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Decarbonisation pathways for the UK

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Broad Methodology

- 4 core scenarios
- variants > key energy policy issues
- four cross-centre working groups:
  - energy supply
  - energy demand
  - energy markets and security
  - energy policy

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Modelling Tools

- ***System level models***
  - *MARKAL Elastic Demand (MED):* a technology rich optimization model of the integrated UK energy system, including a wide range of supply and demand side responses
  - *E3MG:* econometric model, which can be used to forecast changes in economic structure, the energy system and associated environmental impacts
- ***Network Industry Models***
  - WASP: Wien Autonomous System Planning Model – electricity system planning
  - CGEN: Combined gas and electricity network
- ***Energy Demand Sectoral Models***
  - Domestic buildings
  - Non-domestic buildings
  - Transport

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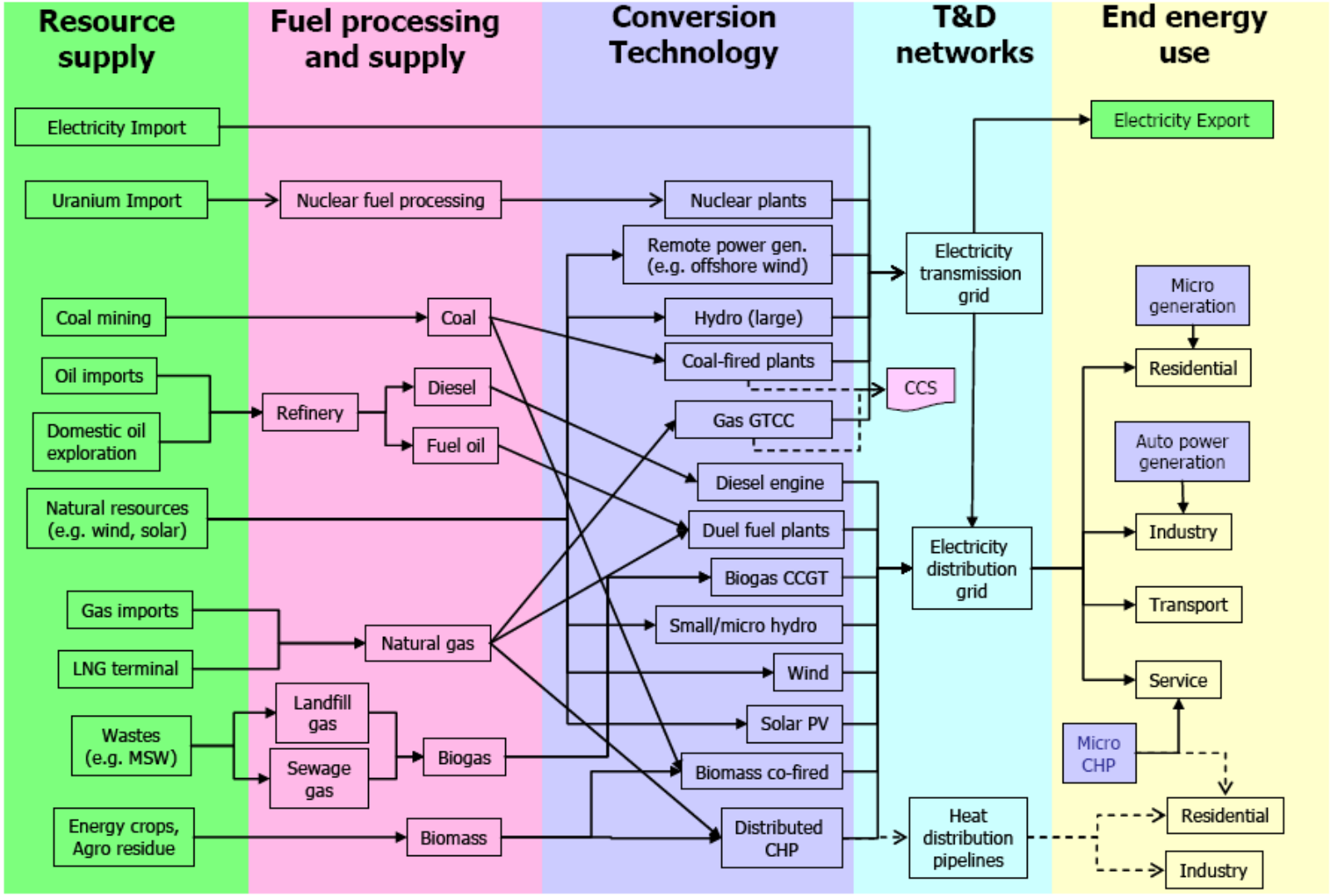
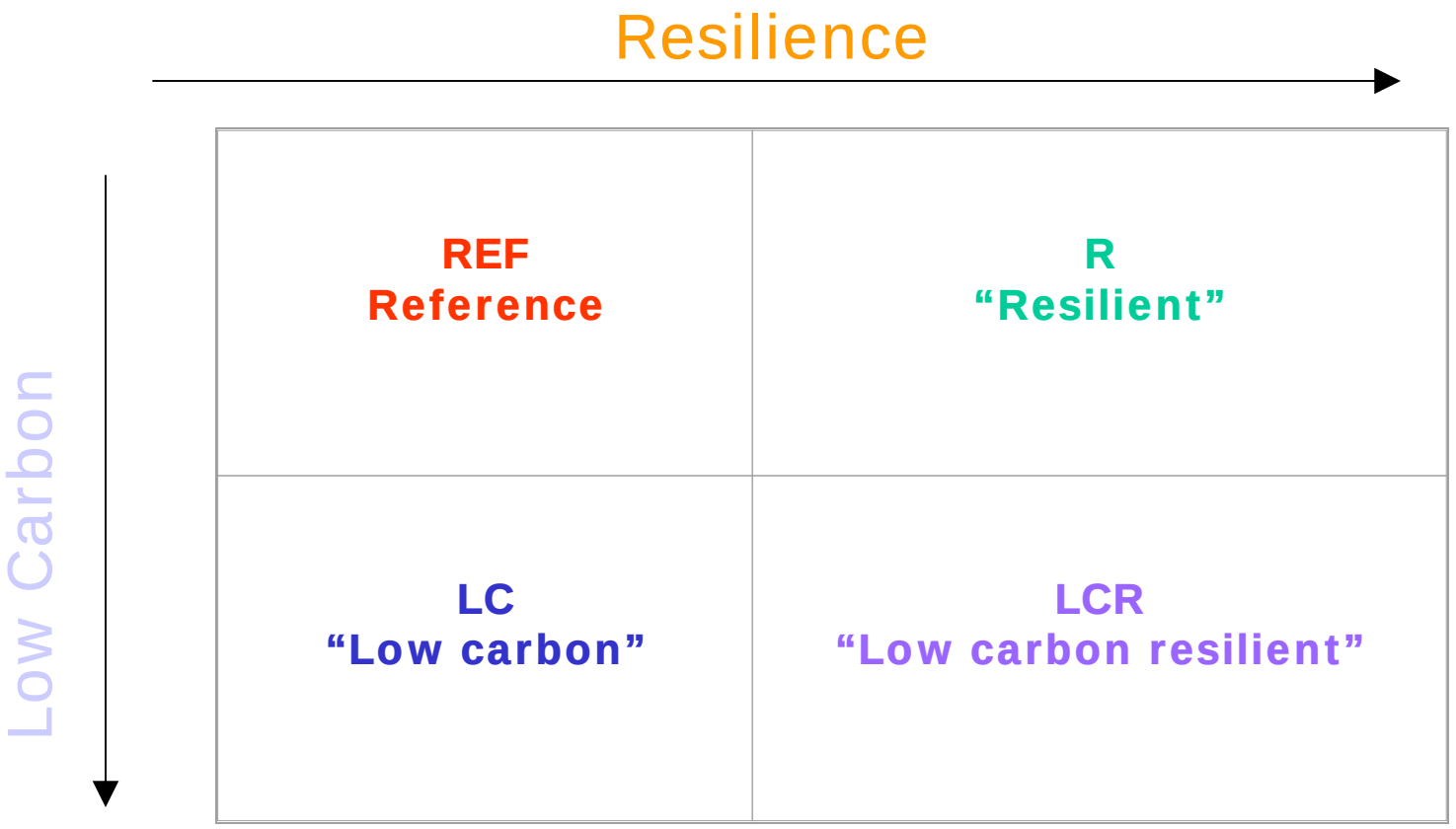
Energy system



Core Scenarios

ENERGY SYSTEM ATTRIBUTES



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Resilience Indicators

Resilience is the **capacity** of an energy system to **tolerate disturbance** and to continue to deliver **affordable energy services to consumers**.

A resilient energy system can withstand shocks and provide alternative means of satisfying energy service needs in the event of changed external circumstances.

- **Supply**
  - Diversity of primary supply
  - Diversity of fuel inputs for electricity generation
- **Infrastructure**
  - Capacity margins in the network industries
  - Storage (coal, oil and gas)
  - Redundancy in network infrastructure
  - Diverse import options
- **Demand side**
  - energy intensity (and hence energy costs)

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Core Scenarios: Common Assumptions

- Underlying economic growth and level of demand for energy services
- Global energy prices
- The availability of energy sources
- Technology costs and learning rates
- Investment hurdle rates
- Any policy measures embedded in the Reference scenario – policies in place at the time of the 2007 Energy White Paper

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Differences Between Core Scenarios

- Carbon constraints
- Levels of demand reduction
- Policy assumptions
- Constraints on energy mix reflecting diversity goals
- The costs and technical performance of energy infrastructure (transmission, distribution, storage etc)

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2050 Scenario Variants

	Name	Short Name	Target Date
1	*Pathways to a Low Carbon Economy*	Carbon Pathways	**Now**
2	*Technology's Contribution to a UK Low Carbon Economy*	Technology	**Imminent**
3	*Building a Resilient UK Energy Economy*	Security and resilience	**December 2008**
4	*Sustainable Energy Lifestyles and Behaviour*	Lifestyles and Behaviour	**February 2009**
5	*The Environment and Sustainable Energy*	Environment	**March 2009**
6	*The UK and Long-term Global Energy Markets*	Global markets	**March 2009**
7	*A De-Centralised Energy System*	De-centralisation	**April 2009**
8	*SYNTHESIS REPORT*	Synthesis	**April 2009**

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Carbon pathways scenarios

Reference		
CFH	Faintheart	-40% by 2050, -15% by 2020
CLC	Low carbon	-60% by 2050, -26% by 2020
CAM	Carbon ambition	-80% by 2050, -26% by 2020
CEA	Early action	-80% by 2050, -32% by 2020
CCP	Least cost path	-80% post 2050, cumulative emissions budget (2010-2050) as CEA
CCSP	Least cost social path	as CCSP but social discount rate

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Discounting assumptions

- default assumptions – investor rates of return
  - 10% real rate of return
  - higher investment hurdle rates, e.g. 25% for private cars
- “social path” assumptions
  - 3.5% real rate of return
  - investment hurdle rates in ratio social discount rate/default discount rate, e.g. 8.75% for transport

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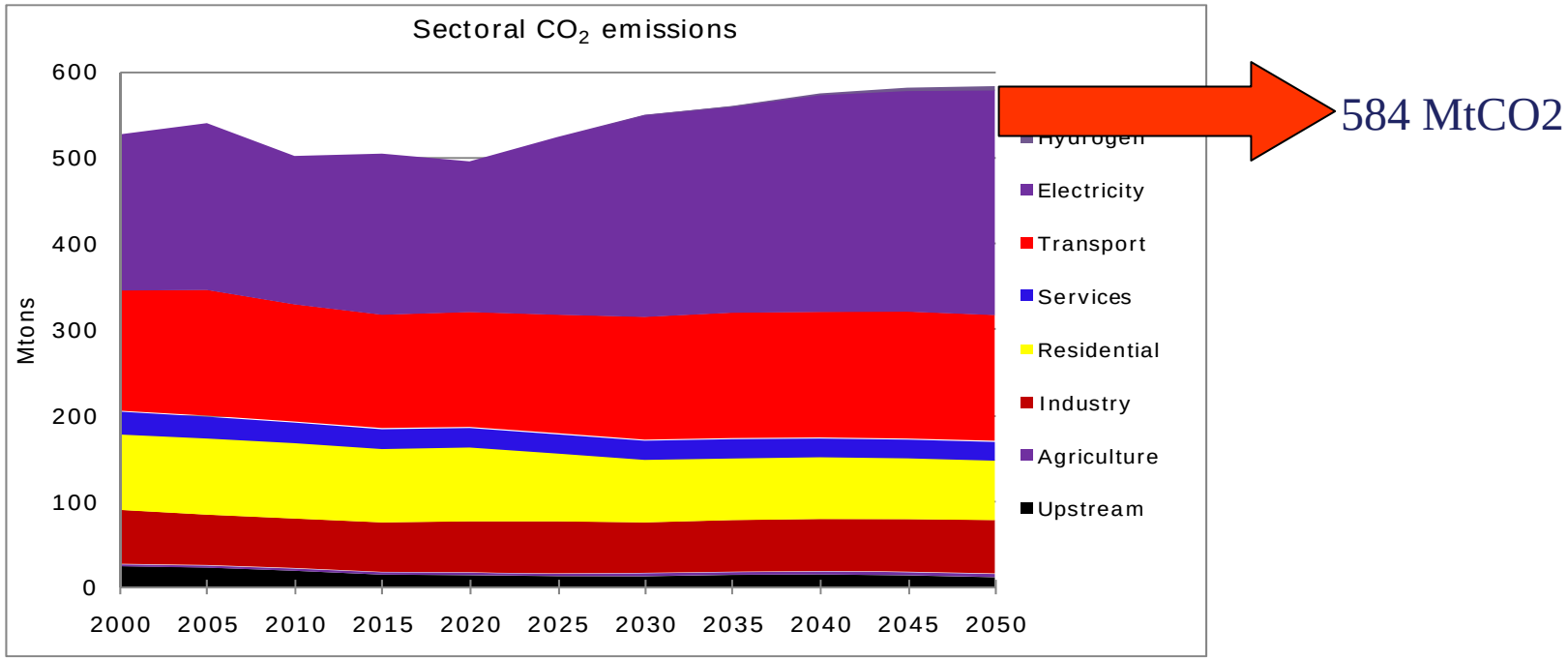
Base Reference Case CO_2 Emissions



- Business as usual> base case CO_2 emissions 2050> 584 $MtCO_2$: 6% higher than 2000 levels and 1% lower than 1990 levels.
- Existing policies> bring down emissions in 2020 to about **500 $MtCO_2$** - a **15%** reduction (government target of -26% by 2020).
- **Power sector** is the **largest contributor** + transport + residential sectors.

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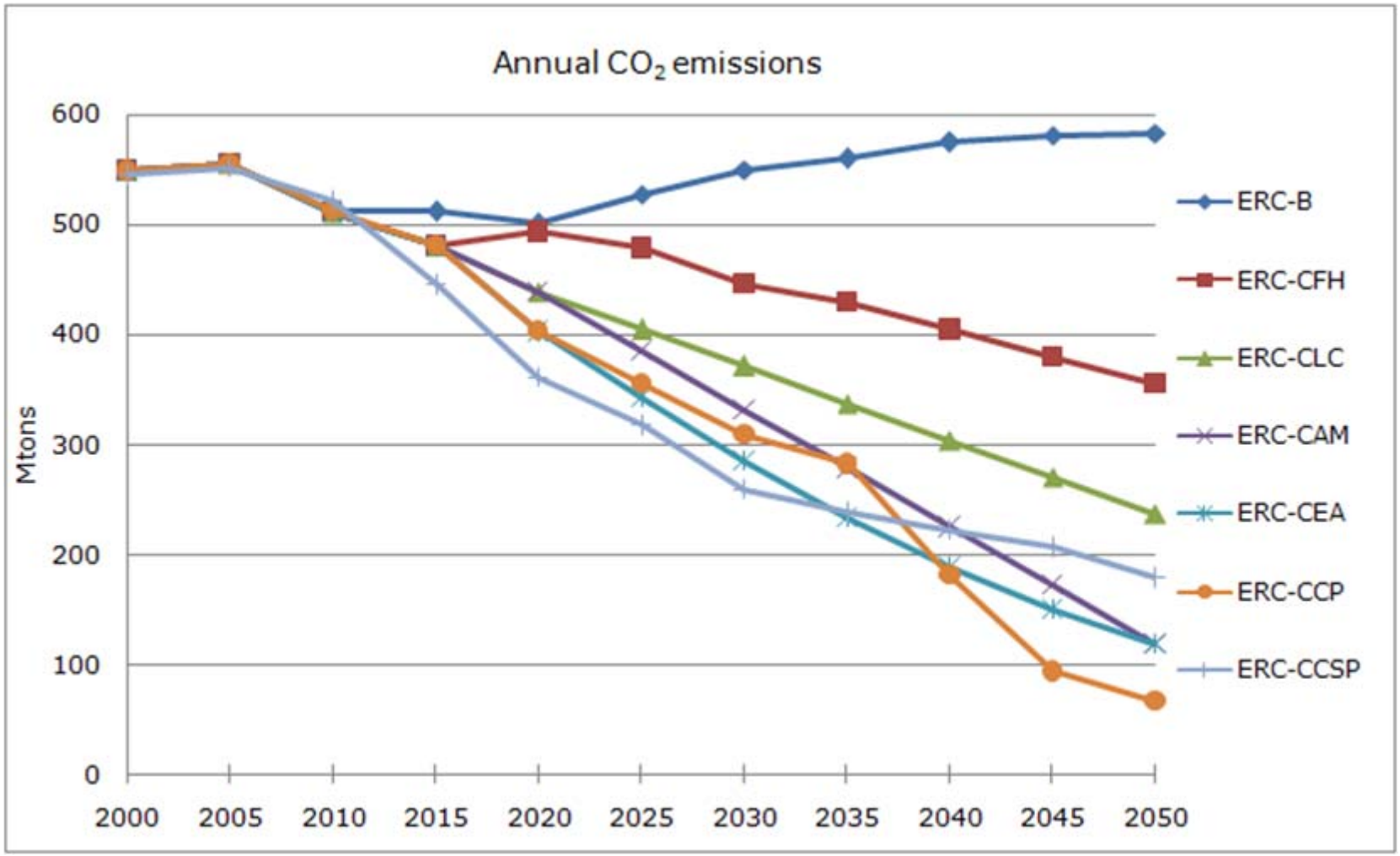
CO_2 Emissions: Low Carbon Scenarios



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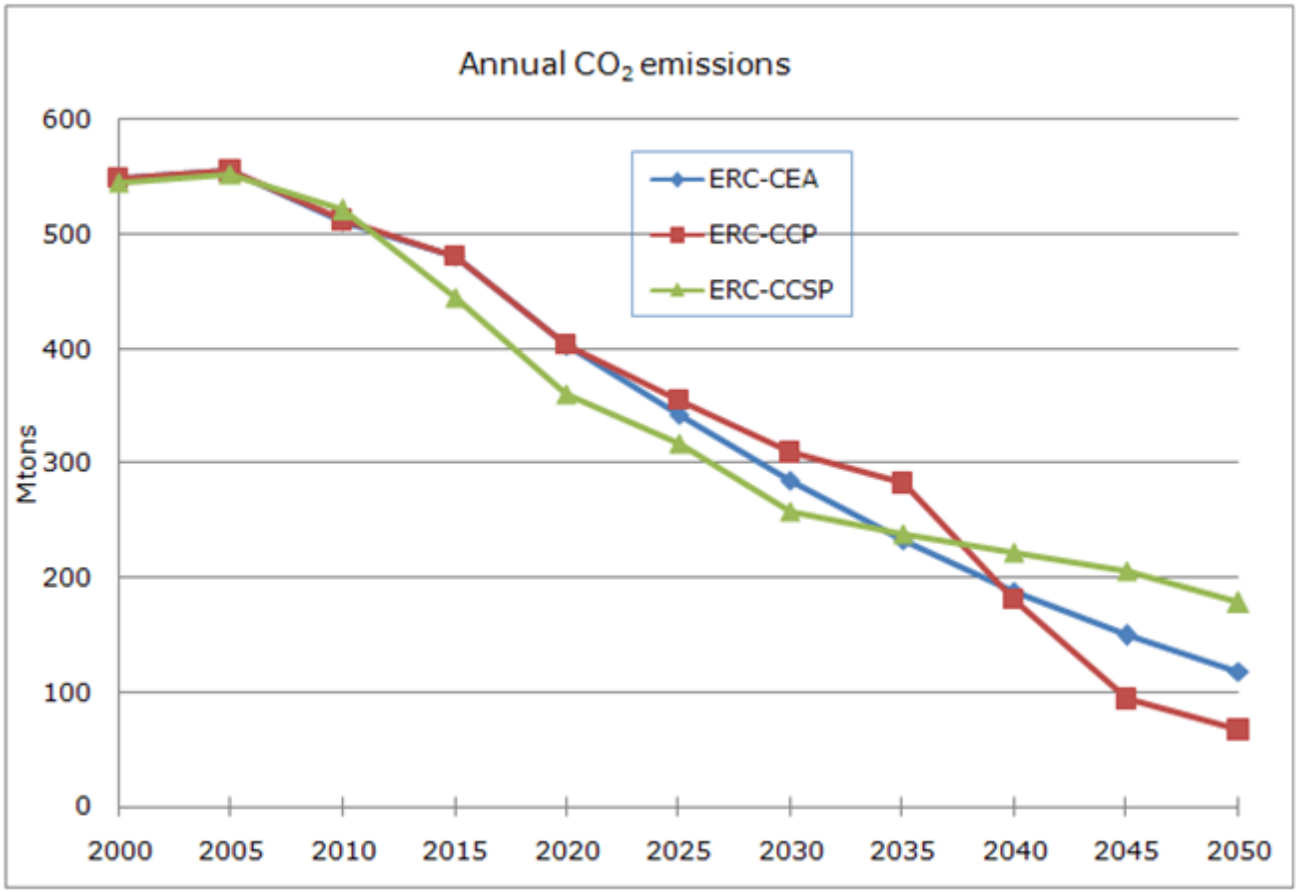
Cumulative Cases CO_2 Emissions



CCSP- Early action reducing 39% in 2020 and 70% in 2050
CCP- Later action reducing 32% in 2020 and 89% in 2050

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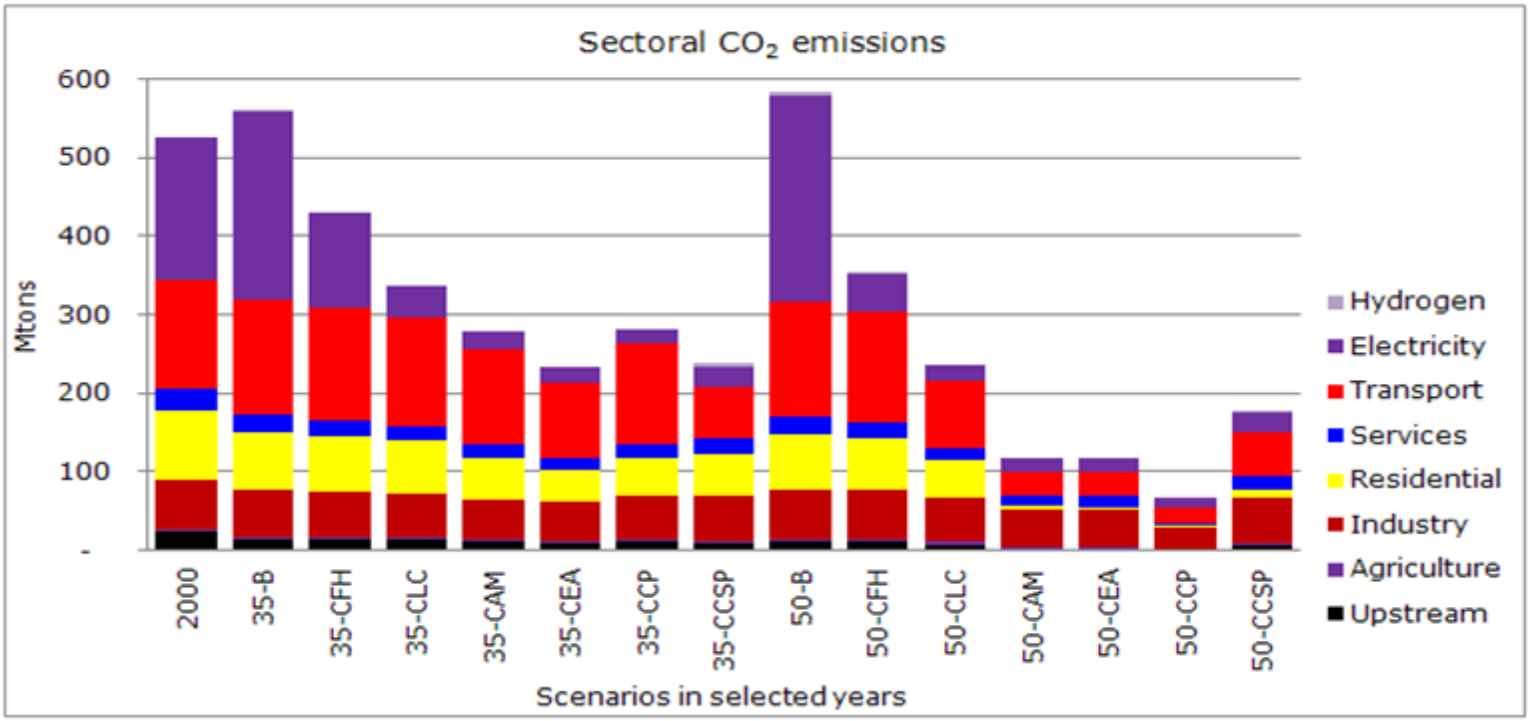
Decarbonisation



- Decarbonisation- power sector.
- Switch to the residential and/or transport sector.
- Service sector>CCP case +transport + industry.
- CEA and CCSP> **earlier action** > transport sector works harder.

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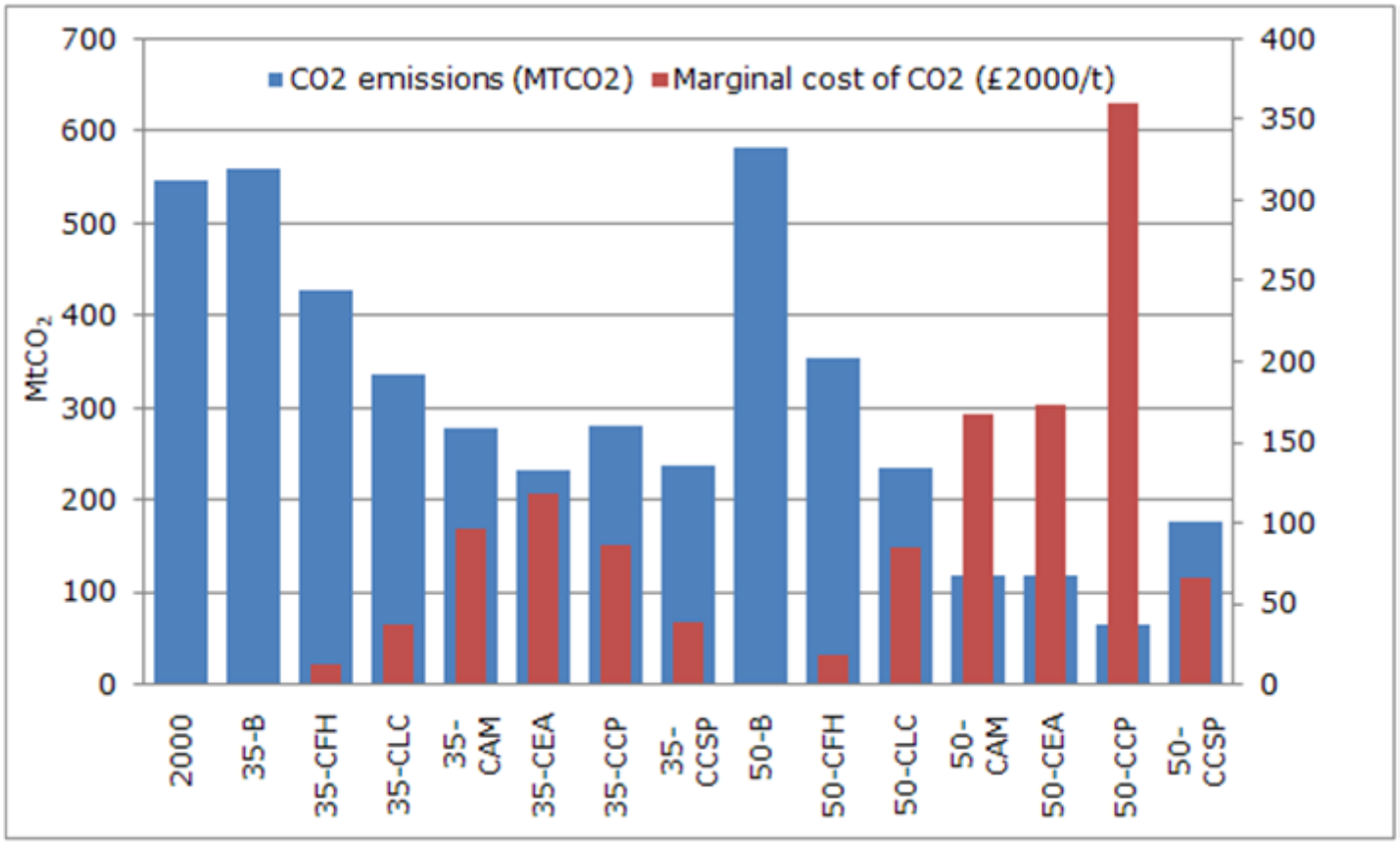
CO_2 Emissions & Marginal Costs



- Rising CO_2 marginal costs with target stringency
- As expected CEA gives higher early costs
- CCP gives 90% CO_2 reduction with very high marginal cost

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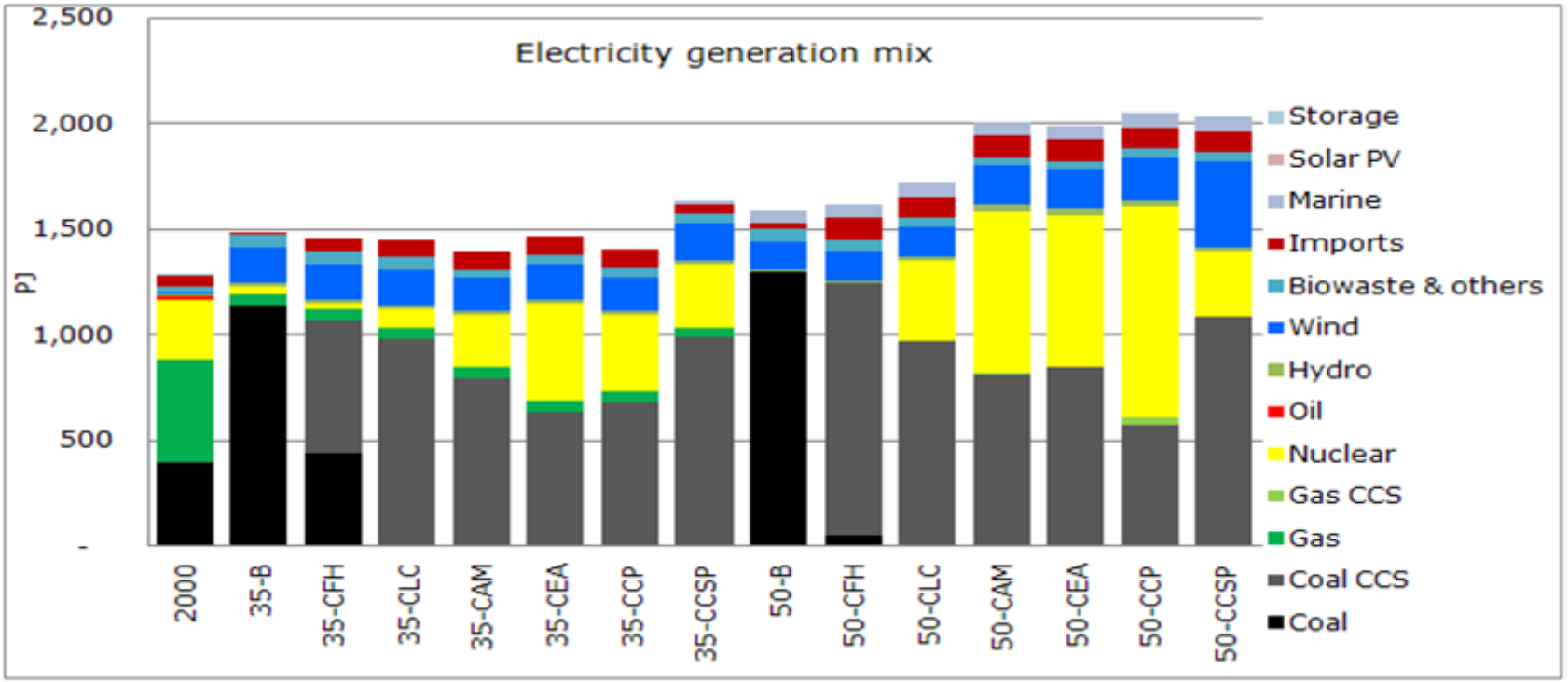
Decarbonisation of Power Sector



- Deployment of CCS for coal plants in 2020-2025 in **all** mitigation scenarios.
- 3 Technologies/resources:Coal-CCS, Nuclear and Wind.
- Coal-CCS> **main technology** in CFH and CLC.
- Increased target > **nuclear** instead of CCS in CAM, CEA and CCP
  > **wind** is selected in CCSP

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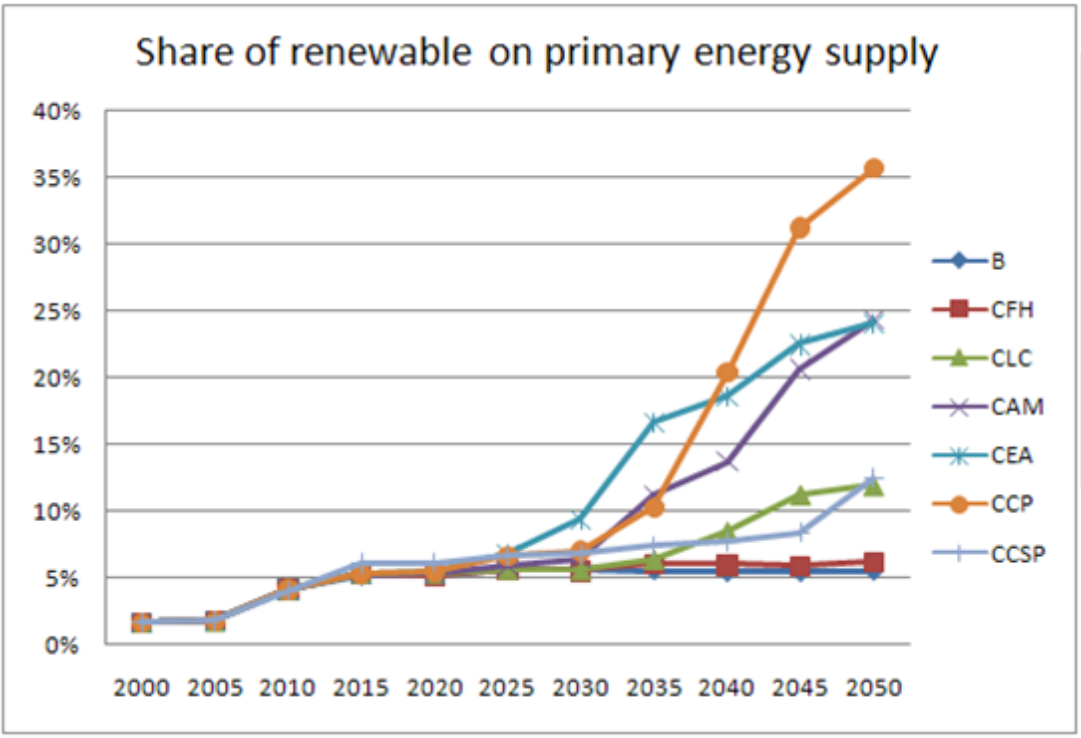
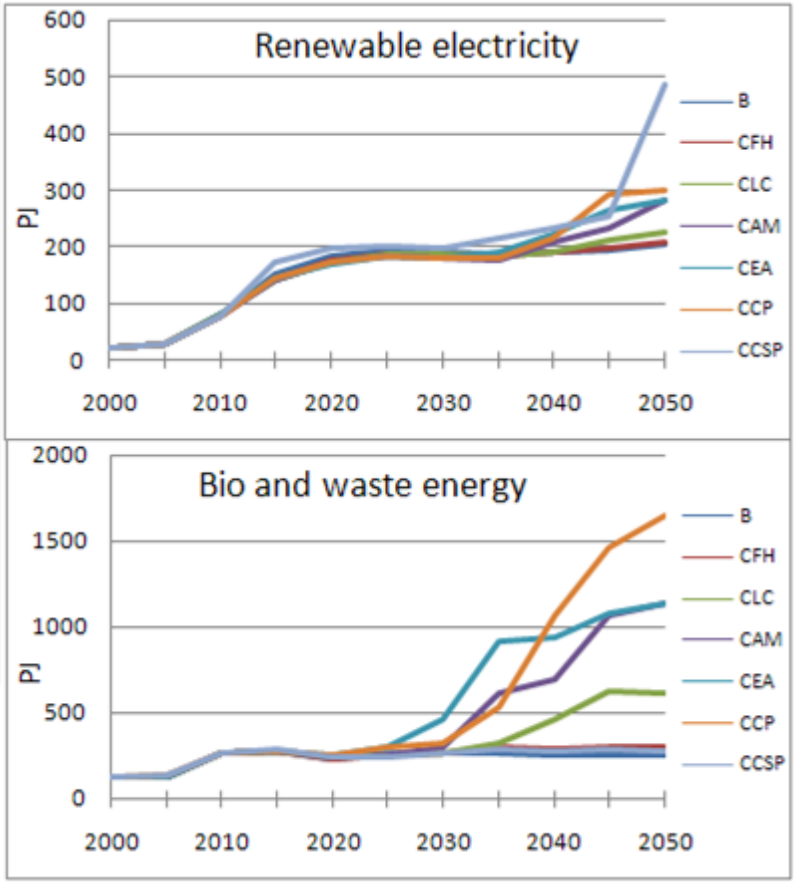
Renewable Energy





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Decarbonisation of End-use Sectors

- **Residential sector**> shifting to electricity (from gas) as well as from boilers to heat pumps for space heating and hot water heating.

- **Transport sector** > fuel switching: hybrid, hybrid plug-in (diesel and petrol), ethanol, hydrogen and battery operated vehicles.

- **Service sector** > shifting to electricity and to biomass (CCP).

- Besides efficiency, fuel switching and technology shifting, price-induced demand reduction plays a **major role** in reducing CO_2 emissions (5% - 25% depending on the scenario)

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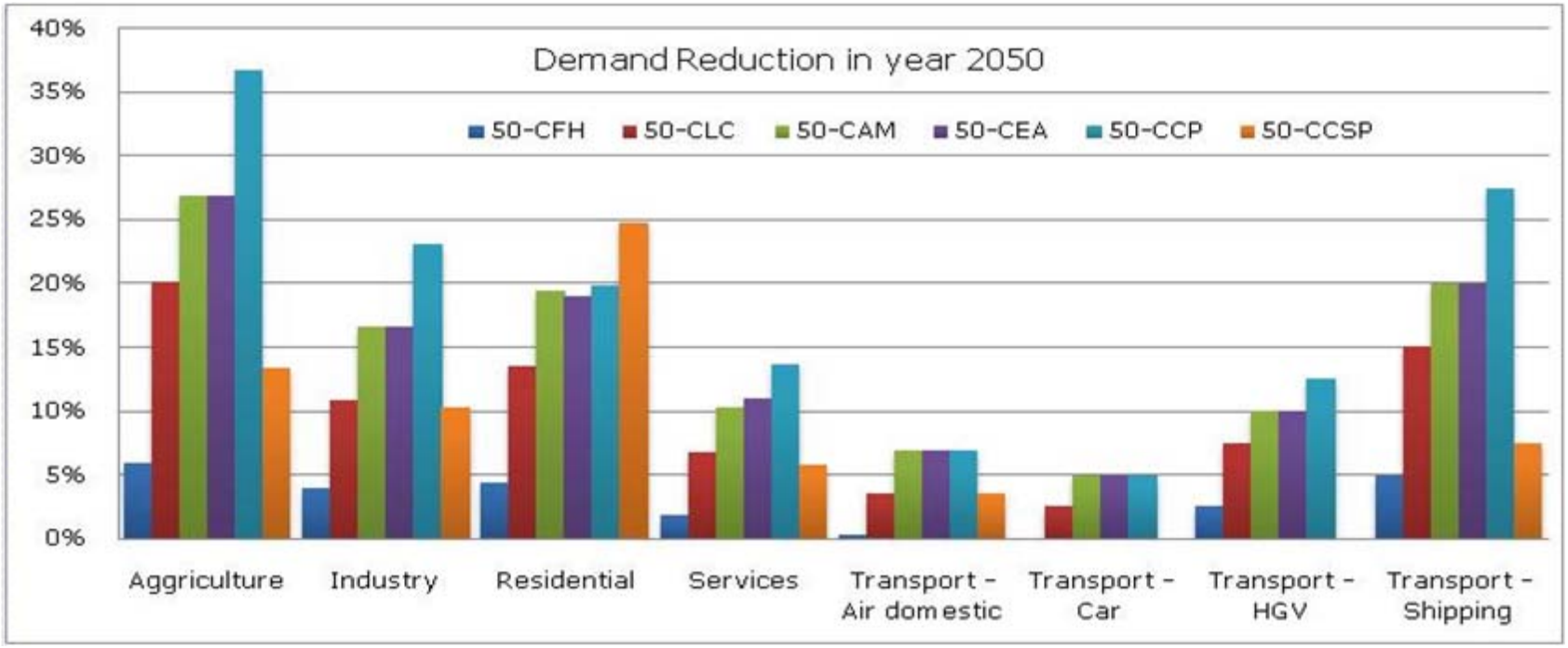
Demand reductions



- Demand reduction level is relatively higher in 2050 than in 2035 as the CO_2 reduction level is relatively high in 2050 under all scenarios.
- Agriculture, industry, residential and international shipping have higher demand reductions than that of air, car and HGV (heavy good vehicles) in transport sectors.
- There is a social welfare loss due to demand reduction

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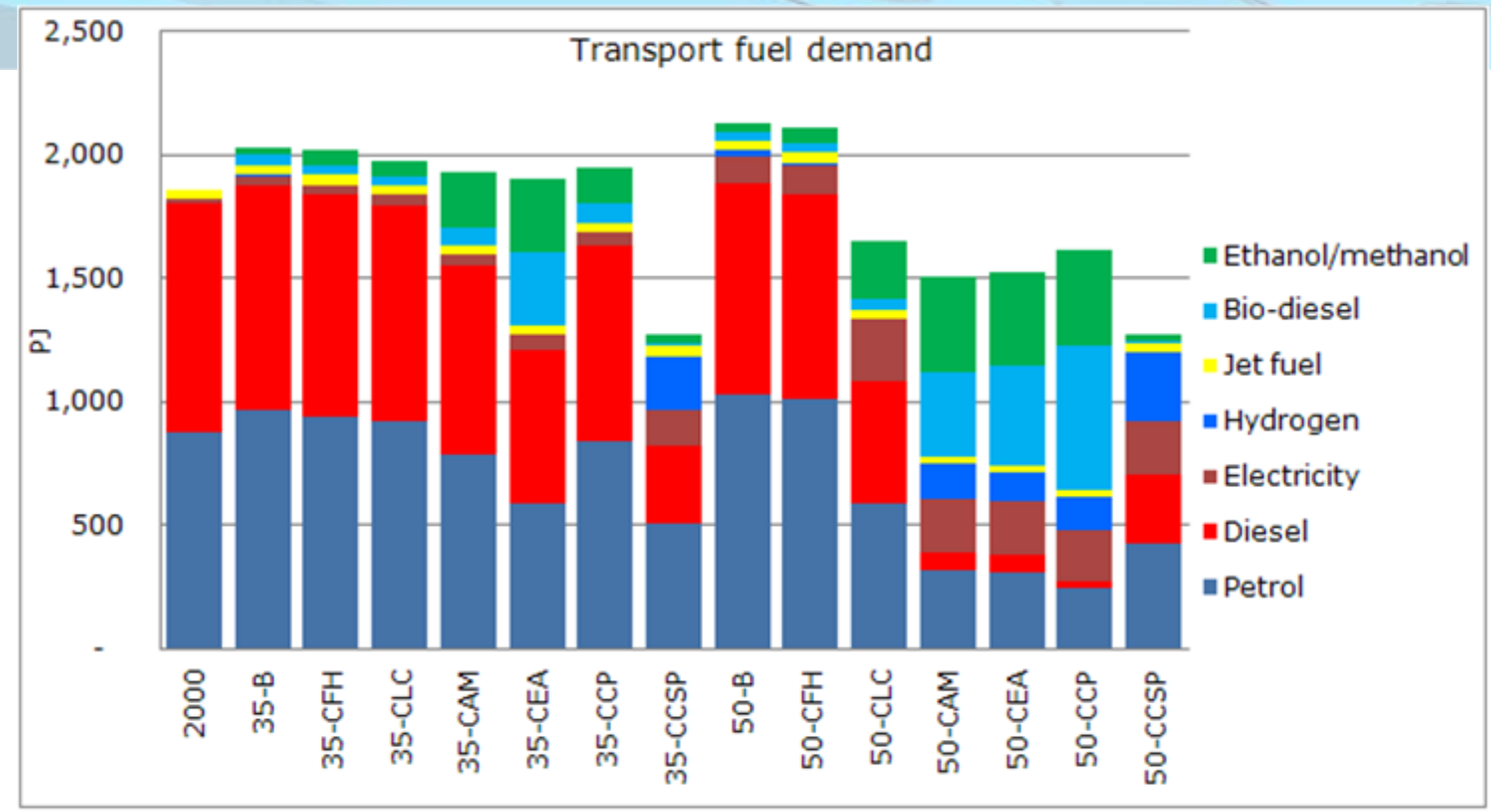
Transport Sector Fuel Demand



- Electricity demands> buses and car hybrid plug-in.
- Ethanol> car (E85)
- Biodiesel>car, HGV and LGV
- Hydrogen >goods vehicles especially HGV (consumes over 80%)
- Car is the dominant mode consuming 2/3 of the transport energy

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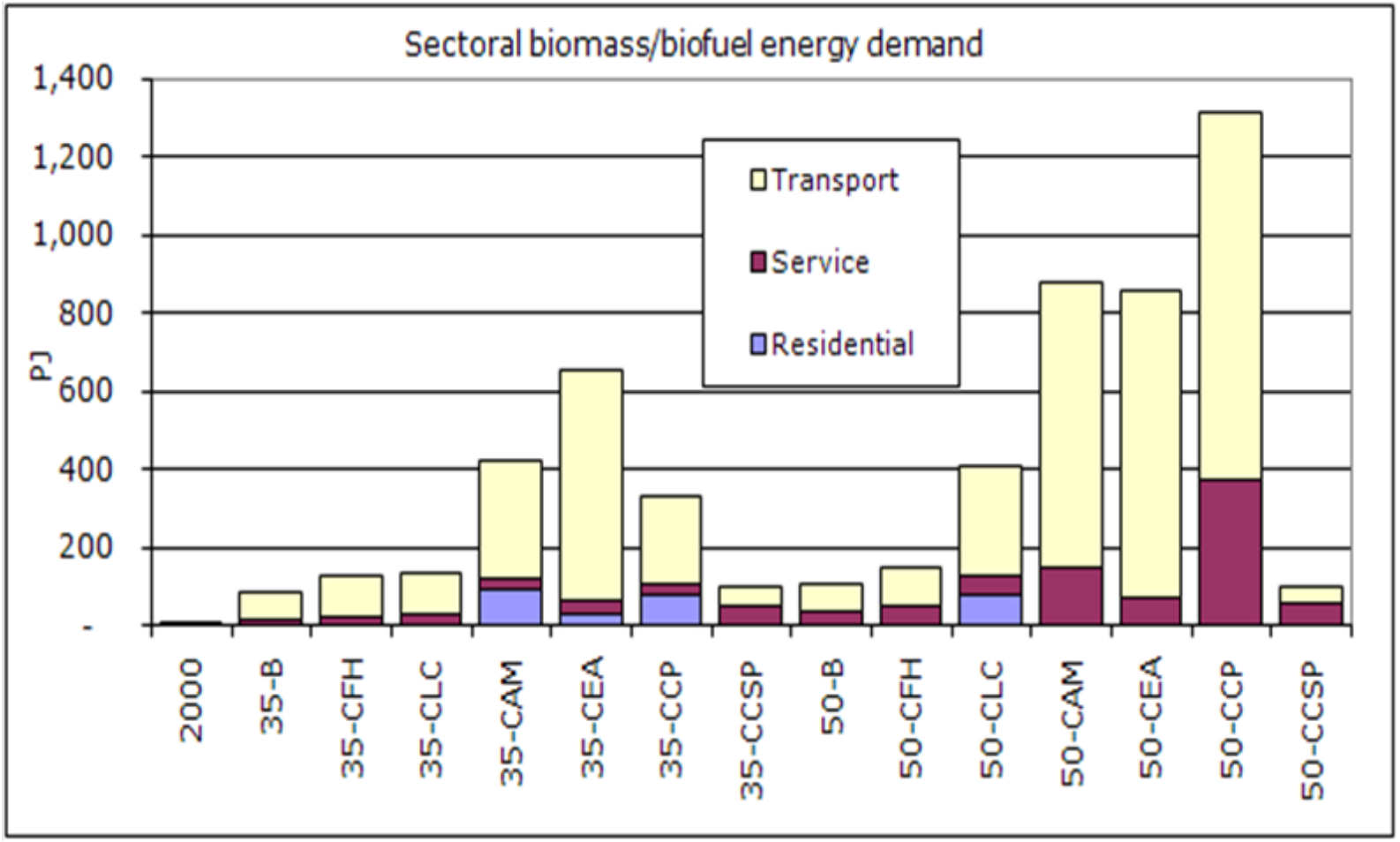
Demand for Bio-fuels / biomass by sector



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Conclusions

- Carbon Ambition scenarios offer insights on technology, resources and demand pathways, as well as resulting costs. They **don't** predict the future.
- Power sector decarbonisation occurs early and is critical
  - Uncertainties in optimal technology mix (CCS vs. nuclear vs. wind)
  - Interactions with transport (plug-in vehicles) and buildings (boilers and heat pumps)
  - End-use sectors contribute significantly to later period decarbonisation
- Early versus late action
  - Alternate sectors (transport), alternate resources (wind, bio-fuels)
- Very wide range of economic impacts
  - marginal costs in 2050 from £20 - £360/tCO_2
  - Welfare costs in 2050 from £5-48bn
- Near term Government policy should provide viable options, in the long term society through markets mechanism should decide the winning technology portfolio

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