# Sensitivity Study

The graph plots the improvement in fuel consumption obtained when the given parameter value is reduced by 10%.

Different drive cycles have different sensitivities to parameter variations, sometimes in different directions. Only looking at one drive cycle would lead to a different decision on how to optimise the design, as well a different decision about which parameters to investigate.
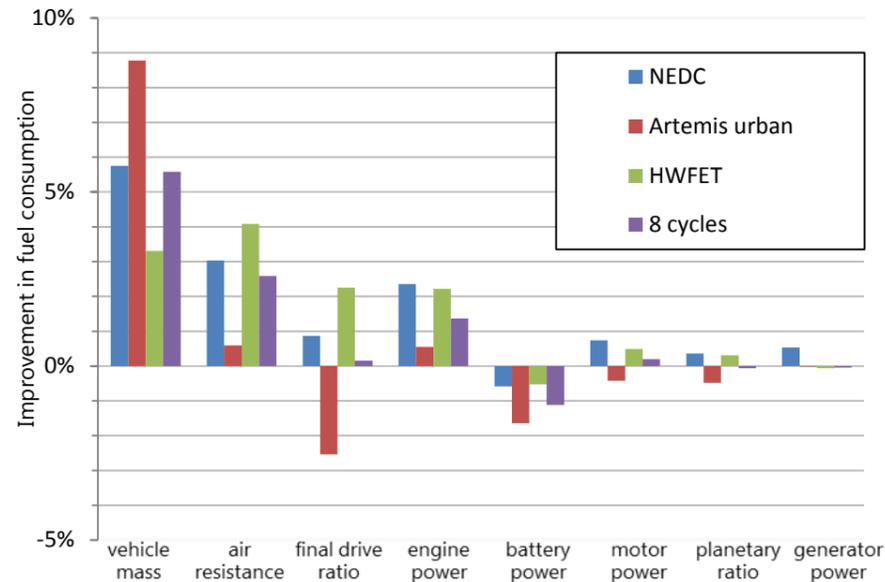
The following drive cycles were use in the Prius case study:

- **New European Drive Cycle:** the legislative cycle for Europe is not very realistic, with periods of constant speed, constant accelerations and decelerations
- **Artemis Urban:** this represents city driving, with low average speed and lots of starting and stopping
- **Highway Fuel Economy Test:** the US legislative cycle represents motorway driving with high average speed and low acceleration
- **8 cycles:** WLTP, JC08, HWFET, NEDC, Artemis Urban, UDDS, FTP, SC03
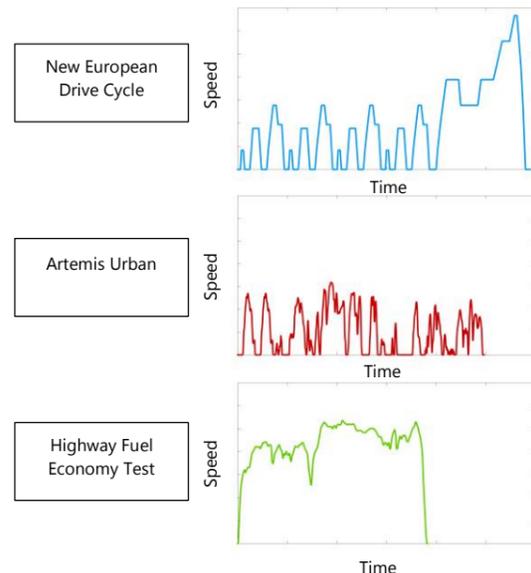
The consortium

- **Romax Technology** is a leading global provider of integrated software and services for gearbox, bearings and driveline systems for automotive, wind energy, bearings, off road, rail, marine and aerospace.
  Romax makes significant year-on-year investments in market-driven development to deliver innovation for its clients and partners, and to maintain its position as the world's number one independent gearbox and driveline simulation experts.
- **cmcl innovations** is a software developer and consultancy service provider for the chemical, engineering, and technology sectors. It has over a decade of experience in delivering highly innovative computer aided engineering (CAE) solutions to the automotive, non-road, marine, motorsport, clean energy & chemical industries.
- **The University of Sheffield Electric Machines and Drives Group** is based in the Department of Electronic and Electrical Engineering. The Group undertakes fundamental and applied research on enabling technologies which are likely to be central to future developments in electrical power engineering. Its strategy, therefore, is to maintain a balanced portfolio of projects on a broad range of research topics, and to promote pull through of its R&D to commercial exploitation and applications encompassing different market sectors.

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ProtoDrive:
Integrated Tool for the Rapid Concept Design of Hybrid Electric Vehicle Systems

The ProtoDrive research and development project aims to implement a rapid concept design and analysis tool for application to the conventional, hybrid and electric vehicle market, with all parties providing support across the entire vehicle powertrain, including transmission, electric systems and internal combustion engine design.

Project activity

- Efficiency models for the engine, transmission, electric machines, battery and power electronics
- Integration of components into a drivetrain model
- Case studies based on end users' requirements to demonstrate the value of the tool
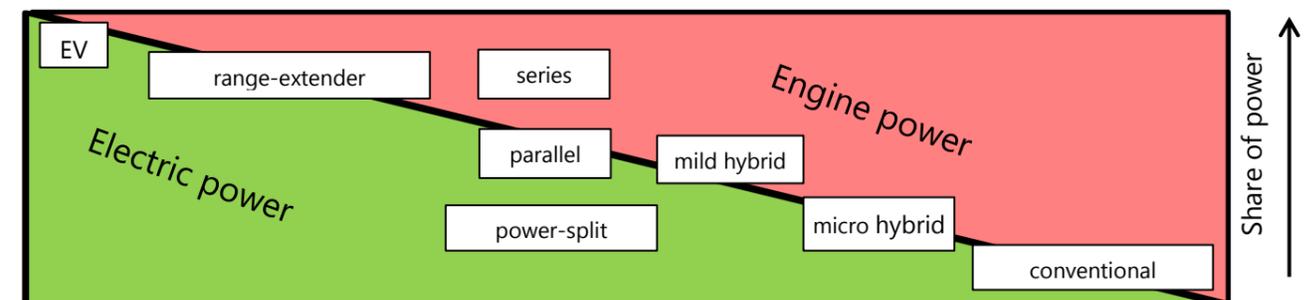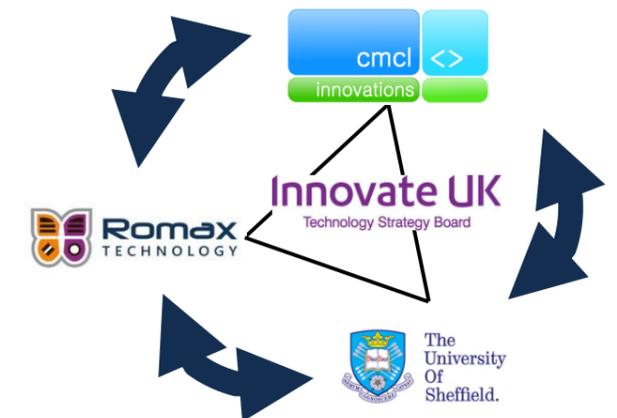
- Drivetrain simulation scans across the spectrum of drivetrain designs from pure electric to pure conventional
- Speed is more important than modelling detail at the concept stage
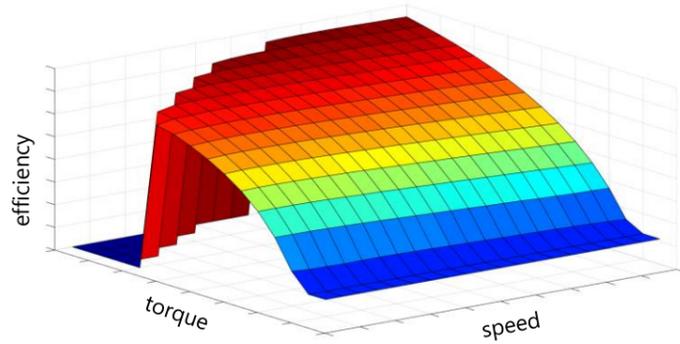- Model fidelity is sufficient to enable engineering judgements

Romax has developed a vehicle simulation tool for rapid analysis and evaluation of concept driveline layouts

- Simultaneous component sizing and control strategy optimisation
- Integrated drivetrain, engine, transmission, and electrical component efficiency models
- Fast simulation over multiple drive cycles with sufficient model fidelity to enable engineering judgements
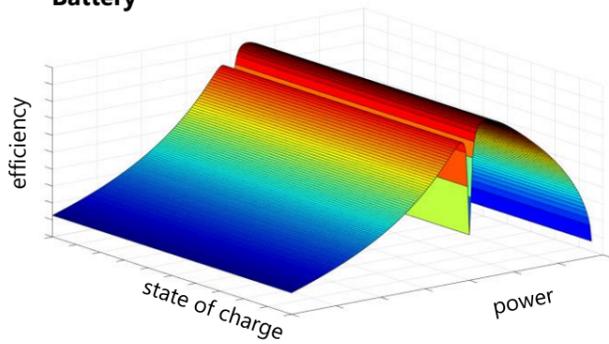
Planetary gear set

The planetary gear set splits the power between the engine and motor/generators. A control strategy is used to determine how much of the power demand comes from the engine and how much from the battery.

Motor/generator 1

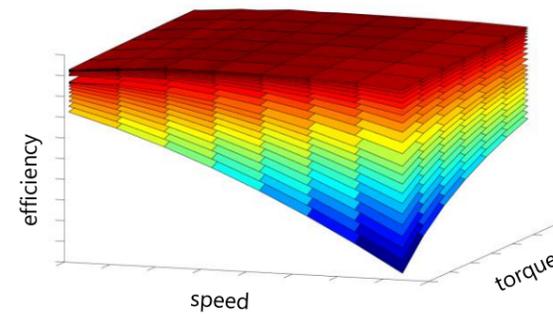Motor/generator 1 mainly operates as a generator, and is also used for engine starting.

Engine

The engine is controlled to operate at high efficiency, with engine speed effectively decoupled from wheel speed by the electro-mechanical power path (blue).

Engine

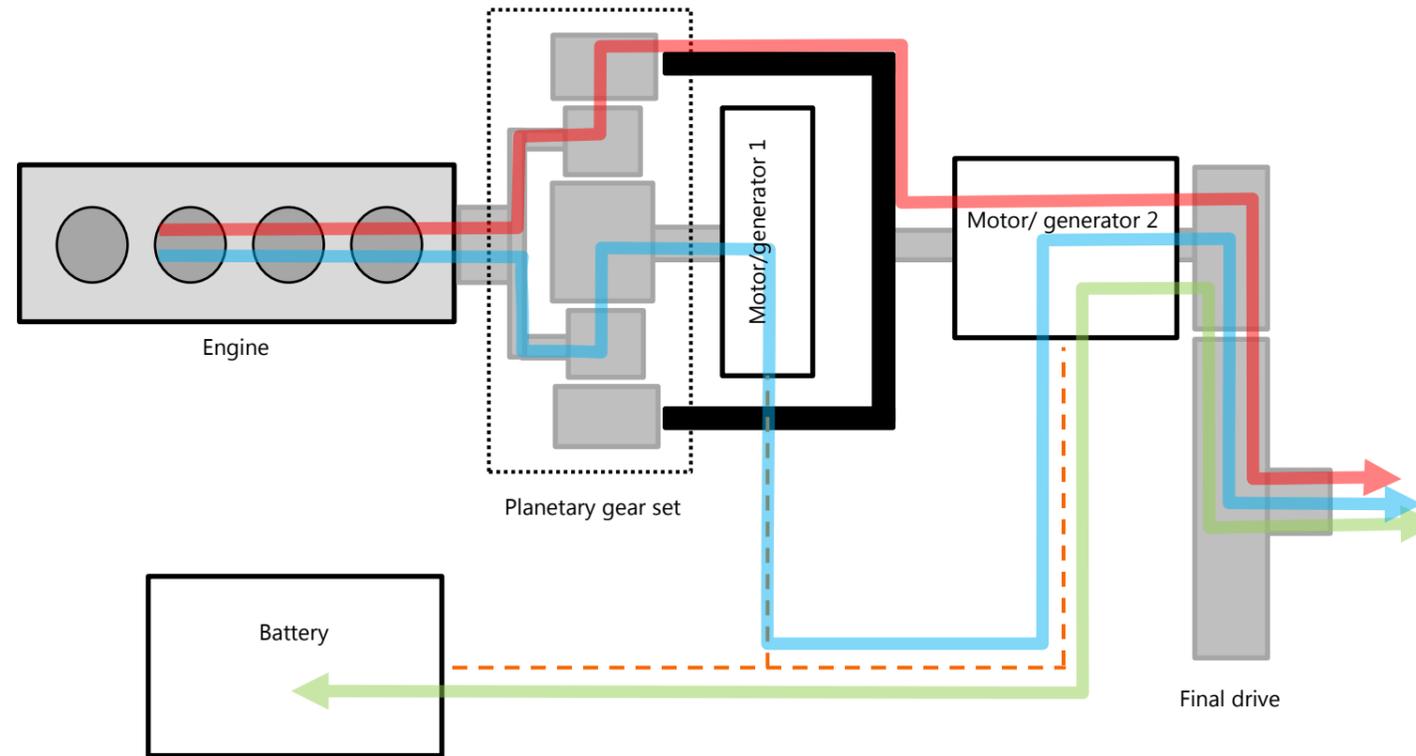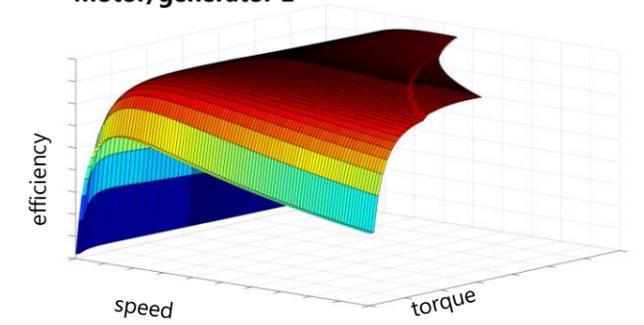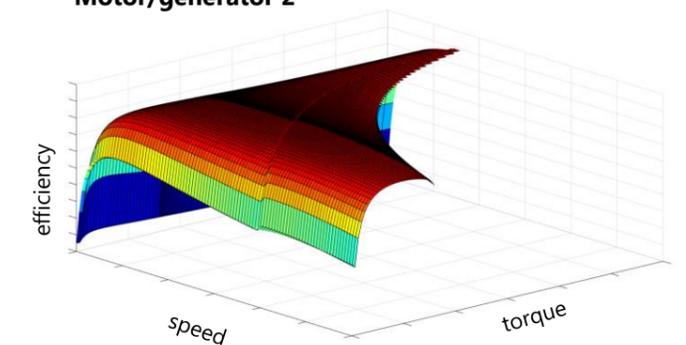Motor/generator 1

Motor/ generator 2

Planetary gear set

Battery

Final drive

Battery

The battery stores energy from engine and regenerative braking, and is used to power the vehicle in electric-only driving mode (green).

Motor/generator 2

Motor/generator 2 enables electric-only driving mode, or provides electrical boost when the engine is running. It is also used for regenerative braking.

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