The Energy-System GMM Model for Integrated Assessment

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Outline

- The Energy-System GMM model
- Technology clusters in GMM
- The passenger car sector
- The GMM baseline scenario
- Linking GMM to the MAGICC climate model
- Concluding remarks

The Energy-System GMM Model

- GMM (Global Multi-regional MARKAL Model) developed at PSI
- "Bottom-up" energy-system model with detailed supply technologies and stylized end-use sectors
- Global, 5-region model, time horizon 2000-2050
- Calibrated to year-2000 statistics
- Clusters approach to technology learning
- Transport sector emphasizing passenger cars
- Marginal abatement curves for CH_4 and N_2O
- CO_2 capture and storage in electricity and hydrogen production
- Other synfuel production technologies (H_2, alcohols, F-T liquids)

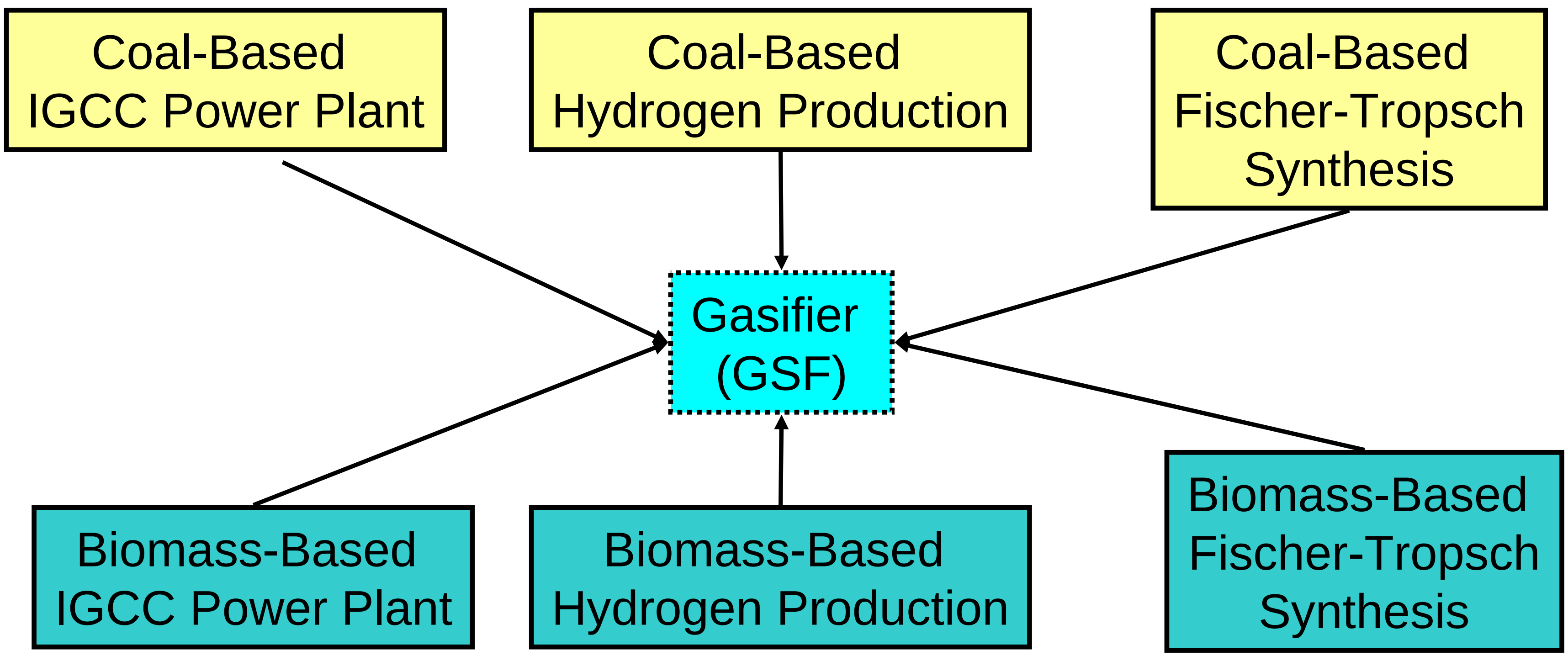
Technology Clusters in GMM

- Clusters are groups of technologies that co-evolve and cross-enhance each other, among others by sharing common key components (learning spillovers)
- In GMM, 15 key learning components in electricity generation, fuel production, CO_2 capture and passenger car technologies are included following Seebregts *et al*.(2000) and Turton and Barreto (2004)

15 Key Learning Components

- Electricity generation technologies: Wind turbines, Solar PV, advanced nuclear, gas turbine, stationary fuel cell (5)
- Synthetic fuel production: Gasifier, biomass-to-ethanol, steam methane reformer (3)
- CO_2 Capture: Conventional coal power plants (post-combustion, natural gas CC (post-combustion), coal and biomass IGCC (pre-combustion), coal and biomass hydrogen production (pre-combustion) (4)
- Passenger cars: Mobile fuel cell, battery, mobile reformer (3)

Example of Technology Cluster



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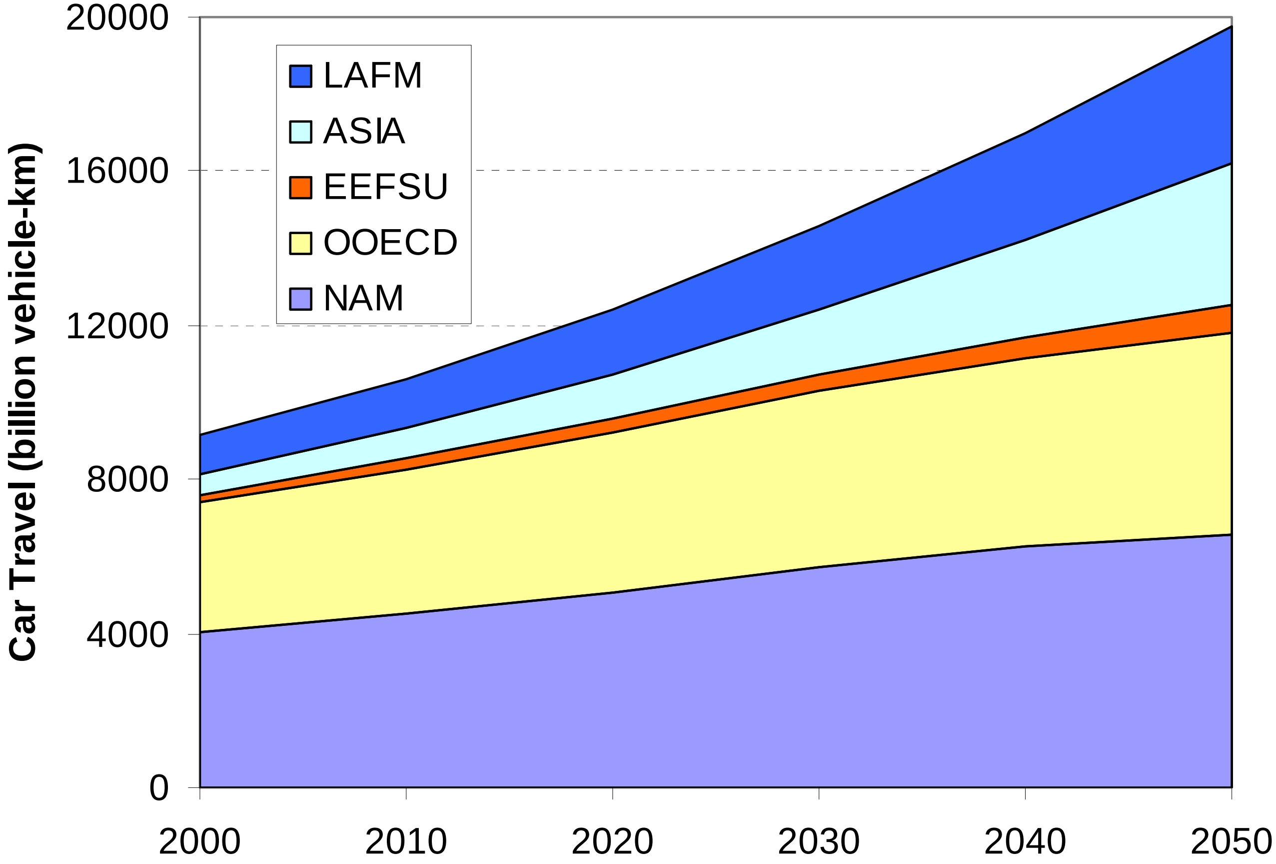
The Transportation Sector in GMM

- Passenger car sub-sector with technological detail in automobile technologies (ICEV, HEV, FCV)
- Aggregate air transport sub-sector at the final-energy level with only oil-based technologies
- Aggregate “other transport” sub-sector with generic technologies mimicking final-energy consumption

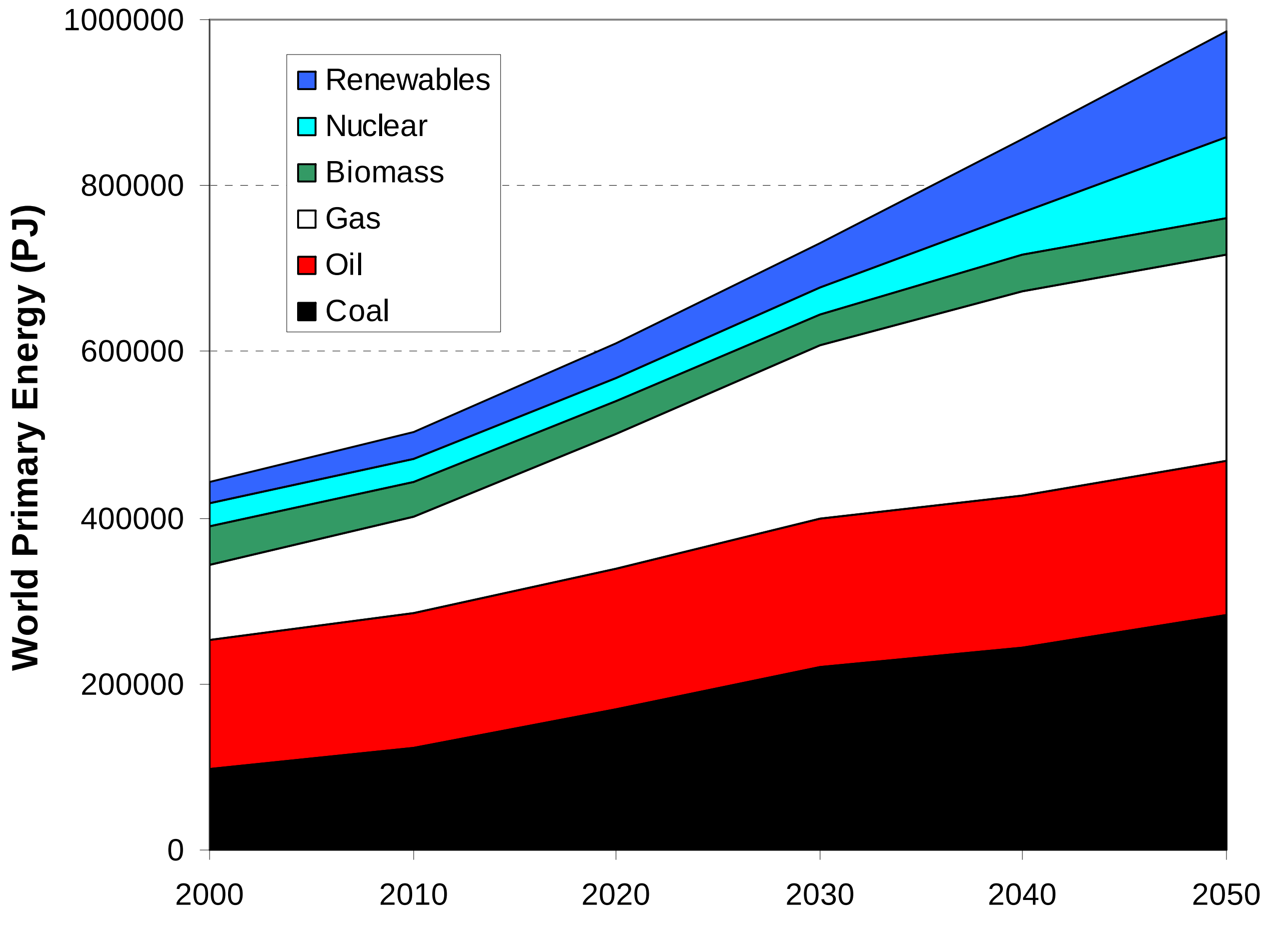
Passenger Car Demand in GMM



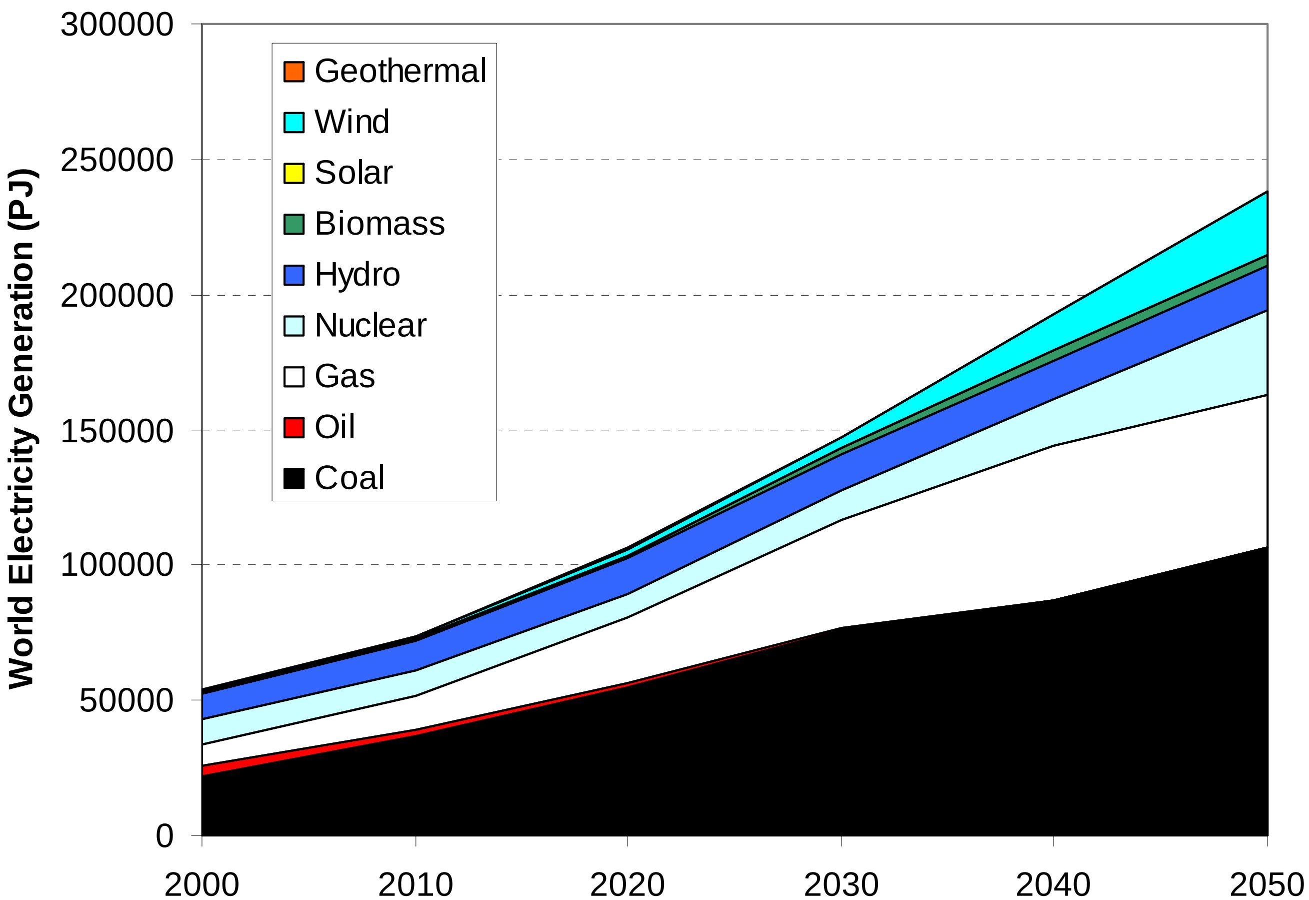
The GMM Baseline Scenario

- GDP, population, end-use demands (except for cars) and resource assumptions from SRES B2 scenario quantification with the MESSAGE model (Riahi and Roehrl, 2000; Rogner, 1997,2000) but a more fossil-intensive technology dynamics
- Primary energy consumption reaches 960 EJ and energy-related CO_2 emissions reach 15 Gt C in the year 2050.
- World demand for passenger cars (vehicle-km) doubles by 2050

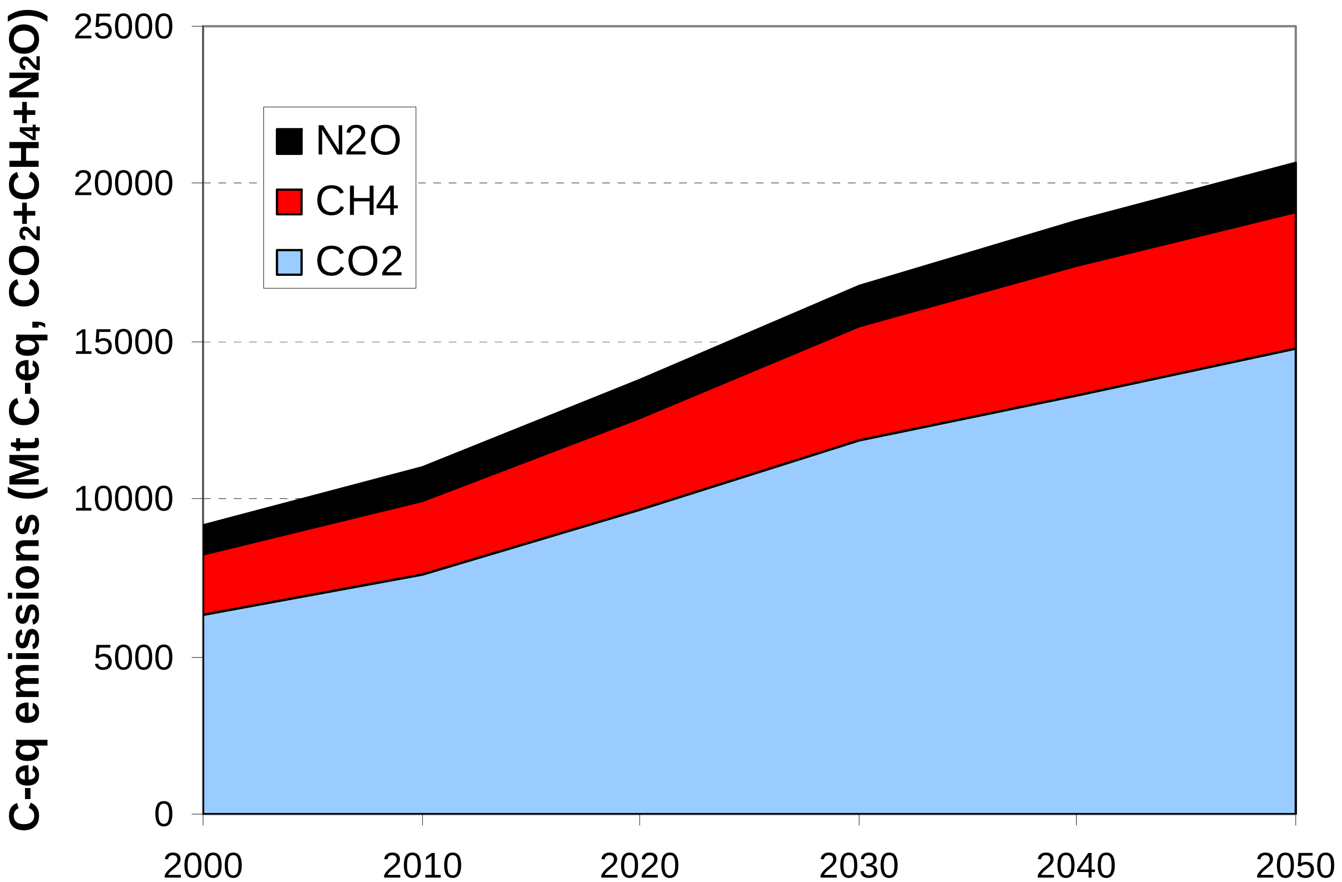
World Primary Energy



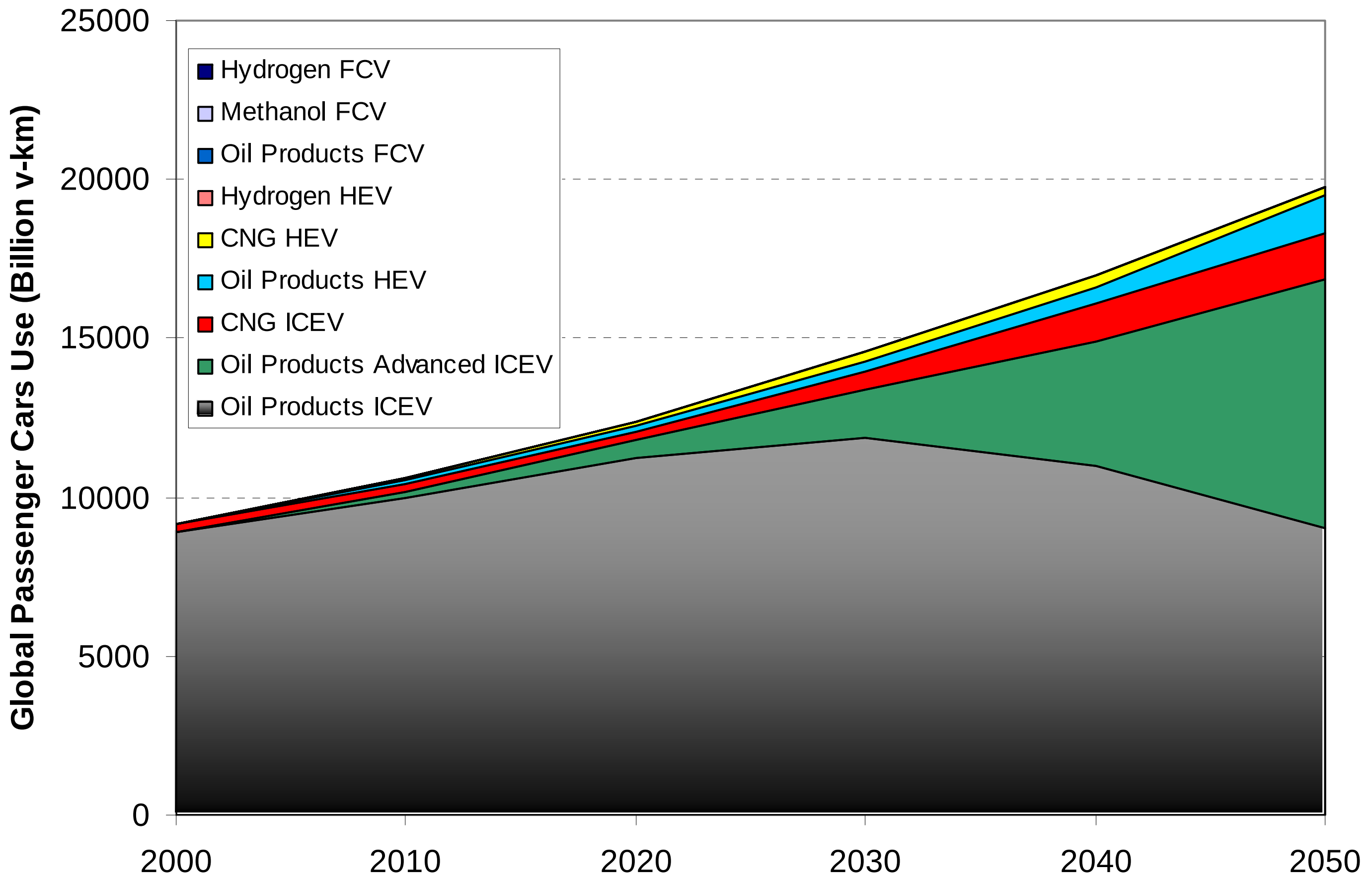
World Electricity Generation



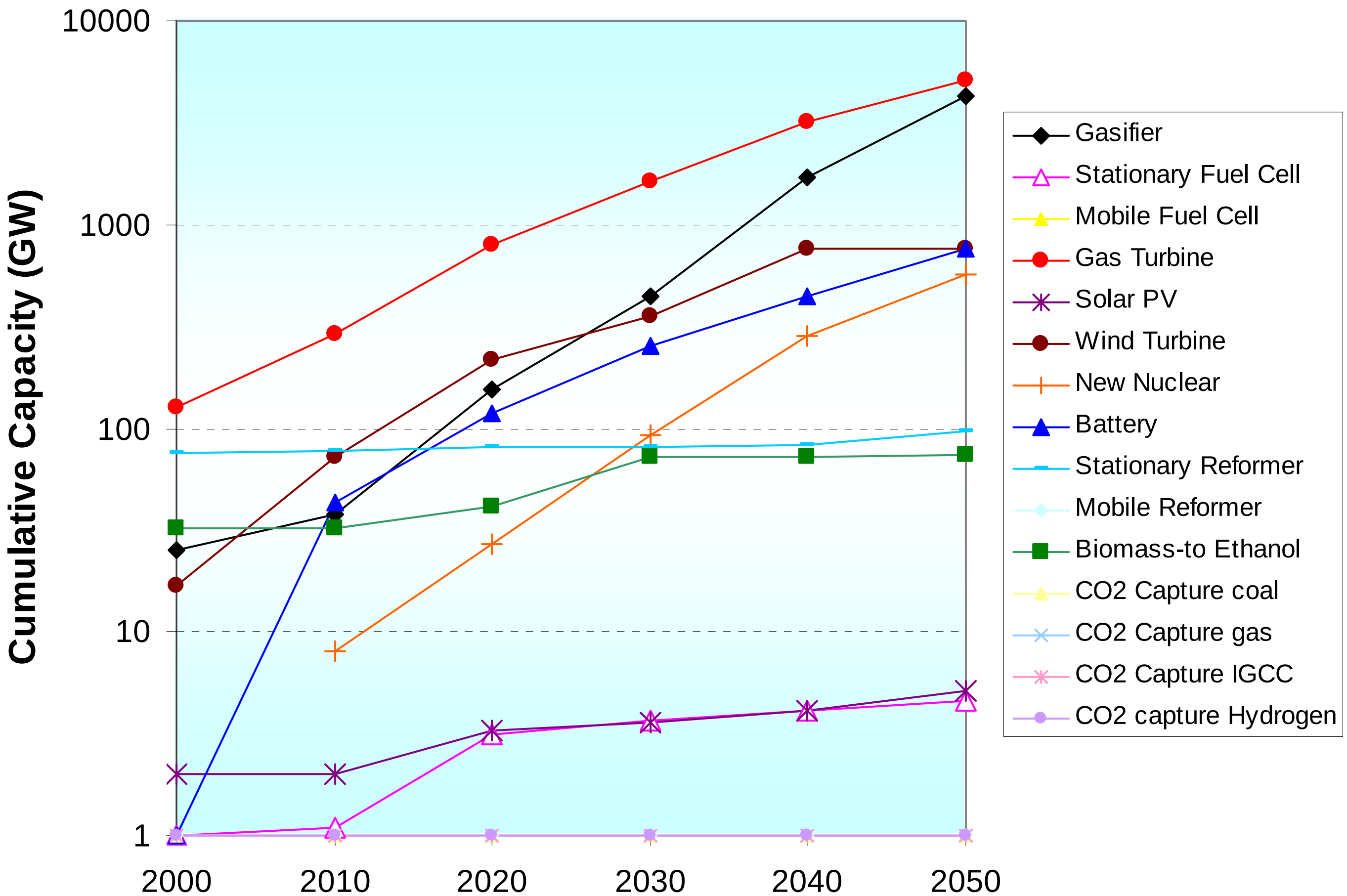
Global GHG Emissions (CO_2 ,CH_4, N_2O)



Passenger Cars: Technology Mix



Key Components: Cumulative Capacity



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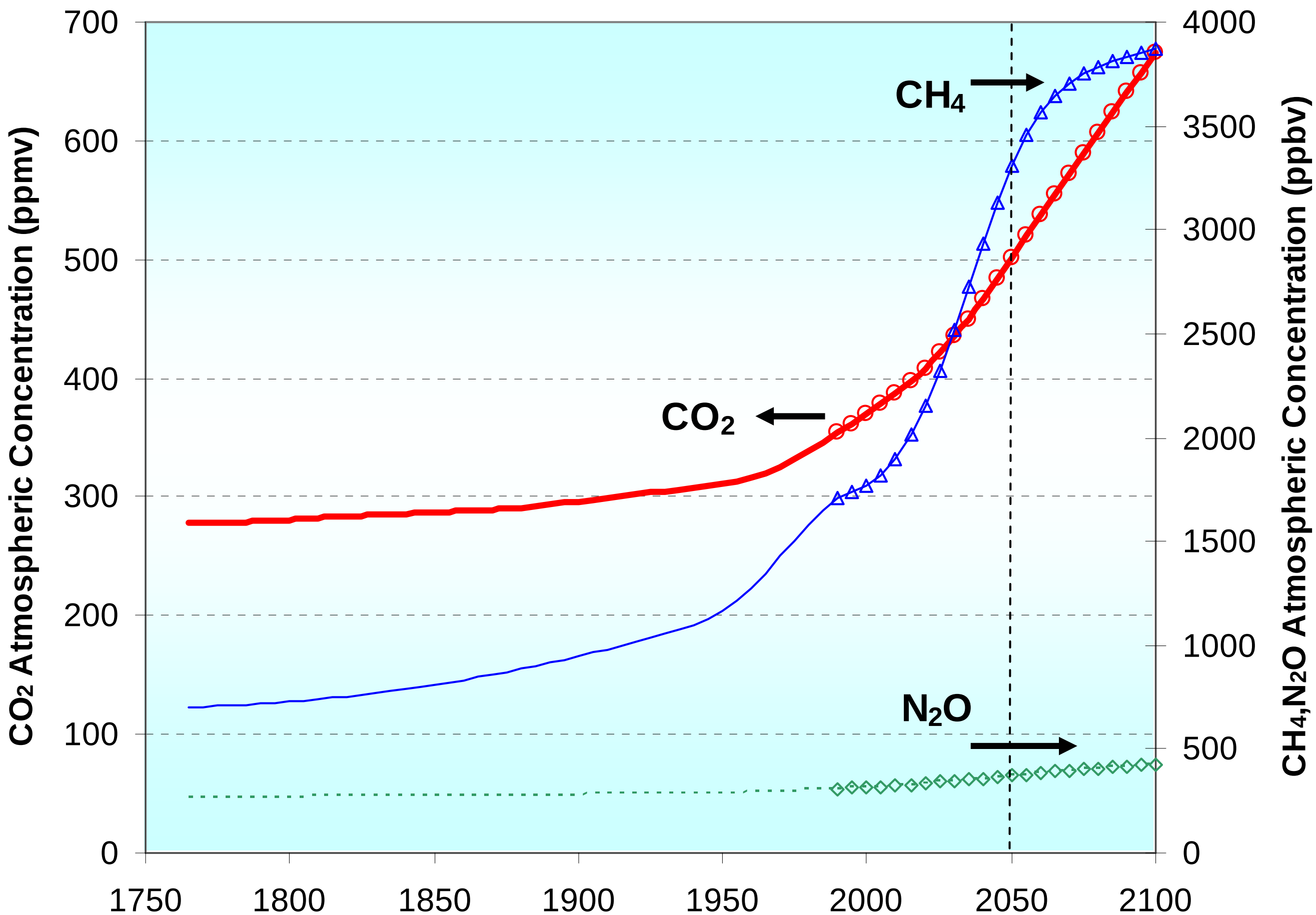
NFS NCCR climate

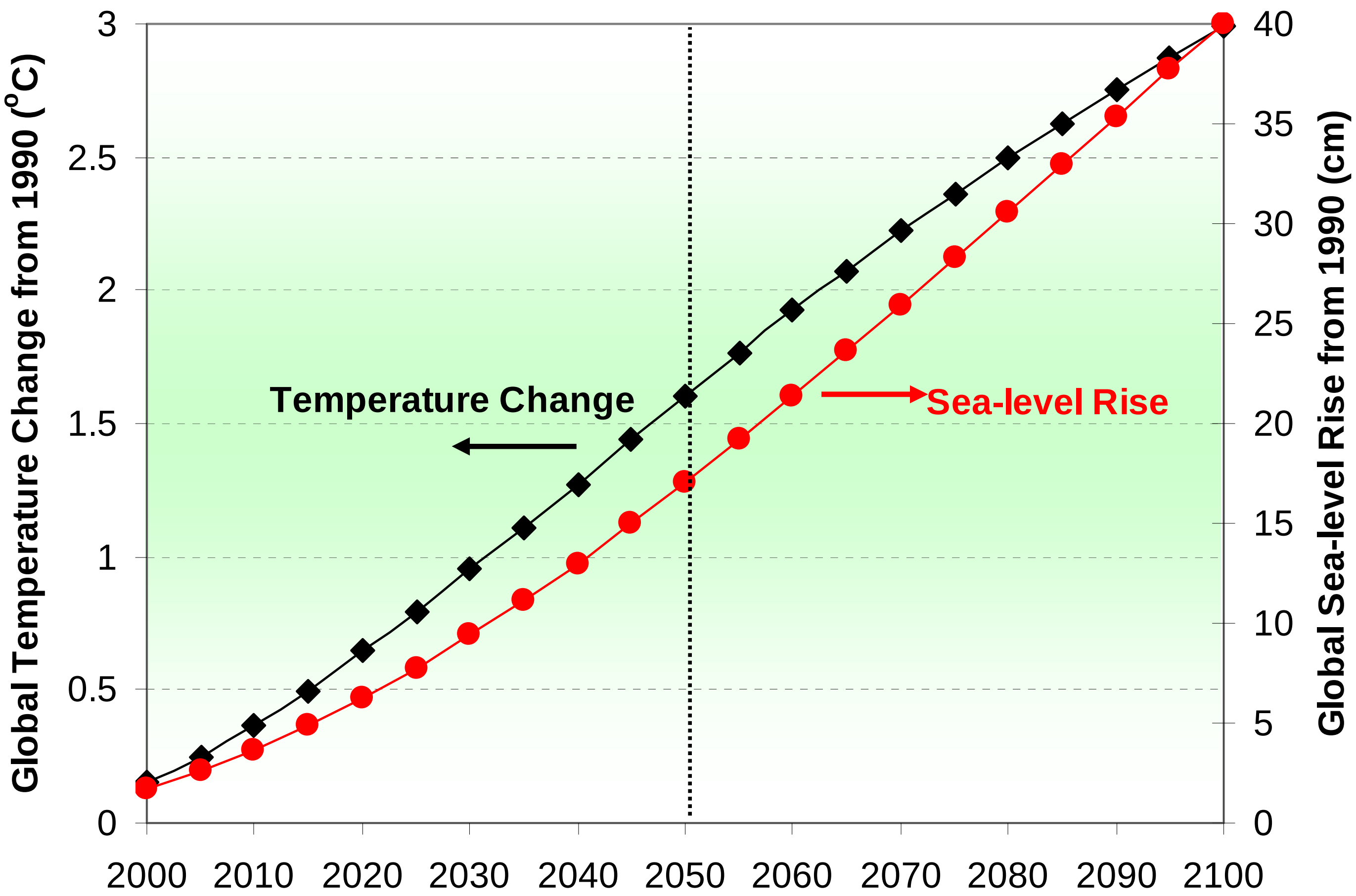
Linking GMM to a Climate Model

- The energy-system GMM model has been linked to the simplified climate MAGICC model version 4.1 (Wigley, 2003)
- Energy-related CO_2, CH_4 and N_2O emissions are computed by GMM. Non-energy-related emissions for these GHGs are extrapolated from U.S EPA (2003)
- Emissions for other GHGs are taken from the SRES-B2 scenario (SRES, 2000)

GHG Atmospheric Concentrations



Temperature Change and Sea-level Rise



Concluding Remarks

- The energy-system GMM (Global, Multi-regional MARKAL) model has been extended as follows:
  - Clusters approach to technology learning
  - Passenger car sector
  - Hydrogen and Fischer-Tropsch production technologies and CO_2 capture technologies
  - Marginal abatement curves for CH_4 and N_2O
  - Link to the climate model MAGICC

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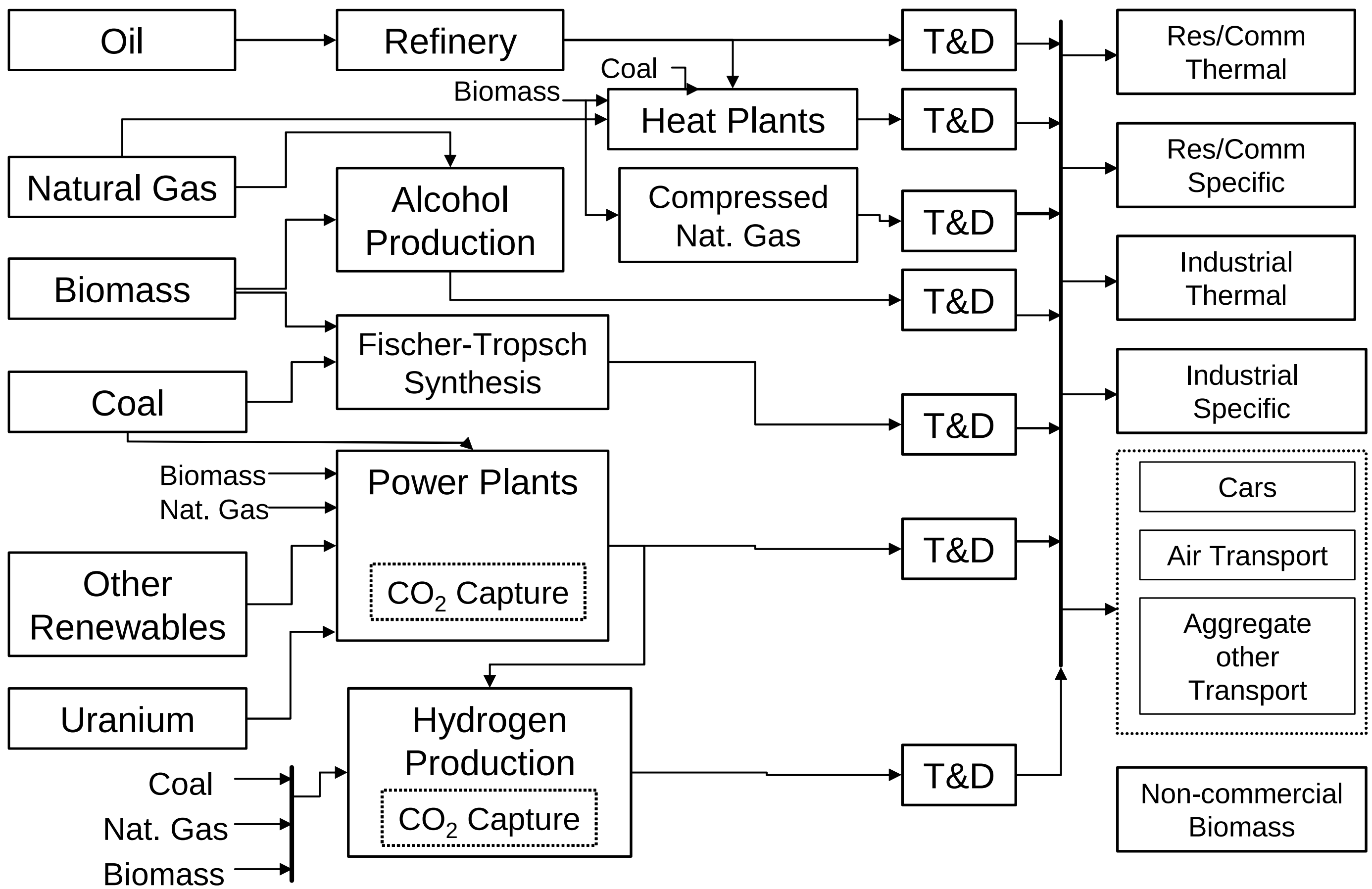
- The support from the Swiss National Center of Competence in Research on Climate (NCCR-Climate) funded by the Swiss National Science Foundation is gratefully acknowledged

Support Slides

The Energy-System GMM Model

- Clusters approach to technology learning
- Transport sector emphasizing passenger cars
- Energy-carrier production technologies (H_2, alcohols, F-T liquids, oil products, CNG, etc)
- Marginal abatement curves for CH_4 and N_2O
- CO_2 capture and storage (CCS) in electricity and synthetic fuel production
- Link to the climate MAGICC model

Reference Energy System in GMM



Passenger Car Demand

- Based on estimates of vehicle-km per region for the year-2000 from Turton and Barreto (2004) and growth rates from WBCSD (2004) up to 2050
- Doubling of global vehicle-km traveled over the time horizon 2000-2050
- Faster growth in developing regions but a “car mobility divide” still persists towards the middle of the 21st century

Car Technologies in GMM

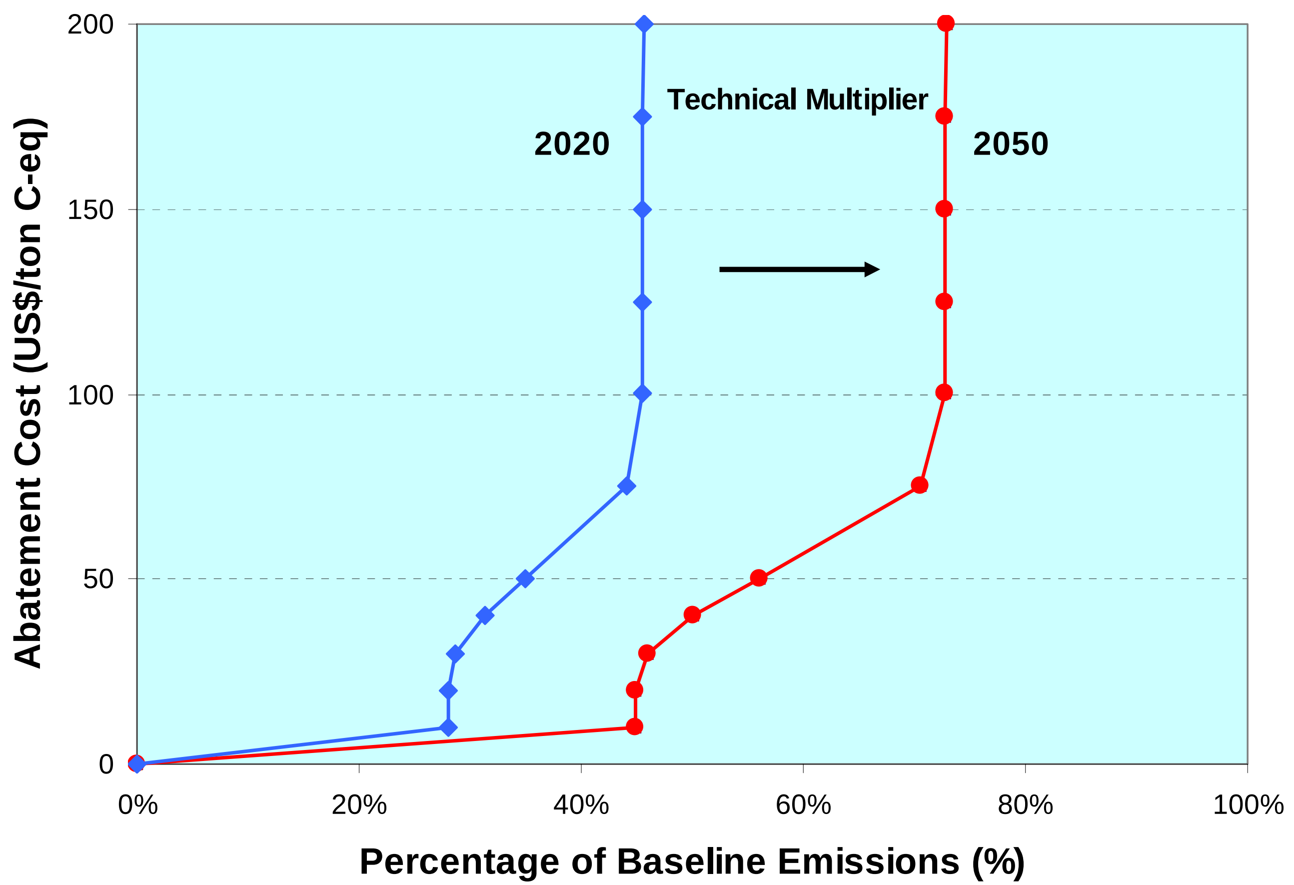
Technology	Fuel Efficiency (v-km/MJ)	Initial Investment Cost (US$2000 per car)	Starting Date
Internal Combustion Engine (ICEV)			
Oil products standard ICEV	0.21-0.354	12425	2000
Oil products advanced ICEV	0.599	12825	2010
CNG standard ICEV	0.19-0.32	12625	2000
Hybrid-electric Vehicles (HEV)			
Oil products HEV	0.761	14338	2010
CNG HEV	0.658	14498	2010
Hydrogen HEV	0.814	15598	2020
Fuel Cell Vehicles (FCV)			
Oil products FCV	0.656	35736	2020
Methanol FCV	0.735	31107	2020
Hydrogen FCV	1.060	25371	2020

Source: Adapted from Ogden, J.M., Williams, R.H., Larson, E.D., 2004: Societal Lifecycle Costs of Cars with Alternative Fuels/Engines, *Energy Policy* **32**, 7-27.

Marginal Abatement Curves (MAC)

- Implementation of MACs for methane (CH_4) and nitrous oxide (N_2O) following approach of MERGE (Manne and Richels, 2003) and ERIS (Turton and Barreto, 2004)
- Three categories: exogenous baseline, endogenous baseline, non-abatable emissions
- Data from the U.S EPA (2003) study, potentials are relative to baseline emissions
- Technical-progress multipliers to extrapolate abatement potentials beyond 2020

Technical Multipliers for Non-CO_2 Abatement Potentials



Hydrogen Production and CCS

- Hydrogen production from coal gasification, biomass, gasification, steam reforming of natural gas, electrolysis, nuclear high-temperature reactors
- CO_2 capture technologies for hydrogen production from coal, gas and biomass and electricity production from conventional coal, biomass and coal-based IGCC, NGCC

CO_2 Emissions