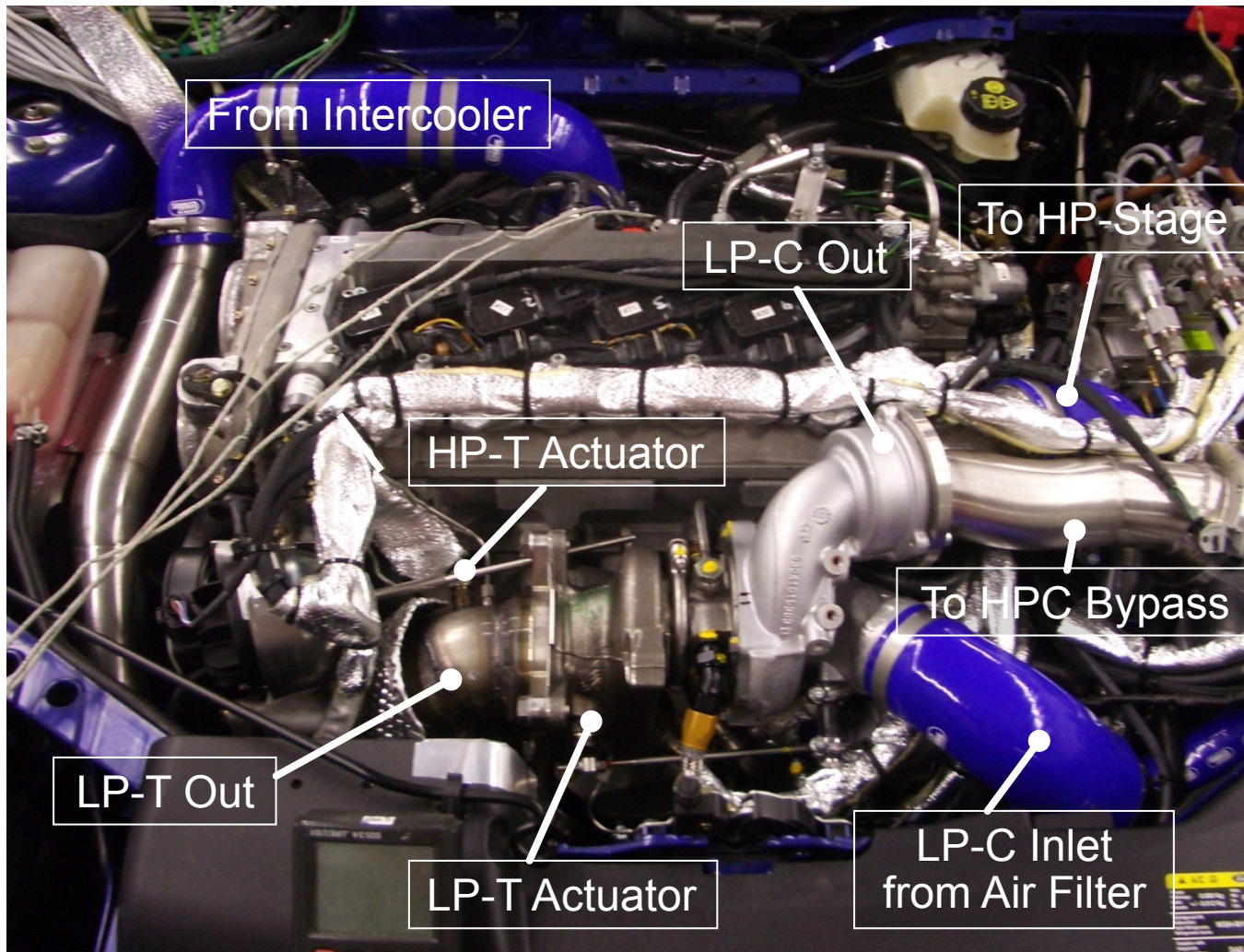
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## Vehicle Build – Compact Integration



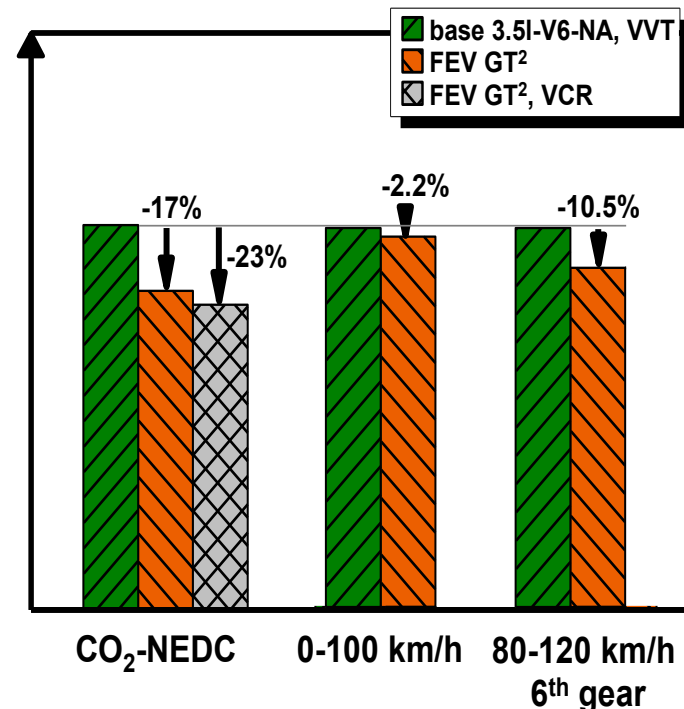
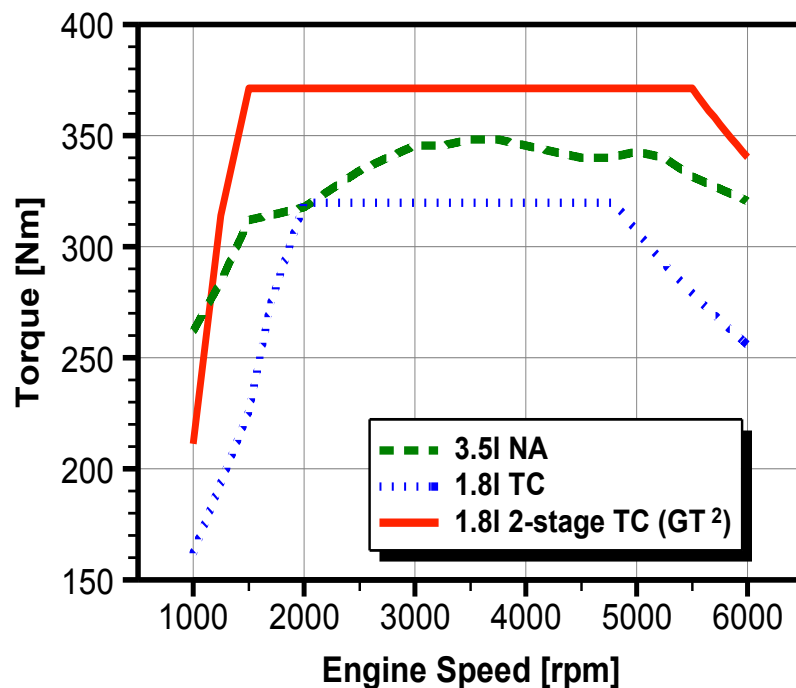
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# The FEV GT<sup>2</sup> Engine Demonstrator Development

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## Achievements

- Significant improvements in fuel consumption and acceleration were made over a baseline 3.5L NA engine
- 2-Stage turbocharging is a flexible concept for extreme downsizing
- CMD developed combustion system enables high pressure charging



Simulation based on  
calibrated GT<sup>2</sup> 1D model  
for a 1,900kg vehicle

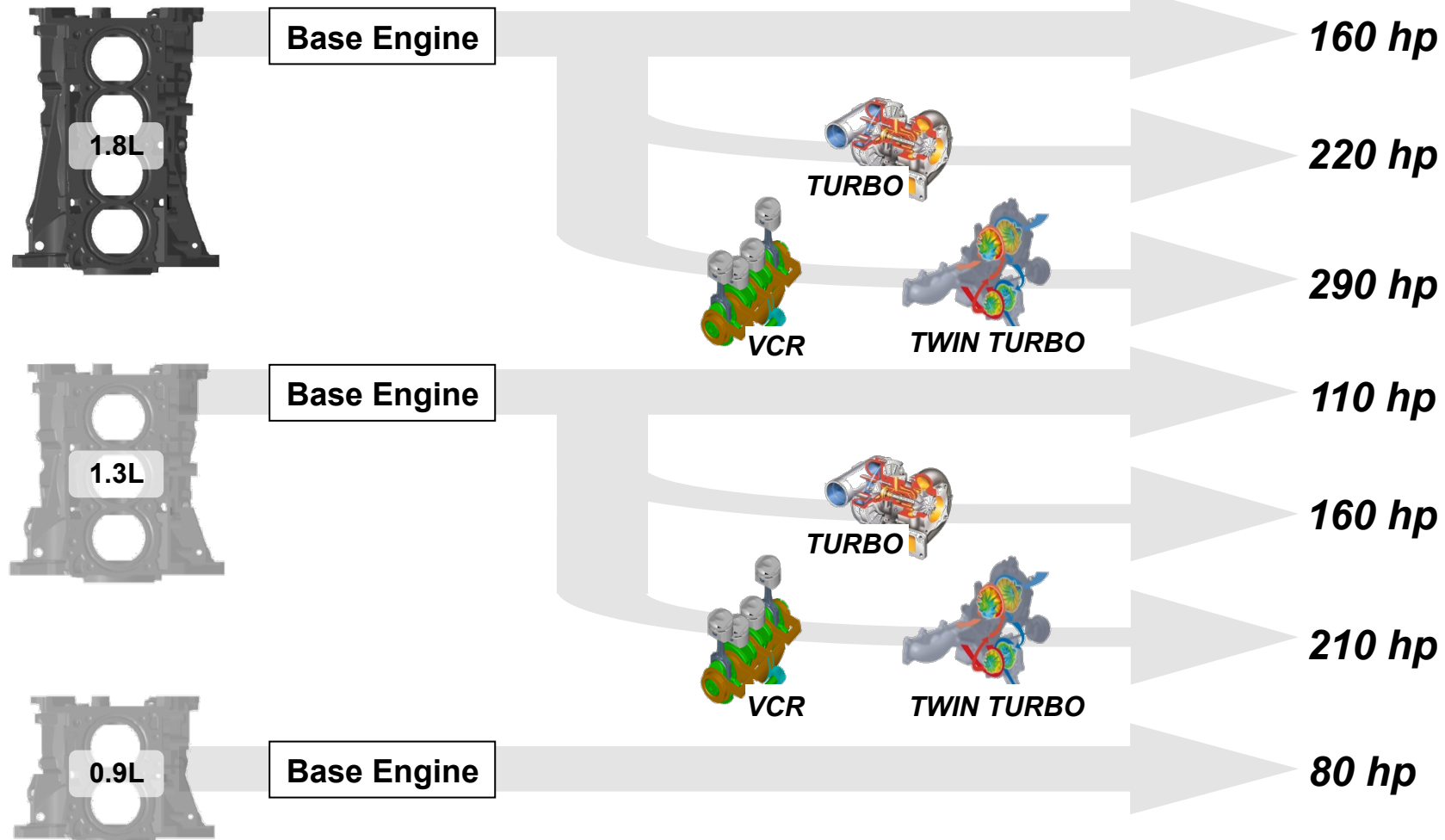
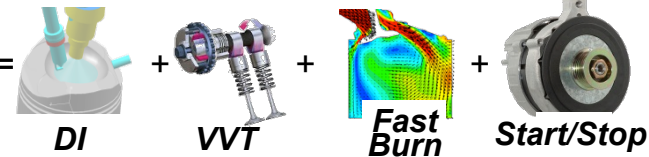
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# The FEV GT<sup>2</sup> Engine Meeting Future CAFÉ Standards

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## Potential GT<sup>2</sup> Engine Family

Base Engine


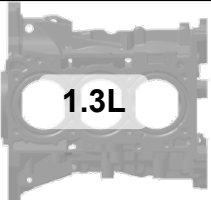
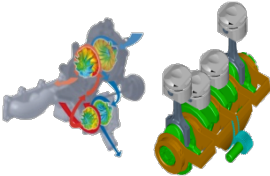


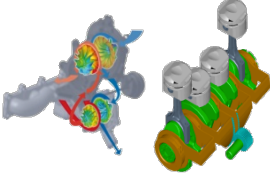

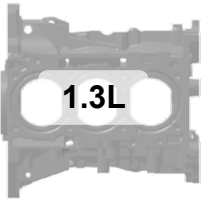
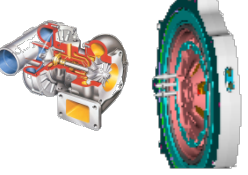





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# The FEV GT<sup>2</sup> Engine Meeting Future CAFÉ Standards

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## Example Mid-Size Vehicle Line-up

<i>Application</i>	<i>Powertrain</i>	<i>Technology</i>	<i>MPG</i>	<i>2025 Output</i>	<i>2011 Output</i>
 <b>Entry Level</b>	 <b>1.3L</b>		<b>46</b>	<b>210hp</b> (-25% vs '11)	<b>280hp</b> ~50% Market
 <b>Sport/Premium</b>	 <b>1.8L</b>		<b>41</b>	<b>290hp</b> (-17% vs '11)	<b>350hp</b> ~20% Market
 <b>Hybrid Electric</b>	 <b>1.3L</b>		<b>65</b>	<b>140hp</b>	<b>N/A</b> ~25% Market
 <b>RE Electric</b>	 <b>0.9L</b>		<b>~100</b>	<b>80hp</b>	<b>N/A</b> ~5% Market

Assumed vehicle enablers:  
 20% road load imp.  
 7% driveline imp.  
 750lbm reduction

**Example Product Mix Averages 50.6mpg**

**\*\*excluding credits for hybrid and electric vehicles**

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# The FEV GT<sup>2</sup> Engine

## Meeting Future CAFÉ Standards

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### Conclusions

- Highly boosted and extremely downsized engines can be a cost competitive approach to meeting future CAFÉ standards
- Reduction in the number of engine families and the increased use in technology will reduce the cost penalty
- Energy recovery, mild and full hybrid, will need higher penetration but will not be required for all vehicles
- Internal combustion engines will remain the primary propulsion system for automotive applications for the foreseeable future