Future Heavy Duty Trucks:

Powertrain technology/choices
Simulation challenges & opportunities

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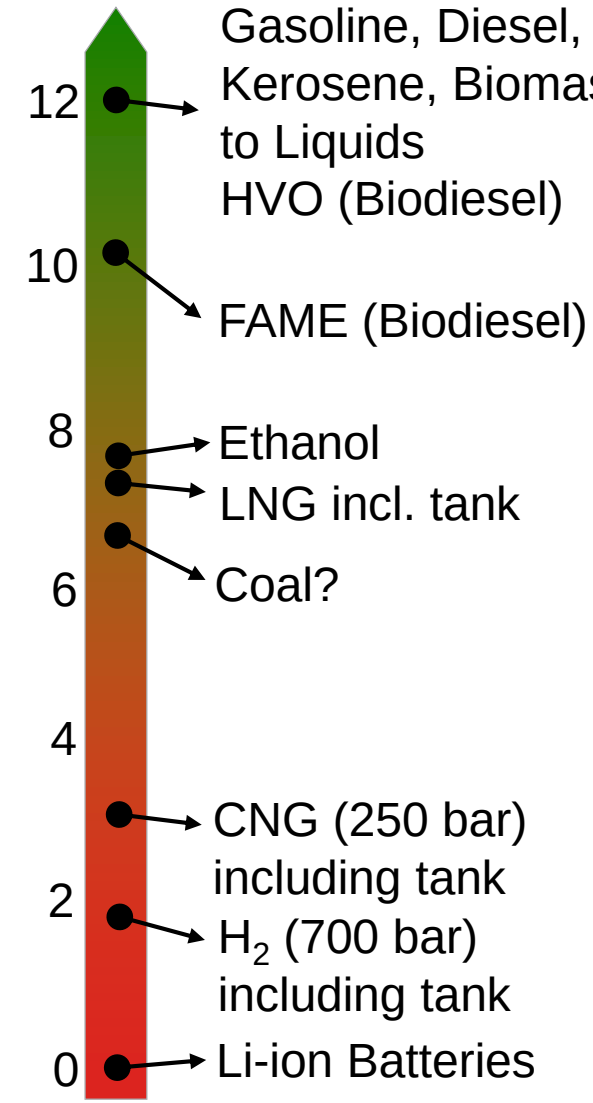
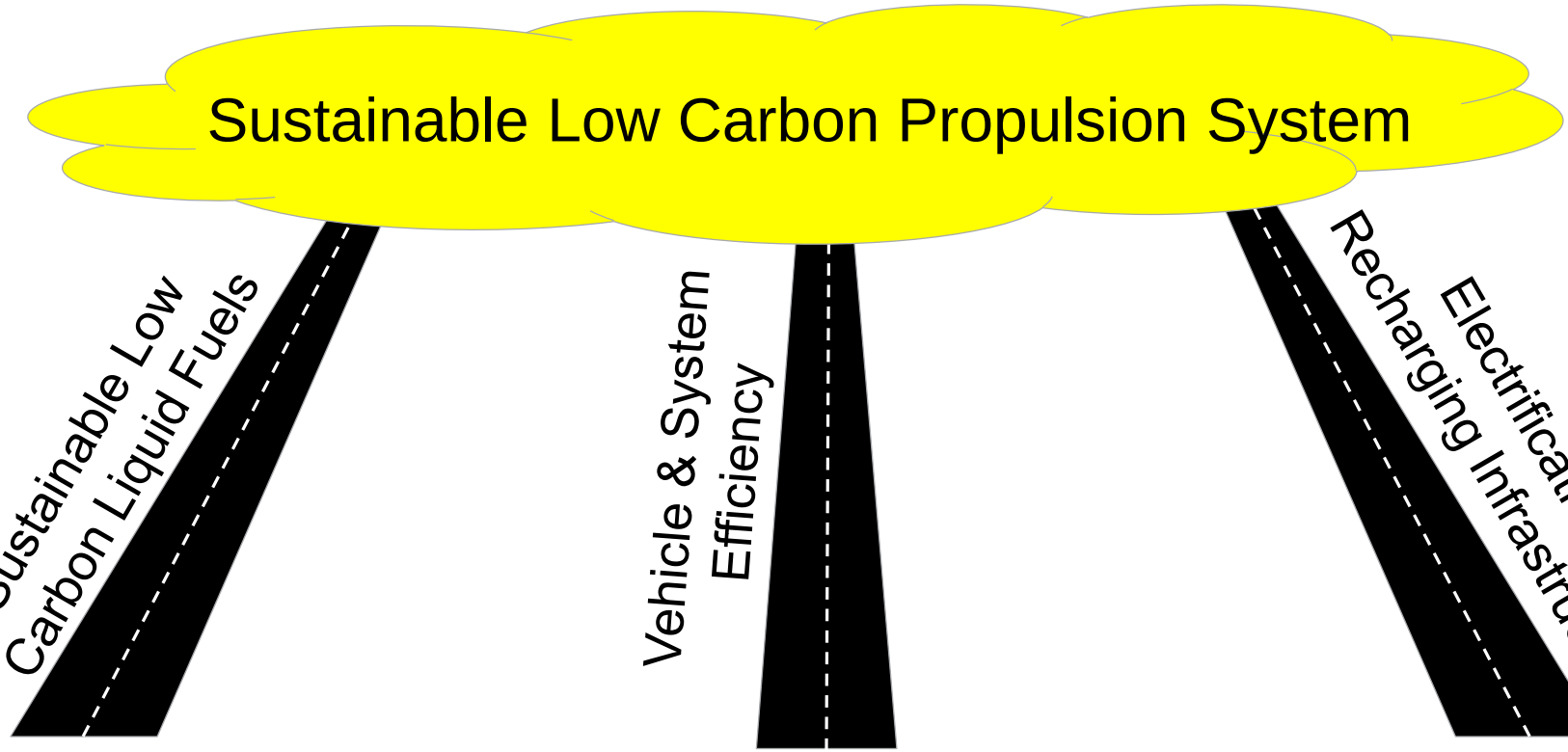
Electrification is only one part of the future transport solution – we will still require low carbon liquid fuels for many decades…





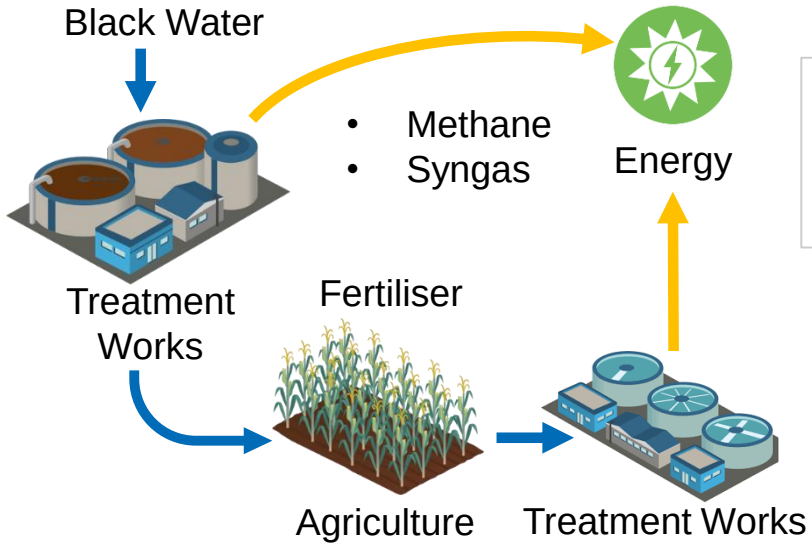
Source: Ricardo

Electrification for heavy duty applications?

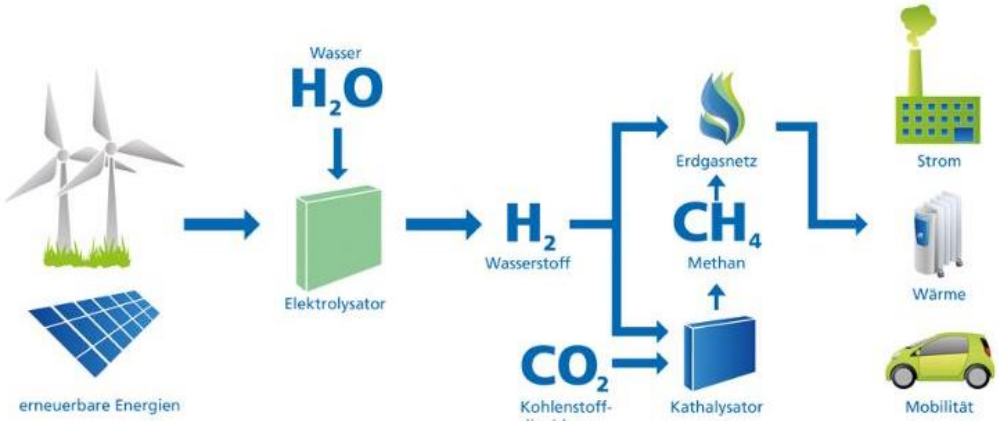
- Safety Issues:
  - Need dual catenary as no road surface connection
- Power:
  - Total power input for multiple HGV's on an incline likely to be 5-10 MW
  - Initial trials at 600 volts - not compatible with multi-vehicle demands
- Costs
  - $5–6 million per km likely to be prohibitive
  - Who pays?

Source: recombu.com:Sweden is testing electric roads for trucks, ITS International: Using electricity to power road freight

Ultra Low or Zero carbon trucks – probably a choice between H_2 Fuel cells with renewable hydrogen or Bio-Waste/Power to Liquid Fuels



Waste to Hydrocarbon Liquid Fuels



Renewable Electricity to Liquid Fuels

H_2 Fuel Cell Trucks – Toyota/Nikola Motors **<>** **Renewable "Synthetic" Fuels**

Advances in computing power, AI & flexible manufacture offer significant productivity, cost & ADAS/Platooning validation benefits

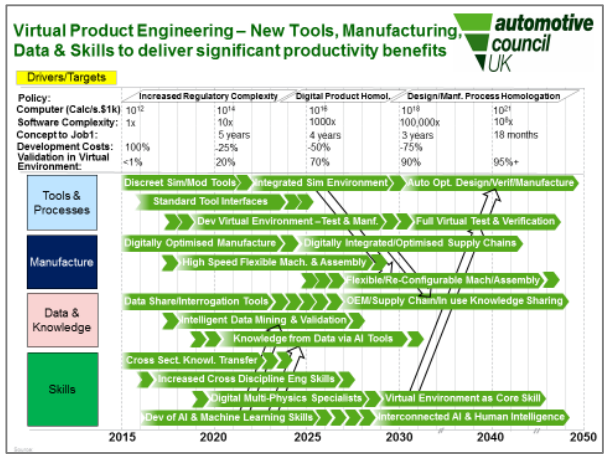
Challenges

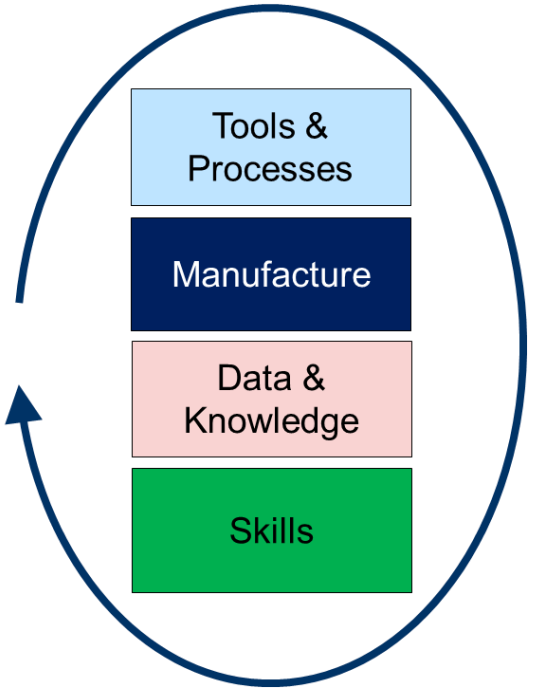
- **Productivity Improvements**
  - Increasing future truck complexity & optimisation requirements
    - Current PD durations of 5-7 years not sustainable in the digital age
- **Product Development Costs**
  - Cost of new product launch ~ Many €100m's for new powertrain
    - Need route to lower total costs despite increases in complexity
- **Connected & Autonomous Functions**
  - Optimisation, validation & certification of ADAS & Autonomous functions
    - Not feasible via physical testing – need virtual test environment

Opportunities/Enablers

- **Exponential growth in Computing capabilities**
  - Increase in hardware via parallel computing and GPU's (10^{12} FLOPS)
    - Affordable computer systems competing with human brain by 2020-25?
- **Growth of Machine Learning & Artificial Intelligence**
  - Significant progress in Machine Learning & AI in FinTech & Medicine
    - Self learning systems, turning data into knowledge, auto-optimisation
- **Flexibility in Advanced Manufacturing Technologies**
  - Machine & routing flexibility with Computer Integrated Manufacture
    - Ability to accommodate new products – reducing dedicated operations

To deliver productivity benefits in design/development/validation, focus should be on fundamentals, connectivity, virtual environment and new skills in ML/AI





Key requirements:

- **Improved models and physics for all system elements:**
  - Combustion physics/chemistry, tribology, fluid dynamics etc.
  - Improved models for electric motors, wide band gap semiconductors
  - Battery chemistry and system models
  - Auto-optimisation methods
- **Connectivity:**
  - Ability to create full multi-physics modelling environment – compatible input/output data sets and multi-vendor components
- **Virtual Environment:**
  - Validated virtual environment that represents all real world events and interactions – agent based modelling
- **Manufacturing:**
  - Full digital manufacturing environment built into auto-optimised design process
- **Skills:**
  - Specific skills in gaming technology & virtual environment
  - Growth of machine learning & Artificial Intelligence capabilities