



FEV Racing Engines

What or who the hell is FEV ?



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Short overview of FEV capability & experience to date



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FEV relevant design experience and expertise (non sensitive)

GT Racing V8 also used at LeMans

Engaged on design of 3 x F1 V8's for 2006 season

Direct injection

Racing marine engine

7 speed transmission for WRC

Diesel –

Design improvement, performance development and testing for Paris-Dakar

Light weight Aero engine

High performance / light weight race Diesel engines

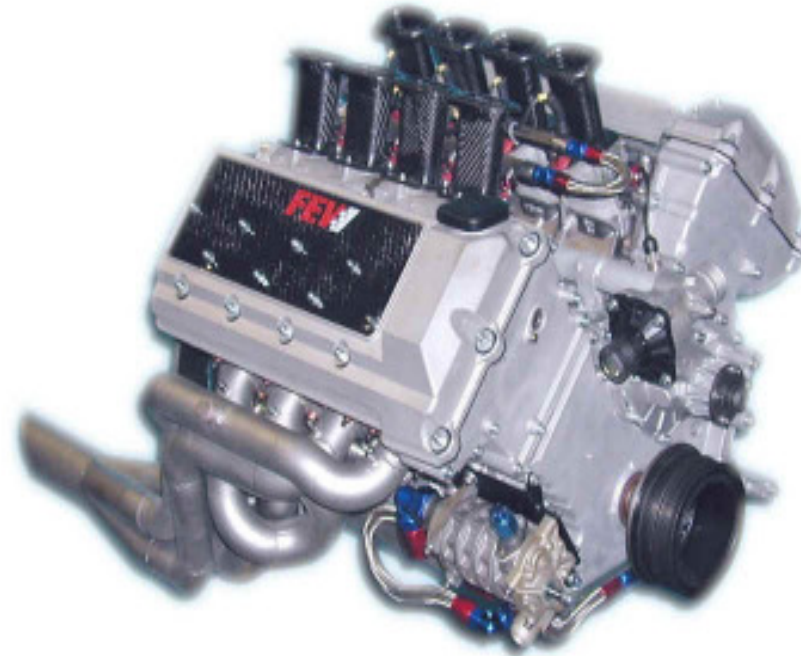
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FEV relevant design experience and expertise



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FEV relevant design experience and expertise

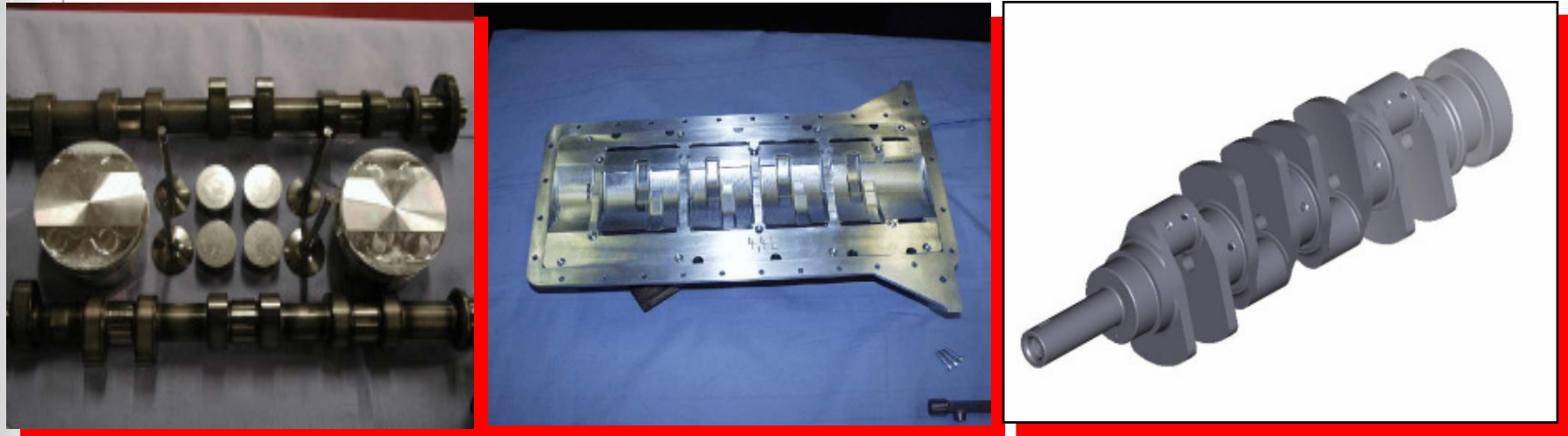


FEV's race engine powering a BMW E46 M3 GTR

FEV

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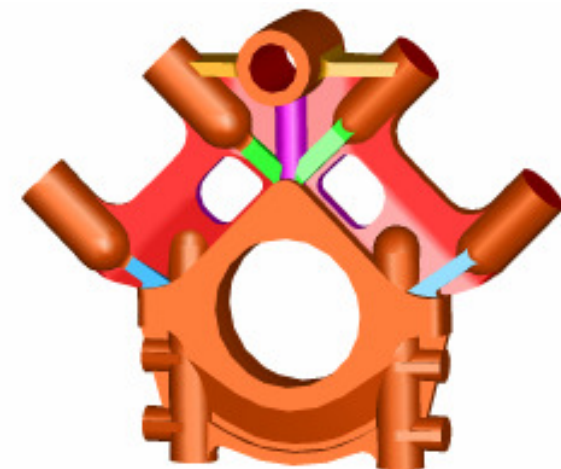
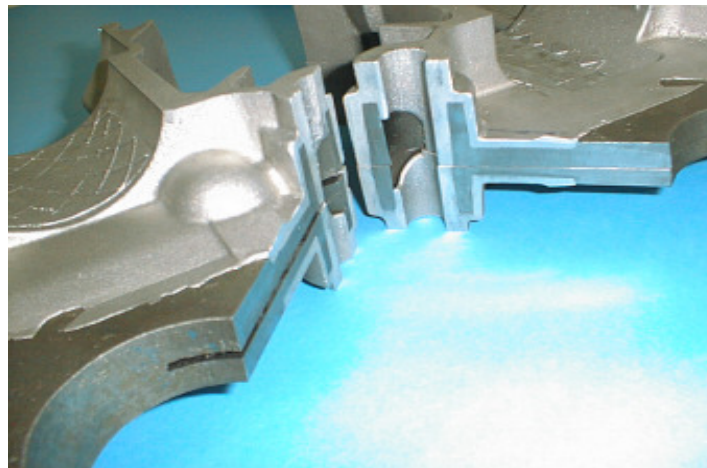
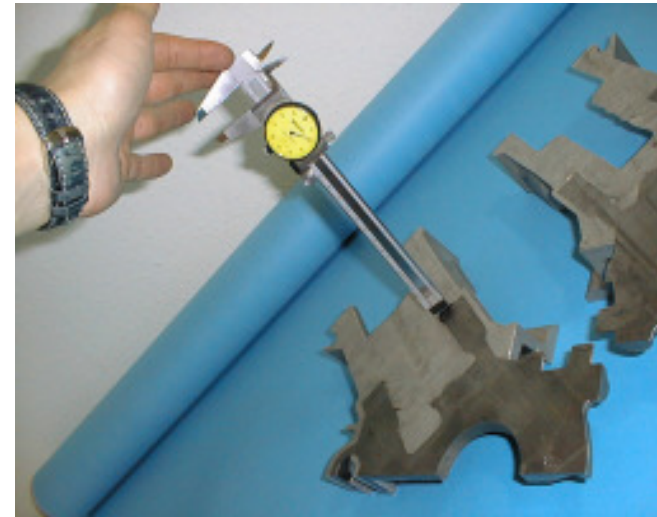
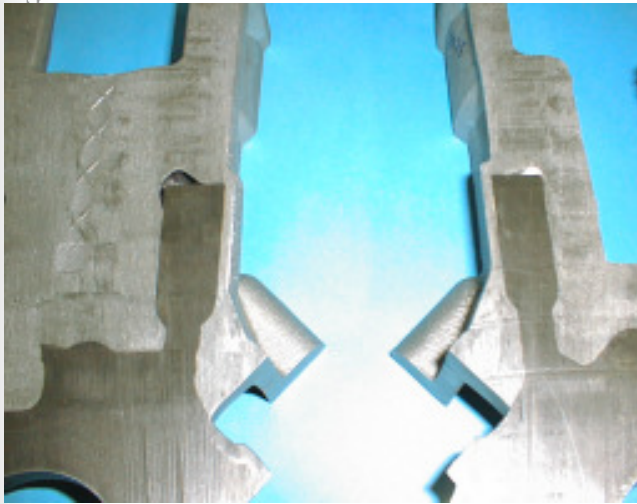
FEV relevant design experience and expertise



Lightest weight component design
fully supported / optimised by FEA

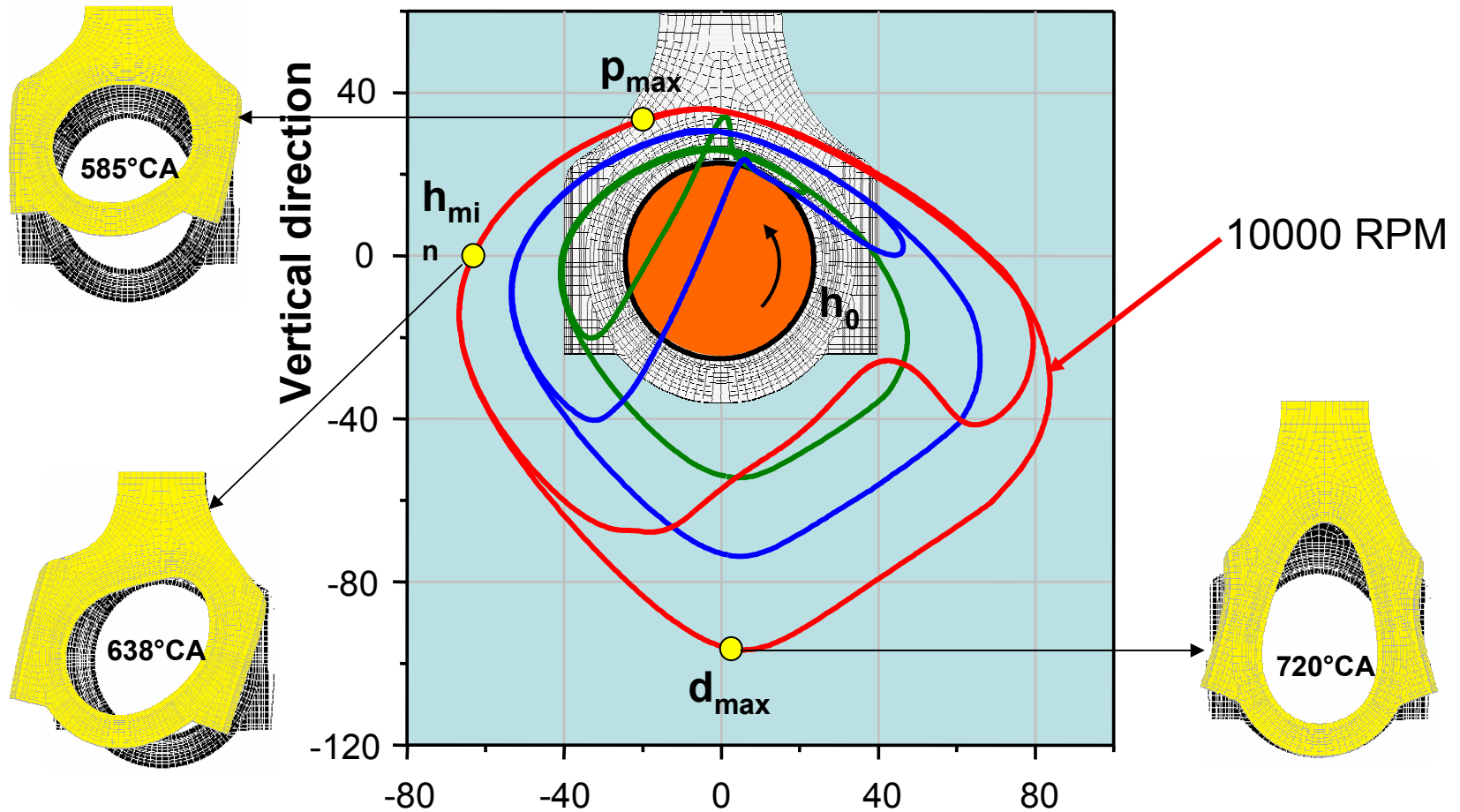
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Weight (and package size) reduction by design



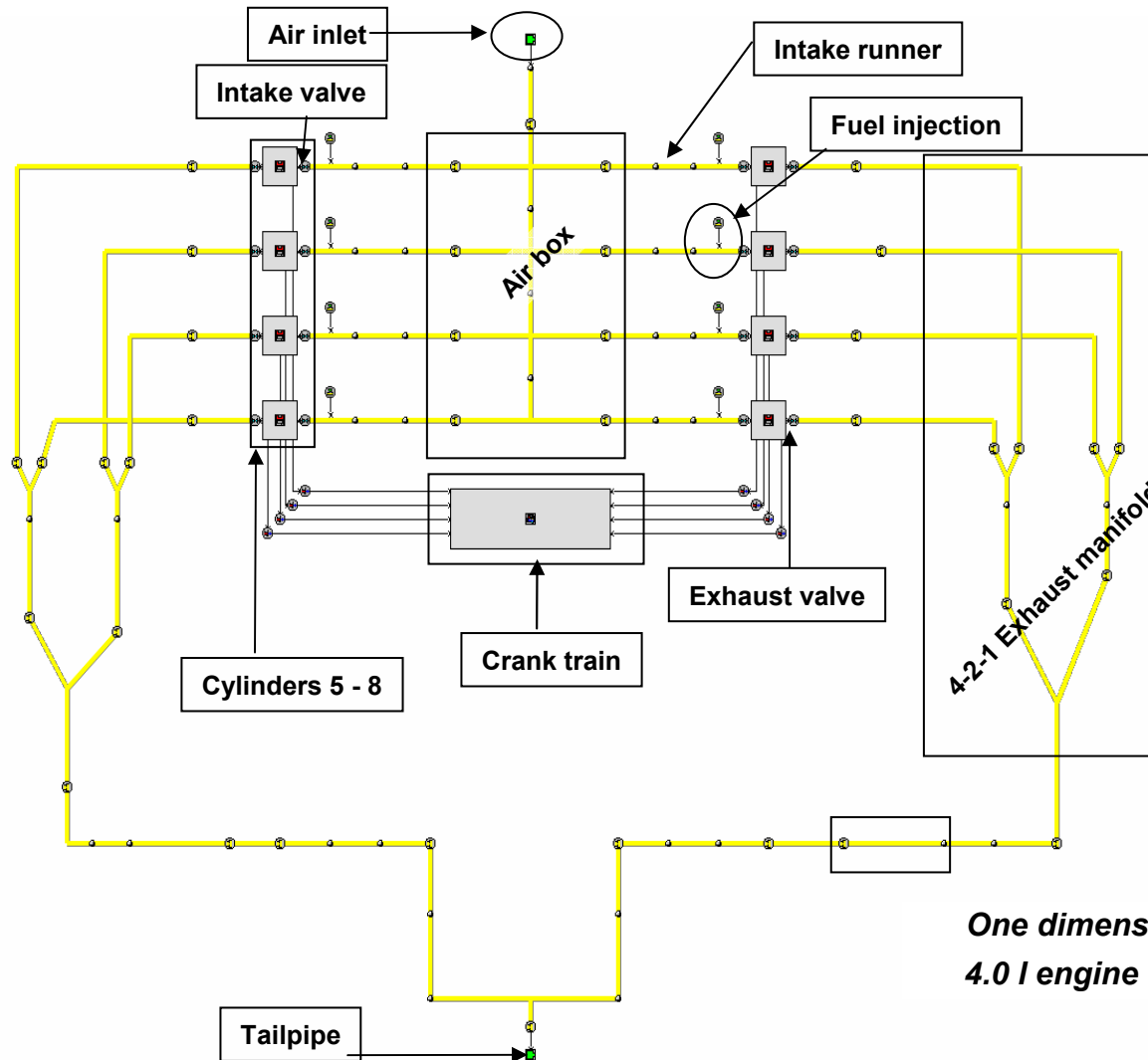
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Fully optimised lightest weight design through extensive analysis



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Fully optimised performance through extensive analysis

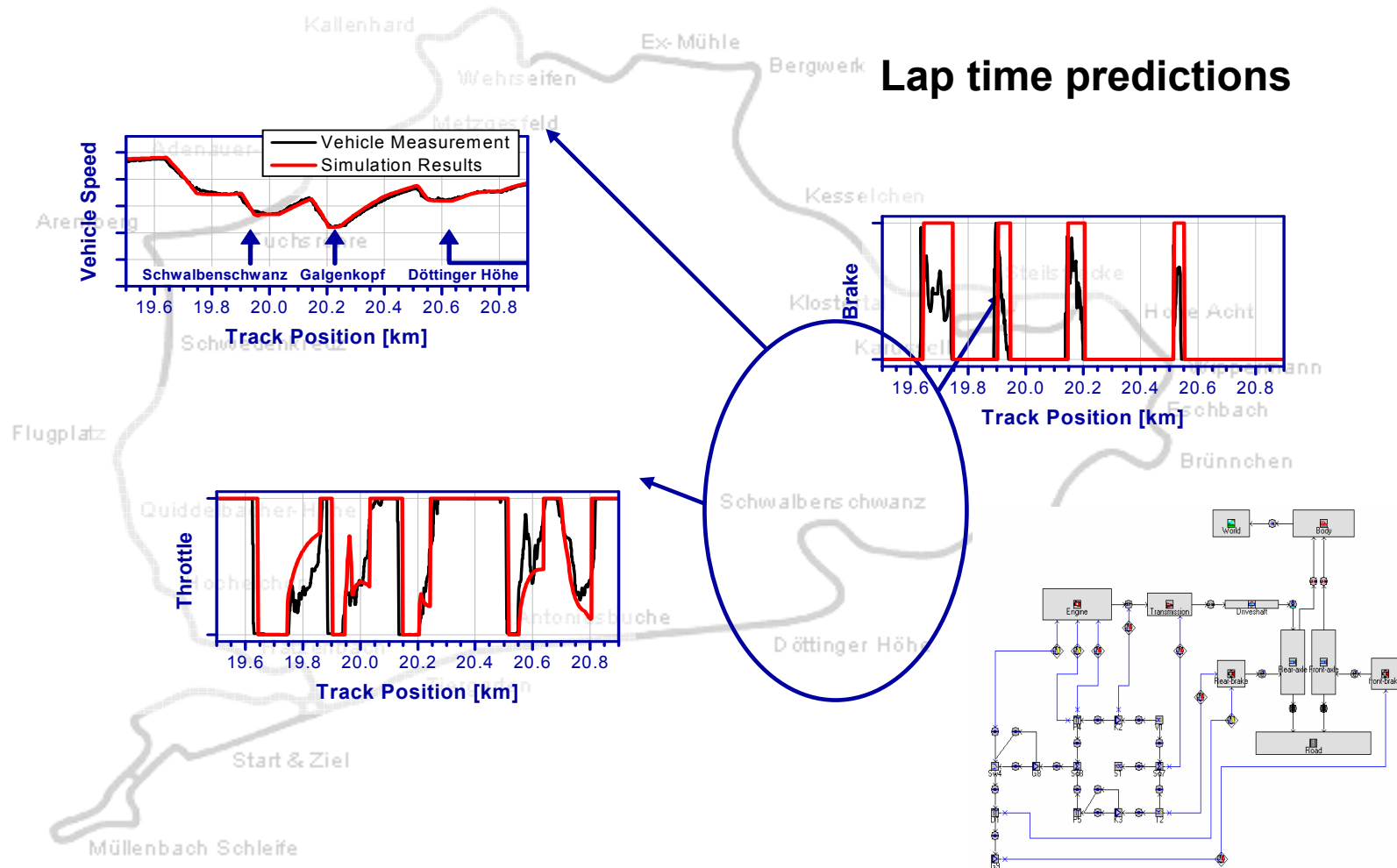


One dimensional calculation model of 4.0 l engine with 4-2-1 exhaust system

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Fully optimised performance through extensive analysis

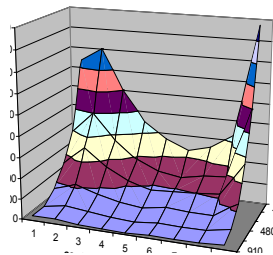
Lap time predictions



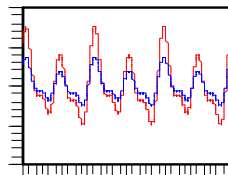
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Complete driveline capability – not just the engine

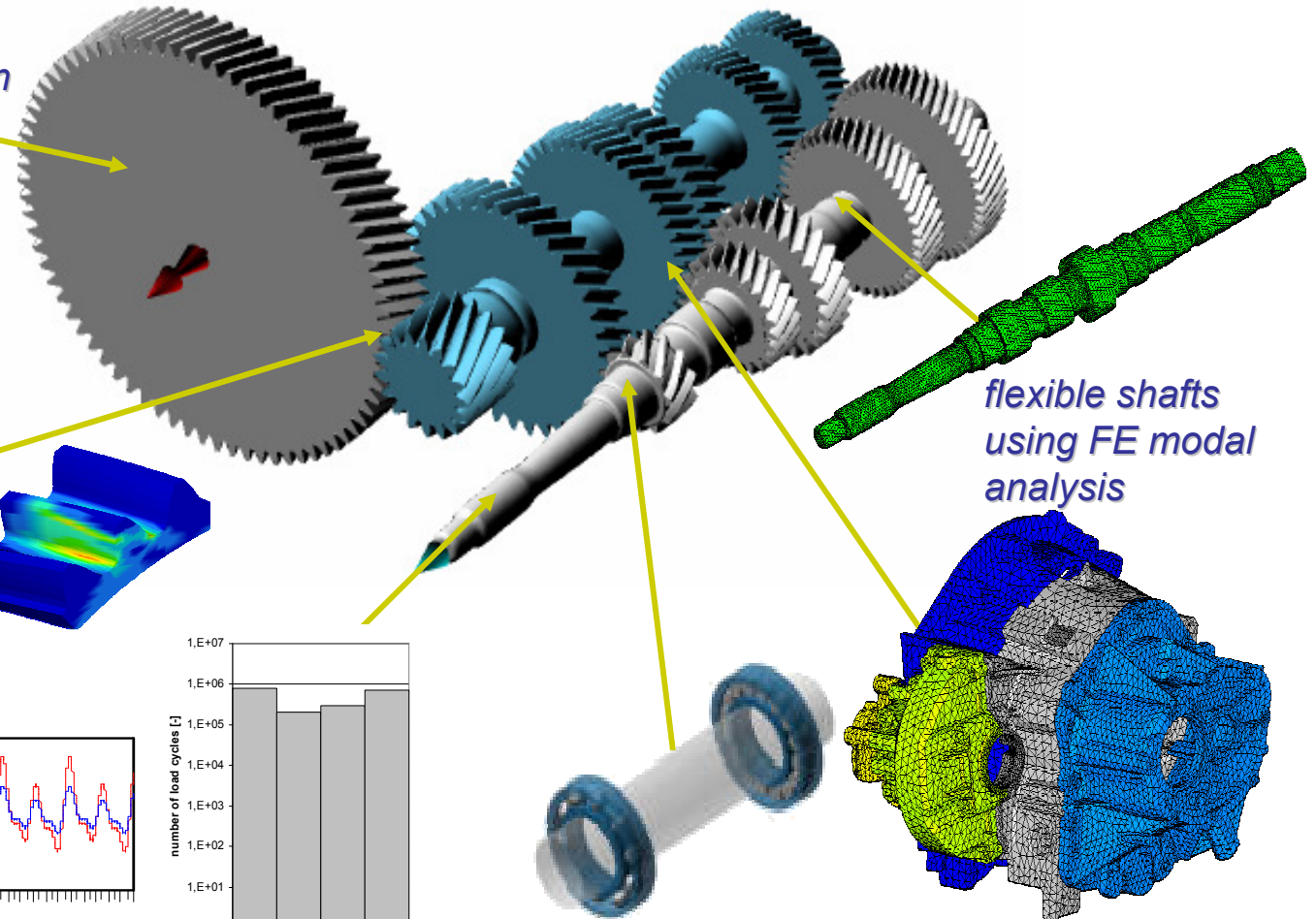
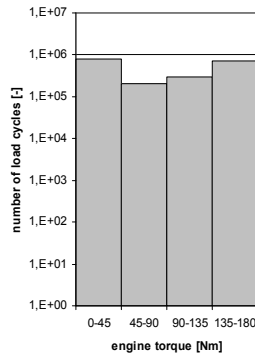
*Geometry
detailed description
of the gear
geometry*



*meshing contact
stiffness maps*



- load collective
- crankshaft / clutch excitation



*flexible shafts
using FE modal
analysis*

*bearing stiffness
using FE analysis*

*flexible housing
using FE modal
analysis*



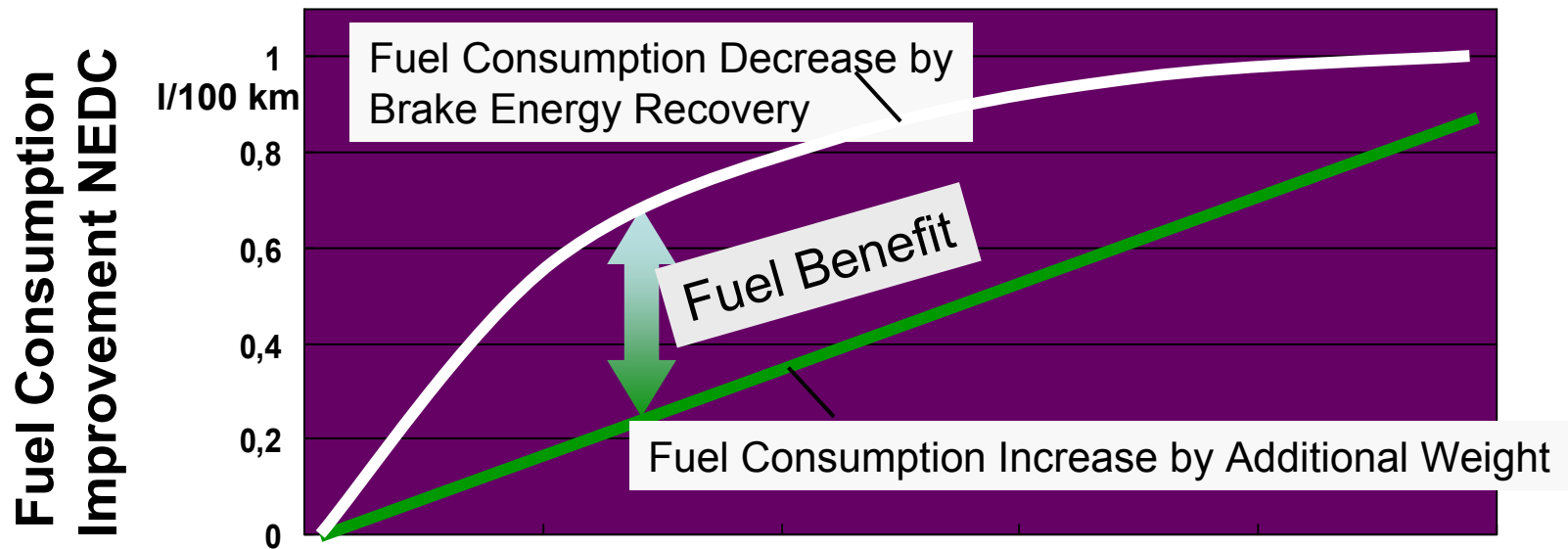
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Concepts

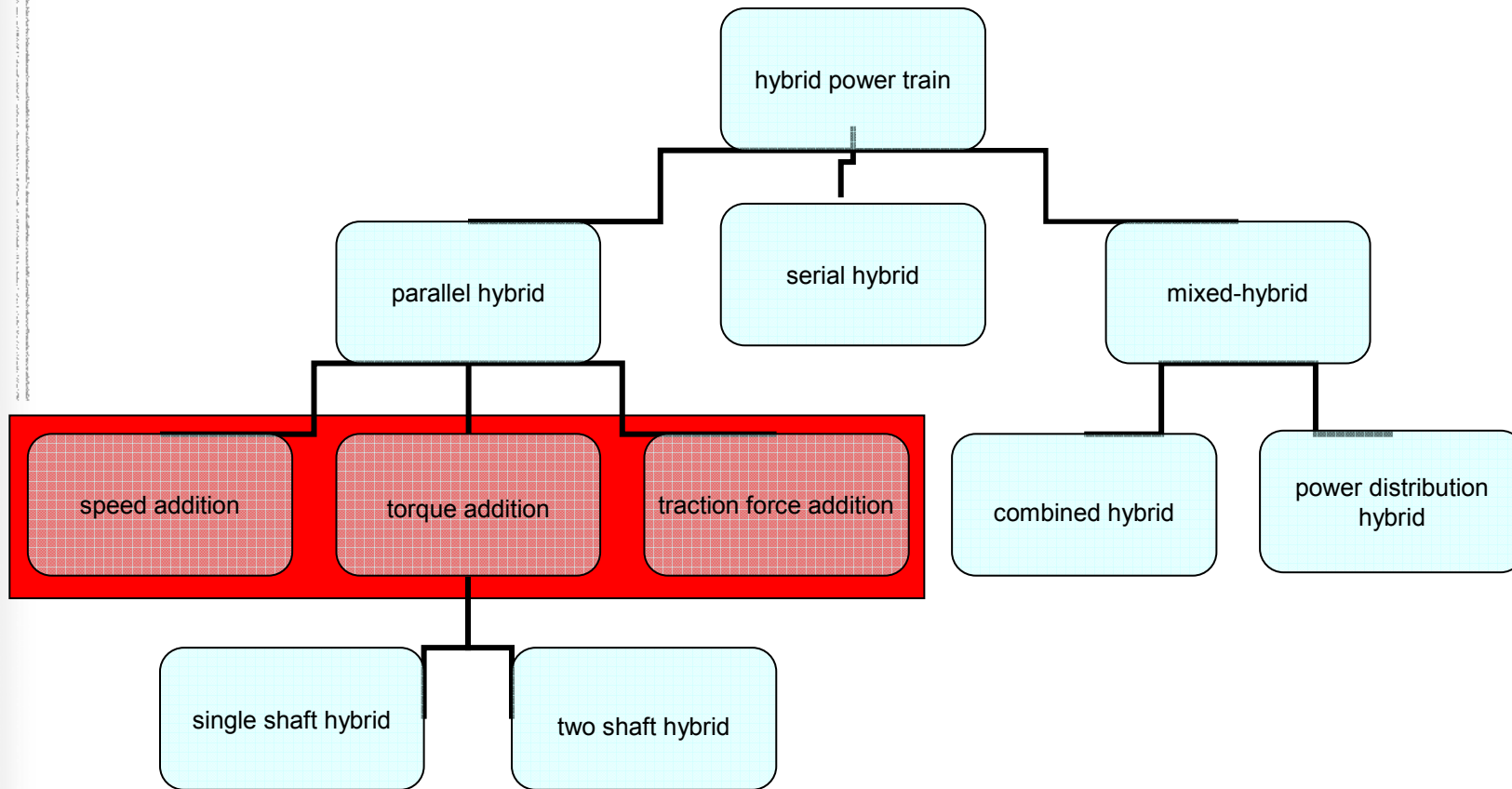
- **Start / Stop**
- **Operating Point Shifting**
- **Brake Energy Recovery**
- **Downsizing**
- **Boost**
- **All Electric Operation**

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Brake Energy Recovery (Example)



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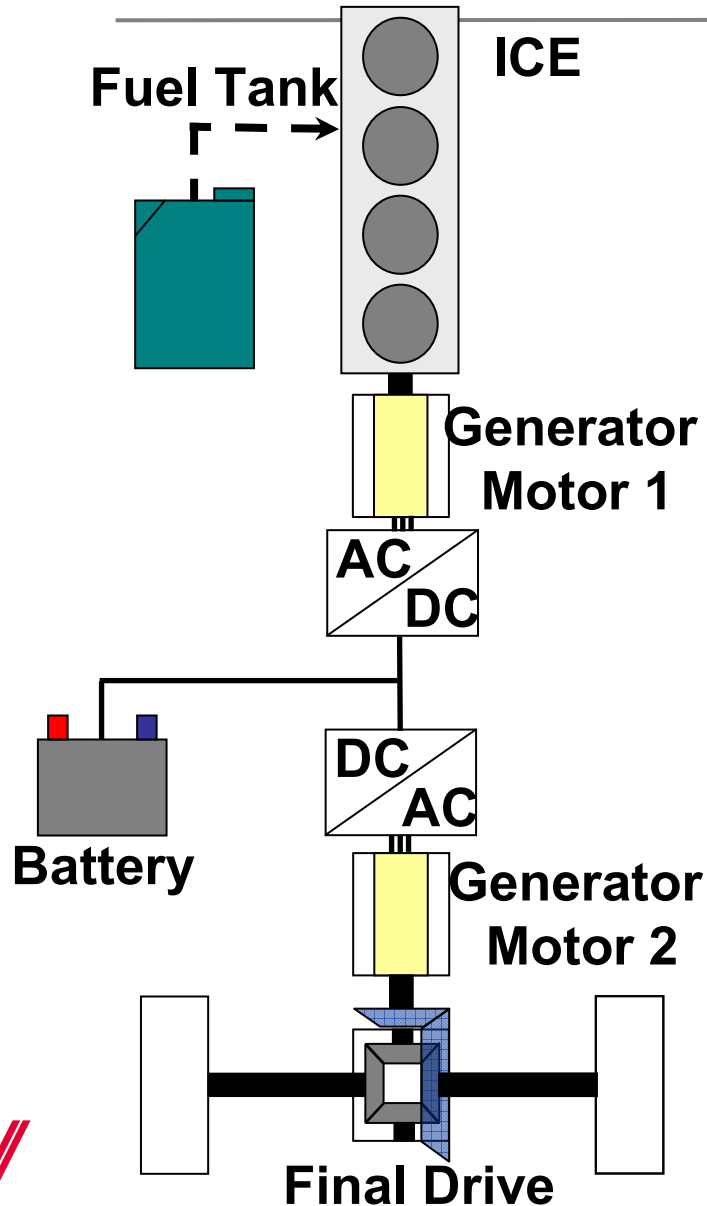


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Degree of Hybridization

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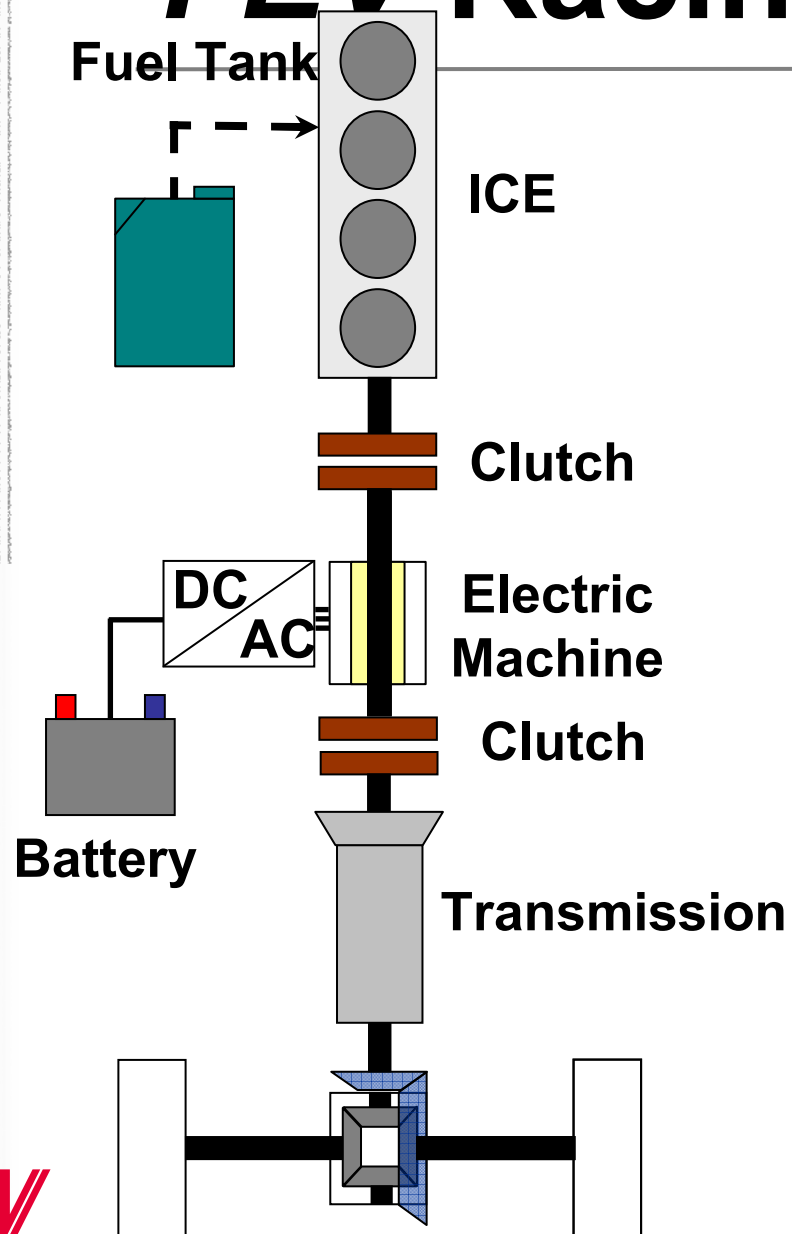
BENEFITS

- Electric driving
- Combustion engine operation in sweet point
- Vehicle design, new degree of freedom

DRAWBACKS

- Peak power requirement for ICE, GM1 and GM2
- **Significantly higher system weight**
- Poor overall efficiency for extra urban driving cycles

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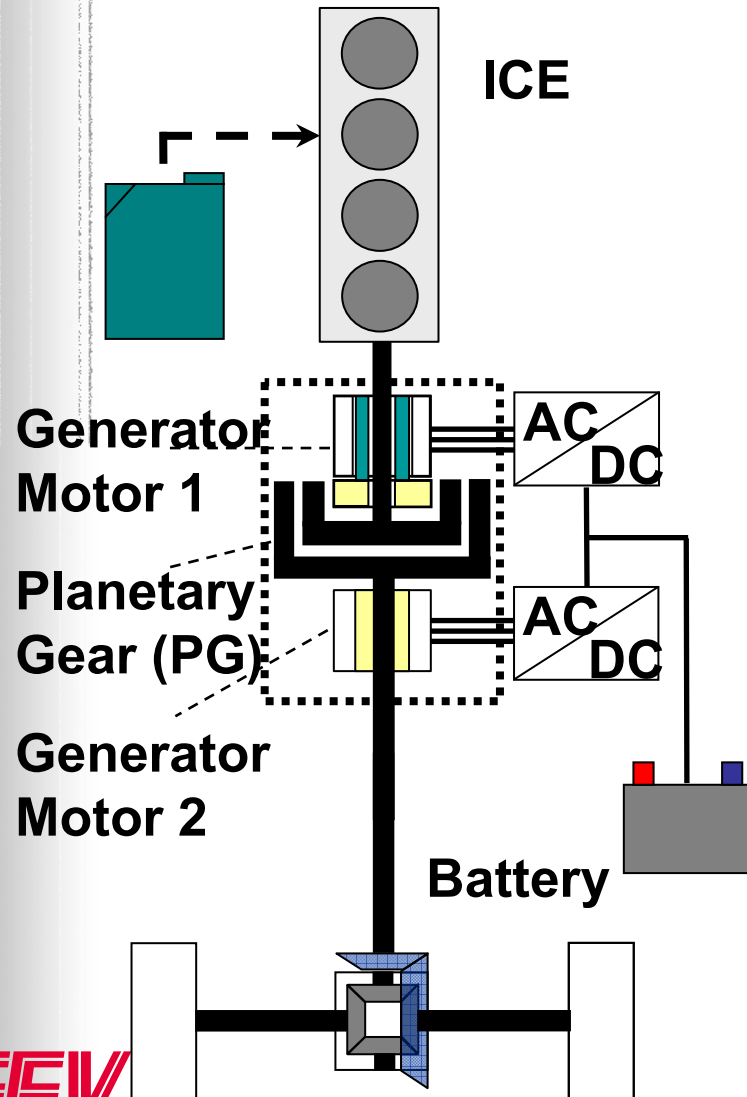
BENEFITS

- High electric wheel torque due to transmission
- Good dynamic torque response
- Carry over of transmission possible
- Modular integration / combination with all transmission types

DRAWBACKS

- Reduced recuperation benefit due to transmission losses
- Torque converter or clutch for drive away required
- Package constraints for vehicle integration
- **High mechanical complexity**

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BENEFITS

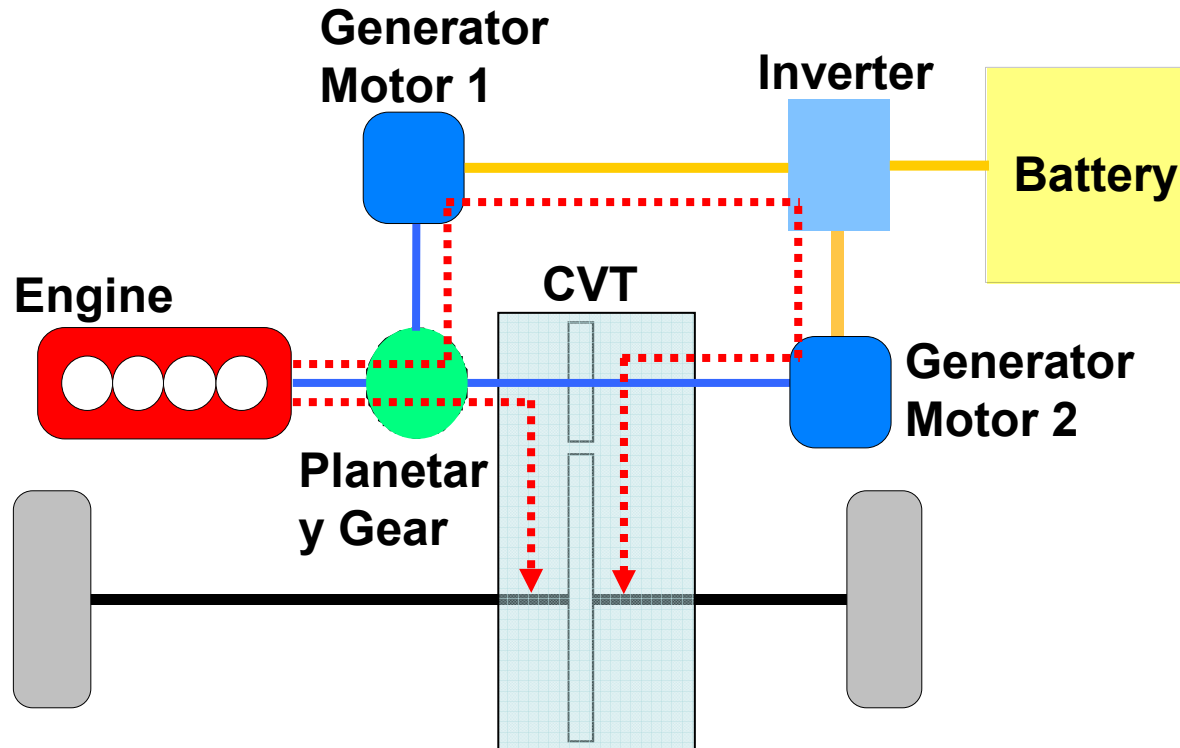
- Electric driving efficiency and recuperation efficiency high due to position of electric boost machine
- Electric CVT function (programmable characteristic of electric torque conversion)
- Reduced mechanical transmission complexity (one PG, no clutches, brakes)

DRAWBACKS

- **Two electric machines**
- Electric power requirement ~ 60% of ICE power
- **Delayed response at acceleration due to inertia of generator**
- Drive away torque reduced due to ratio limitation

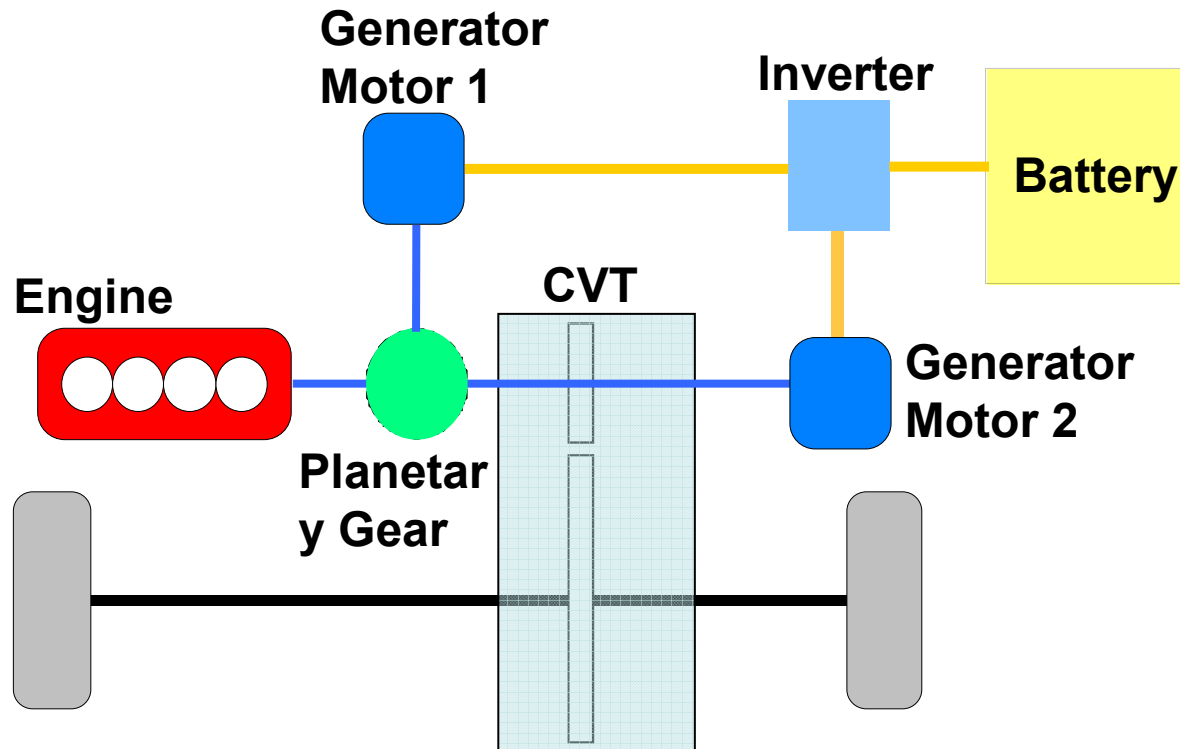
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Power Split



— Mechanical Power Flow
— Electrical Power Flow
- - - Power Flow

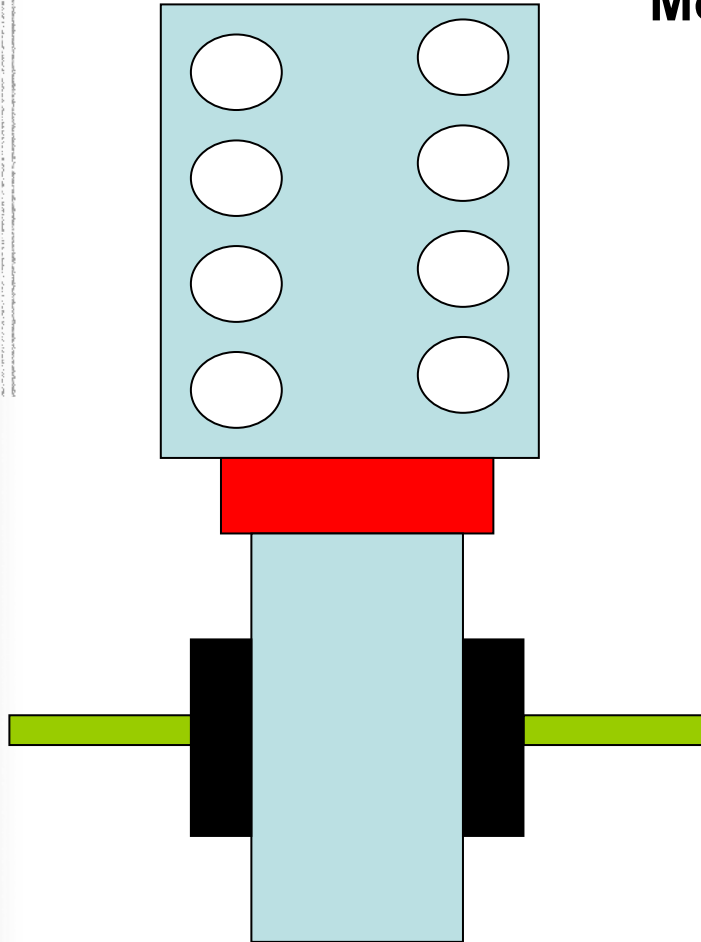
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— Mechanical Power Flow
— Electrical Power Flow
- - - - - Power Flow

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Motorsport (mild) Hybrid



GOALS

- Lowest system weight
- Simplicity
- Multiple collections and deliveries
- Multi sources for components – not e.g. 4
- Controllable repeatable and fast energy collection
- Controlled delivery
- Flexibility of where energy stored
- Low end engine torque boost



***FEV* Racing Engines**

FEV has been in the Hybrid sector for more than 10 years.

FEV knows the limitations of all available concepts