cenex

Low Carbon Vehicle Event 2012

Ride & Drive, Conference and Exhibition

Millbrook Proving Ground

MOVING TOWARDS SUSTAINABLE GROWTH

Technology Strategy Board
Driving Innovation

VIPER – Vehicle Integrated Powertrain Energy Recovery

LCV12

IDP4 – Strengthening the UK Supply Chain

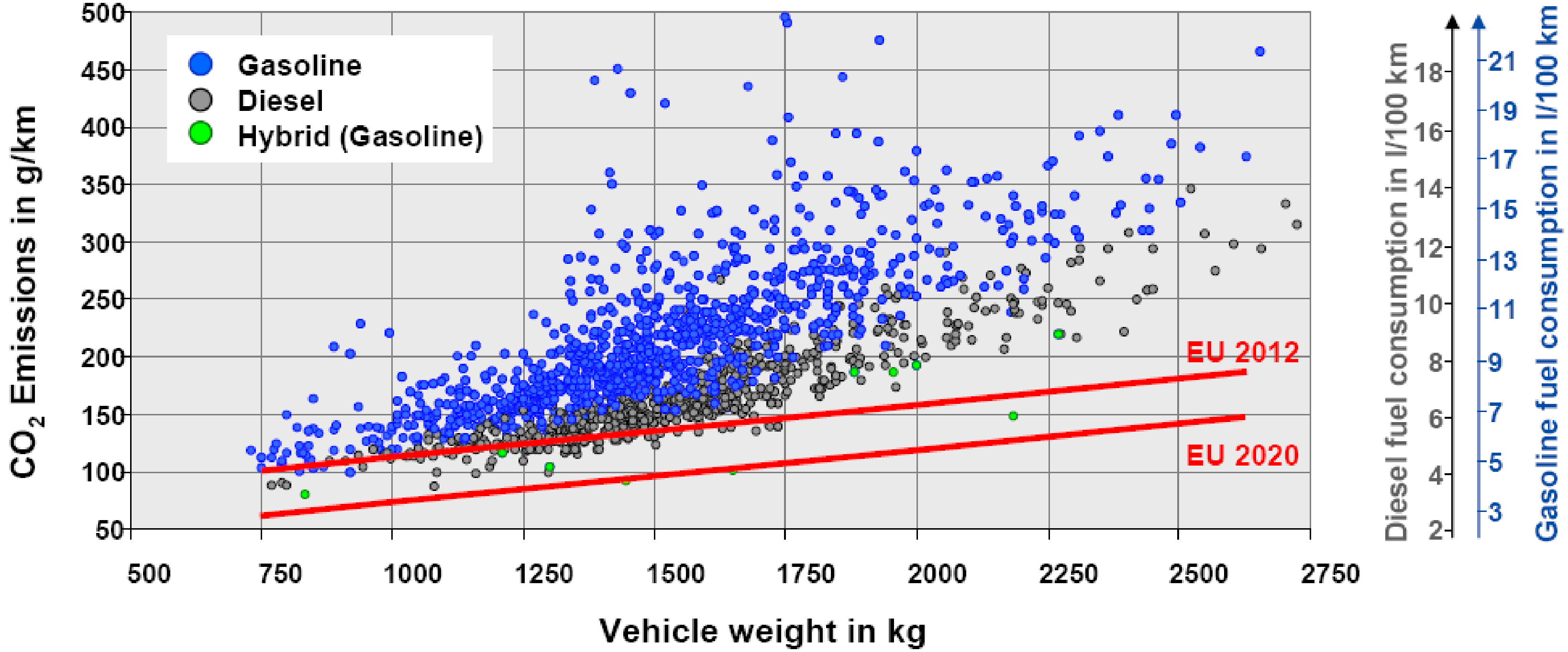
Meeting Location: Millbrook

POWERTRAIN ADVANCED ENGINEERING
Bob Gilchrist
September 2012

Project Overview

- JLR Leading
- Total project value c.£5.2m
- Three years duration - Started September 2010, Finishes September 2013
- Sponsored by TSB
- Partners – as shown below
- Aim - to show how a CO_2 emissions reduction of 4.5% could be achieved over a broad range of new vehicles on the NEDC by efficiently optimizing control of heat energy in current conventional vehicles.
- Suppliers with the VIPER project are to develop new technologies to harness, manage, and store heat energy and integrate it into a Jaguar vehicle demonstrator.

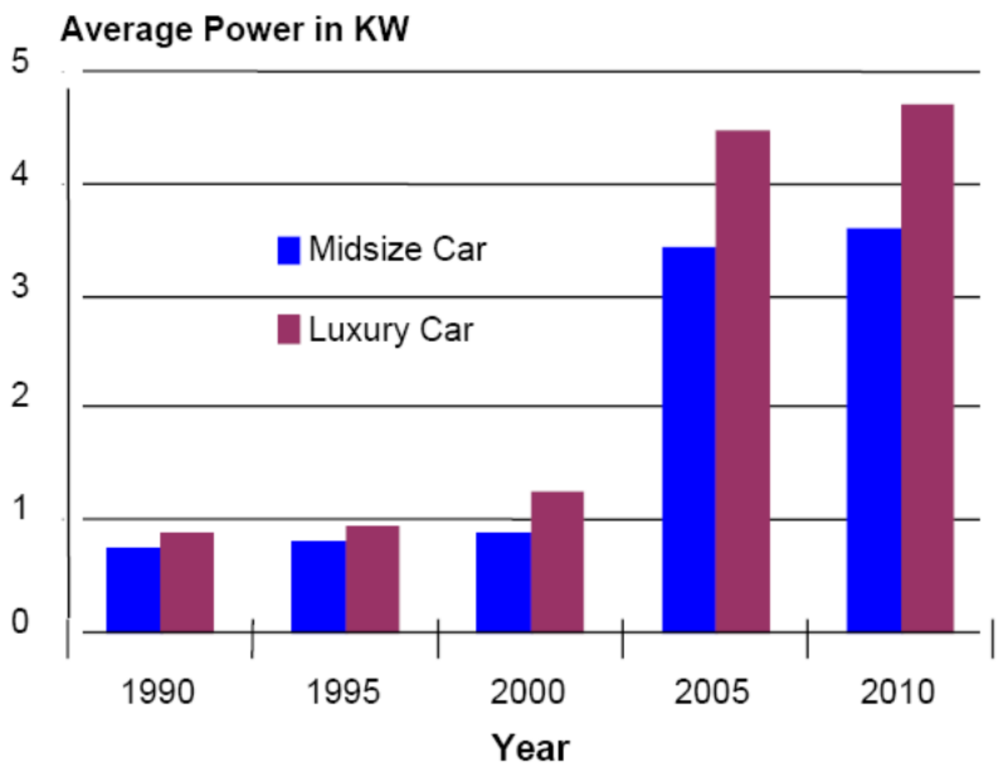
Key grand challenge is CO_2



Source: presentation to VIPER consortium "2010-02 IAV expertise TEG for TSB competition"

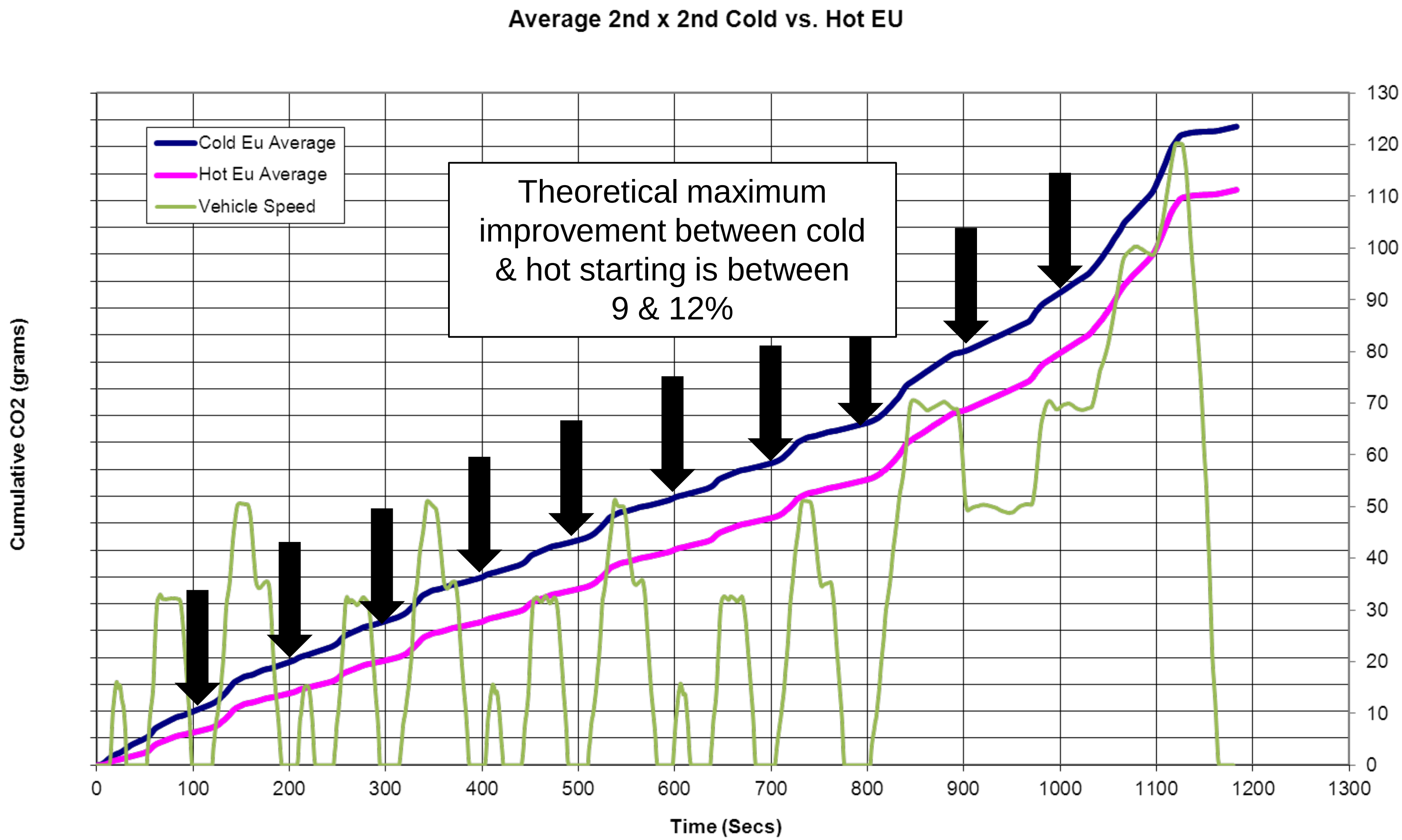
- More than 80% of current passenger vehicles produceCO_2 emissions that are too high
- From 2015 OEM's will have to pay a fine of Eu95 per vehicle, per gram CO_2 exceeding the limit

Vehicle electrical demand has risen & expected to jump again

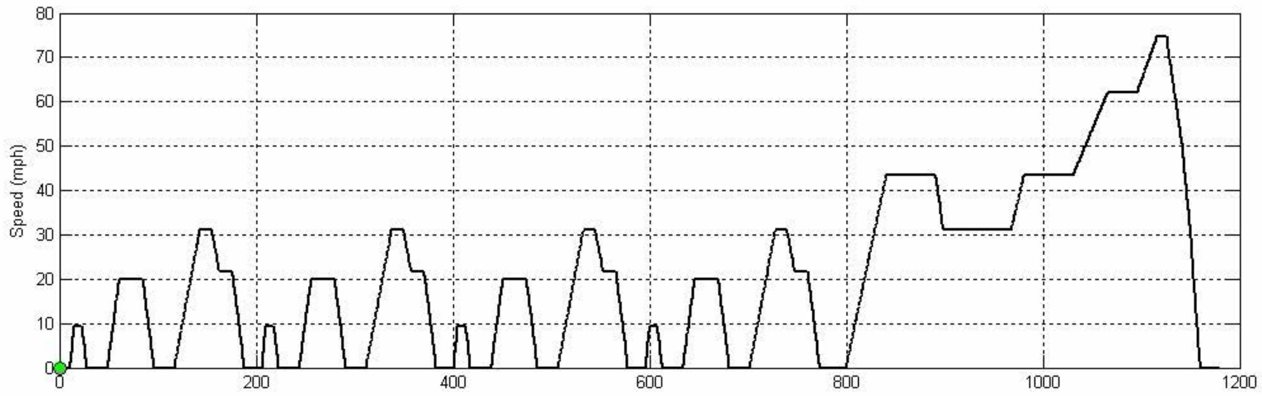


- Consumption of electrical energy is forecast to increase dramatically leading to increased on-time of alternators, larger batteries or even secondary alternators.

Moving vehicle closer to the hot start condition will decrease FC

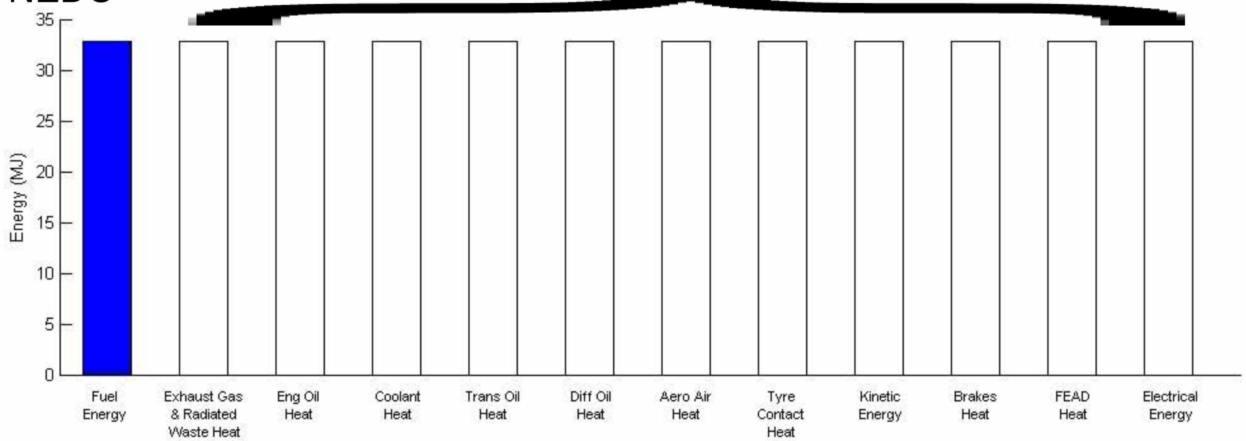


Fuel energy flows during NEDC

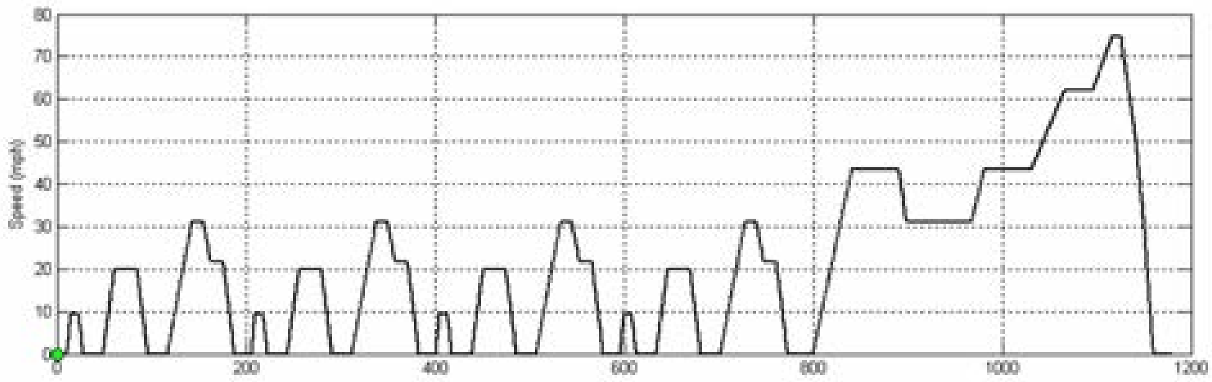


Total fuel used for NEDC

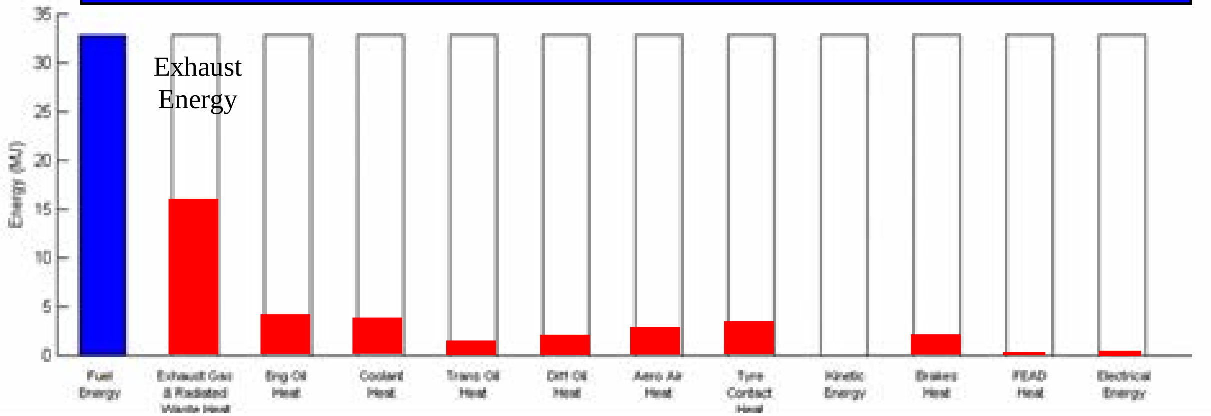
Distribution of fuel energy throughout the cycle



Energy flows are not always ideal

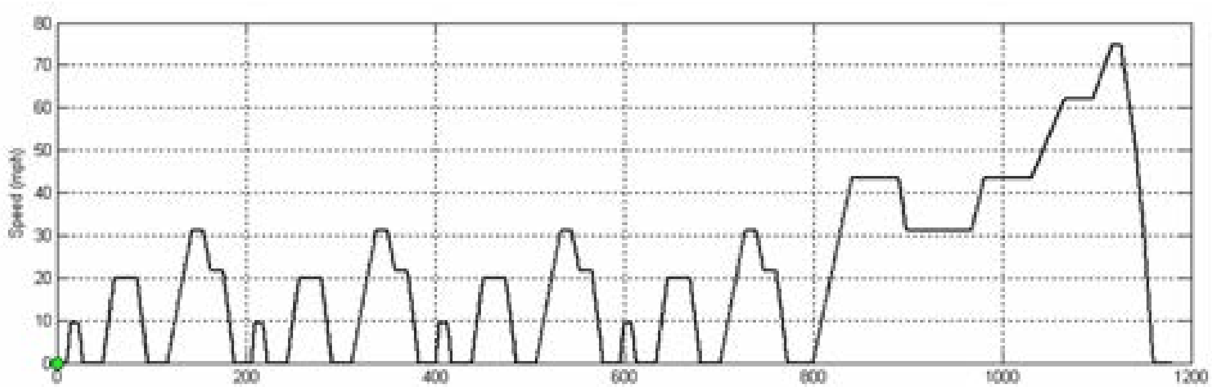


NEDC at start – all energy contained in fuel

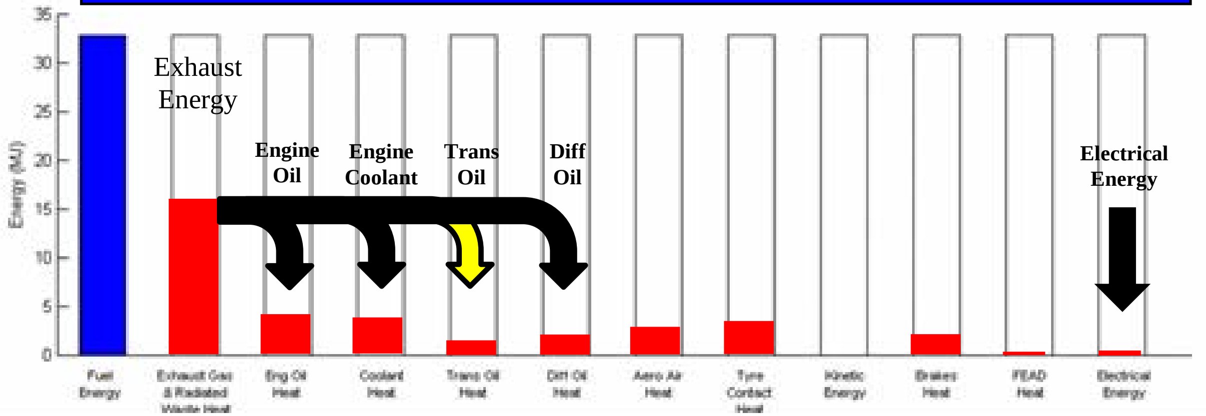


NEDC at end – fuel energy converted to other forms of energy

Energy can be diverted to perform useful work



NEDC at start – all energy contained in fuel



NEDC at end – fuel energy converted to other forms of energy

The energy harvested needs to be optimally placed

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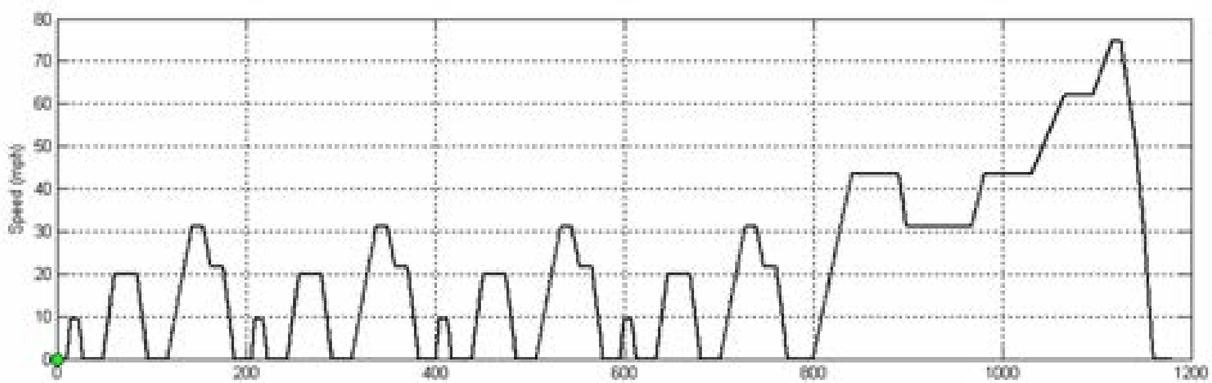
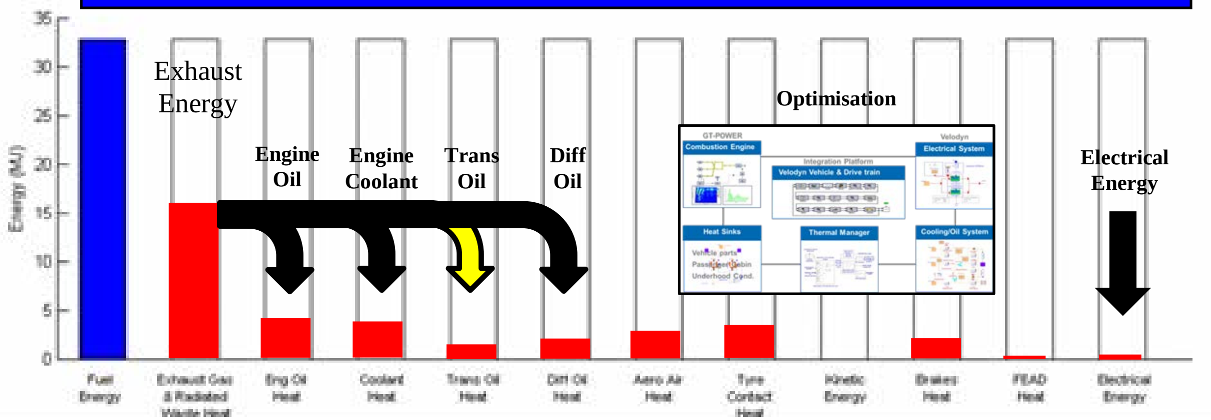


NEDC at start – all energy contained in fuel



NEDC at end – fuel energy converted to other forms of energy

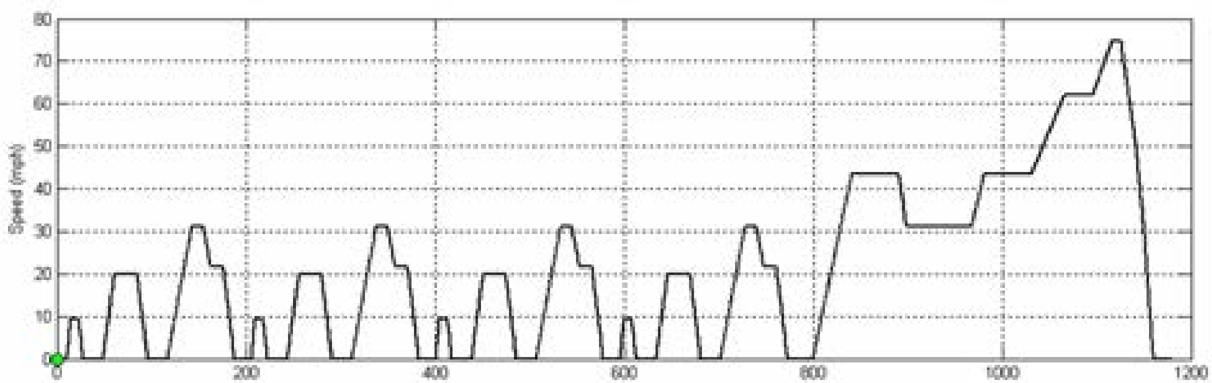
automotive engineering iav

bp

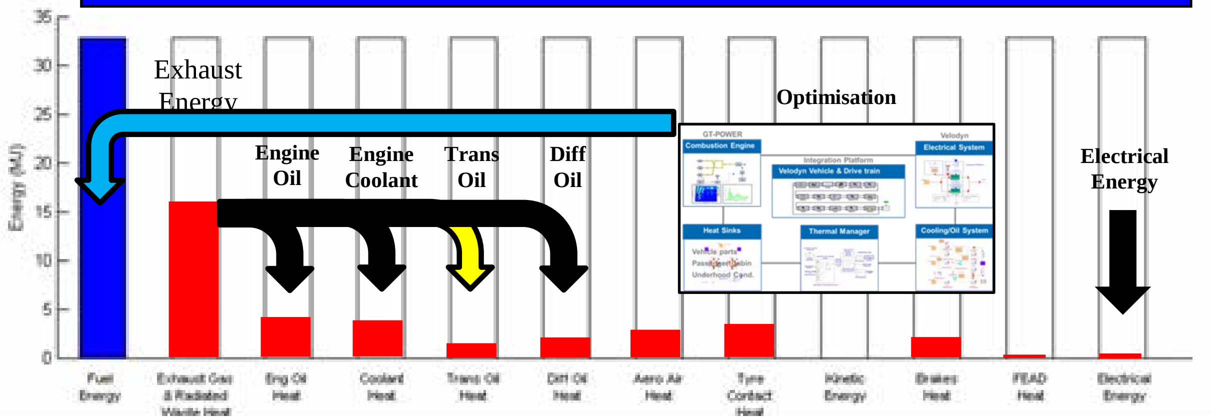
The University of Nottingham

Imperial College London

Finally the overall fuel energy can be reduced



NEDC at start – all energy contained in fuel

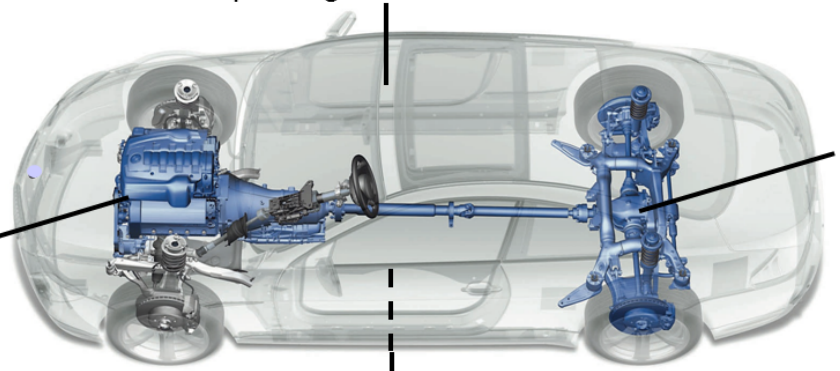


NEDC at end – fuel energy converted to other forms of energy

VIPER Project work-packages

WP6: ***Demonstrator Vehicle***
Demonstrate cumulative CO_2 benefit of technologies developed in the previous work packages in a vehicle

WP2 & 3: ***Engine Design for Low Thermal Inertia***
Clean sheet approach to thoroughly evaluate and understand heat flows in a current engine, and the effects of blocking or transferring them in order to provide a definitive guide that can be applied to all future engine designs



WP5: ***Driveline Parasitics & Warm-up***
Evaluate state of the art technologies for reducing parasitic RDU losses, improving thermal management & lubrication properties

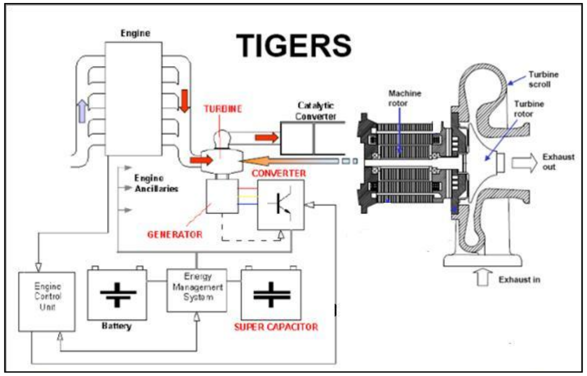
WP4: ***Exhaust Thermal Energy Recovery***
Thermo-electric and turbo-generator devices will be evaluated for extraction of practical, useable, otherwise wasted energy from the exhaust system

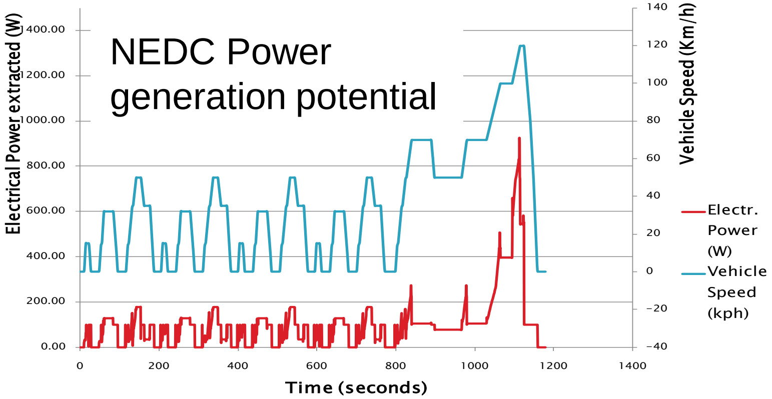
WP1: Powertrain Thermal Analysis & Optimisation
Development of an analytical tool in order to determine optimal placement of thermal energy for best CO_2 reduction.

TIGERS – Turbo-generator

What it does:

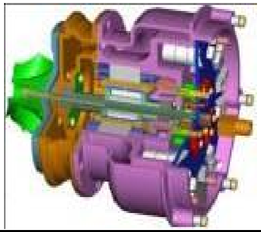
- TIGERS extracts energy from the engine exhaust stream by 'expanding' the exhaust gas to lower temperature and pressure. The resultant shaft power is used to drive a high speed generator.
- When exhaust energy flows permit, the output of the generator can supply the vehicle electrical system as a more efficient alternative to the alternator.





How is the machine configured?

- The turbine end of the machine is similar to that found in a fixed geometry turbocharger.
- The switched reluctance generator is directly driven by the turbine at over 50,000 rpm and the 3 phase power stages/inverter and associated high speed control electronics are package at the 'cold end' of the machine.



TEGS – Thermo-electric generator

What it does

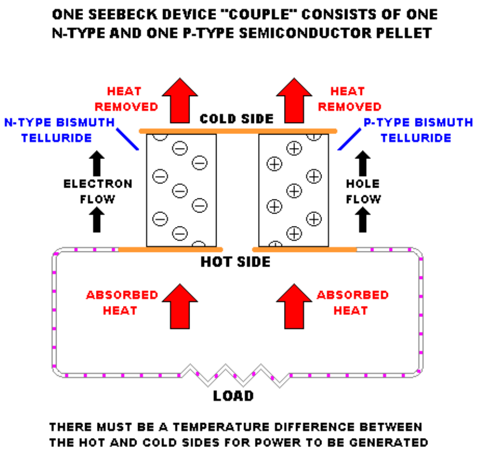
- The generator produces electricity in proportion to the temperature differential which can be maintained across the device.

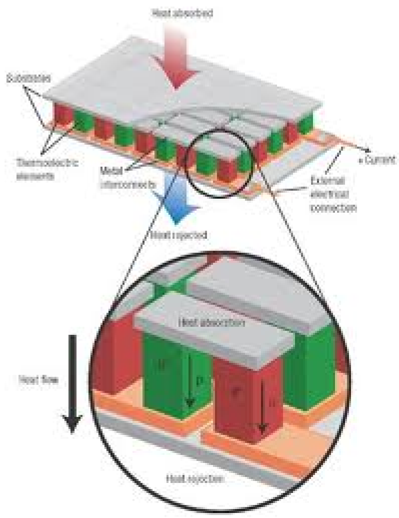
Why do we get this behaviour?

- In response to an applied temperature gradient mobile charge carriers in metals and semiconductors move from the hot end to the cold end producing a potential difference.
- This is known as the Seebeck effect.

$$zT = \frac{\alpha^2 \cdot T}{\rho \cdot \kappa}$$

- α: Seebeck coefficient – V/K
- ρ: Electrical resistivity - Ω.m
- κ: Thermal conductivity – W/K.m





Source: Mark Ellis – TS Conference 2010

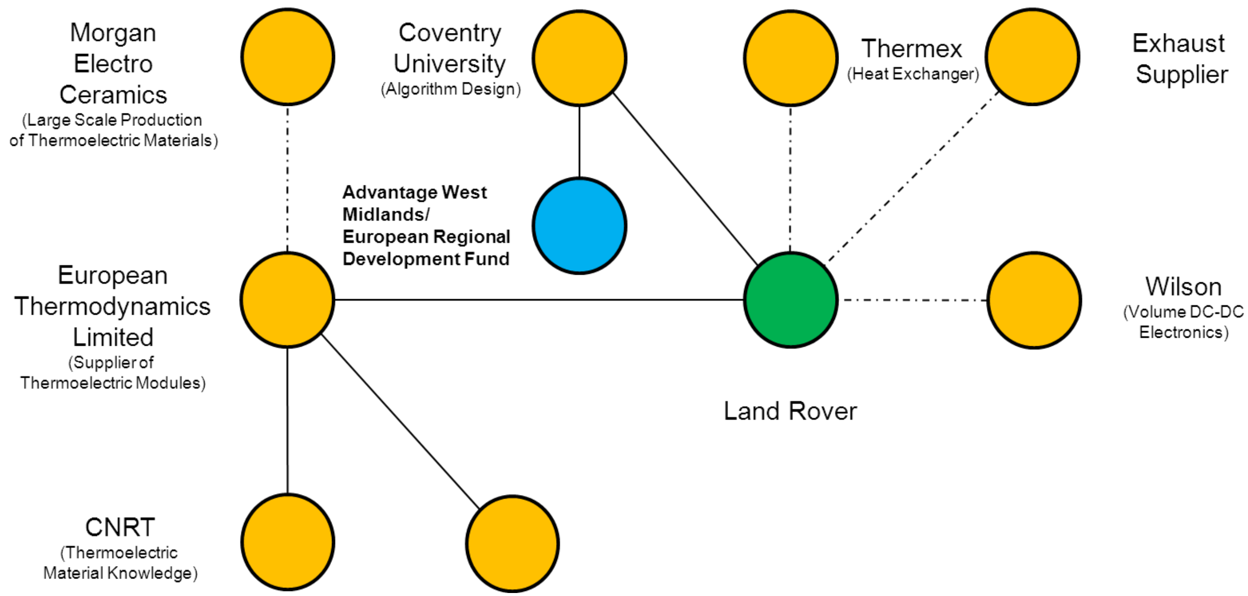
VIPER Outputs

- Outputs
  - Validated engine thermal system model that feeds into vehicle model for warm-up & friction
  - A model that can be used for goal seeking optimal placement of energy in subsystems for best CO_2
  - Evaluation & comparison of Thermoelectric and Turbo, generator concepts
  - Design guide for TEG
  - Performance & optimisation models for Thermo-electric Generators
  - Advanced lubricants developed for engine and differential
  - Definitive engine design guide for application to future low thermal inertia engine designs
  - Thermally managed Rear Differential Unit
  - Demonstration vehicle

VIPER enhances SME growth

- Giving OEMs and Tier 1s good reasons for
  - Staying in / growing in / coming to the UK
- Having the most attractive automotive manufacturing sector in Europe
  - Research, development and production
  - High value adding SME Tier 2/3 foundation
- Contributing to profitability of all collaborators through increased competitiveness
- Reaffirming the Powertrain and Engine engineering footprint in the UK
- Building the new technology and consultancy supply base
- Increasing product desirability and engineering presence by demonstrated capability
- Enhanced research base in UK academia and industry
- Supplier opportunity in major new product developments

VIPER enhances SME growth - Example



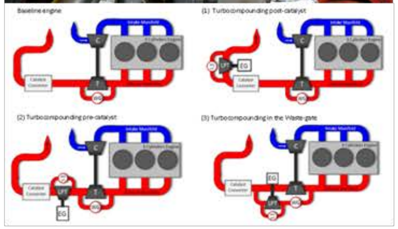
- Thermo-electric Generators
  - > Currently no supply chain in place in UK (strong in France, Germany & USA) – creation of product supply chain solely in UK
  - > Lifting an SME from Tier 2/3 supplier to development/research partner level
  - > Exploitation of UK Academia thermo-electric materials & electronics knowledge (applicable to other industries)
  - > Leveraging of large scale UK semi-conductor material manufacturing industry

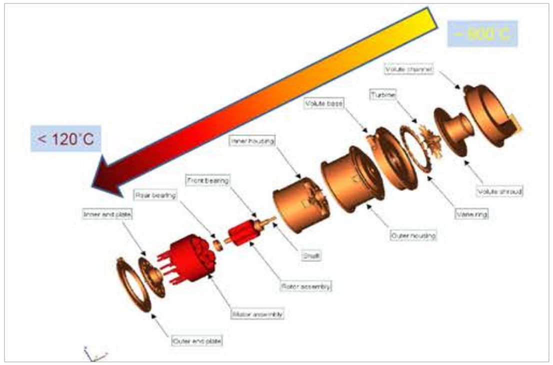
Backup Slides

TIGERS Issues

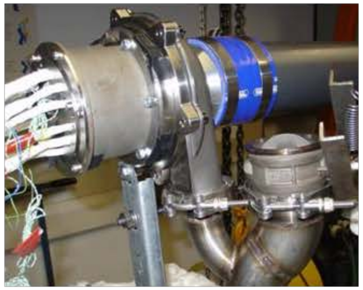
Electronics Development
Costs
Power
Efficiency
Voltage range
Durability

System Integration
Thermal management
Back pressure
Bypass control
Weight
Complexity
£/w/CO_2 & BSFC
System Control & OBD
NVH
Location/Packaging
Operating strategies
Service & Life cycle considerations

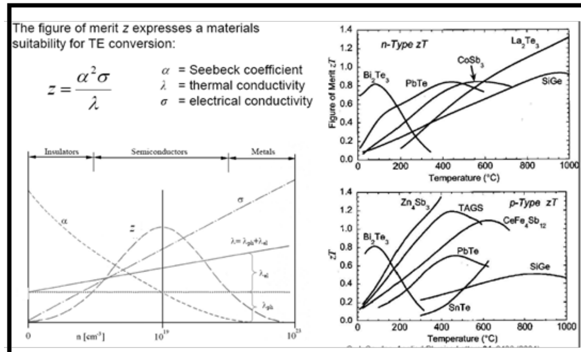




Component Development
Temperature management
Cooling jacket configuration
Thermal barrier development
Sealed bearing life optimisation
Turbine wheel material selection
Shaft critical speed optimisation
Bypass design



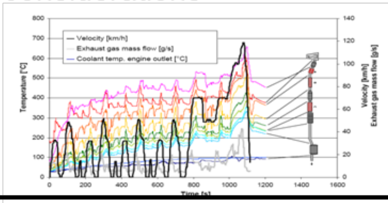
TEGS Issues

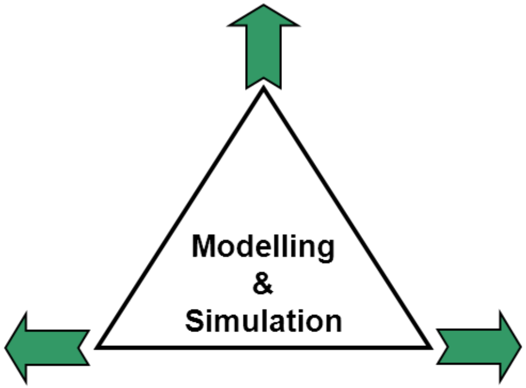


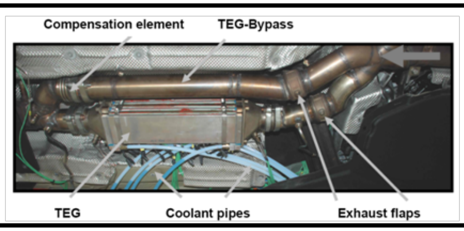
$$z = \frac{\alpha^2 \sigma}{\lambda}$$

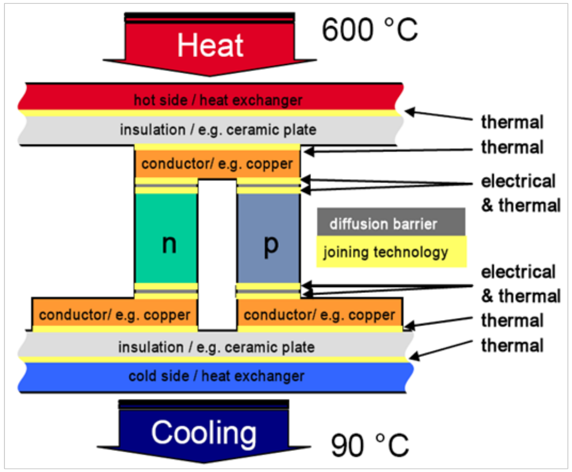
Material Development
Costs
Durability
Environmental friendliness
Availability
Insulative and conductive properties
Stability
Operating range
Process development

System Integration
NVH
Back pressure
Weight
Complexity
£/w/CO_2 & BSFC
Control & OBD
Packaging
Operating strategies
Service & Life cycle considerations









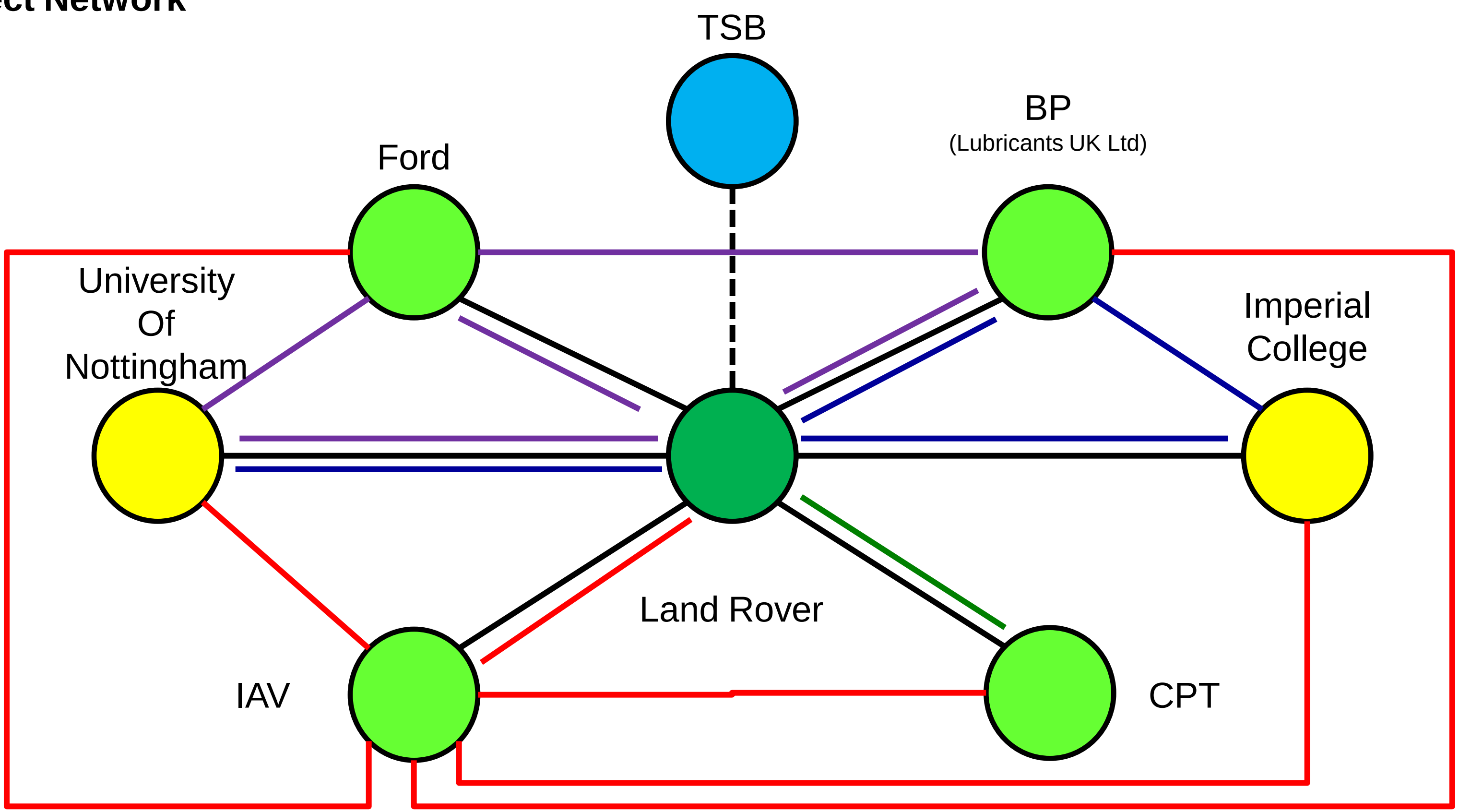
Component Development
Durability
Oxidation
Joining technologies
Flat plate hot & cold heat exchanger tolerance
Heat transfer (Hot & cold sides)
Thermal expansion/cycling stresses
Bulk supply of TE materials
Manufacturing simplicity

Source: Mark Ellis – TS Conference 2010

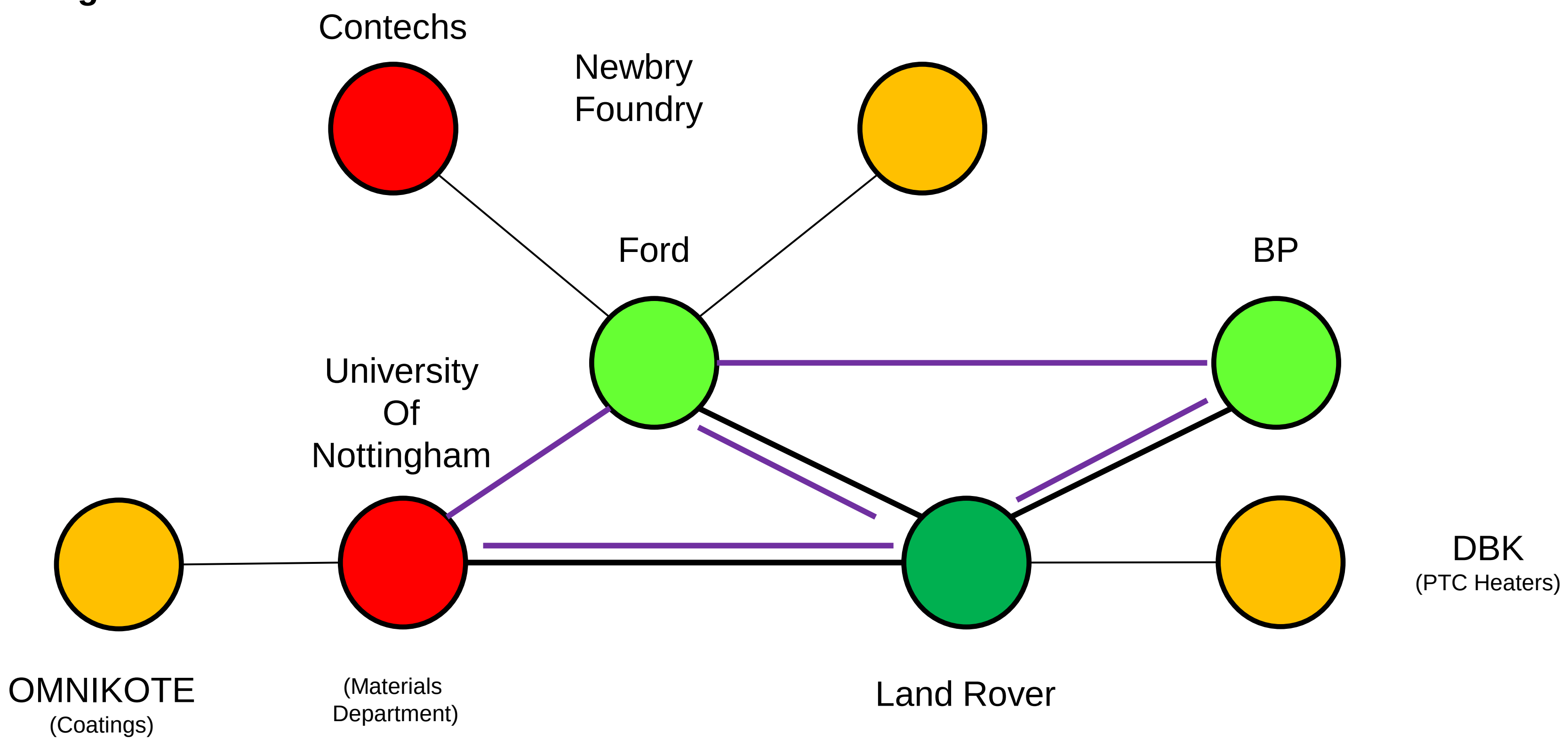
automotive engineering

Green circle	Project Lead	Red line	**Work Package 1: Powertrain Thermal Analysis & Optimisation** Development of an analytical tool in order to determine optimal placement of thermal energy for best CO_2 reduction.
Blue circle	Sponsor - Funding	Purple line	**Work Package 2 & 3 : *Engine Design for Low Thermal Inertia*** . Clean sheet approach to thoroughly evaluate and understand heat flows in a current engine, and the effects of blocking or transferring them in order to provide a definitive guide that can be applied to all future engine designs
Yellow circle	Partner - Academic Research	Green line	**Work Package 4: *Exhaust Thermal Energy Recovery*** Thermo-electric and turbo-generator devices will be evaluated for extraction of practical, useable, otherwise wasted energy from the exhaust system
Red circle	Supplier – Information Partner	Dark blue line	**Work Package 5: *Driveline Parasitics & Warm-up*** Evaluate state of the art technologies for reducing parasitic RDU losses, improving thermal management & lubrication properties
Orange circle	Supplier – Part/Information Supplier	Dashed line	Funding
Light green circle	Partner - Industrial	Dotted line	Proposed

Project Network

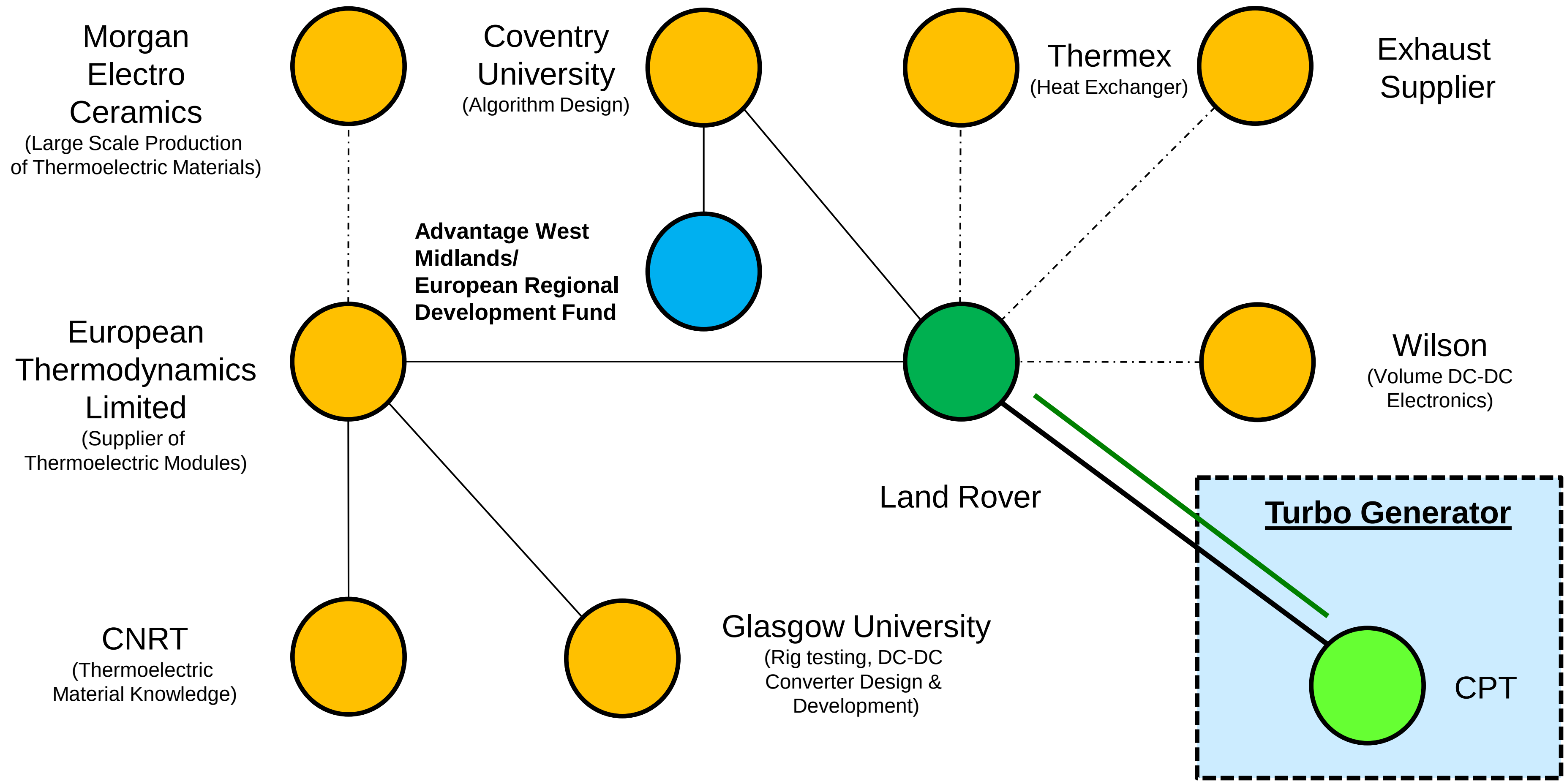


Work Package 2 & 3



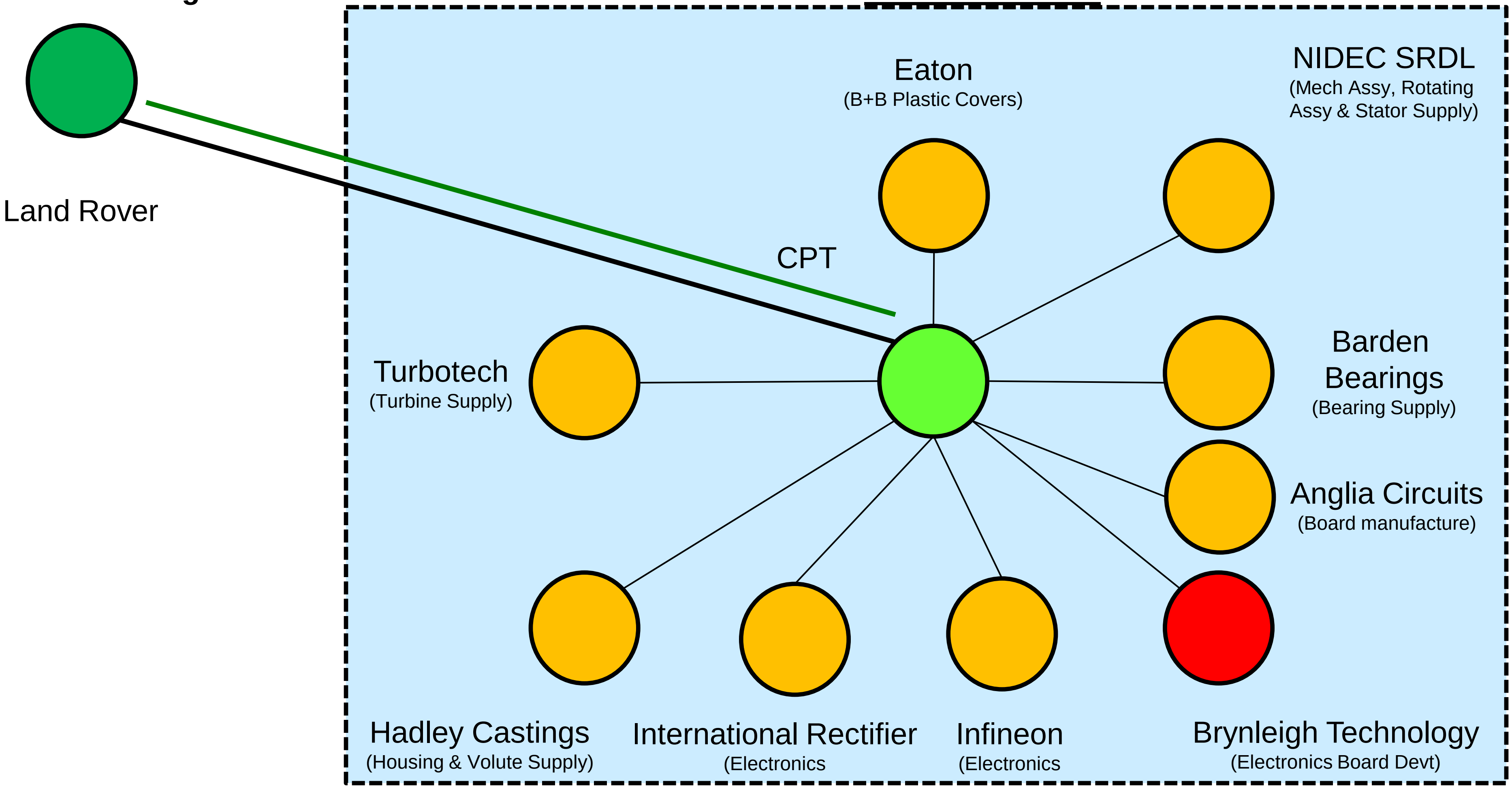
Work Package 4

Thermoelectric Generator

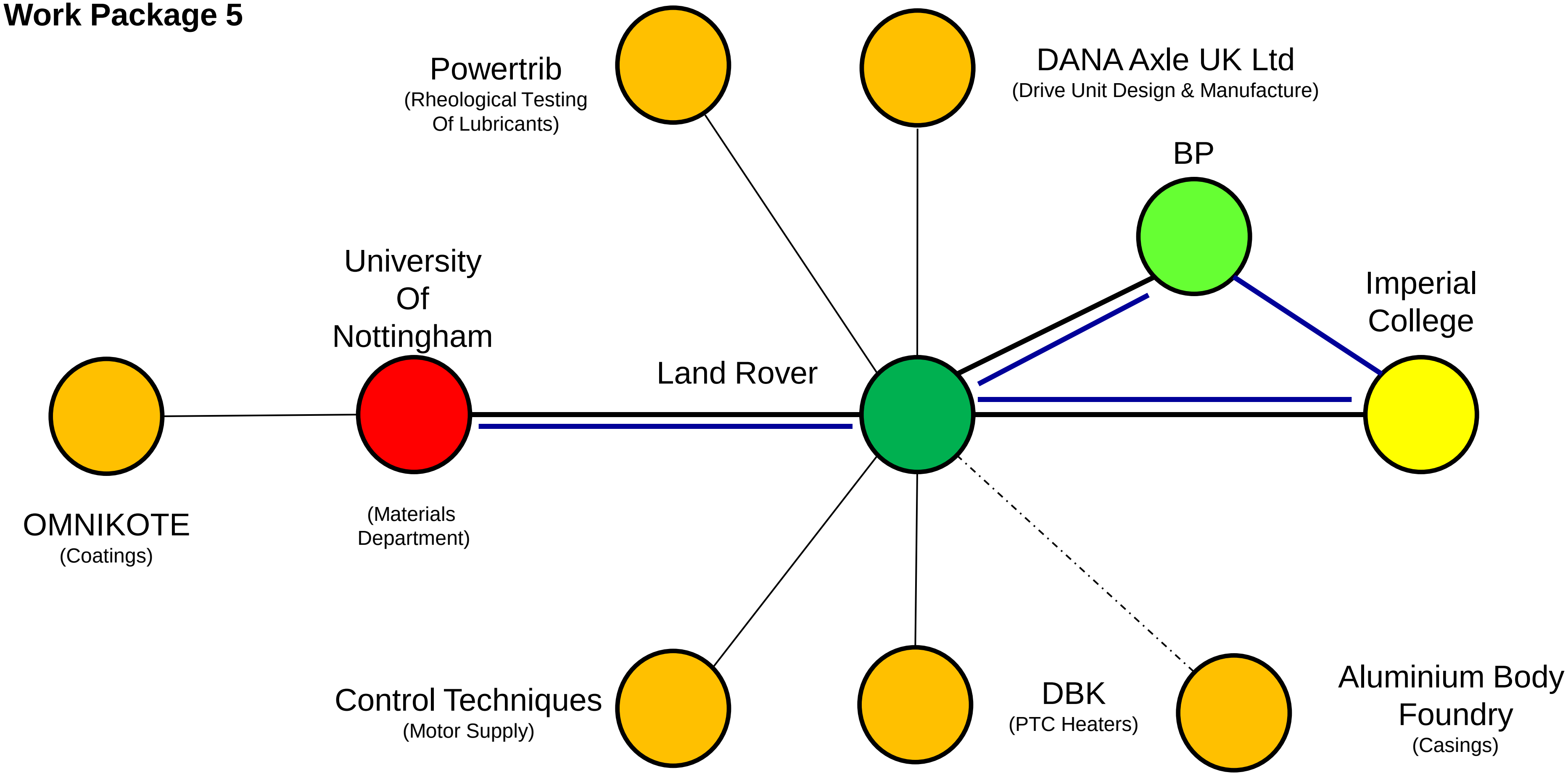


Work Package 4

Turbo Generator



Work Package 5



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