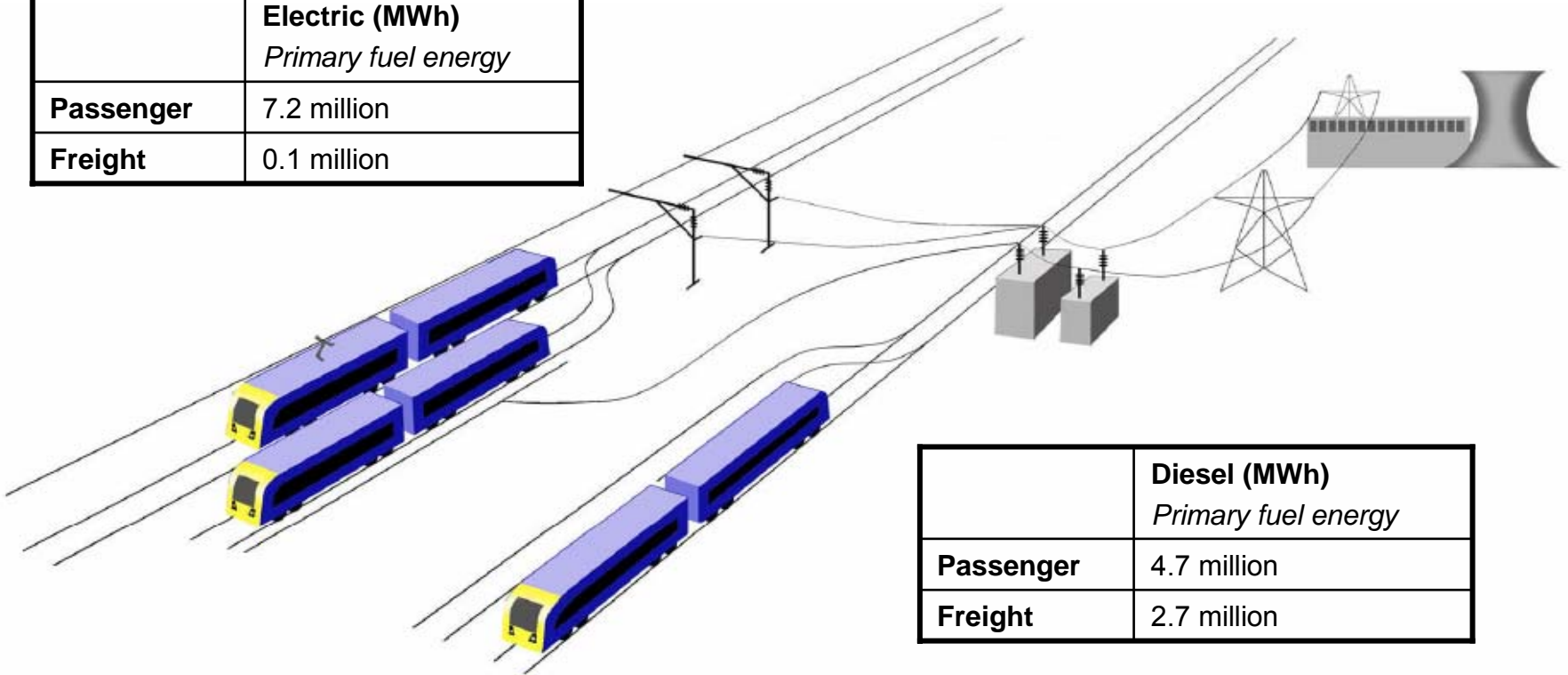


# RRUK C7 Research Project: Strategies for Minimising Railway Energy Consumption

Matthew Read, Professor Rod Smith  
Future Rail Research Centre  
Imperial College London

# Rail Energy Consumption

|                  | <b>Electric (MWh)</b><br><i>Primary fuel energy</i> |
|------------------|---|
| <b>Passenger</b> | 7.2 million   |
| <b>Freight</b>   | 0.1 million   |



|                  | <b>Diesel (MWh)</b><br><i>Primary fuel energy</i> |
|------------------|---|
| <b>Passenger</b> | 4.7 million                                       |
| <b>Freight</b>   | 2.7 million                                       |

# Aims of Research

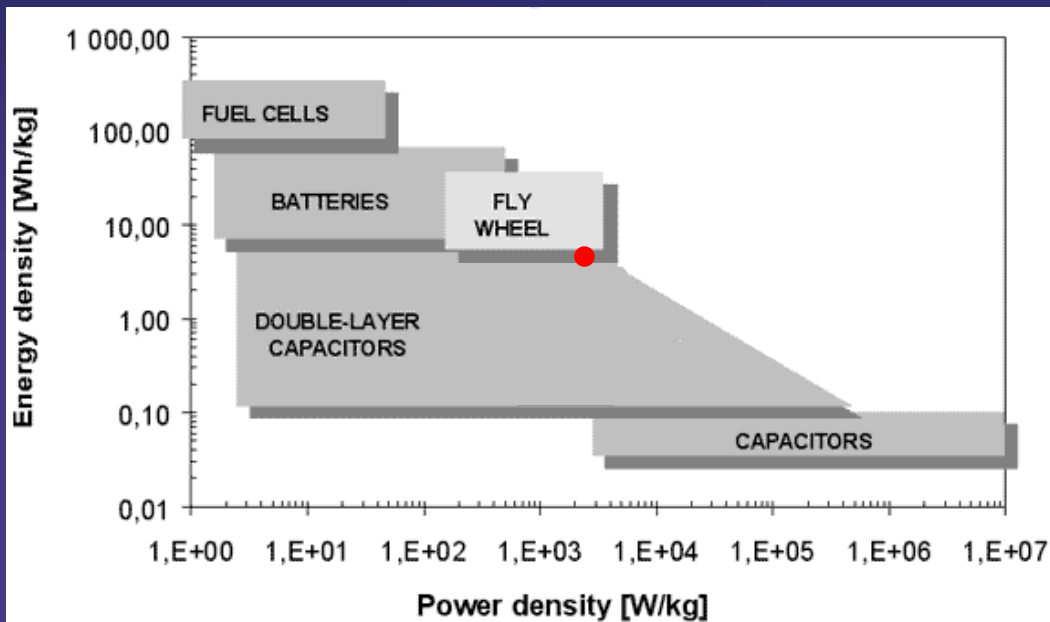
- Focus on options including:
  - Power-train configuration
    - *Regenerative braking*
    - *Energy storage systems*
    - *Intelligent control of distributed power-train*



- Operational strategies
  - *Improved driving technique*
  - *Reduced engine idling*

# Regenerative Braking

- Large energy consumption during acceleration
- Vehicle hybridisation reduces primary energy
- Requires energy storage system



|                 |            |
|-----------------|------------|
| Flywheel speed  | 60,000 rpm |
| Power           | 60 kW      |
| Useable storage | 400 kJ     |

# Flywheel Energy Storage

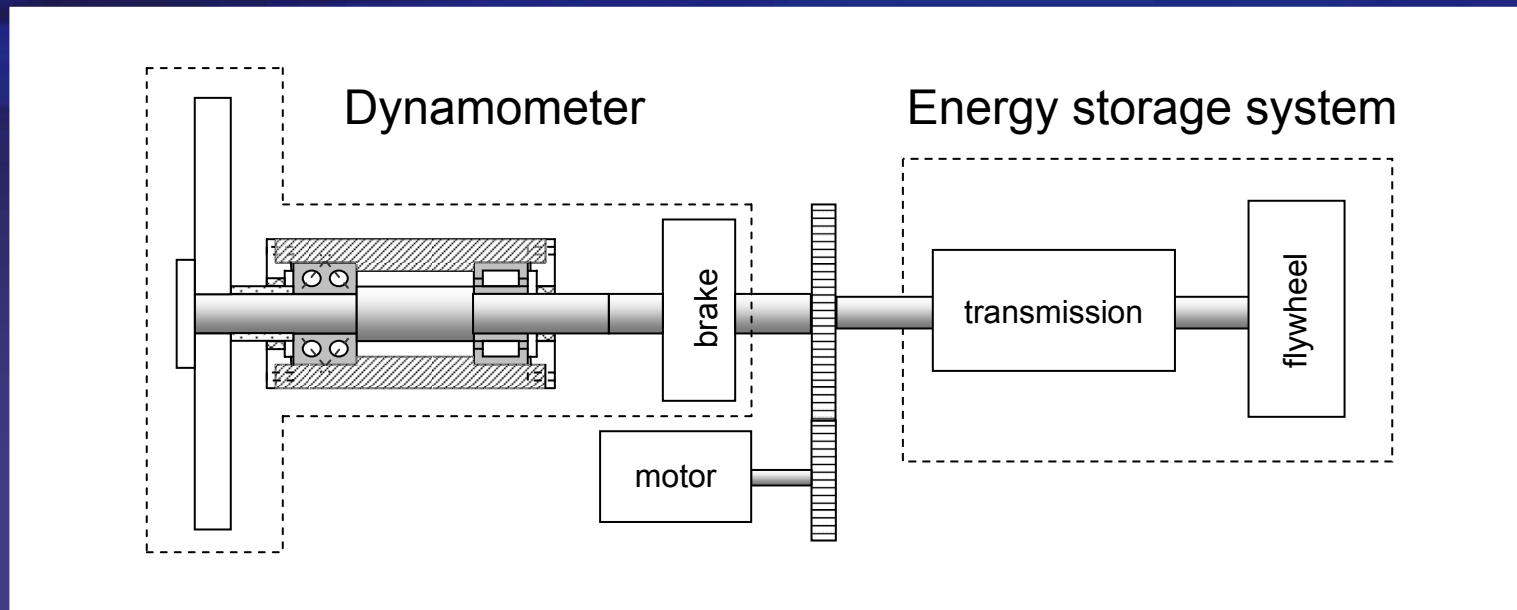


- Research at Imperial into high speed composite flywheels for automotive applications
- Designed for 1.2 MJ storage
- Tested at 22,000 rpm, 2500 Pa

- Modelling of innovative ‘mechanical hybrid’ power-train
  - Considerable benefits for passenger and commercial vehicles
  - Various configurations possible
  - Application to rail to be investigated

# Vehicle Test-Rig

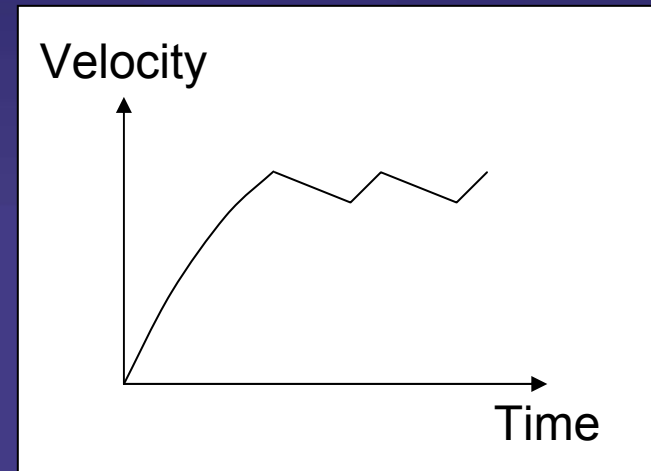
- Energy storage devices and control strategies to be tested for representative duty cycles



- Effect on energy consumption and vehicle performance to be measured

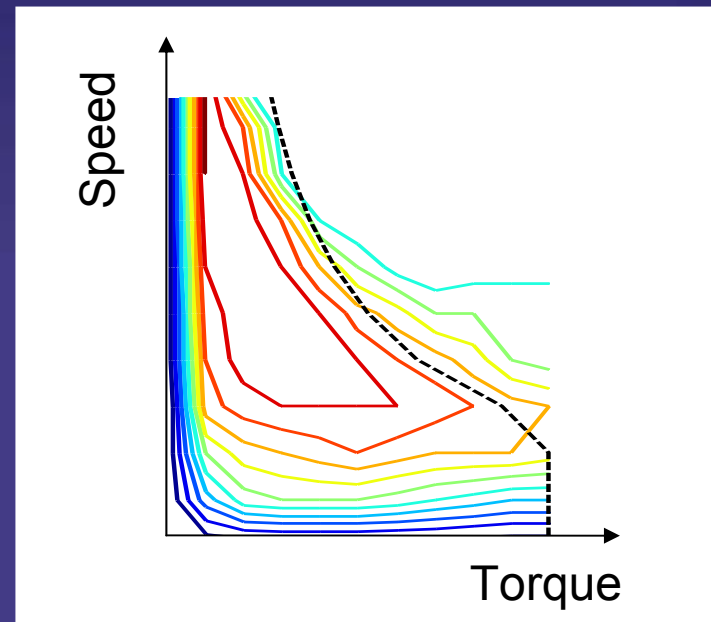
# Driving Technique

- Previous studies have investigated energy-efficient train control
  - Theoretical solution of optimal control problem
  - Most efficient trajectory identified
- Power-coast cycles often part of optimal solution
- Necessary for vehicles with discrete power notches
- Effect for maintaining cruise speed investigated

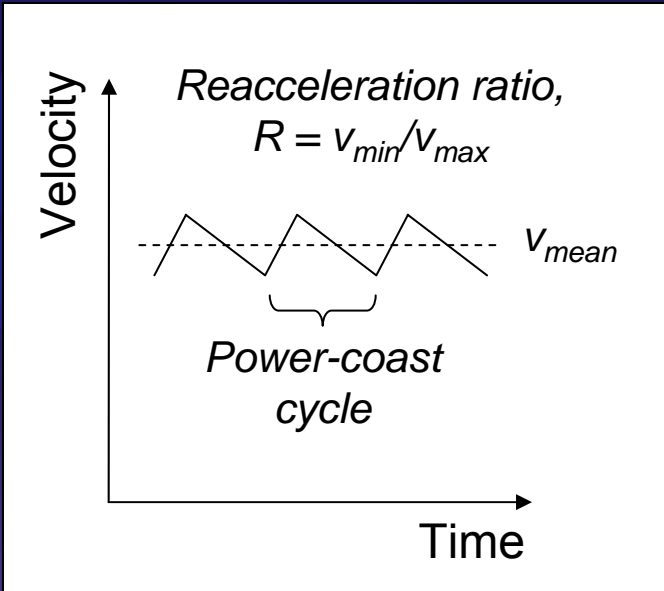


# Power-Coast Model

- EMU vehicle model created using Class 319 parameters
- Energy consumed at power-line calculated
- Power-train components
  - AC induction motor efficiency map used
  - Other component efficiencies assumed constant

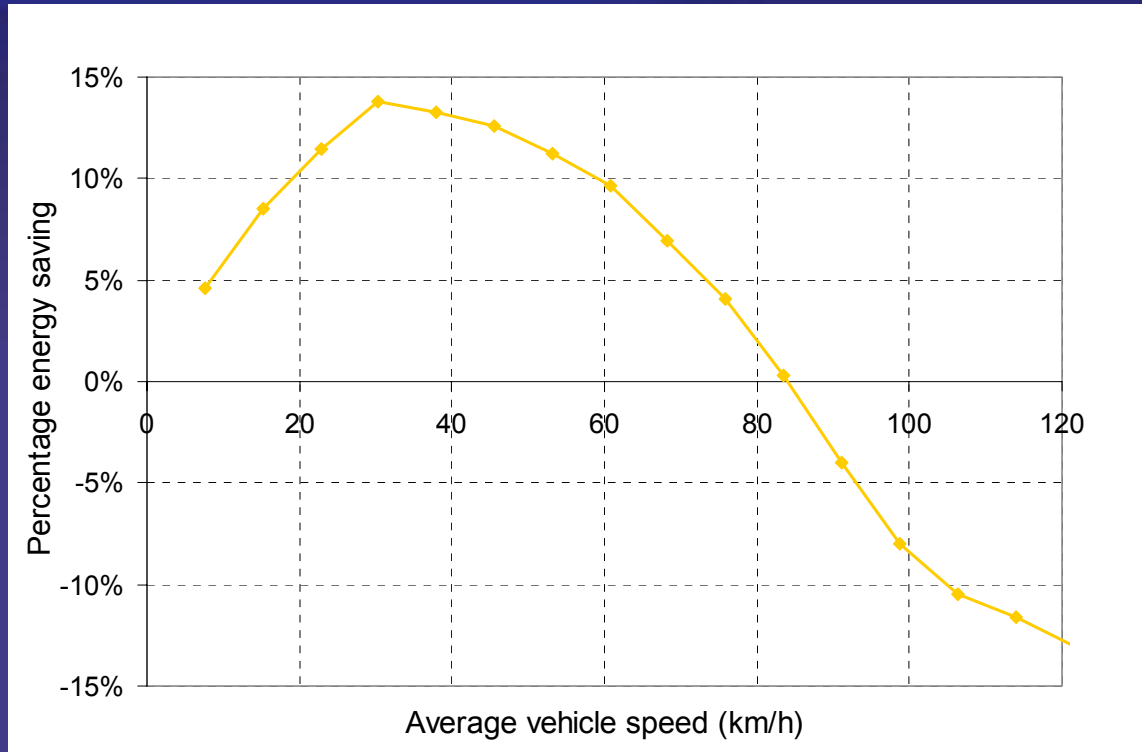


# Power-Coast Model



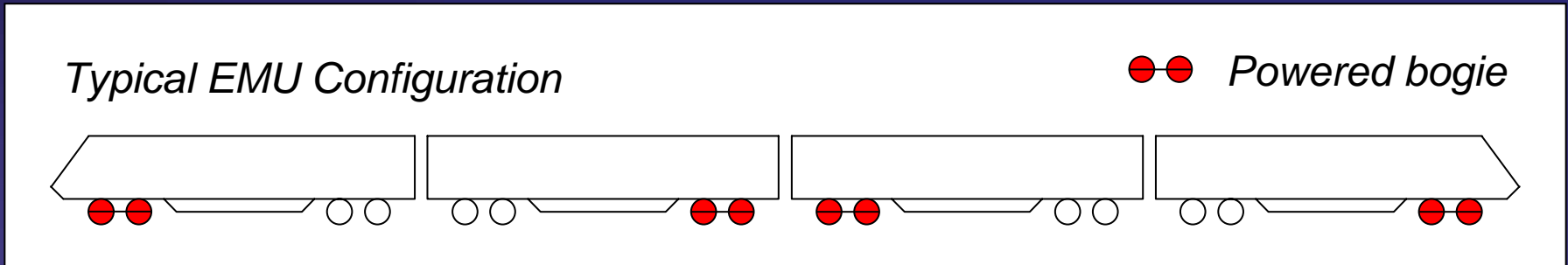
- Energy calculated for single power coast cycle
- Compared to constant speed case

- With  $R=0.9$ ...
  - energy saving at low cruise speed
  - increases above 85km/h



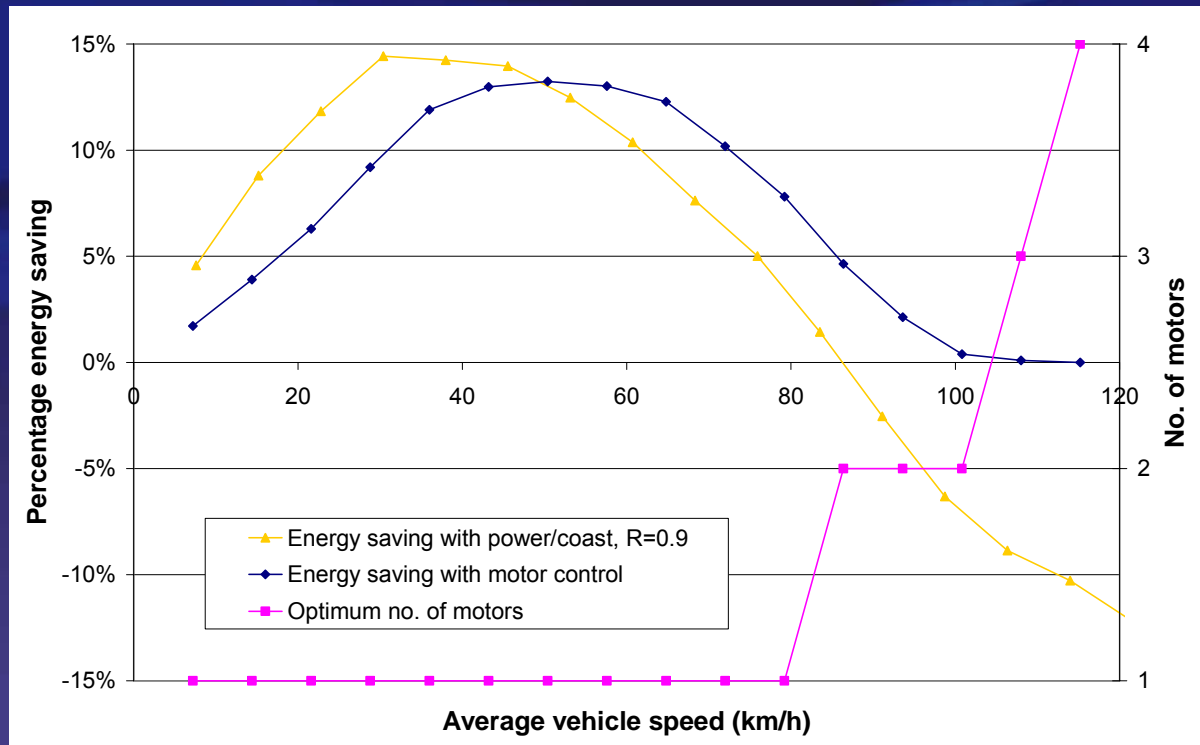
# Motor Control

- Power-coast allows energy consumption to be reduced by operating power-train in more efficient region
- Can also be achieved by motor control:



- If train has four motors, can choose how many to operate for maximum efficiency

# Motor Control



- Can achieve similar energy savings at low speed cruise
- No increase in energy consumption at high speed cruise

# Future Work

- Development of simulation tool to investigate...
  - Driving technique
  - Power-train design and control
- Development of driver model based on current practice
- Detailed computational modelling and scaled experimental testing of mechanical hybrid power-trains

The universities' centre for railway systems research

*Rail Research UK* 

Thank You