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When and How to Decarbonize the Transport Sector?

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IEW Cape Town
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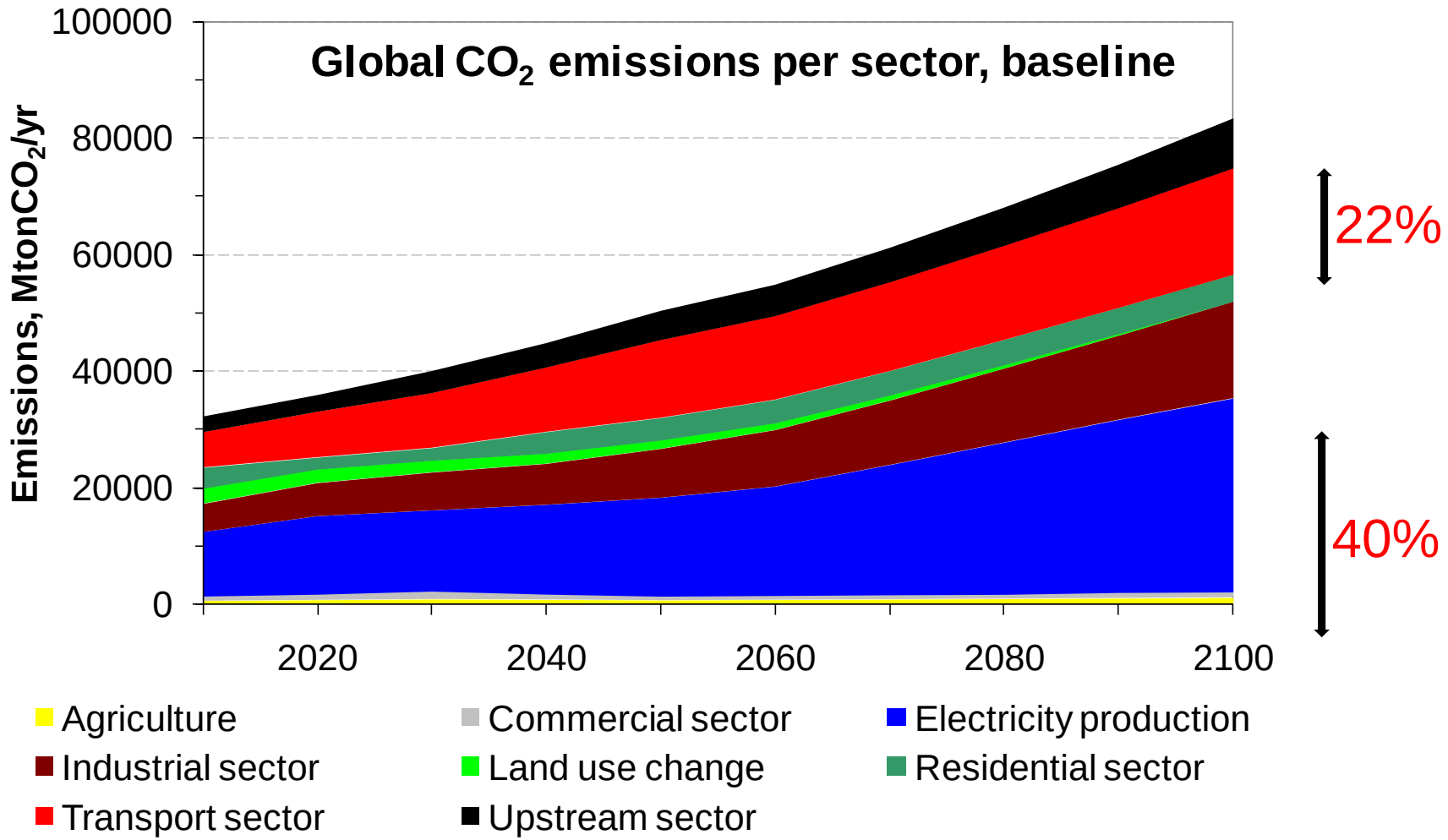
Why decarbonize the energy system?

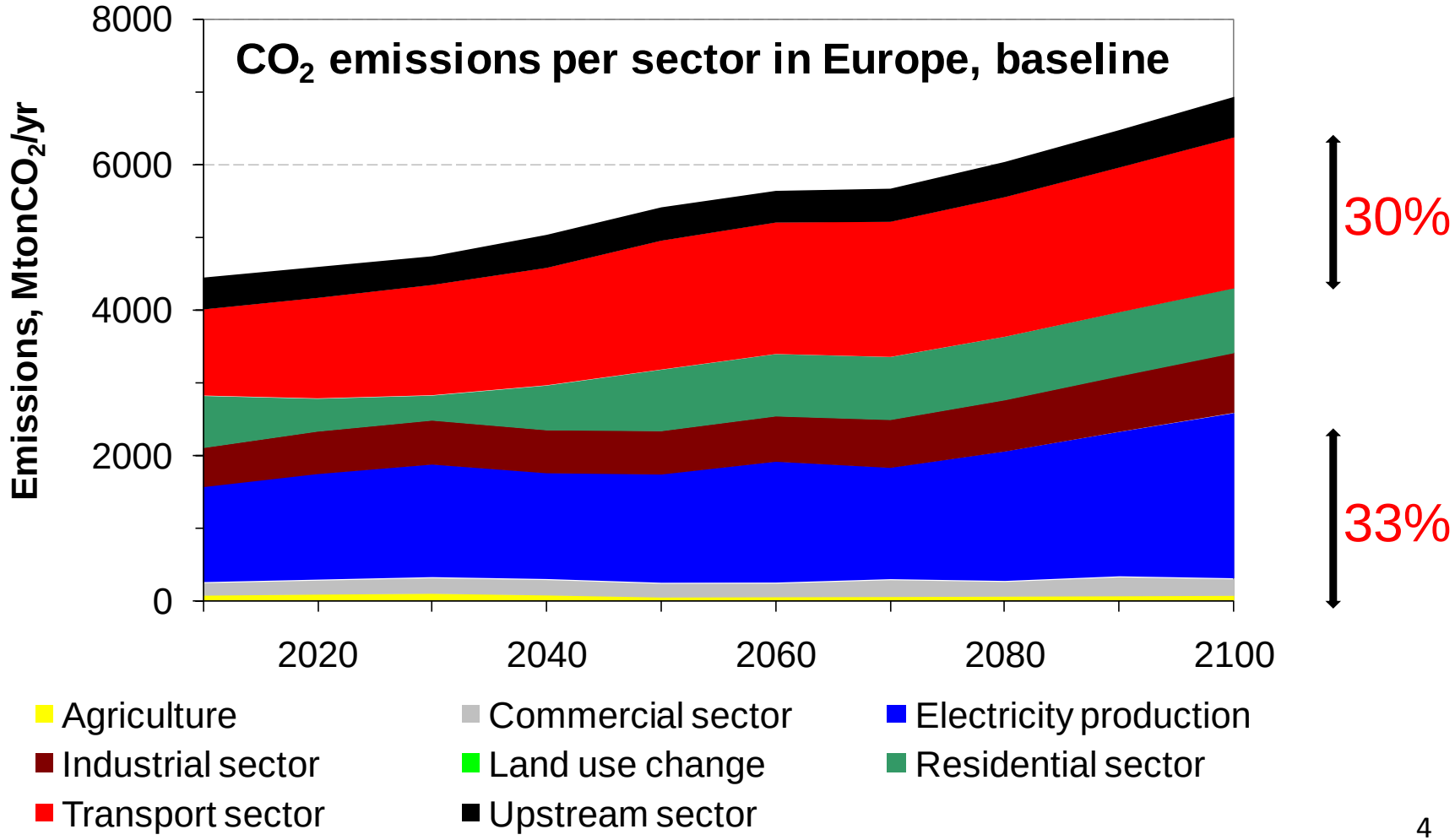
- Increasing global primary energy use
  - US 320 GJ/cap
  - Europe 140 GJ/cap
  - China 25 GJ/cap 1980, 75 GJ/cap 2010
  - India 12 GJ/cap 1980, 25 GJ/cap 2010
- Increasing fossil fuel use leads to increasing CO_2 emissions
- Global temperature change

- How an when to reduce emissions?

Why the transport sector?



Europe: currently >25% of total CO_2 emissions from transport in Europe



Study set-up

- We need to transform transport sector away from fossil fuels
- Clean alternatives transport options are available: hydrogen, electricity and biofuels.

What drives a transformation?

- Increasing fossil fuel prices
  - limited availability
  - CO_2 pricing

- Use TIAM-ECN model
- Focus Europe, passenger cars

TIAM /TIAM-ECN

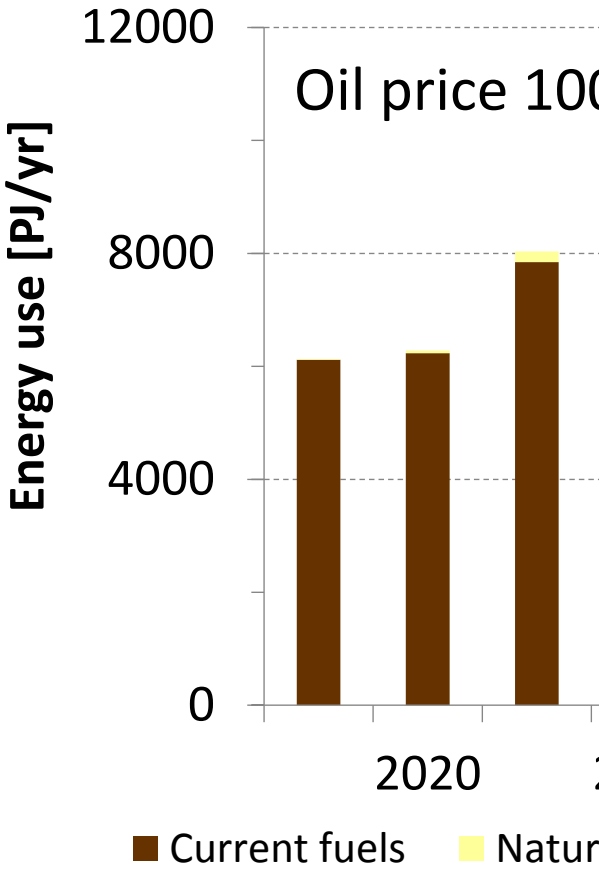
- TIAM:
  - Global, technology rich, long term energy system model
  - Time frame from 2005 to 2100
  - World divided into 15 regions
- Describes energy system from resource extraction to the final end use of energy
- Economical optimalisation: Determines cost optimal configurations of system which fulfil energy services demand

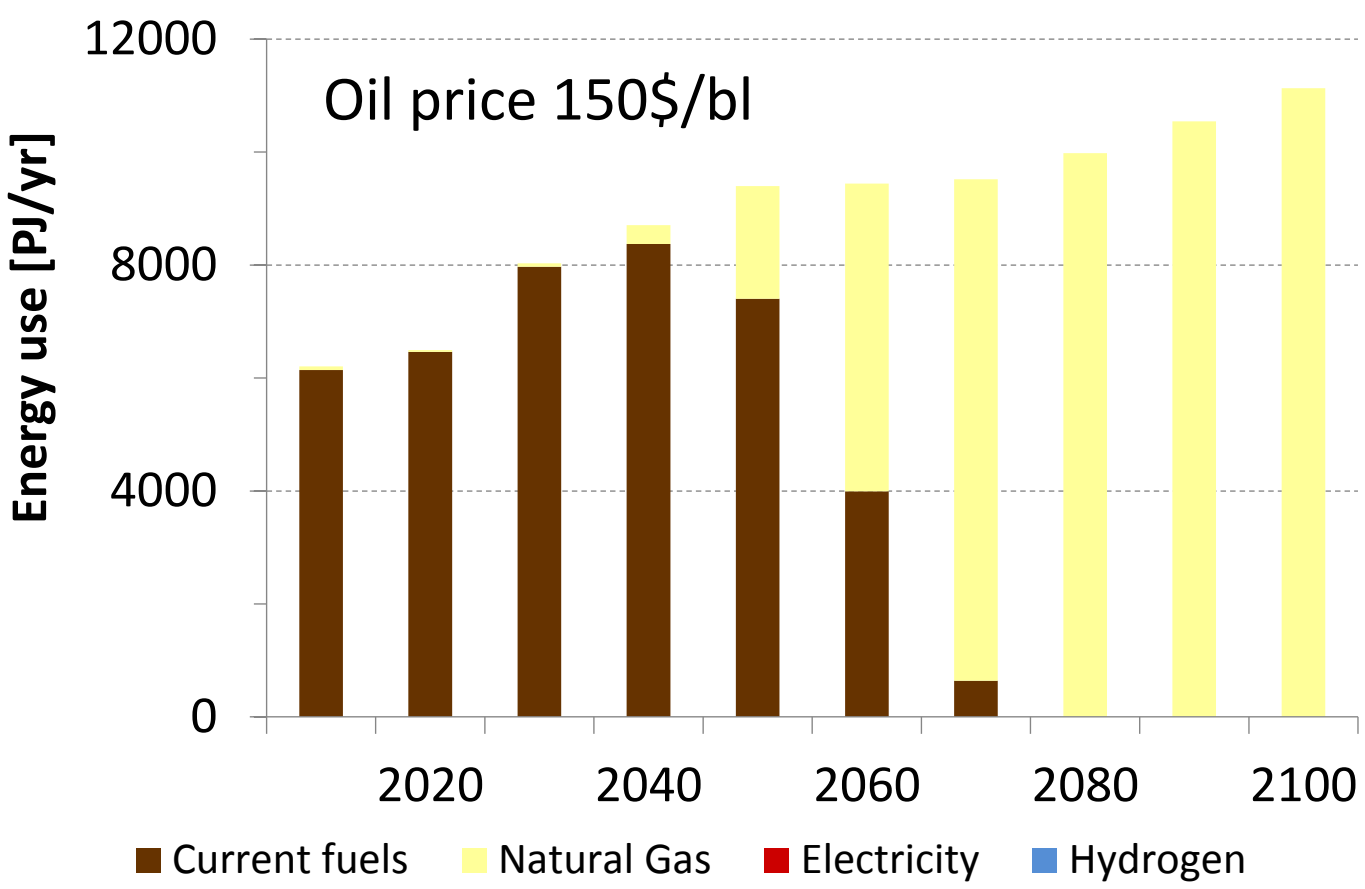
- TIAM-ECN:
  - Improved representation hydrogen sector, including transport and distribution
  - Improved passenger transport sector
  - Improved representation biofuels

Fuel price as a driver of transformation transport sector?

- Oil price 100 $/bl and 150 $/bl
- Gas price increases, but do not follow completely (also not fully decoupled)
- Driven by limited availability

Increasing oil prices lead to natural gas use for transport





New infrastructure needed, possible, but not preferable, since still carbon intensive

High fuel prices are not enough to trigger decarbonization

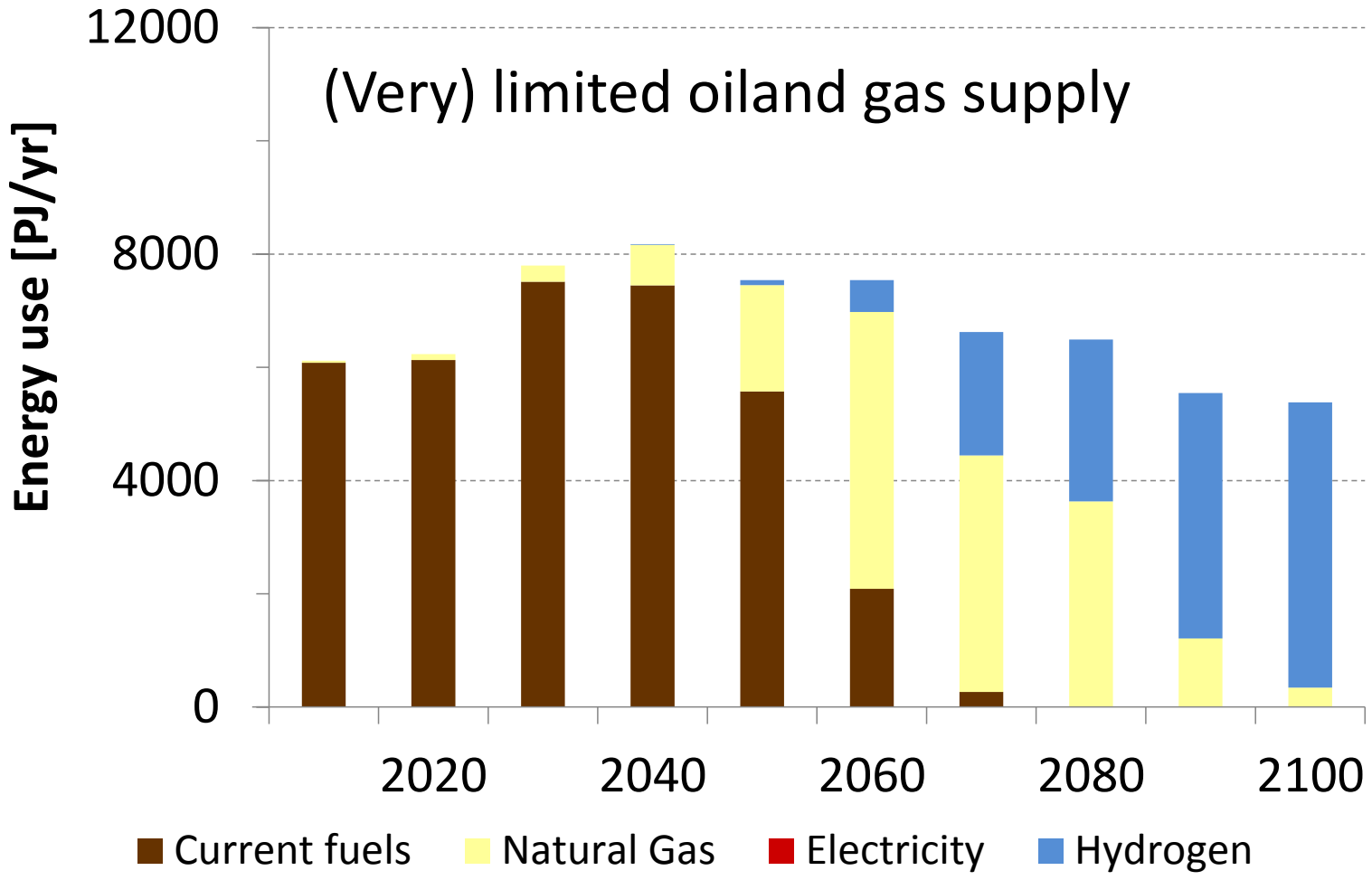
Conclusion:

Increasing fuel prices are not enough to trigger hydrogen nor electric vehicles for transportation

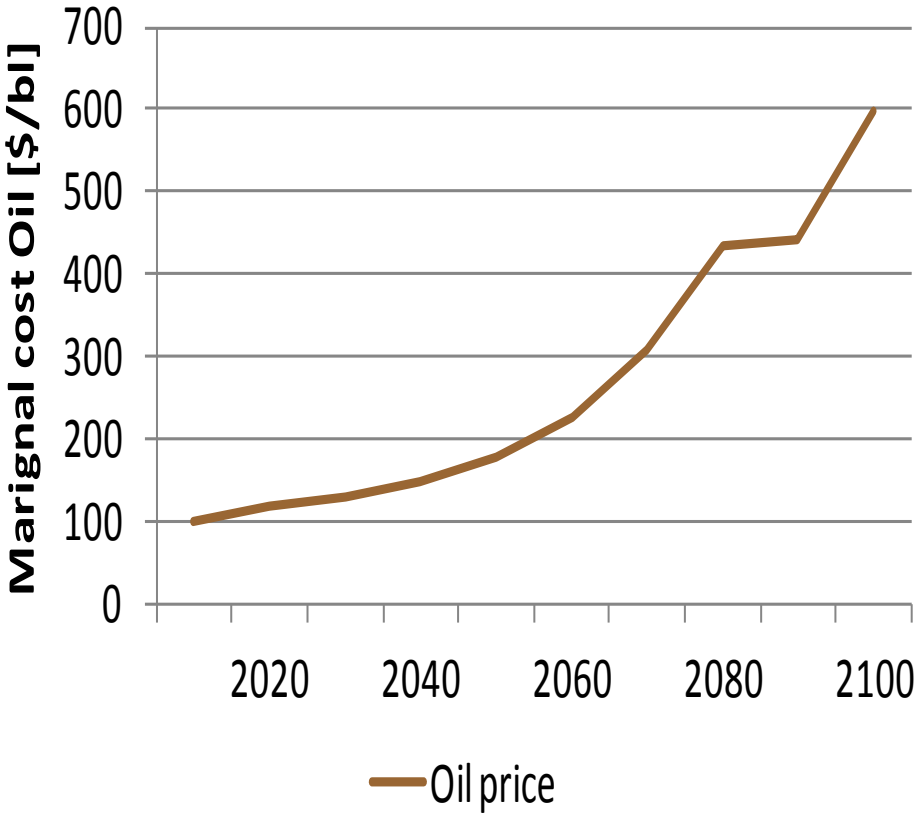
Unless ....

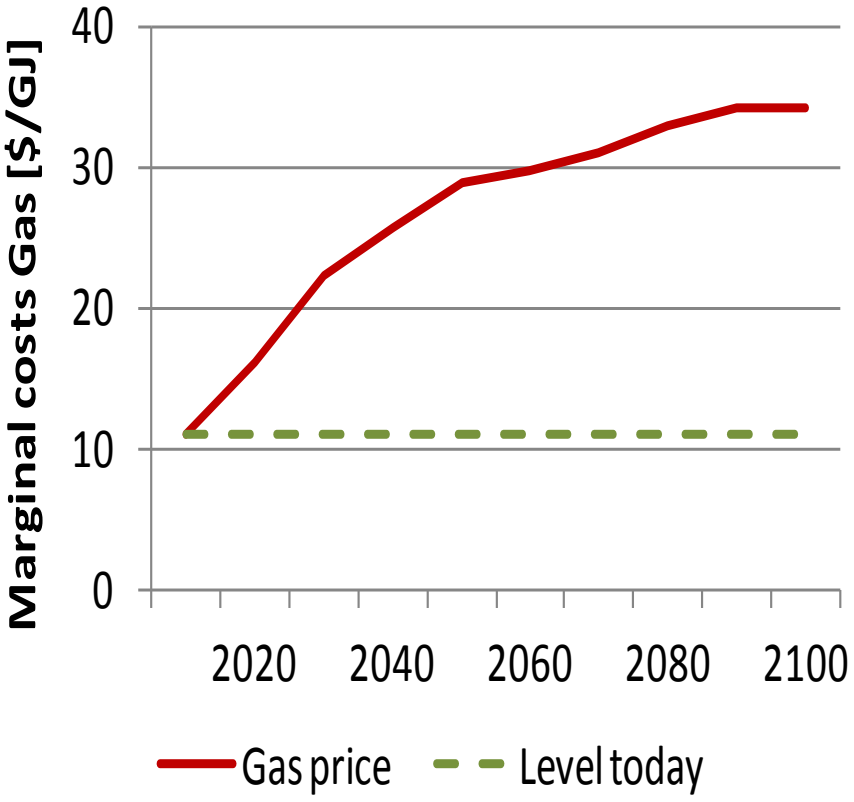
- Very tight limitations on oil and gas reserves
  - Domestic reserves of gas and oil limited to 10%
  - Cumulative gas import 22%
  - Cumulative oil import 40%

Hydrogen can play a role in transport under very limited oil and gas supply

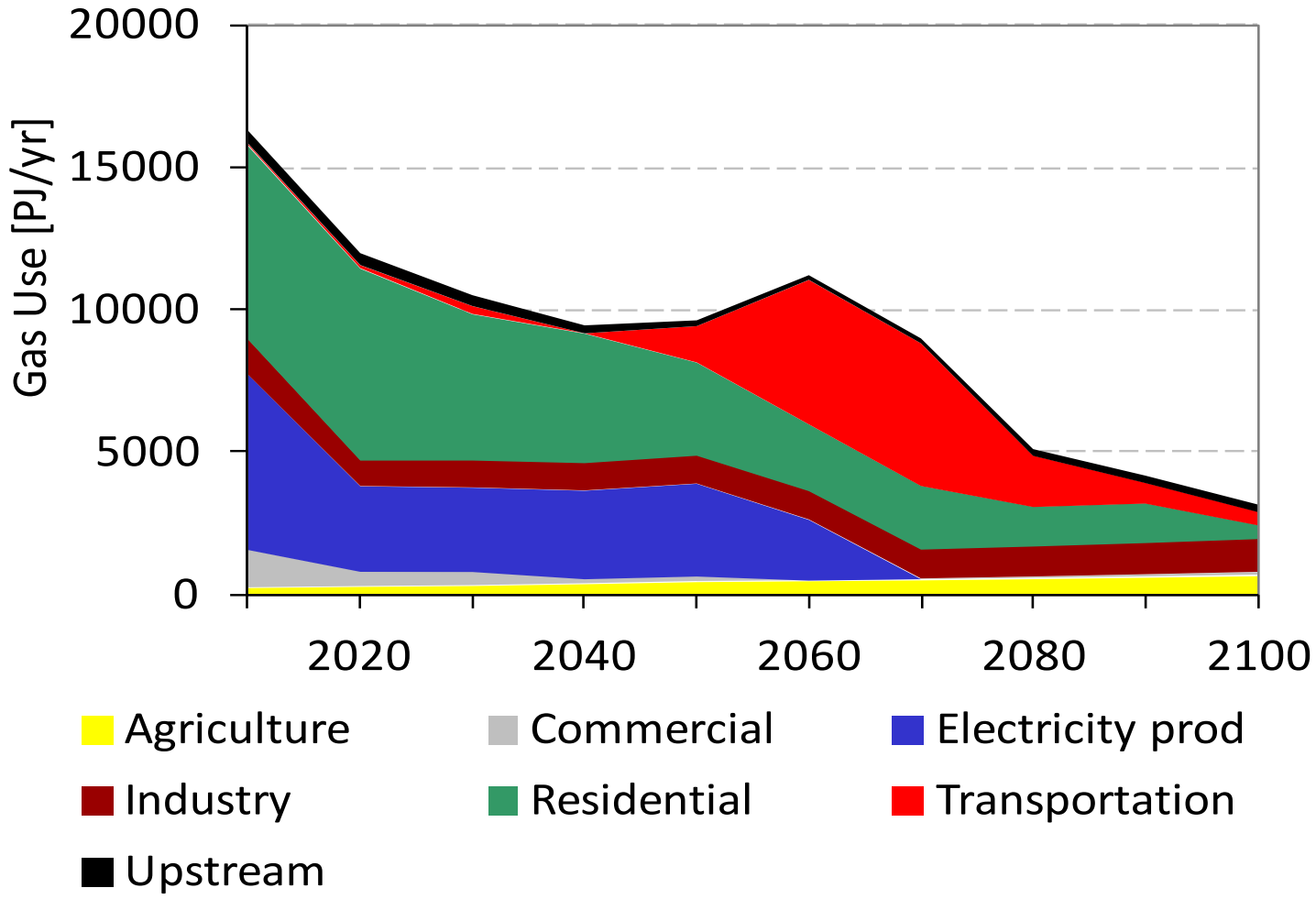


but at very high cost

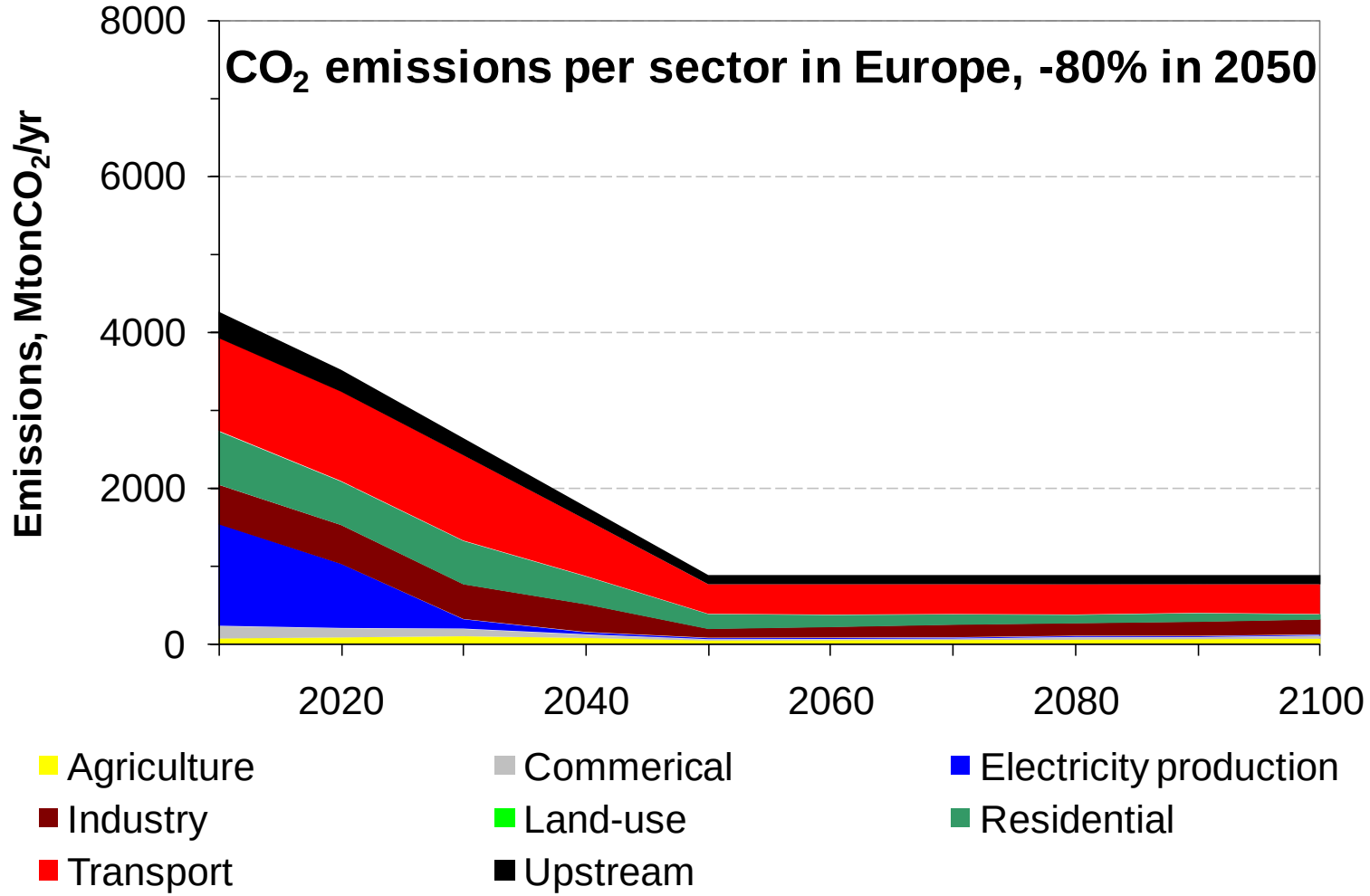




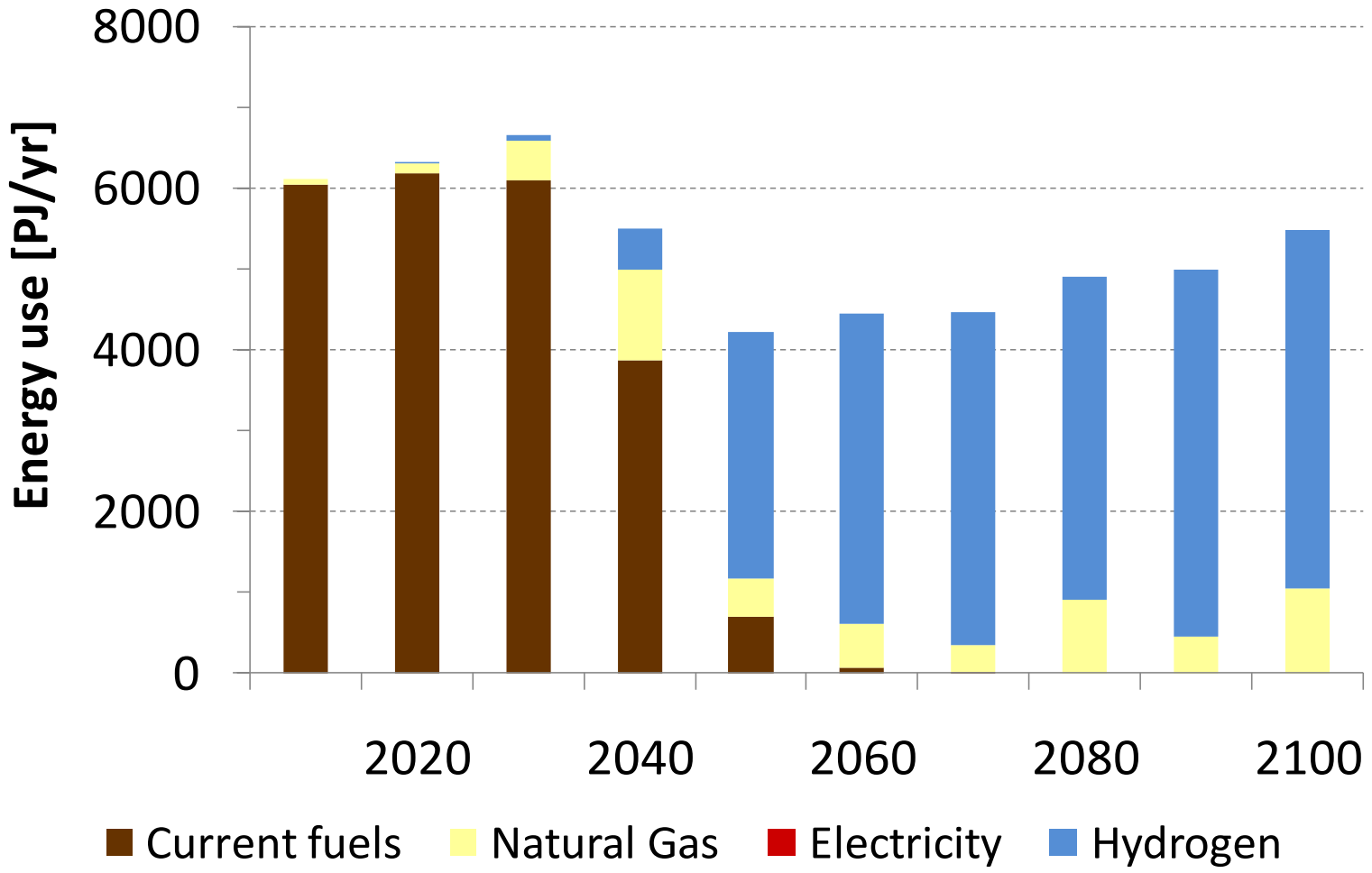
and still prefer to continue with fossil fuels for transportation as long as possible



CO_2 pricing as a driver?
European target: -80% CO_2 in 2050



In 2050 hydrogen FCV dominating passenger car transport in - 80% scenario



Carbon pricing necessary to transform transport sector

- Ambitious climate control (in combination with high oil prices, or not) CAN achieve decarbonization of transport sector

However, the model

- preferable reduce emissions in the power sector first
- and postpone reductions in the transport sector,
- because alternative vehicles such as FC and Battery are (too) expensive

- On the other hand, also other factors such as local air quality can drive alternatives

- Under ambitious reduction of CO_2 emissions hydrogen FC vehicles are the economical preferable option and from 2050 dominating the private passenger transport

Hydrogen versus Electric
Why are there no electric vehicles?

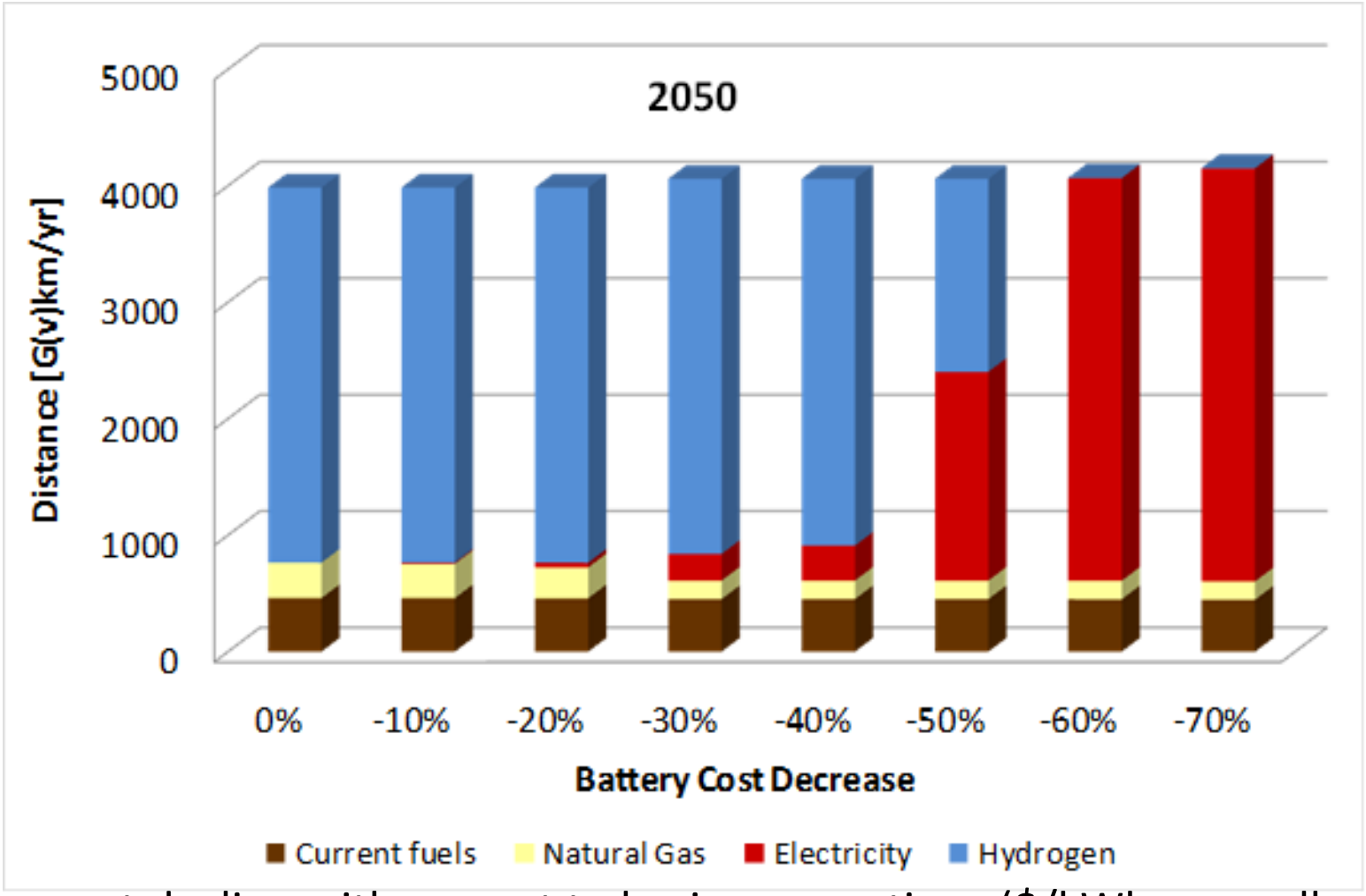
- Battery also in future very expensive.
  - 2010 970$/kWh (McKinsey), 700$/kWh this year
  - Conservative basic cost decline between for long term 2020 – 2040 25% (IEA 2005, 2007), because mature technology
  - Upper side of the range of projections

Costs	Related assumptions on (storage) capacity	2020	2030	2040
Battery [$(2005)/kWh]	44 kWh (near term) and 36 kWh (long term) for 200 km driving range	450	390	330
Fuel cell [$(2005)/kW]	80 kW system	180	80	50

- Optimistic about battery lifetime, charging infrastructure

- Anyhow progress is likely on multiple fronts (lifetime, charging time and capacity density) including costs.

What are the battery cost improvements necessary for electric cars to dominate?



Battery cost decline with respect to basic assumptions ($/kWh or smaller battery size)

Conclusions

- High oil prices alone will not be able to soon transform the transport sector away from fossil fuels.
- Ambitious climate control can achieve such a decarbonization.
- CO_2 emission reductions in transportation sector are expensive and postponed as long as possibile

- From an economic perspective hydrogen appears the winner, unless battery costs are reduced substantially.
- Of course, non-economic factors may ultimately be at least as important as costs: infrastructure / networks, travelling distance, consumer preferences, safety, etc.
- Most likely co-existence of hydrogen and electricity, e.g. for different travel ranges.

Thank you for your attention

Working papers:

- van der Zwaan, B.C.C., I.J. Keppo, F. Johnsson, 2012, “When and How to Decarbonize the Transport Sector?”, under review.

- Rösler, H., B.C.C. van der Zwaan, I.J. Keppo, J.J.C. Bruggink, 2012, “Two Types of Transportation: Hydrogen versus Electricity under Stringent Climate Change Control”, in progress.

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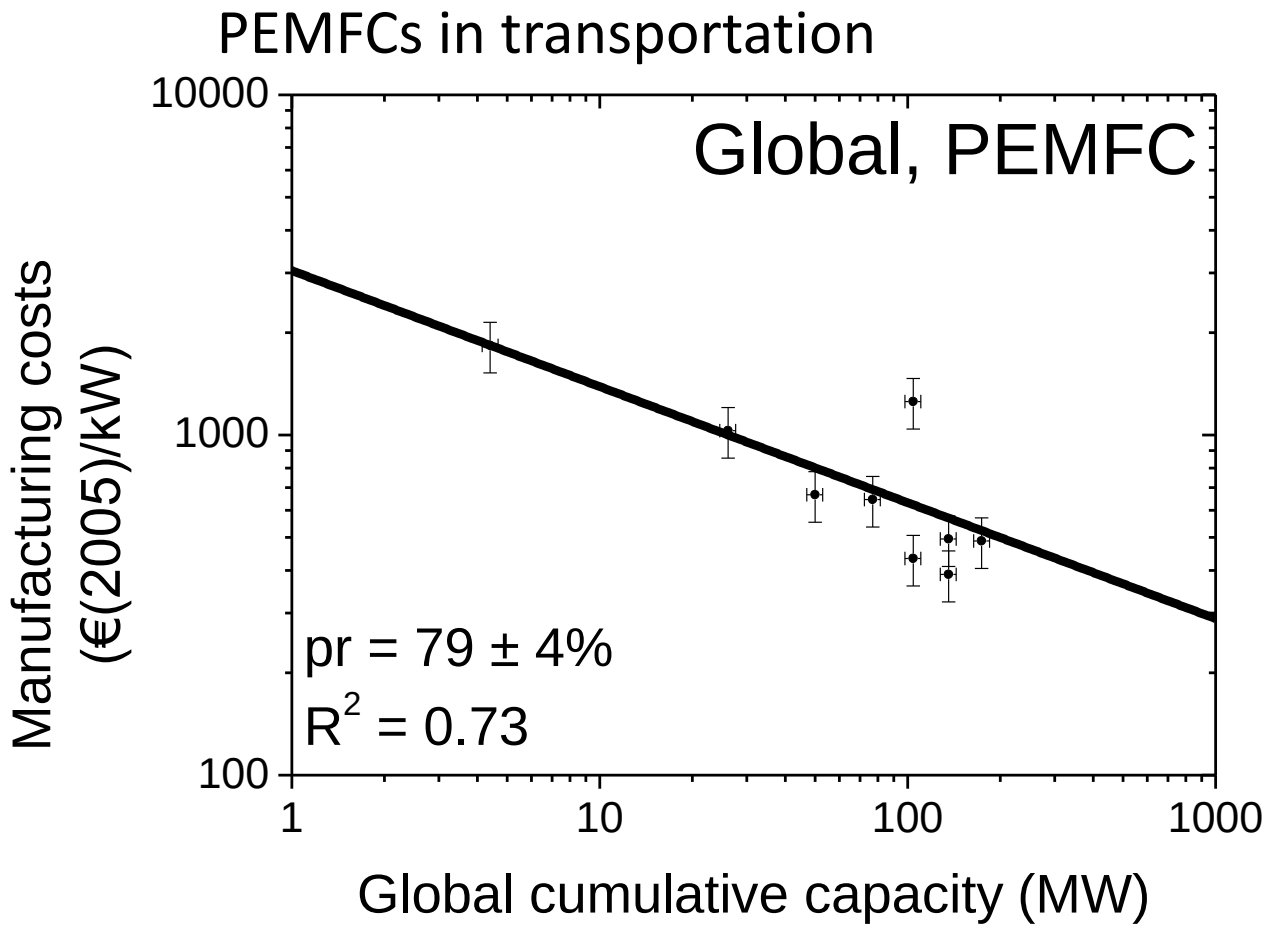
Learning curves for PEM fuel cells



Schoots, K., G.J. Kramer and B.C.C. van der Zwaan, "Technology Learning for Fuel Cells: an Assessment of Past and Potential Cost Reductions", *Energy Policy*, 38, 2010, 2887-2897.