



Project #1: Explore, through linear optimization modelling, under what circumstances fuel cells will be a future cost-effective technology for long-haul freight transport.

Introduction:

Replacing fossil fuels with sustainable alternatives is a vital part of fighting climate change. This project focuses on investigating alternatives for long-haul transport. Long-haul transport led to more than 3 000 000 tons CO₂ equivalents of greenhouse gas emission in Sweden alone during 2021 which means that reducing greenhouse gas emissions from long haul is necessary to reach a sustainable transport sector*.

The analysis in this project was made using linear simulation in the Global Energy Transition (GET) model. (GET) model is a linearly programmed energy systems cost-minimizing model. The model generates the fuel and technology mix that meets the demand (subject to the constraints) at lowest global energy system cost. In the model CO₂ is decreased over time to meet the harder CO₂ concentration targets.



Image source: <https://www.volvotrucks.com/en-en/news-stories/press-releases/2022/jun/volvo-trucks-showcases-new-zero-emissions-truck.html>

Baseline assumptions

The following assumptions are used for the baseline test case:

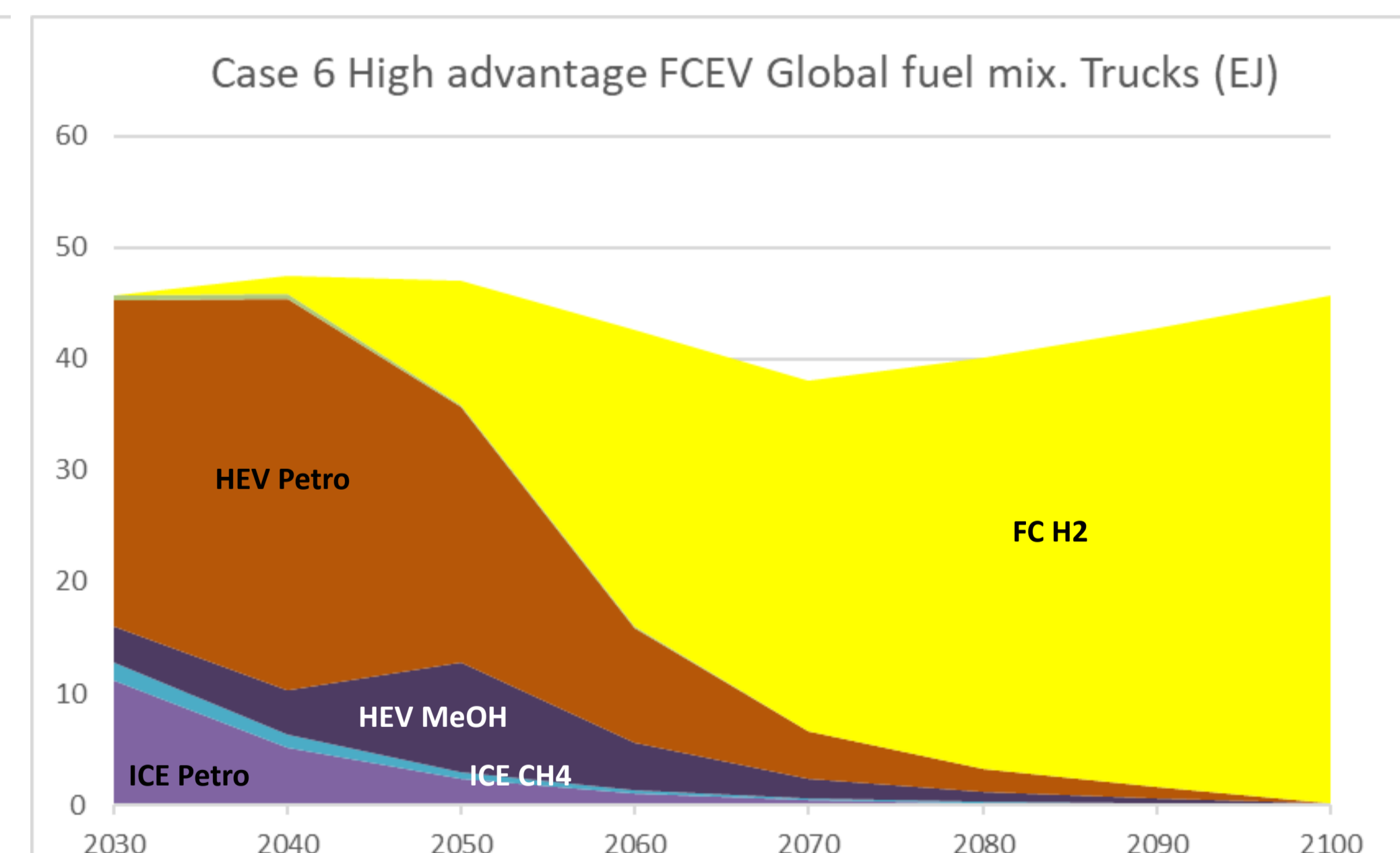
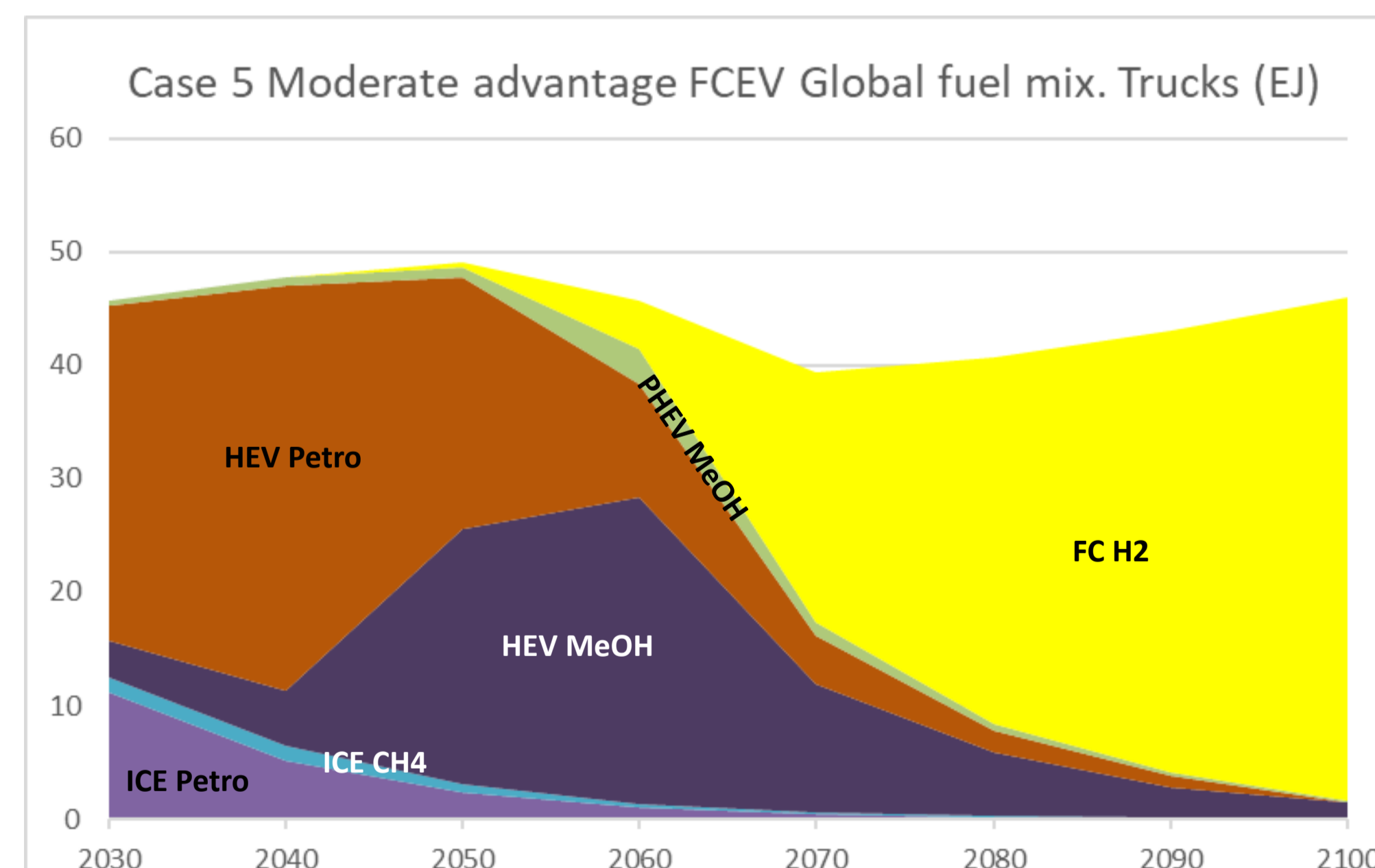
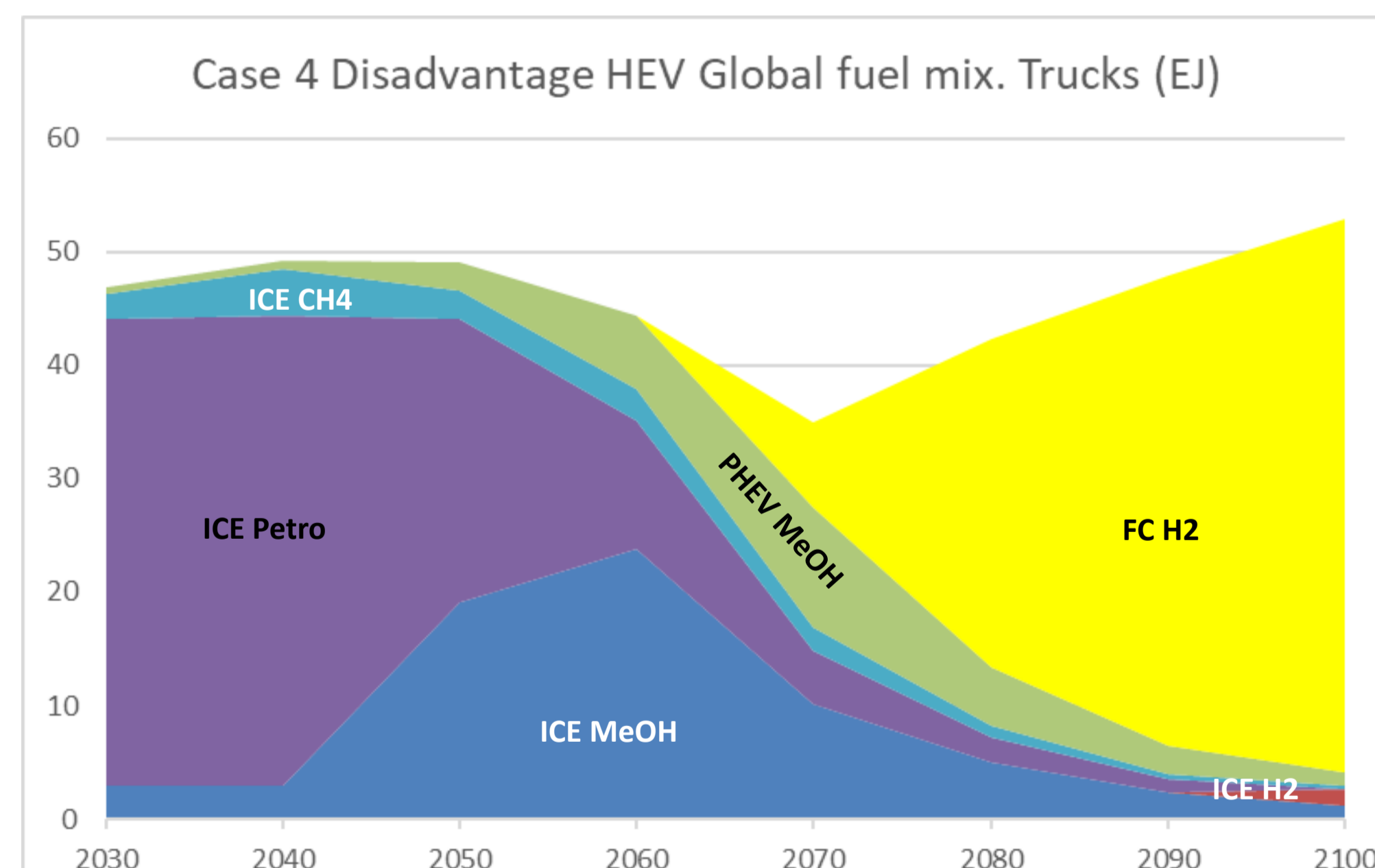
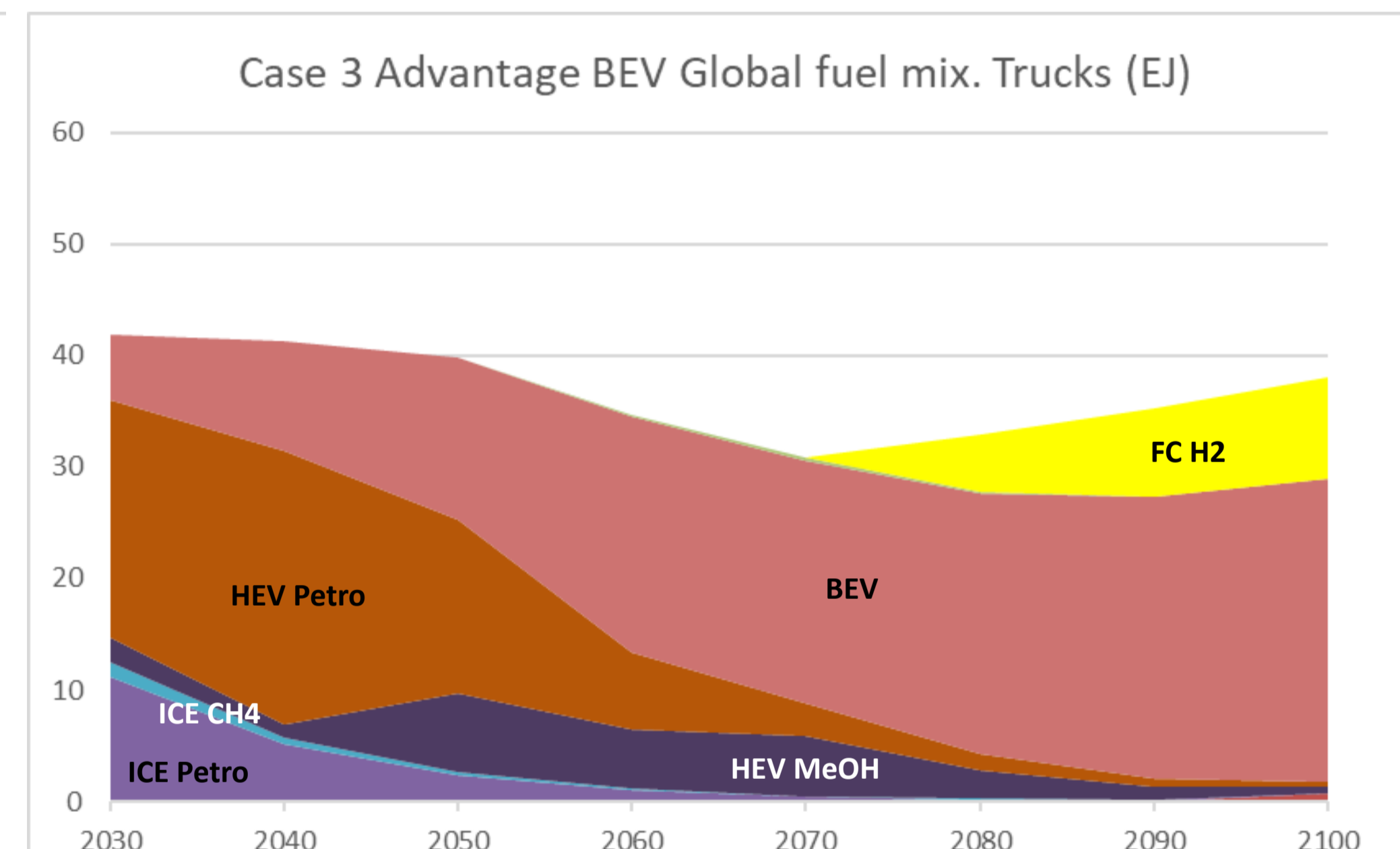
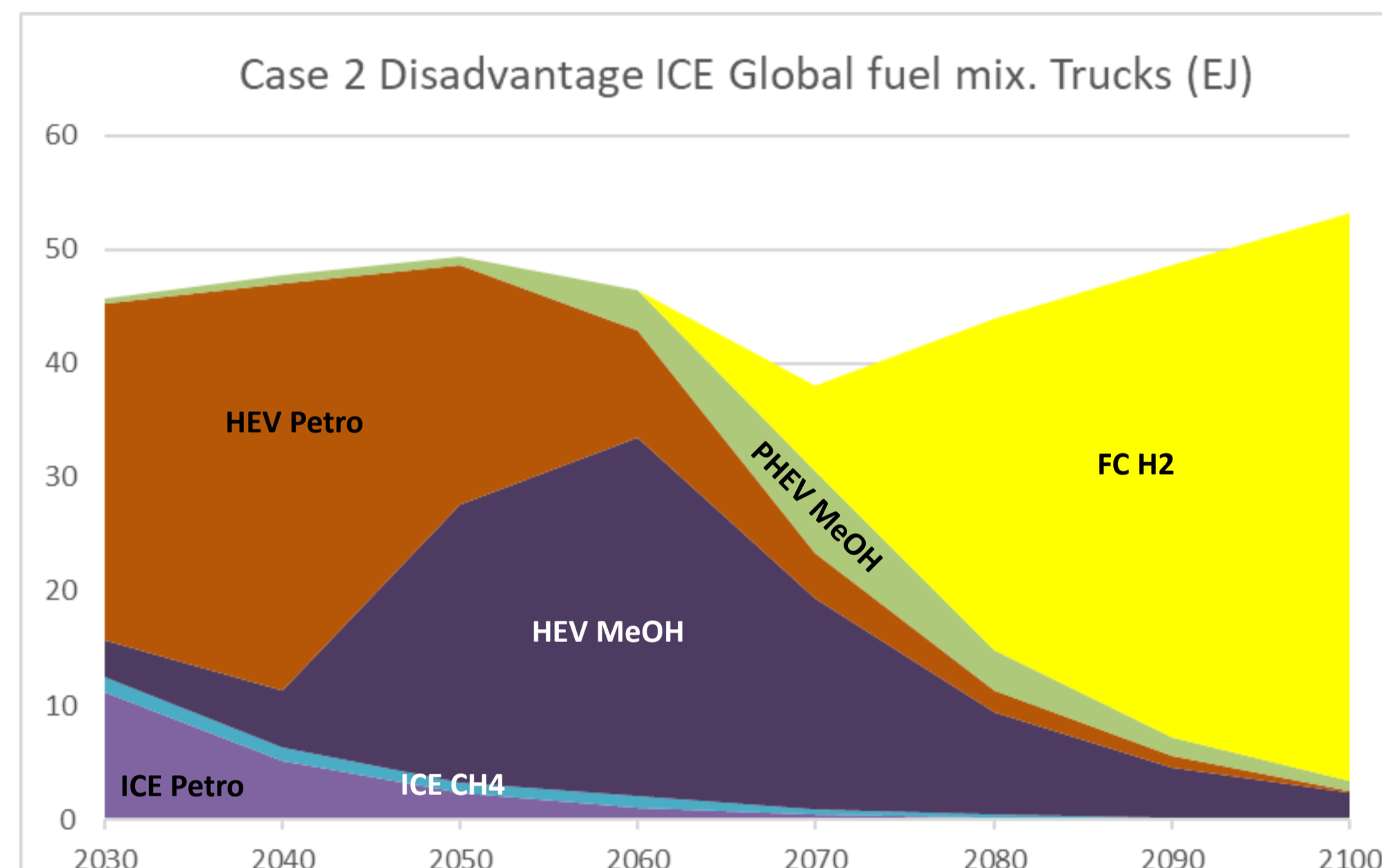
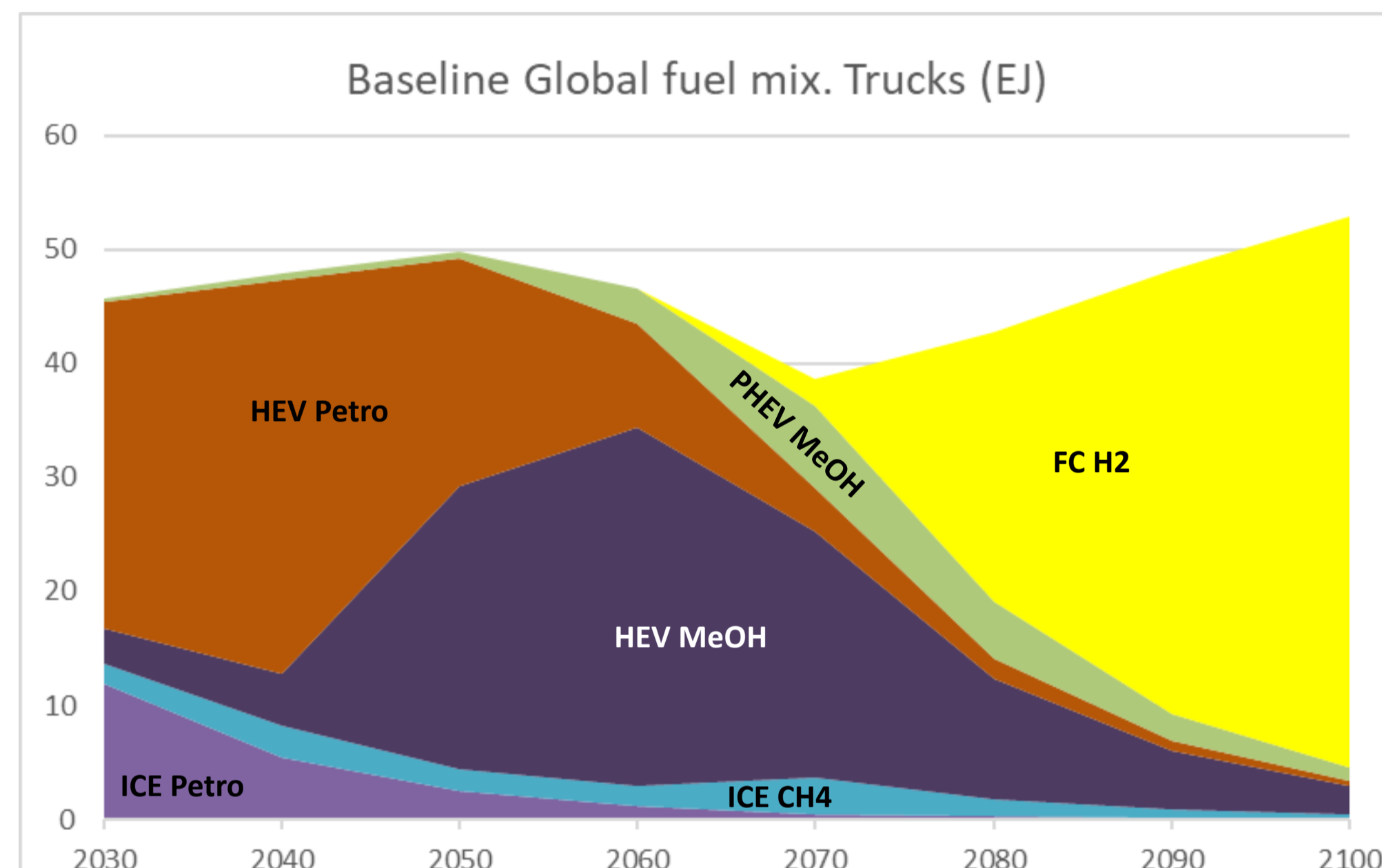
- Specific cost of ICE: 44 USD/kW mech output
- Driving range for trucks (non-electric): 1000 km
- Driving range for BEV: 400 km
- Driving range HEV electric mode: 2 km
- Overall PT efficiency FC driveline: 51 %
- FC stack cost: 65 USD / kWe
- Battery cost: 100 USD / kWh
- PHEV: 2/3 ICE energy, 1/3 battery energy
- Peak mechanical output for trucks: 350 kW

Changed input parameters

To investigate under which circumstances fuel cell electric long-haul transport is a cost-efficient technology, the listed input parameters were altered in the model:

- Specific cost of ICE to meet future emission legislations
- Driving Range battery electric
- Driving Range electric mode HEV
- Overall PT efficiency FC driveline
- FC stack cost

Test case	Key parameters				
	Specific cost of ICE (USD/kW mech output)	Driving Range battery electric (km)	Driving Range electric mode HEV (km)	Overall PT efficiency FC driveline (%)	FC stack cost (USD/kWe)
Baseline	44	400	2	51	65
Case 2 Disadvantage ICE	55	400	2	51	65
Case 3 Advantage BEV	55	200	2	51	65
Case 4 Disadvantage HEV	55	400	20	51	65
Case 5 Moderate advantage FCEV	55	400	2	60	65
Case 6 High advantage FCEV	55	400	2	60	35



Results and discussion

In the baseline the FCEV long-haul vehicles may have a small market share from 2060 and a large share from 2080 and onwards.

Comparing baseline and case 2 Disadvantage ICE, the model shows no significant difference in introductory time of FCEV, which means that increasing specific cost of ICE does not impact the introduction of FCEV long-haul. However, increasing the cost of ICE has a small effect on the scale up of the FCEV technology between 2060 and 2070.

Case 3 advantage BEV with drastically reduced driving range for BEV results in a large market share of BEV over the entire modelled timeline. In all other cases, BEV is not a cost-efficient solution for long-haul trucks.

Increasing the driving range in electric mode for HEV, as in case 4 Disadvantage HEV, results in HEV not being a cost-effective solution instead PHEV is much more dominant in the market share from 2030 to 2060. It does not however seem to impact the introduction of the FCEV technology.

For Case 5 Moderate advantage FCEV and case 6 High advantage FCEV, the model shows lower total energy demand than baseline from 2080 and onwards which is linked to the increase of the FC powertrain efficiency from 51 to 60%. The transport need that is covered by FCEV long-haul can be accommodated with a lower energy amount. The FCEV is a cost-effective solution from 2050 when FCS stack cost is 35 USD/kWe, which means that the higher efficiency in case 5 did not influence the introduction time. An earlier introduction can be reached if the FC stack cost is reduced from 65 to 35 USD/kWe, as visualized in case 6. The cost target from DOE for beyond 2030 is 30 USD / kWe**.

Fuel stack cost and fuel cell efficiency need to be reduced radically for FCEV to be a cost-effective technology by 2030.

The FCEV technology has important role in all the scenarios assessed in the project.

Abbreviations

- BEV: Battery Electric Vehicle
- CH4: Fossil natural gas.
- DOE: US Department of Energy
- FC: Fuel Cell
- FCEV: Fuel Cell Electric Vehicle
- HEV: Hybrid Electric Vehicle
- ICE: Internal Combustion Engine
- MEOH: Methanol as a proxy for all liquid biofuels and electro fuels.
- Petro: Fossil oil-based petroleum fuels (diesel)
- PHEV: Plug-In Hybrid Electric Vehicle
- PT: Powertrain

* <https://www.naturvardsverket.se/amnesomraden/klimatomstallningen/omraden/klimatet-och-transporterna>
 ** https://www.hydrogen.energy.gov/pdfs/review19/plenary_fuel_cell_papageorgopoulos_2019.pdf