Transport 2050:
The Potential Role of Hydrogen

By

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Transport 2050 and hydrogen

Based on insights, scenarios and modelling from Energy 2050

- What will be the transport fuels and technologies of the future?
- What are the prospects for the development of hydrogen vehicles?
- What patterns of mobility do they imply?

Bearing in mind that

- Transport is part of a wider energy system
- Scenarios are ways of exploring different futures under different sets of plausible assumptions
- Models are ways of generating quantitative data for different scenarios

Five minutes each on

- Standard 2050 results
- Results with accelerated hydrogen development
- Results with transport markets segmented by journey length

Key potential developments

- Hybridisation – petrol/electric; petrol/plug-in electric; battery/fuel cell
- Electric vehicles and associated possibilities for grid management
- Energy storage (synthetic fuels?)
- Fuel cells – need for fuel generation (hydrogen?)
- Biofuels – land use, quantity, sustainability
- Infrastructure requirements, spatial implications
- Transport behaviours
  - Personal mobility
  - Patterns of vehicle ownership
- Energy system implications – need for and advantages of an energy systems model

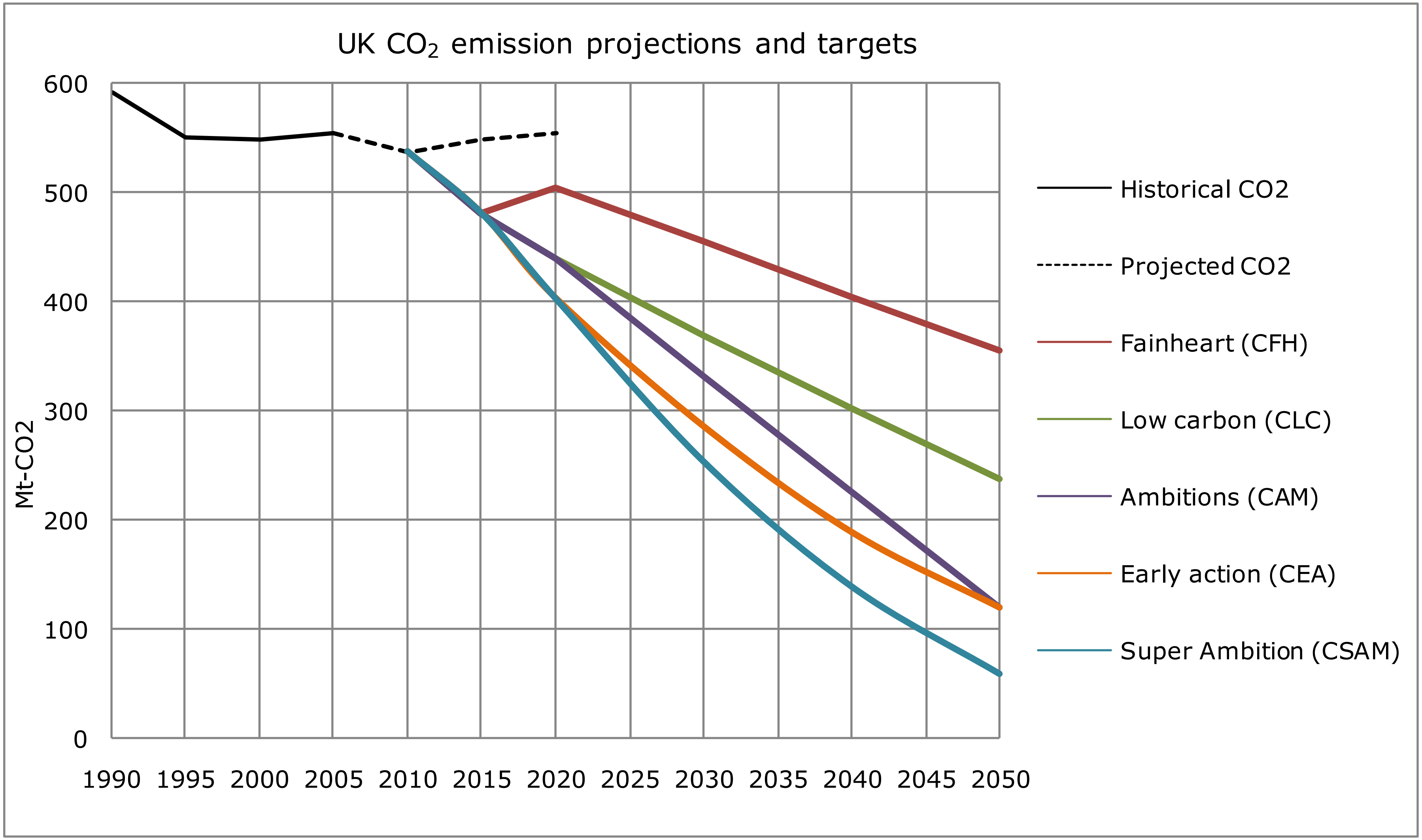
UK MARKAL

- **MARK**et **AL**location dynamic optimization model
- 100+ users in 30+ countries under IEA ETSAP network
- A **least cost optimization** model based on life-cycle costs of competing technologies (to meet **energy service demands)**
- **Technology** rich bottom-up model (e.g. end-use technologies, energy conversion technologies, refineries, resource supplies, infrastructure, etc)
- An **integrated energy systems** model
  - Energy carriers, resources, processes, electricity/CHP, industry, services, residential, transport, agriculture
- Range of physical, economic and policy **constraints** to represent UK energy system
- **In this presentation take strengths and weaknesses of MARKAL as read**

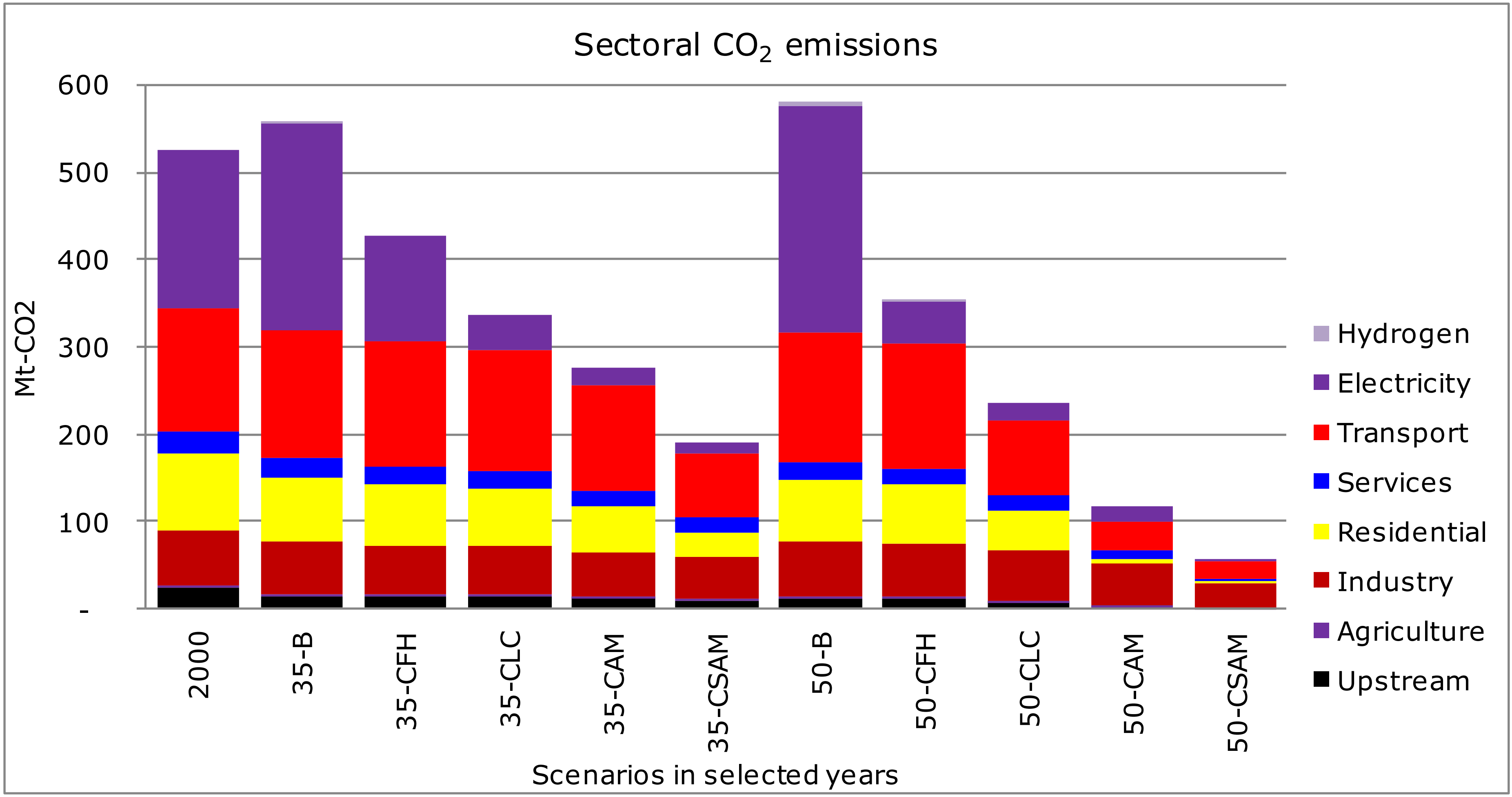
Carbon targets and scenarios

Scenario	Scenario Name	Annual targets (reduction)	Cumulative targets	Cum. emissions $GTCO_2$ (2000-2050)	2050 emissions $MTCO_2$
REF	Reference	-	-	30.03	583.5
CFH	Faint-heart	15% by 2020 40% by 2050	-	25.67	355.4
CLC	Low-carbon	26% by 2020 60% by 2050	-	22.46	236.9
CAM	Ambition (Low-Carbon Core)	26% by 2020 80% by 2050	-	20.39	118.5
CSAM	Super ambition	32% by 2020 90% by 2050	-	17.98	59.2
CEA	Early action	32% by 2020 80% by 2050	-	19.24	118.5
CCP	Least cost path	80% post 2050	Budget (2010-2050) similar to CEA	19.24	67.1
CCSP	Socially optimal least cost path	80% post 2050	Budget (2010-2050) similar to CEA	19.24	178.6

Carbon emissions

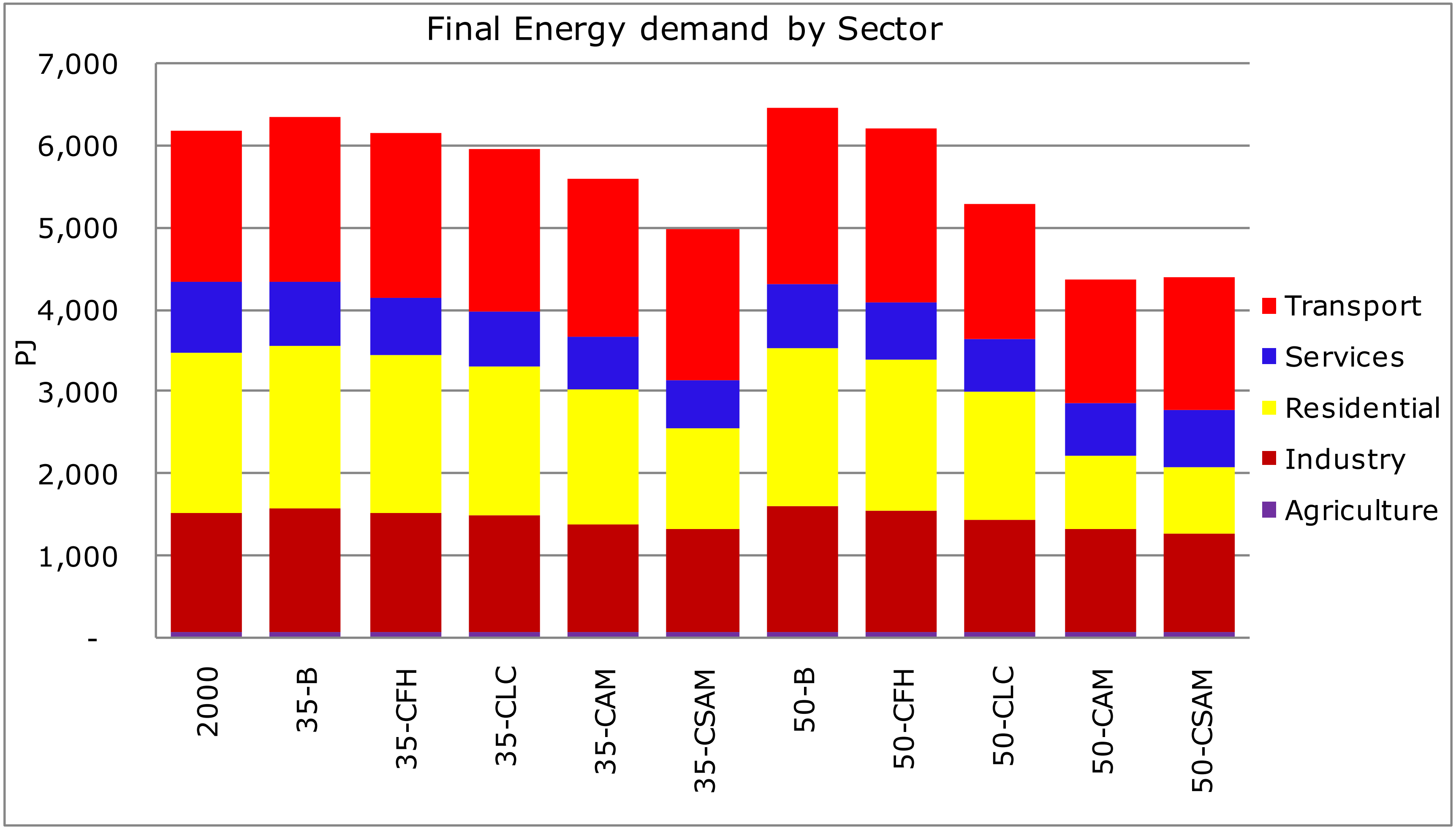


Sectoral carbon emissions

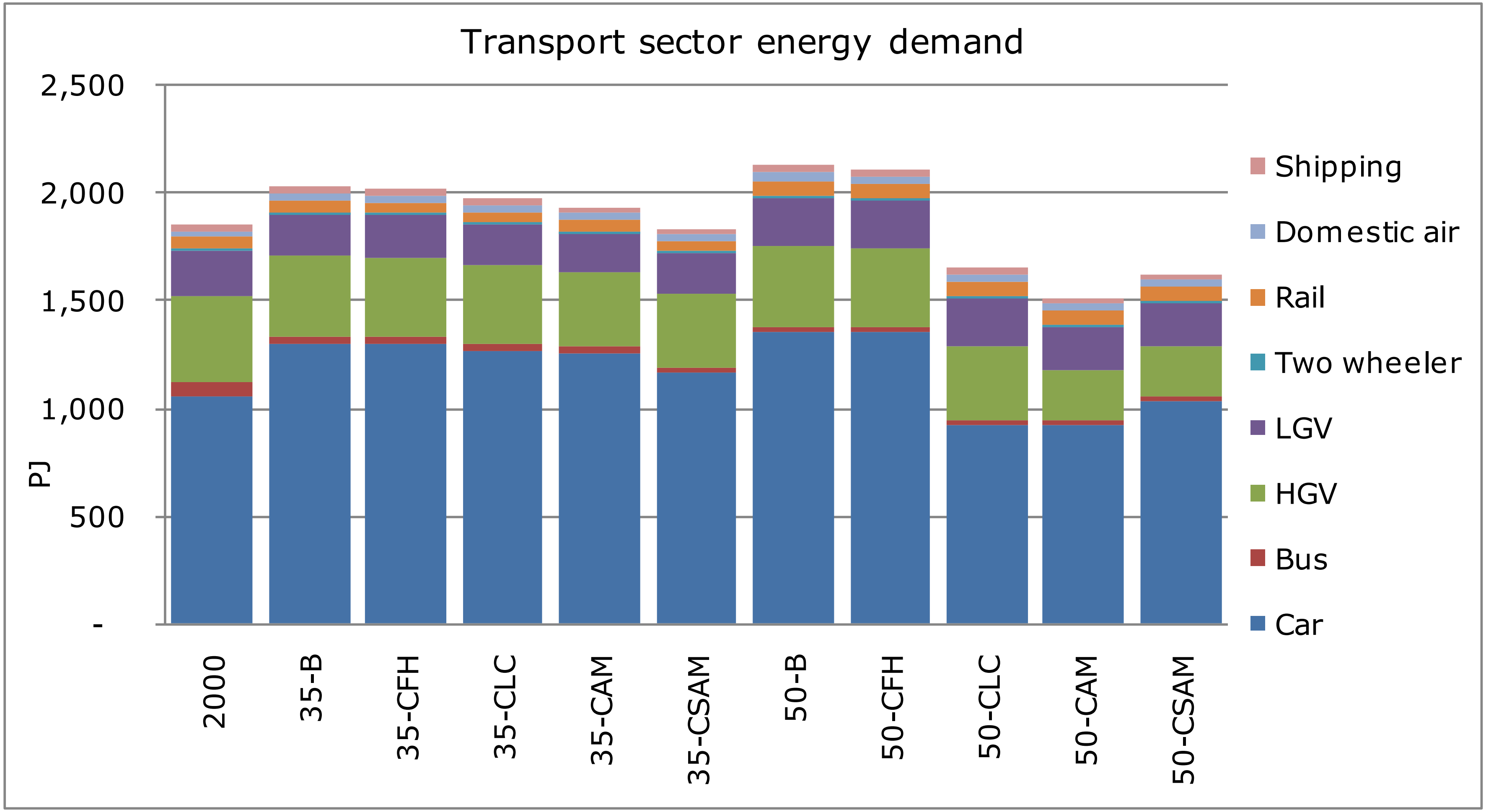


Sectoral energy demand

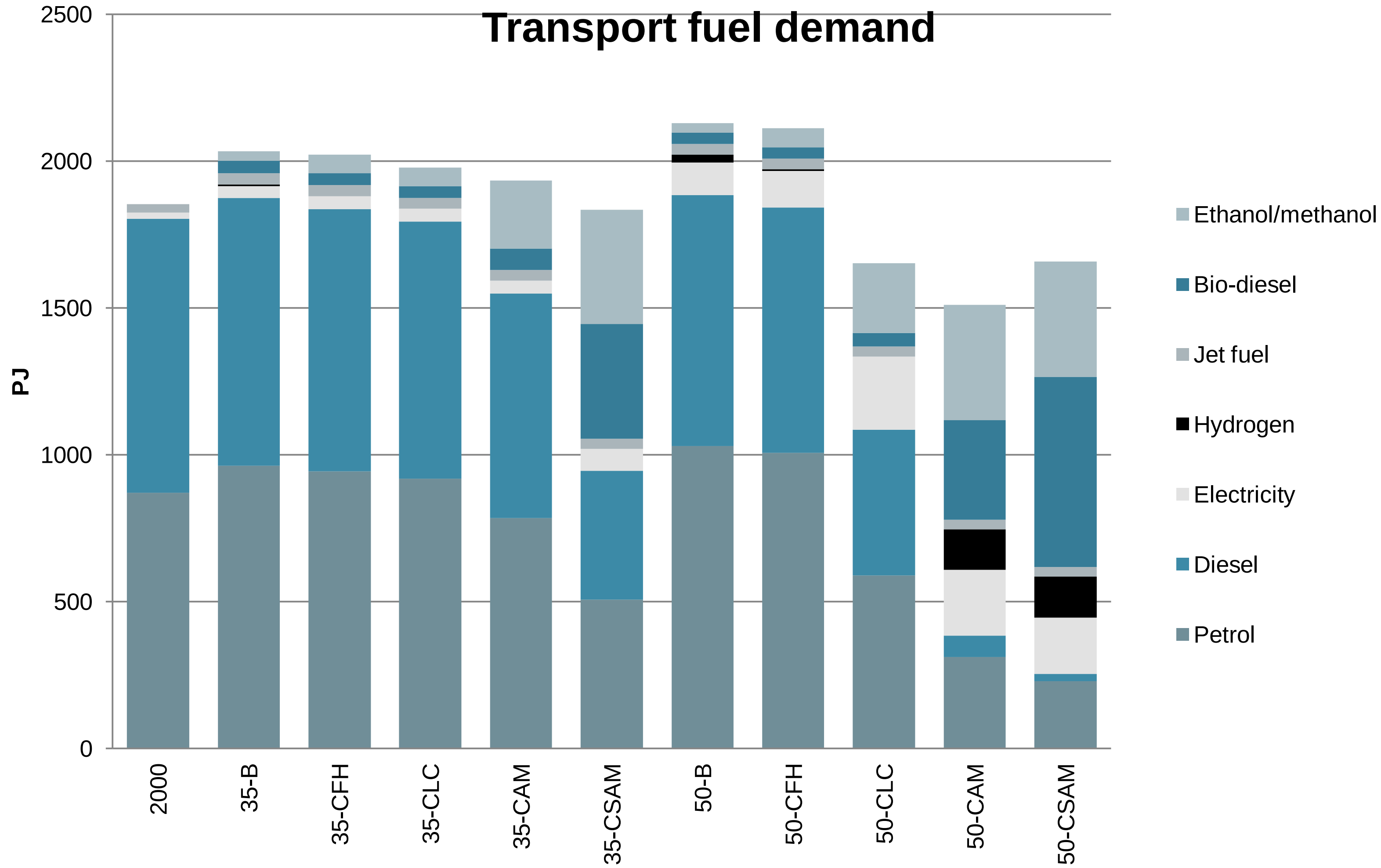
[Road transport energy service demand goes from 488 bvkm in 2000 to 740-780 bvkm in 2035 to 840-890 bvkm in 2050]



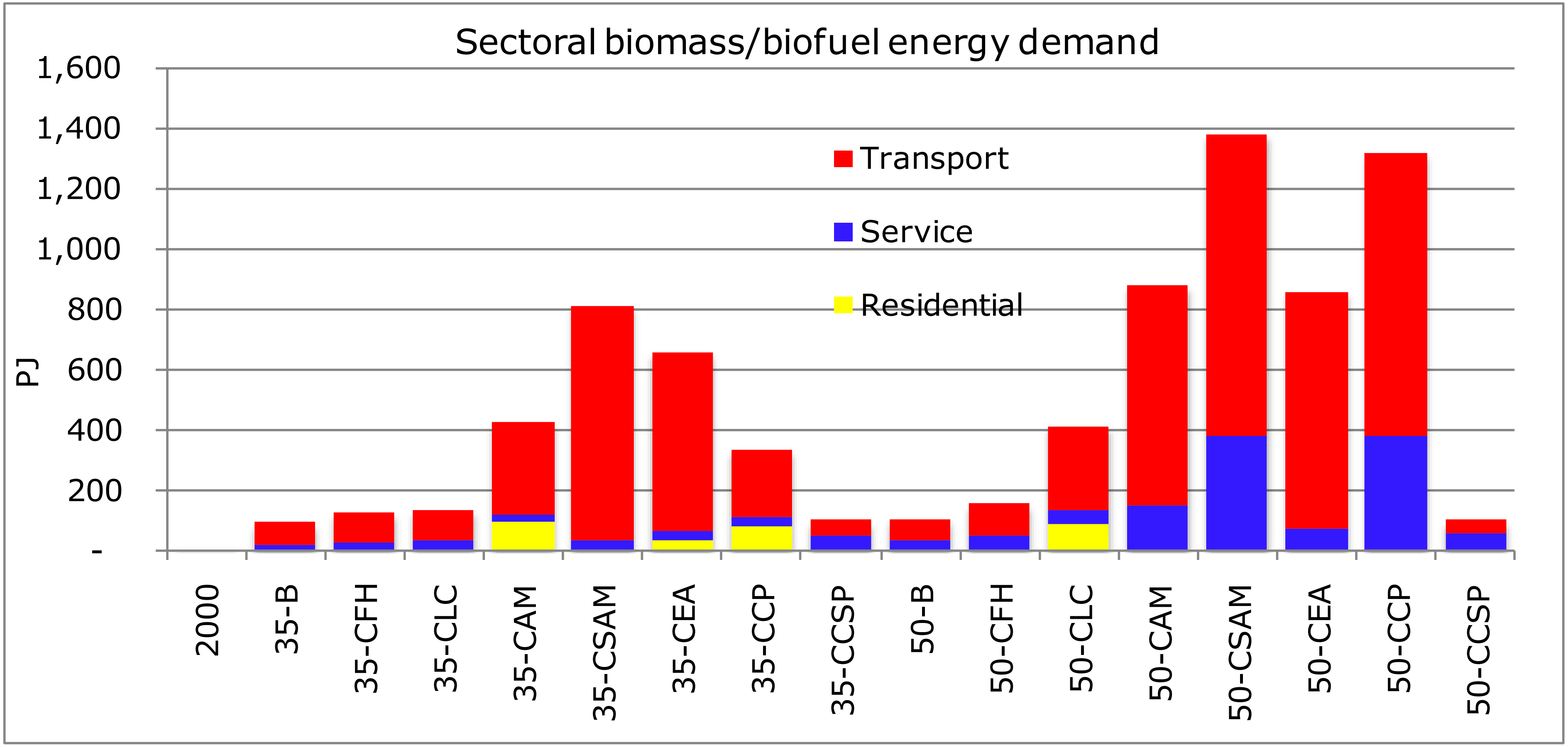
Transport sector energy demand



Transport fuel demand



Sectoral biomass/biofuel demand



Scenario conclusions

- Fuels and technologies are very sensitive to assumptions about
  - Carbon reduction targets
  - Relative technology costs
  - Discount rates
  - Timescale (early/late action)
- How much difference is made by accelerated technology development (ATD) of hydrogen and fuel cells?

ATD – hydrogen and fuel cells

- Obtain significant cost reduction of the H2 drivetrain
  - Component technology development and improvement of PEM and other types of fuel cells
  - Periphery components (air supply, humidification, valves, power and control electronics)
  - Onboard storage
  - Hydrogen ICE integration (including fuel cell APU and hybridisation)
  - System optimization
- Obtain significant cost reduction of hydrogen production chains
  - Electrolysers, biomass gasification systems, CCS as well as standard components and instruments such as compressors, valves, sensors
- System integration for hydrogen systems
  - Integration of main components (drivetrain, onboard storage) and auxiliary equipment (safety equipment, valves, electronics) for hydrogen transport applications
  - Integration of main components for stationary hydrogen applications
  - Integration of renewables and hydrogen in ‘island / remote’ systems
  - d) Use of current low pressure grid for transport of pure hydrogen
- Assure safe and reliable hydrogen applications
- Comply with long-term sustainability requirements
  - Hydrogen produced from renewable energy sources, fossil fuel with CCS or nuclear pathways

Cost reductions

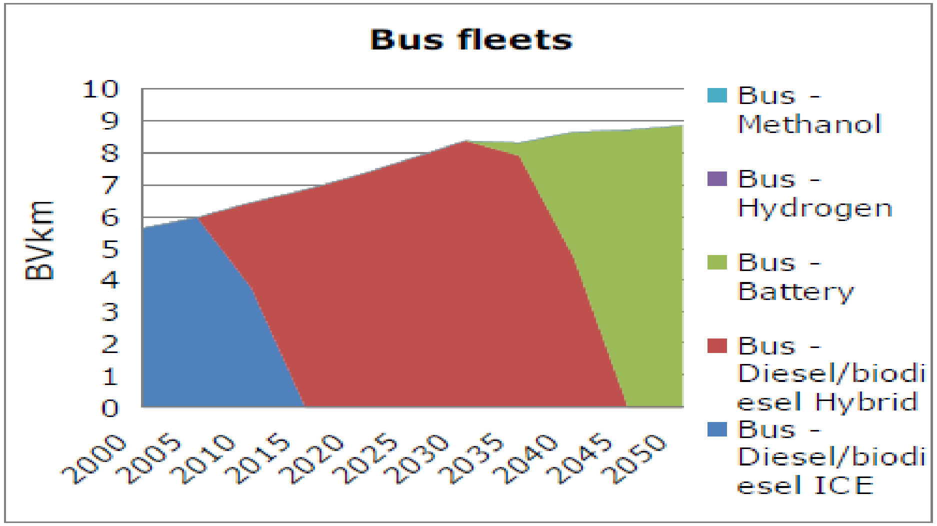
Hydrogen fuel cell Bus

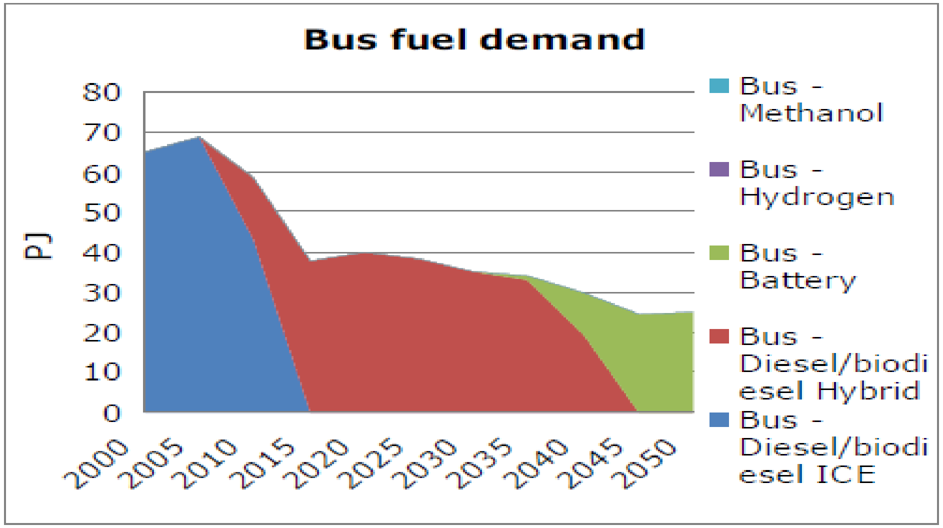
cost	2010	2030	
		CAM	ATD
Capital cost £M/bvkm	3618	2374	1182
Capital cost £/vehicle	229901	150806	75098
Fixed O&M£/v-km	0.447	0.249	0.249

Hydrogen fuel cell Car

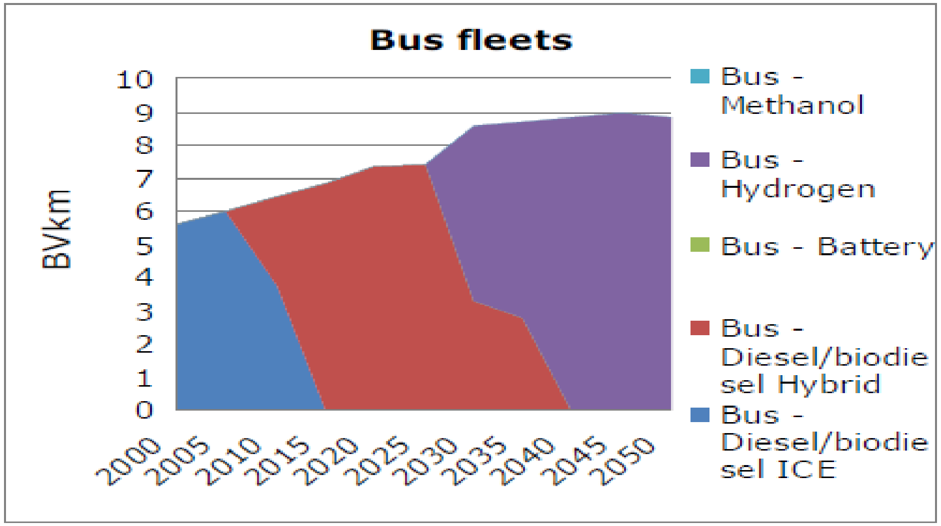
cost	2010	2030	
		CAM	ATD
Capital cost £M/bvkm	2840	1084	847
Capital cost £/vehicle	41124	15692	12267
Fixed O&M£/v-km	0.210	0.090	0.034

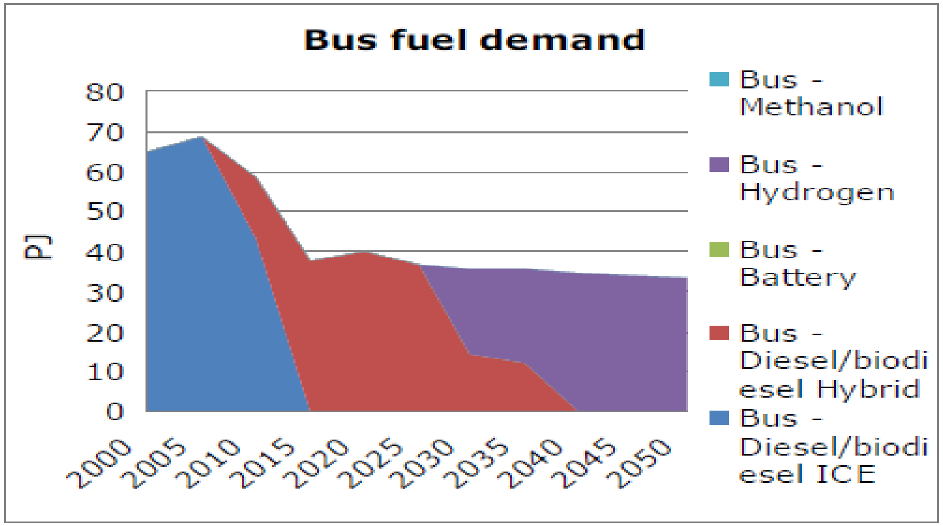
Fuel cell buses





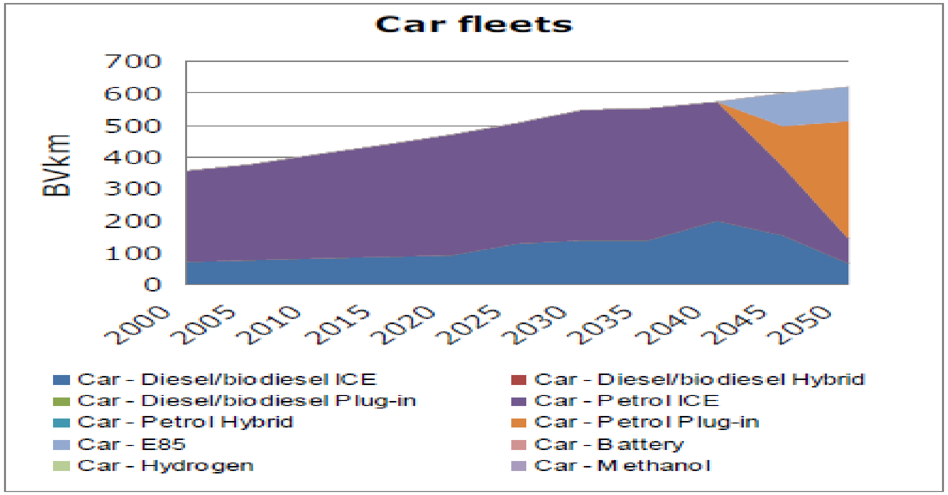
LC-Core (non-accelerated)

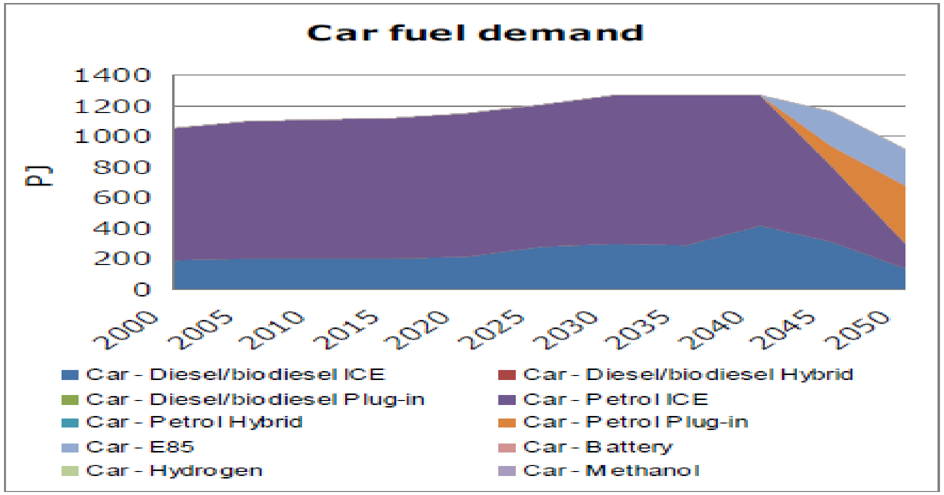




ATD-HFC (accelerated)

Fuel cell cars





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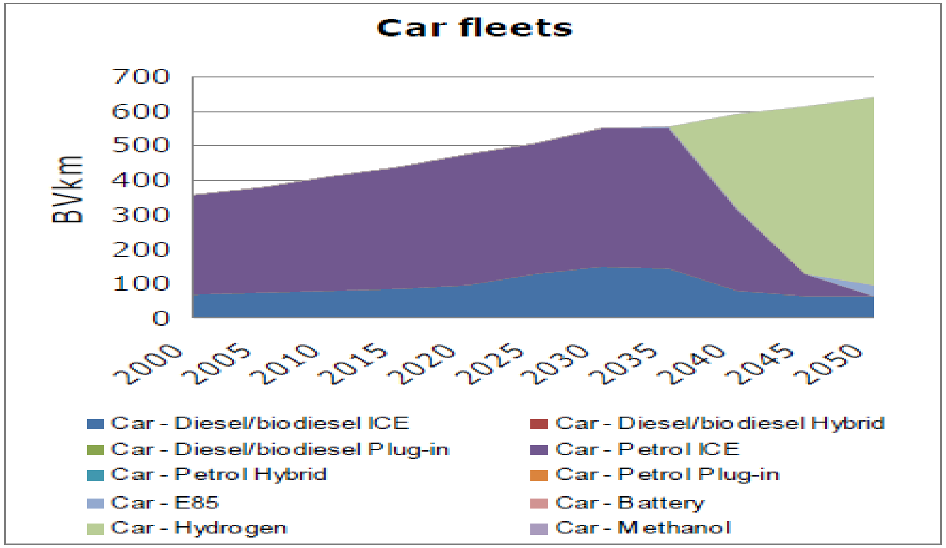
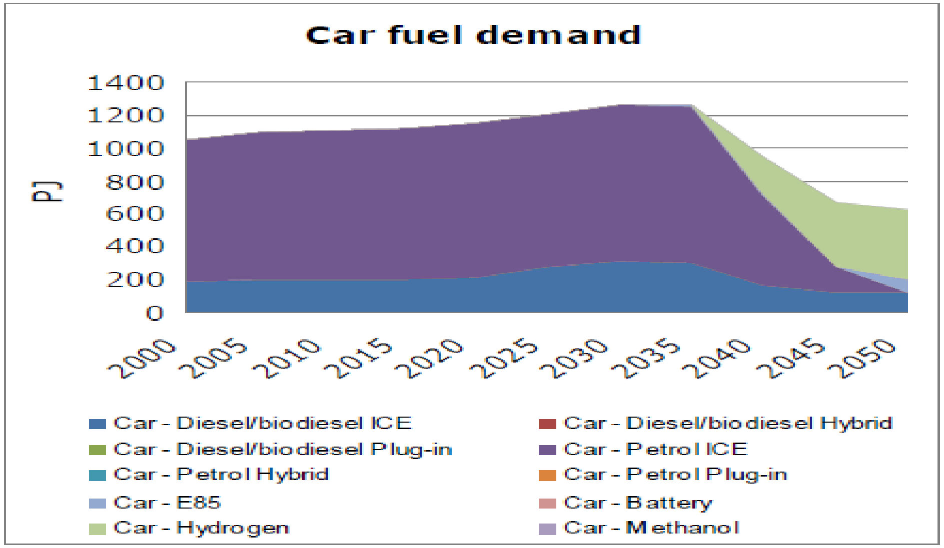




ATD-HFC (accelerated)

ATD Conclusions

- Accelerated technology development demands public policy. What technologies to support, to what extent?
- Infrastructure considerations (model assumes central pipeline and pipeline distribution network, but not detailed filling station hydrogen capability)
- What about behaviours and patterns of mobility?

Transport behaviours (1)

What are the implications of different patterns of consumer demand for vehicles?

- Most scenarios examine a future in which consumers use cars much as they do today, as a multi-purpose vehicle for a wide variety of purposes
- Using UK MARKAL
  - previous analysis uses one 'averaged' vehicle size
  - UK MARKAL, a least-cost optimisation model, gives limited insights regarding travel behaviour, no insights into modal switching
- UK's National Travel Survey gives demand data on journeys of different length; can generate different scenarios

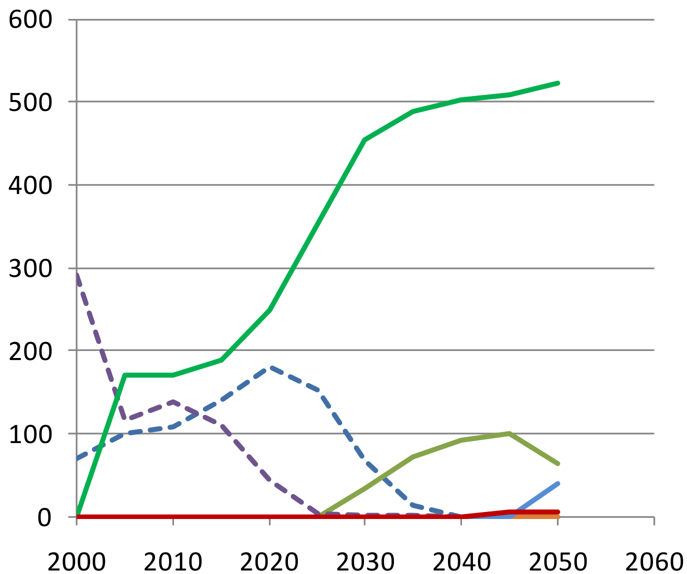
Transport behaviours (2)

- Split car transport energy service demand (i.e. bvkm) by vehicle size: different size vehicles have different characteristics, used in different ways; vehicle technologies have different relative performances for these demands; future technologies are applicable to specific size bands - e.g. unlikely to be large BEVs, as large vehicles tend to drive long distances and would require very large batteries, which are heavy and expensive, increasing cost and reducing efficiency
- Allow independent consumer demands to exist for vehicles of different sizes e.g. large vehicles used for longer journeys, smaller vehicles used as urban 'run-abouts‘
- Scenarios give insights into future transport fuel use, relative importance of technologies within a specific demand, and synergies and trade-offs against other sectors

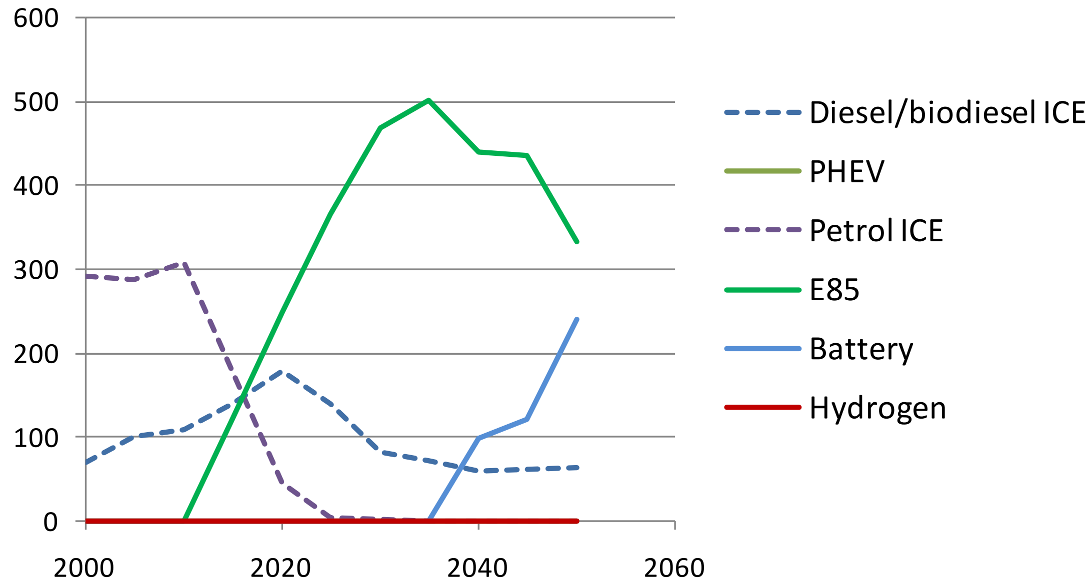
Preliminary results

- Charts show transport demand (in billion vehicle kms) by car type.
- Disaggregated vehicle demand gives smaller role to BEVs, larger roles to FCVs and PHEVs
- Shows strong uptake of biofuels in both models, but late surge in BEVs in the average model and uptake of PHEVs (and a very small number of FCVs) in the differentiated model.

Differentiated consumer demands



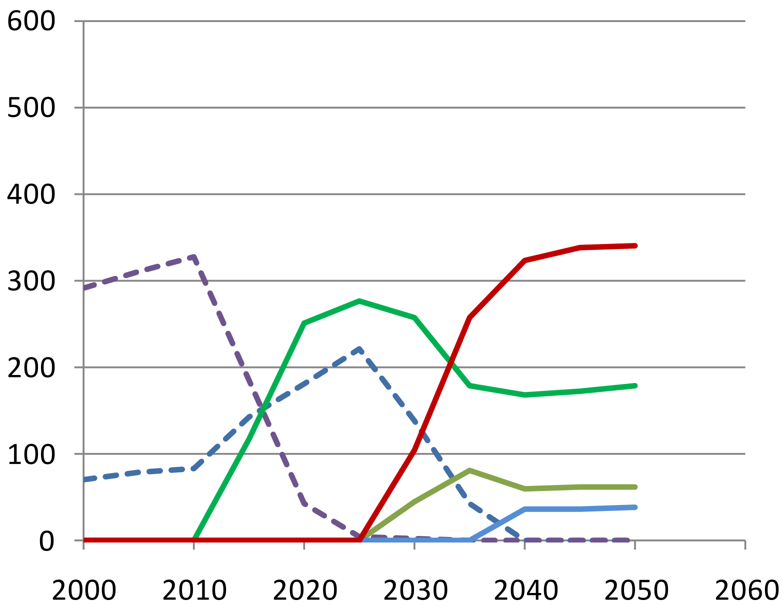
Average, multi-purpose vehicles only



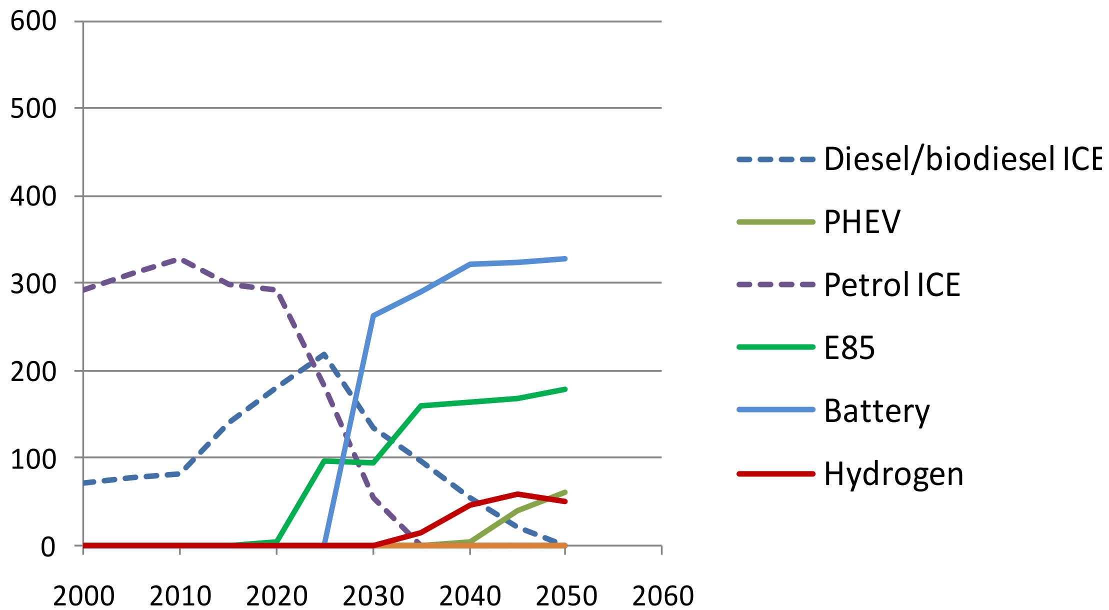
Results sensitive to biomass imports

- We explored a sensitivity run in which no biomass imports are allowed
- Notice here the big differences between the differentiated demand model and the average-only model. In the 'disaggregated demand' scenario, PHEVs and EVs dominate the 'city run-around' market, while H2FCVs dominate the market for large vehicles.

Differentiated demands



Average vehicle only



Conclusions from preliminary results

- Transport technology choices *are* sensitive to assumed patterns of demand, particularly in more-stringent decarbonisation pathways.
- These changes in the transport sector have significant impacts on the overall energy system:
  - Trade-off between biofuels (ICE) and biomass with CCS (BEV)
  - More hydrogen production
    - Electrolysis – requires larger electricity system
    - Gas SMR with CCS – more CCS infrastructure
  - Greater reliance on bio-fuel imports
    - Exposure to uncertainties surrounding sustainability and provenance of biofuels
    - Constraining biofuel imports has massive structural impact

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Thank You

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