

# *Characteristics of the Norwegian Energy System*

## *- Role of Hydrogen in the Transportation Sector*

A.M. Svensson<sup>1</sup>, S. Møller-Holst<sup>1</sup>,  
Christoph Stiller<sup>2</sup>, Ulrich Büniger<sup>2</sup>, Kari A. Espegren<sup>3</sup>

<sup>1</sup> SINTEF Materials and Chemistry, Norway

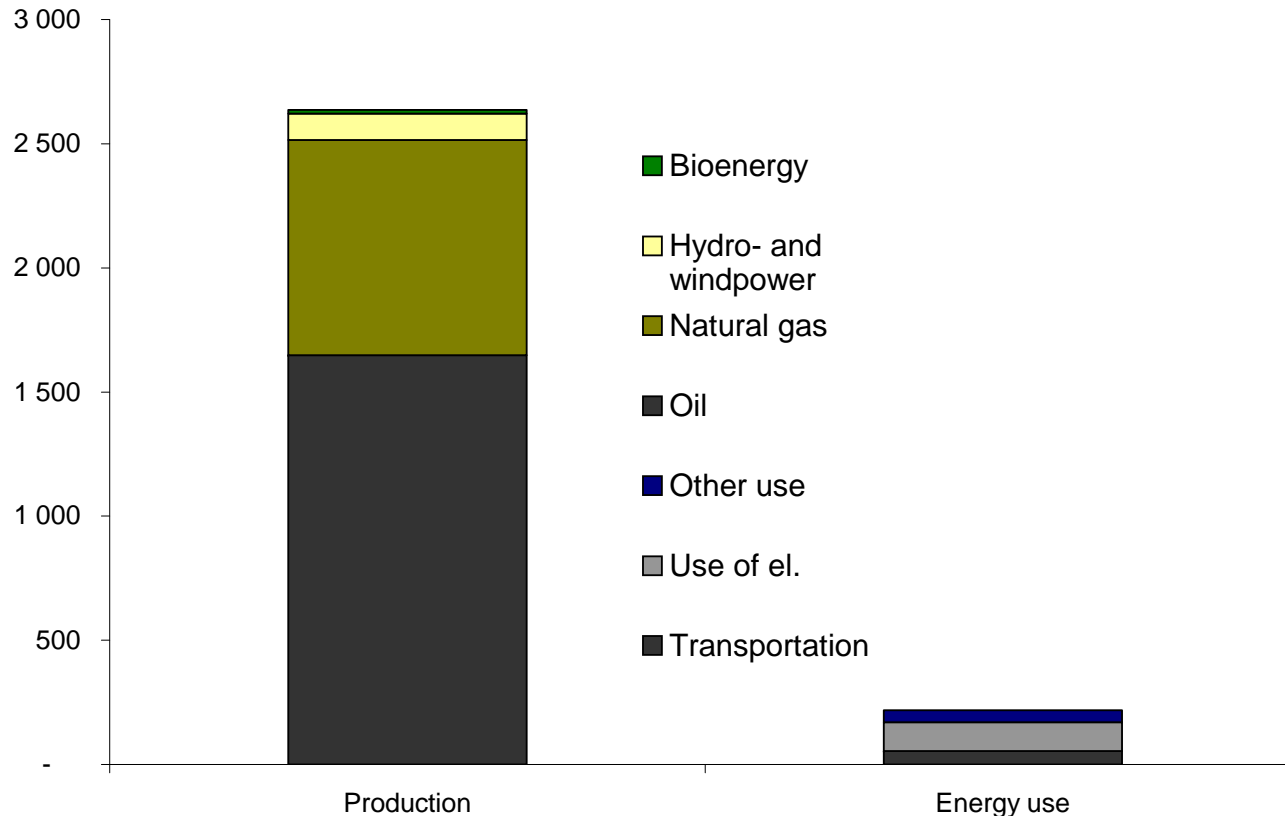
<sup>2</sup> Dept. Energy and Process Engineering, NTNU, Norway

<sup>3</sup> IFE, Norway



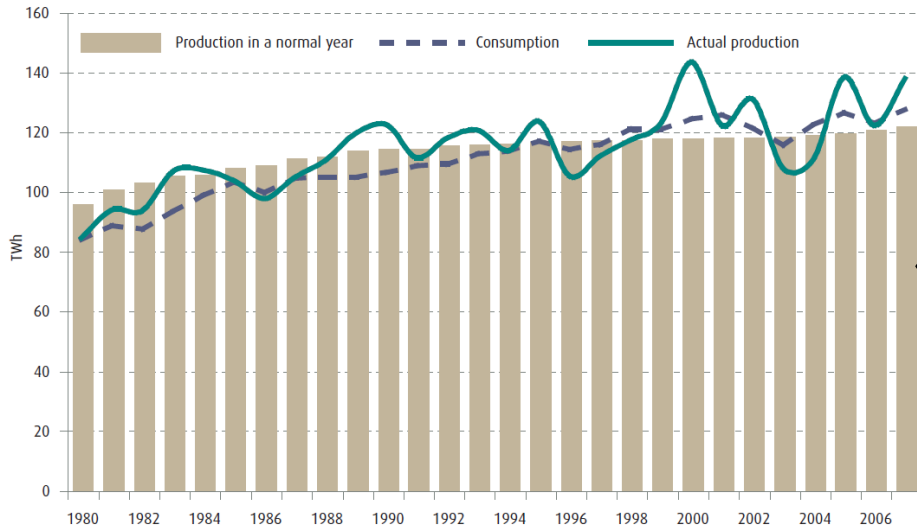
**Workshop: *The Role of Hydrogen as Fuel for Road Transportation***  
*EVS 24, 24th International Battery, Hybrid and Fuel Cell Electric Vehicle  
Symposium and Exhibition*  
*May 13-16, Stavanger, Norway*

# Characteristics of the Norwegian Energy System

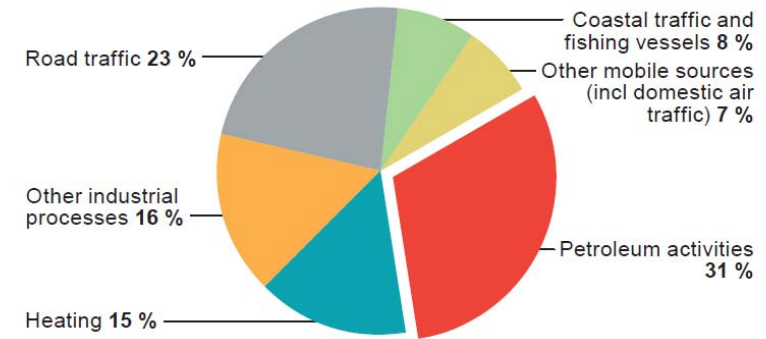


Source: Energidata 2005

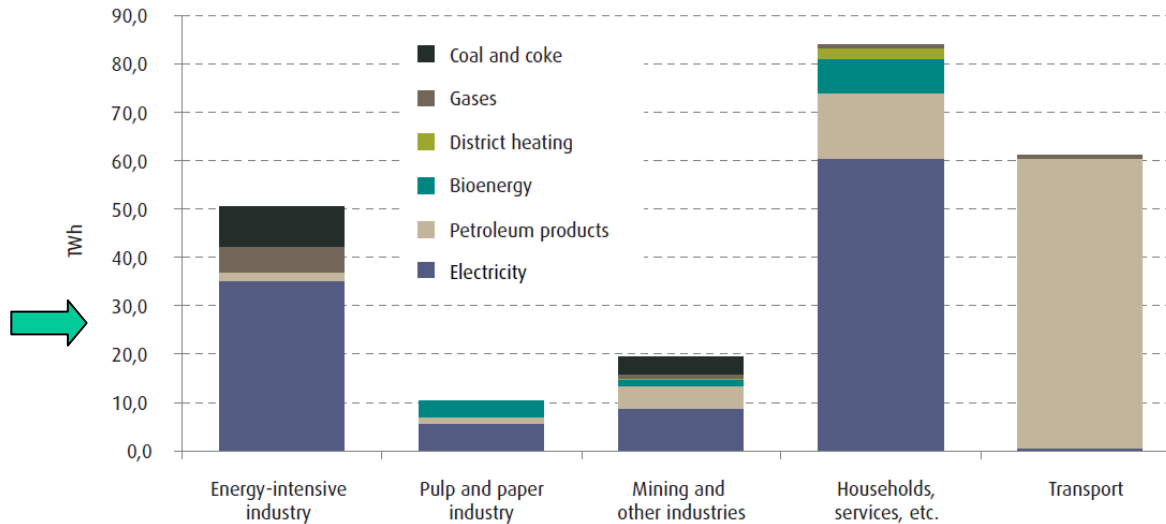
# Characteristics of the Norwegian Energy System



**Electricity production**



**Energy consumption**



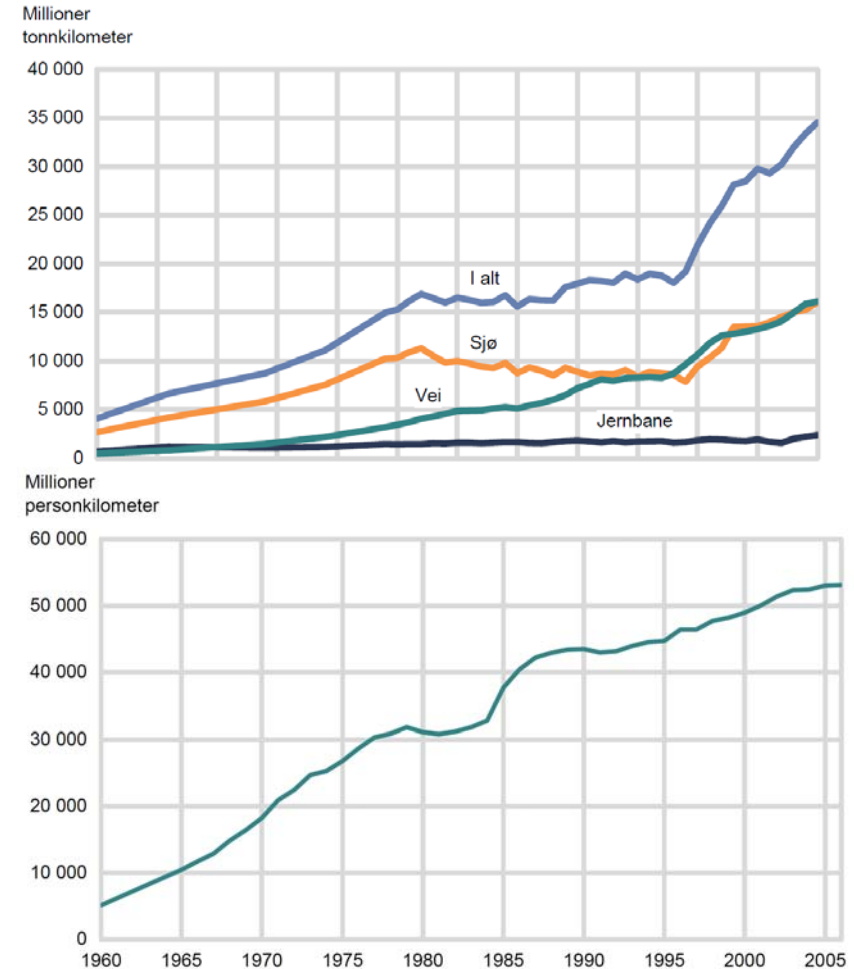
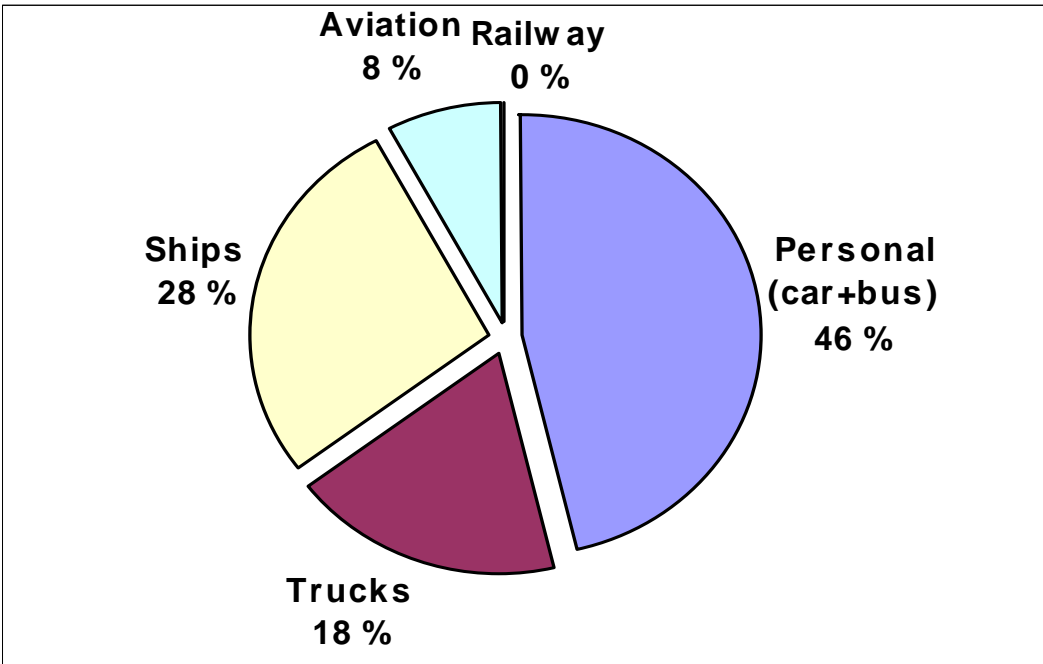
The transportation sector contributes by 38 % to the domestic emission of GHGs

Sources: SSB, Facts 2008

# Increase in road transportation



Share of GHG emissions from transportation



Estimated increase<sup>1</sup>:

Private vehicles: 0.7% (-> 2012) 0.8% (2012-2020)

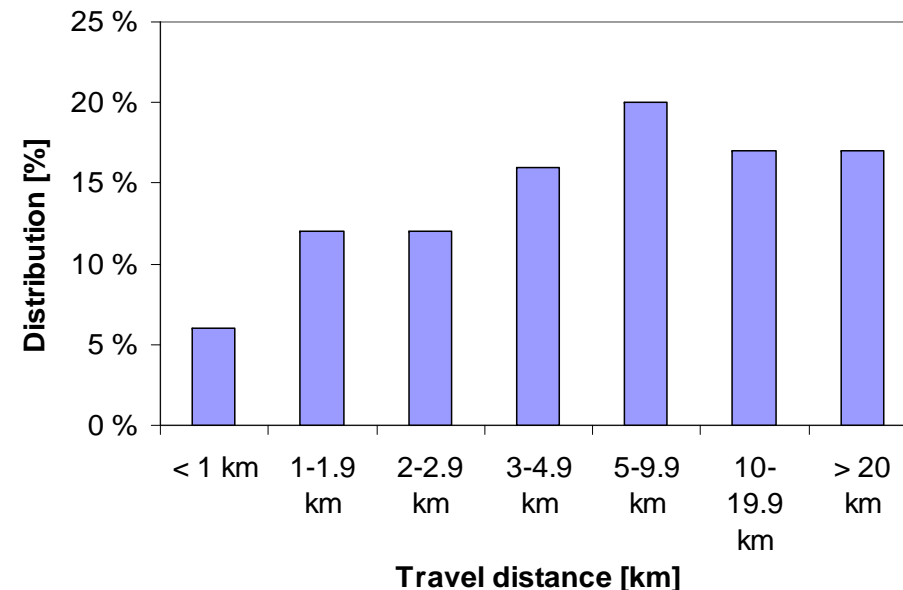
Heavy vehicles: 1.7% (-> 2012) 0.9% (2012-2020)

Source: SSB

# Person transportation

- Decrease in average number of persons per car
- Ca 87 % of trips (52% of person km) are short (< 20 km)
- Average age of wrecked cars (2006): 19.7 years
- Distribution of cars in households:

# cars	% households
0	13 %
1	48 %
> 2	39 %

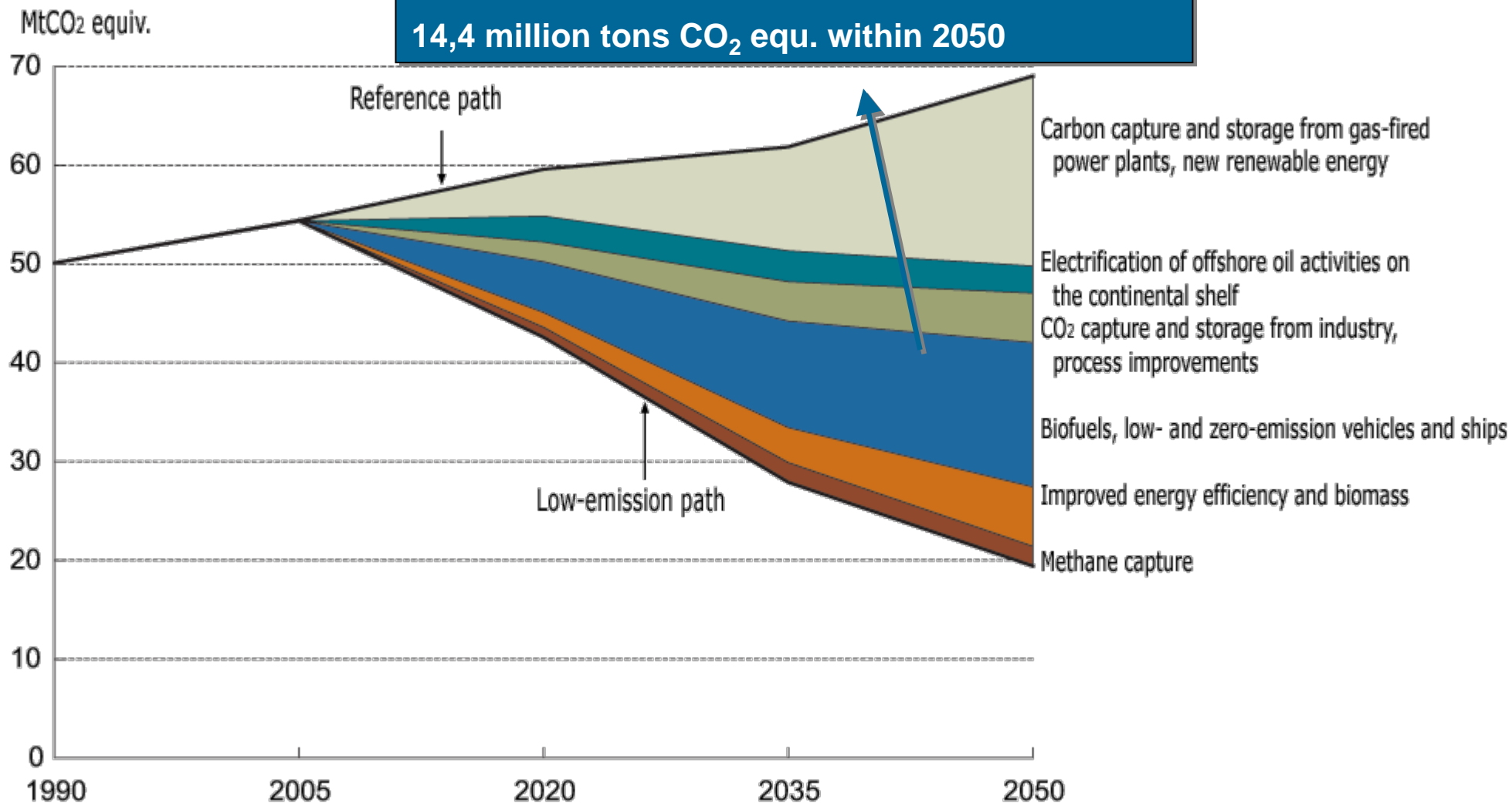


Source: TØI

# Reduction of emissions vs. sector



Emissions from Transportation down by 78 %, 14,4 million tons CO<sub>2</sub> equ. within 2050



# Sustainable options for transportation



## - Biofuel

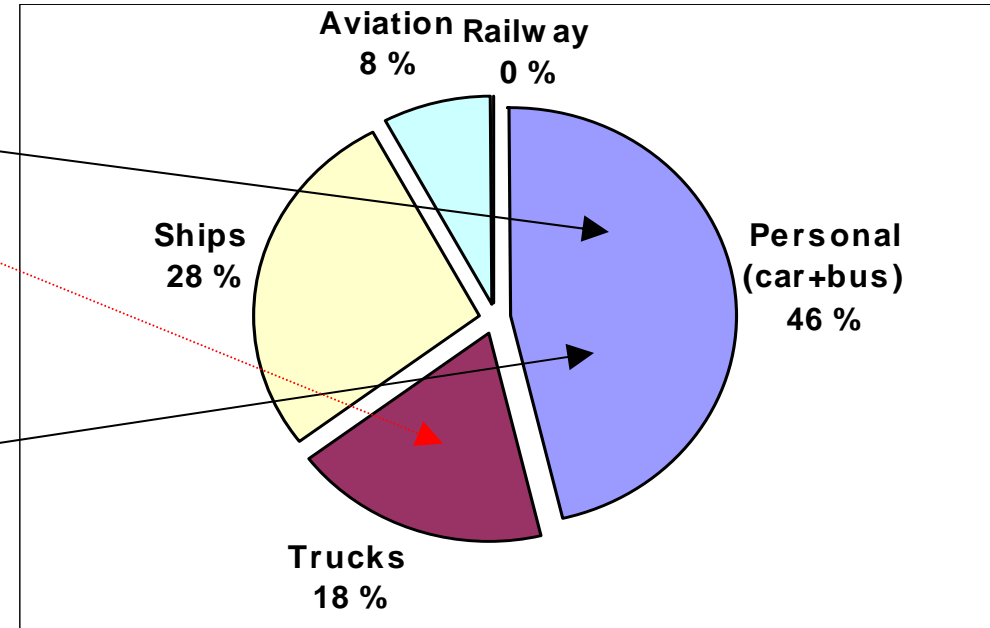
- Replace fossil fuels
- 20 TWh biomass available
- Ca 40 % conversion efficiency WtT

## - Battery/hybrid/plug-in

- Widespread application for personal vehicles, urban buses
- Challenges with range and charging times
- CO<sub>2</sub> emissions dep. on power production

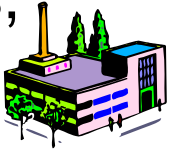
## - Hydrogen

- Flexibility of energy sources
- Widespread application for personal vehicles, urban buses
- Commercial introduction in 2015-2020?



# How to reach ambitious goals for reduction of emissions from road transportation?

- Large scale, domestic production of biofuel, 20 TWh biomass, reserved for heavy duty vehicles:
  - Gradual increase in production until annual production of 1.1 Mton biofuel is reached in 2030
- Growth in transport demand is assumed according to public forecasts, changes drive patterns etc. not considered
- Maximum number of battery electric vehicles:  
31 % of the car fleet, corresponding to 1 car for every household with 2 or more cars.
- City drive cycle for short trips, longer trips with highway drive cycle

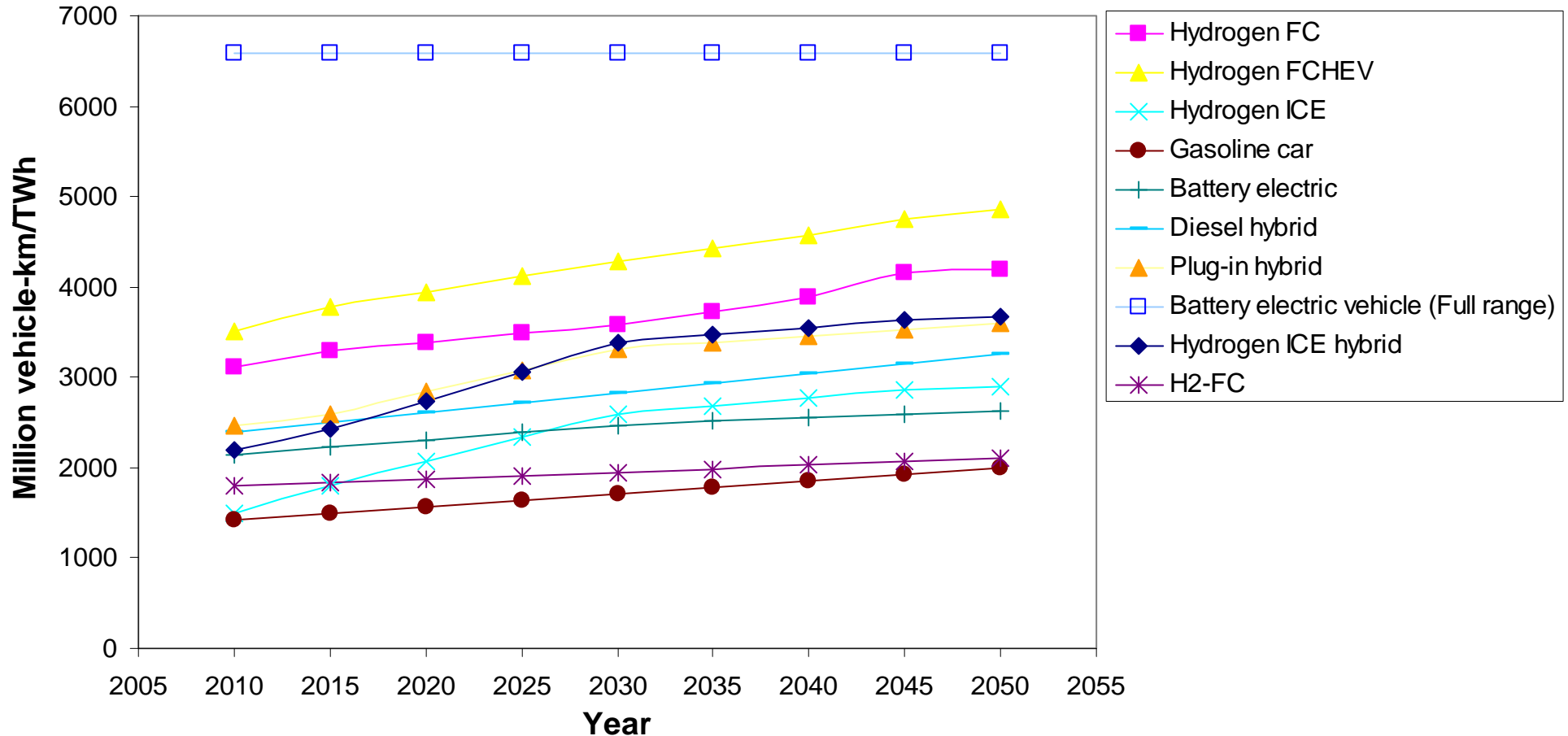




# Energy consumption of vehicles

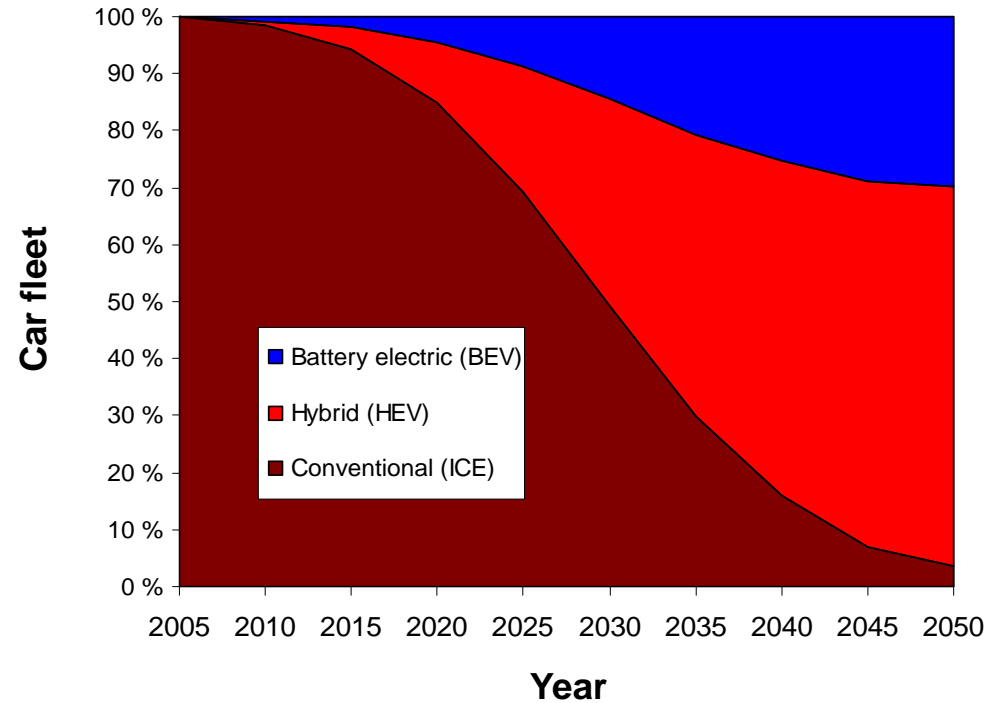
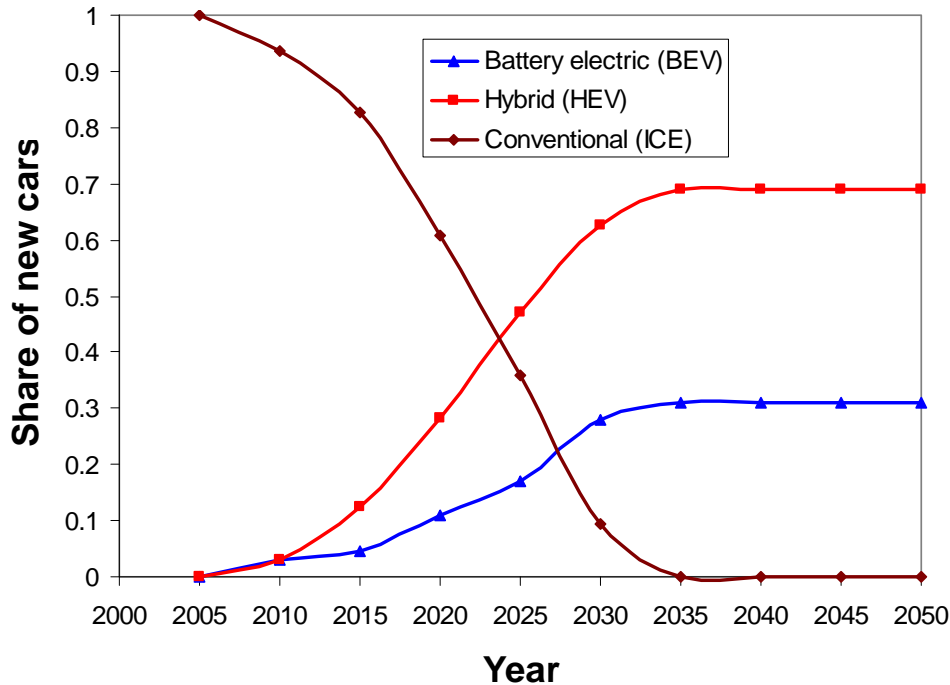


- Learning curves established in the Norways project:



# Scenario BEV + HEV

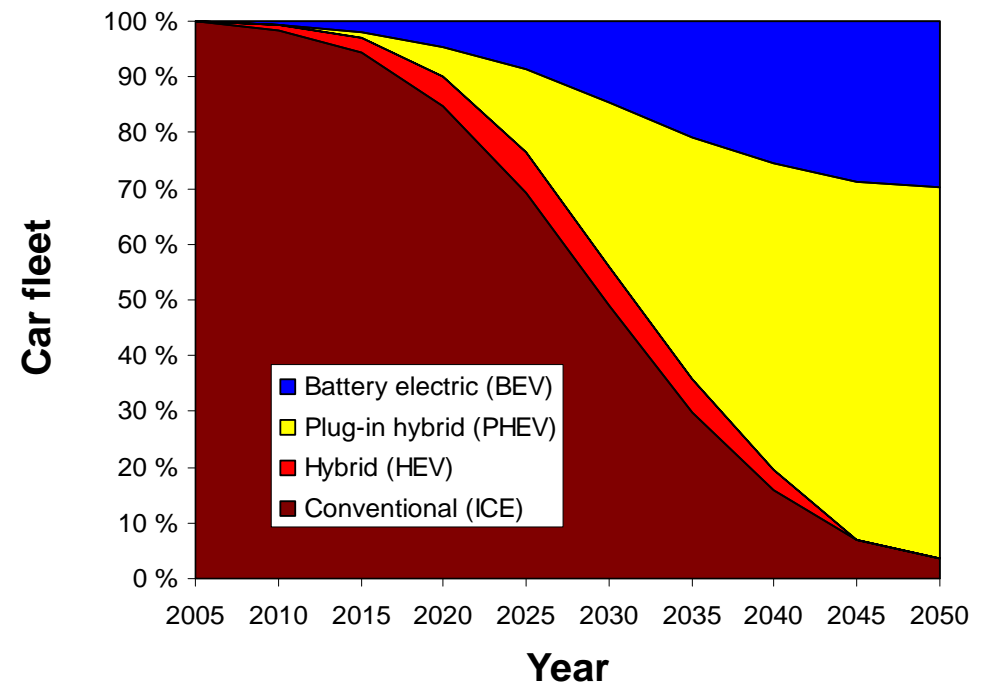
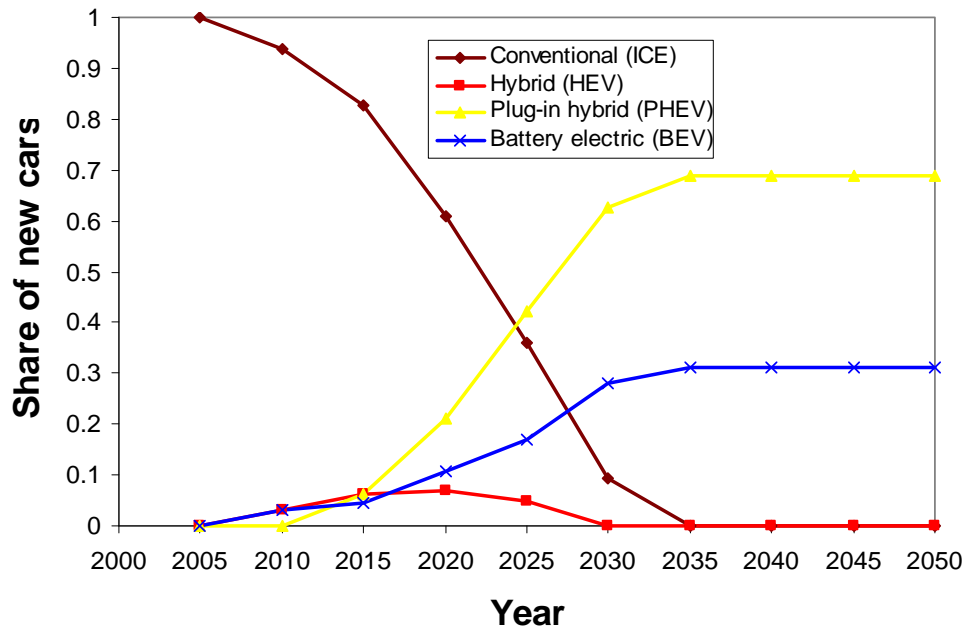
***Battery electric vehicles are introduced in every household with 2 or more cars. All conventional vehicles are eventually replaced by hybrid vehicles***



# Scenario BEV + HEV + PHEV

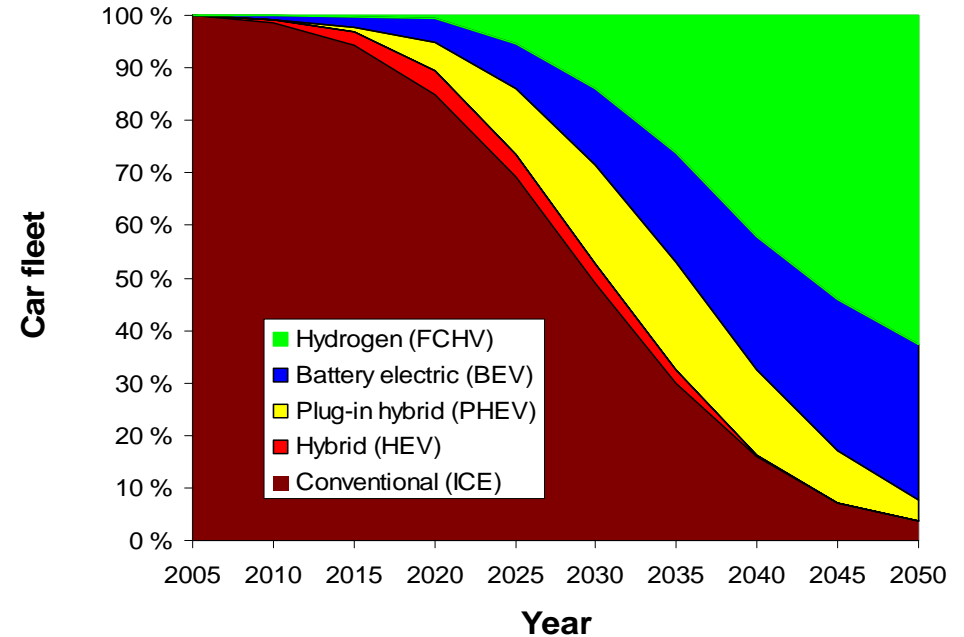
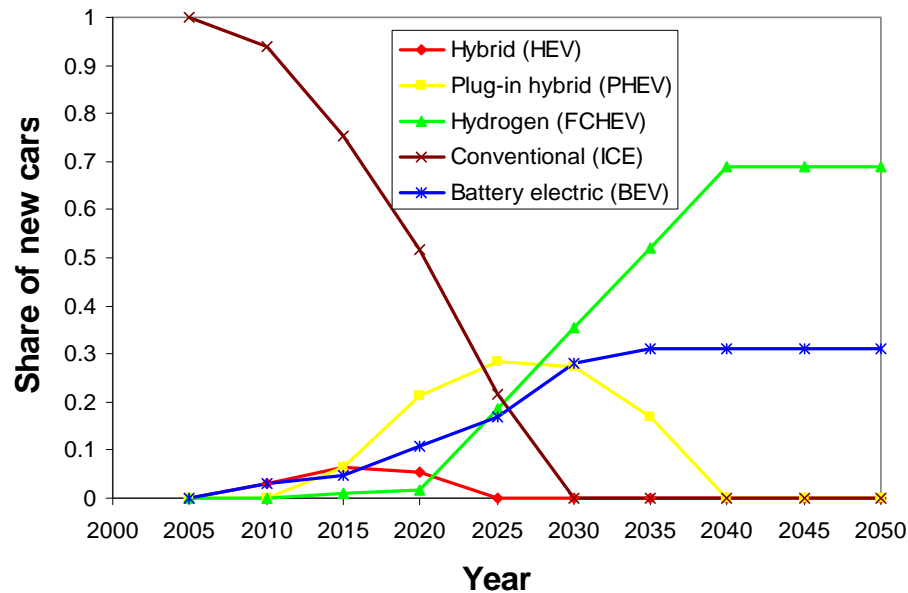


**Battery electric vehicles are introduced in every household with 2 or more cars. All conventional vehicles are eventually replaced by hybrid, and plug-in hybrid vehicles**

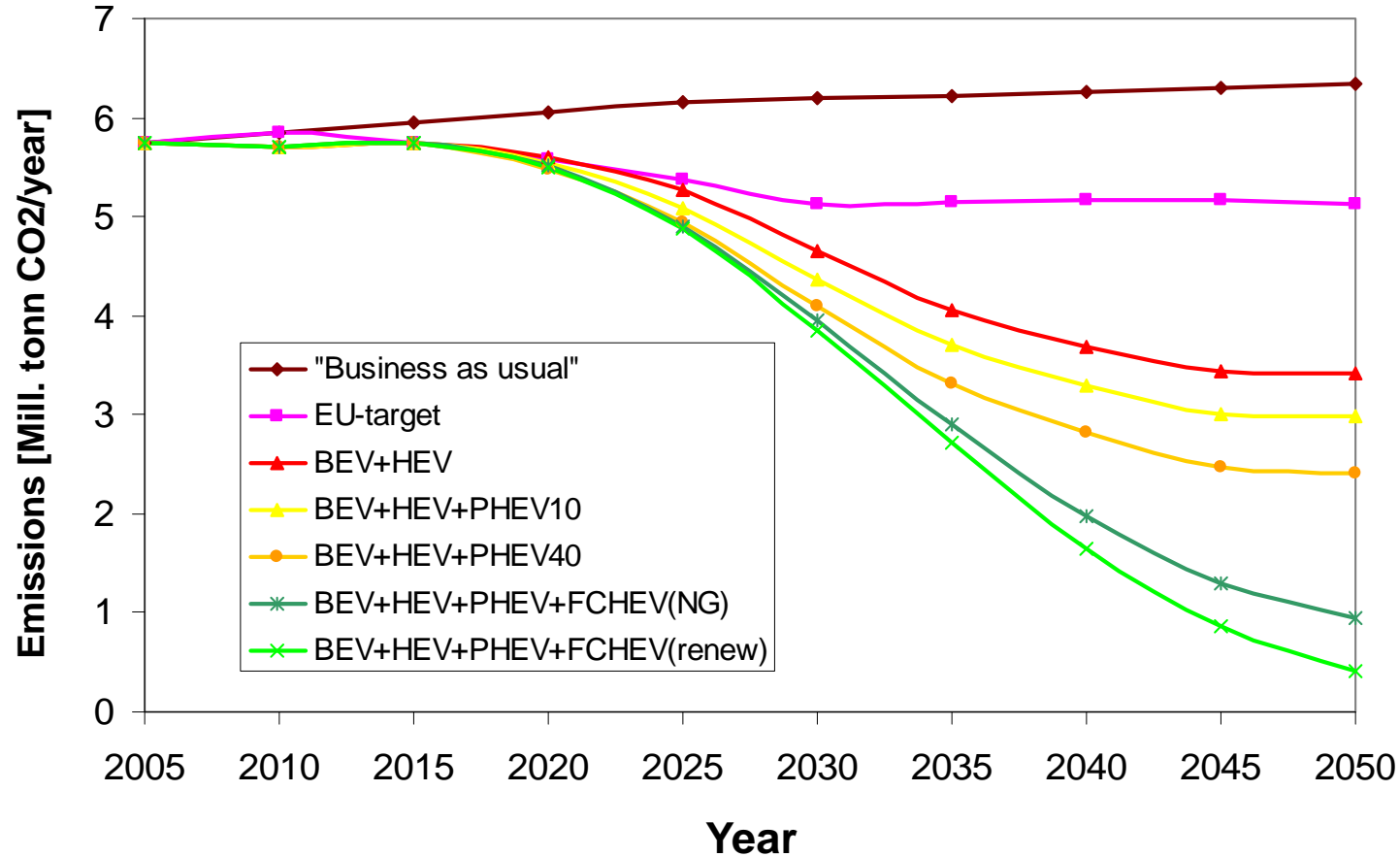


# Scenario BEV + HEV + PHEV + FCHEV

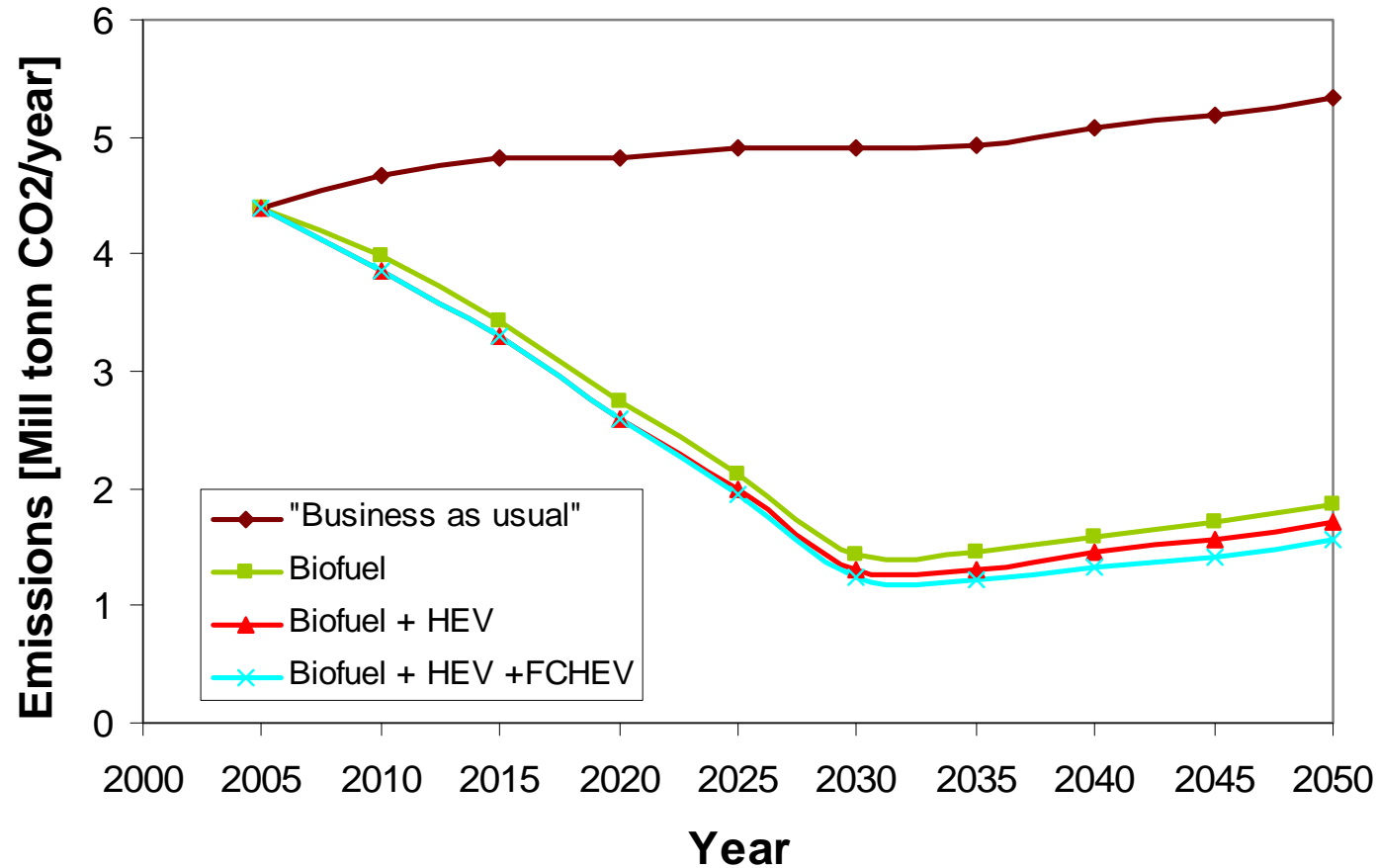
***Battery electric vehicles are introduced in every household with 2 or more cars. All conventional vehicles are replaced by hybrid, plug-in, and eventually hydrogen fuel cell vehicles***



# Forecasts of Emissions, Personal Vehicles



# Forecasts of emissions, goods transportation



# Summary, biofuel

- 70 % coverage of fuel for heavy vehicles from domestic biofuel production (20 TWh → 1.1 Mton/year in 2030)
- Corresponding emission reduction (biofuel) is **3.5 Mton CO<sub>2</sub> equiv per year**
- **20 TWh** biomass for (residential) heating
  - ⇒ replace 15 TWh of electricity,
    - reduction of 11 Mton CO<sub>2</sub> equiv per year, electric vehicles (if transmission of electricity to i.e. Scandinavia)
  - ⇒ Production of H<sub>2</sub> by electrolysis (10.5 TWh H<sub>2</sub>)
    - 90 % of estimated energy consumption for personal cars in 2050 (H<sub>2</sub>-FC)
    - reduction of 6.5 Mton CO<sub>2</sub> equiv per year in fuel cell vehicles
  - ⇒ Production of H<sub>2</sub> by direct gasification (10-11 TWh H<sub>2</sub>)
    - Ca 90% of estimated energy consump. for personal cars in 2050 (H<sub>2</sub>-FC)
    - reduction of 6-7 Mton CO<sub>2</sub> equiv per year in fuel cell vehicles

# Summary, battery electric and plug-in hybrid vehicles

- Electric vehicles (31% of all cars),
  - 24 % of the total vehicle km travelled
  - consumption of **< 2 TWh/year** el. power (2040)
  - emission reductions ~ 1.5 Mton CO<sub>2</sub> equiv per year (2040)
- Plug-in hybrids:
  - Consumption of el. power ca 2 TWh/year
  - Emission reductions ~ 2.1 Mton CO<sub>2</sub> equiv per year (PHEV10), and ~ 2.6 Mton CO<sub>2</sub> equiv per year (PHEV40)



# Summary scenarios, Hydrogen



- Represents a potential zero-emission solution
- H<sub>2</sub> production by electrolysis:  
ca 13-15 TWh el. power per year
- H<sub>2</sub> production by reforming of natural gas:  
ca 17 TWh NG per year
- Reduction of 4-5 Mton CO<sub>2</sub> equiv per year  
(2050)

***Thanks for you attention!***

- Research Council of Norway (contract no.173045/S30 ), StatoilHydro, Statkraft, Hexagon, Næringslivets Idefond are acknowledged for their financial support