ECN

Energy research Centre of the Netherlands

Large-scale rollout of hydrogen powered fuel cell cars in the Netherlands

ALV NWV, Amersfoort, 17 March 2010

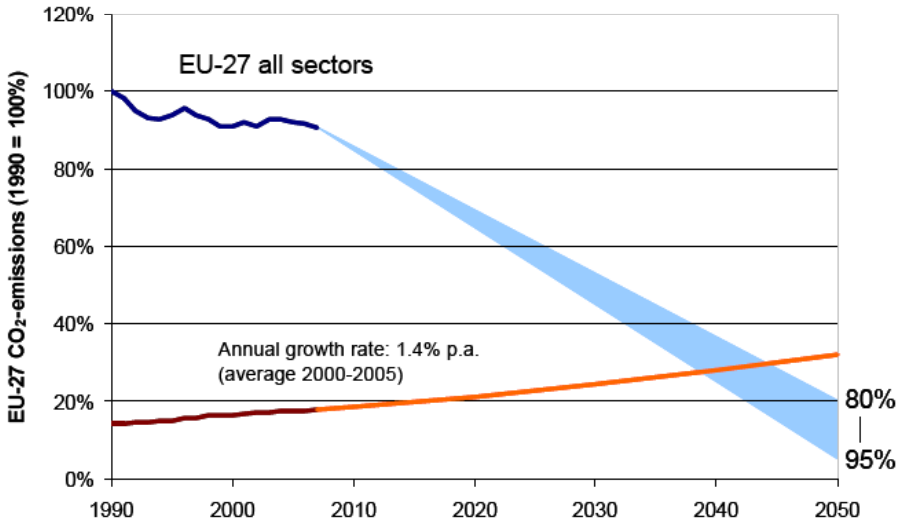
Presented by Marcel Weeda

Outline

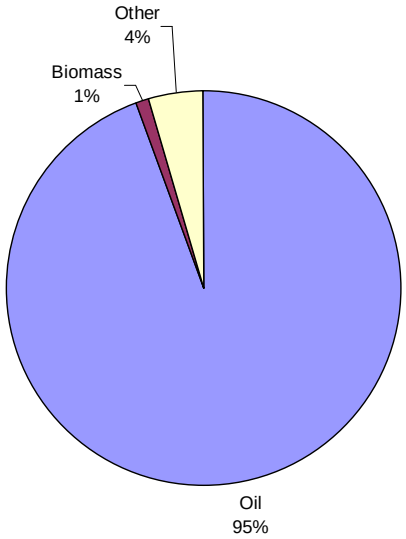
- Introduction: need for transition in mobility
- Low carbon concepts and industry vision
- Status and outlook for fuel cell electric cars
- EOS-LT project THRIVE
  - Simulating roll-out of hydrogen cars and infrastructure
  - Cost analysis refuelling infrastructure and FCEV's
  - Environmental impact
- Summary and conclusions

Drivers for transition …

- Reduce dependency on oil
- Substantial GHG emission reduction needed to limit global warming



Source: European Environment Agency, 2009



World energy consumption transport sector by energy source; IEA World Energy Outlook 2008

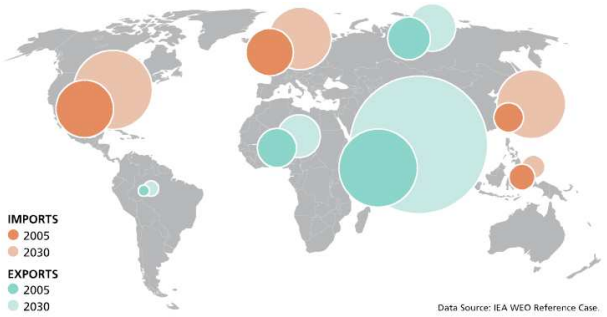
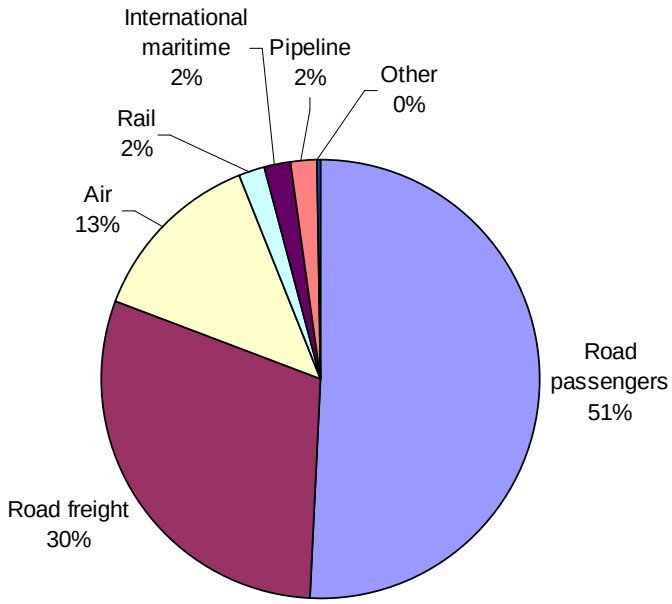


Figure ES-6. Net Regional Oil Imports and Exports

Options for improvement

- Reduce transport demand
- Improve transport efficiency
- Improve driving behaviour
- Improve vehicle efficiency
- Use low carbon fuels

Focus on innovative drivetrains



World energy consumption transport sector by energy source; IEA World Energy Outlook 2008

Several innovative electric concepts available

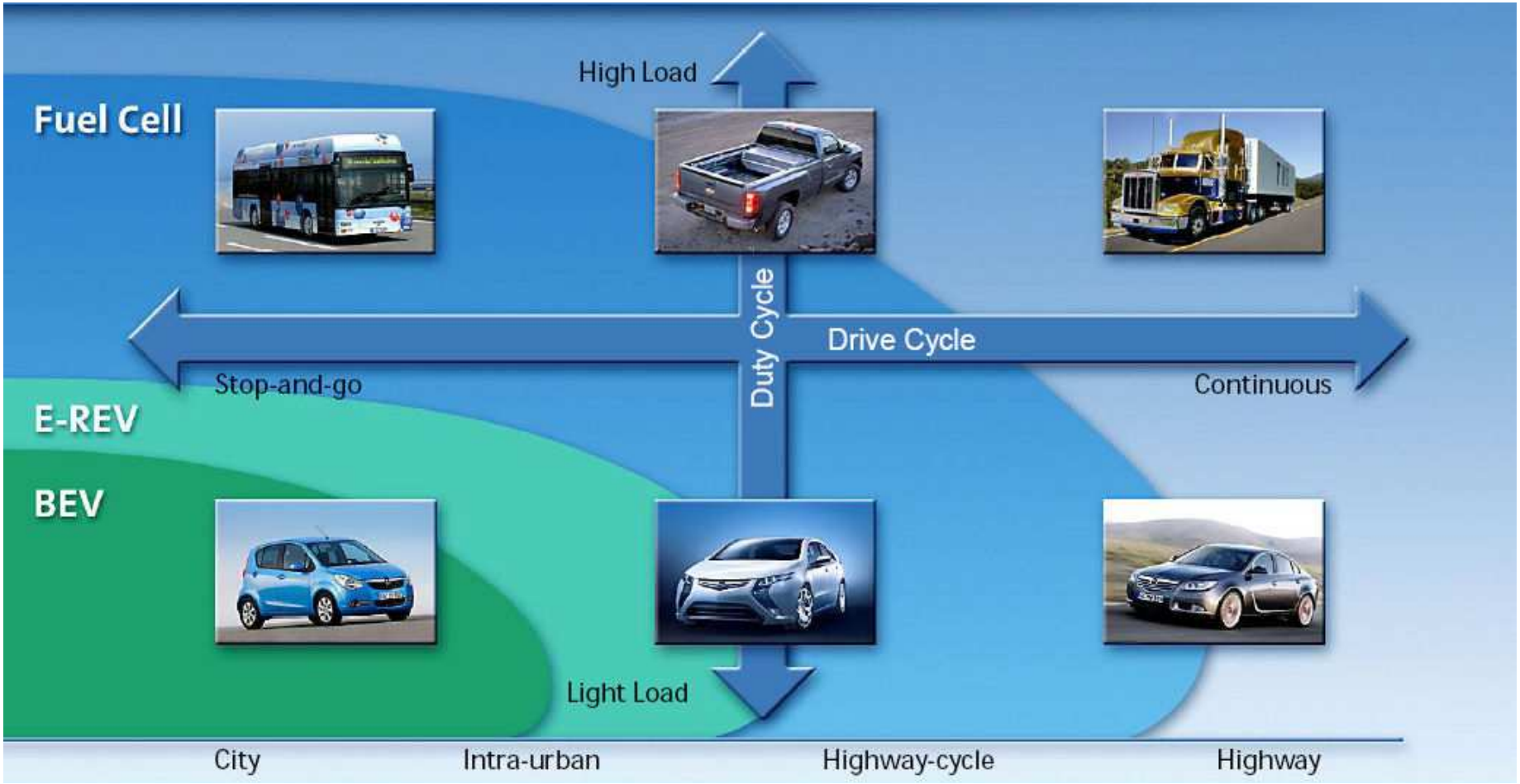
- Electric car:
  - Car driven by an electric motor only
  - Supply of electricity is the challenge, not the electric motor

PHEV:
Plug-in Hybrid
Electric Vehicle

BEV:
Battery Electric Vehicle

FCEV:
Fuel Cell Electric Vehicle

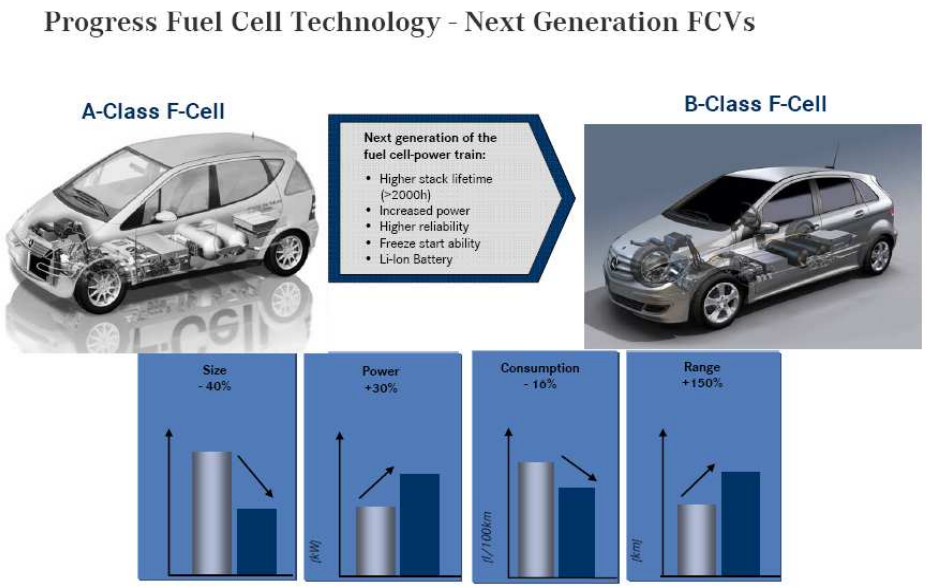
Industry vision



Bron: General Motors Europe, Thiesen

FCEV major accomplishments

- Many millions miles of testing
- First cars reaching 150,000 km without major problems
- Cold start at - 25 ℃ no problem anymore



4th and new 5th generation Fuel Cell system of GM

FCEV major accomplishments and outlook

Average fuel consumption during real world test 3.4 $l_{g.e.}$/100 km

- ‘Toyota’s first fuel-cell vehicle to be priced ‘shockingly’ low’ (16 July 2009)
- Toyota aims for $50,000 production hydrogen sedan (7 May 2010)
- Hyundai-Kia “confident we can beat” Toyota’s $50,000 price on fuel cell cars (6 June 2010)

Line up for market rollout?

Hydrogen and FCEV require coordinated action

- Commercialisation of FCVs – LoI on Market implementation of FCVs

- Anticipated commercialization of fuel cell electric vehicle (FCEV) from 2015 onwards
- Fuel Cell vehicles at a few hundred thousand units over life cycle on a worldwide basis

DAIMLER, Ford, GM, OPEL, HONDA, HYUNDAI, KIA MOTORS, NISSAN, RENAULT, TOYOTA

Project partners:
Daimler, Ford, GM/Opel, Honda, Hyundai/Kia, the Alliance Renault/Nissan, Toyota

- Build up of Infrastructure - MoU on "H2 Mobility Project"

- Leading industrial stakeholders plan the concerted roll-out of refuelling infrastructure , in order to meet the expected commercialisation of FCV´s from 2015 onwards

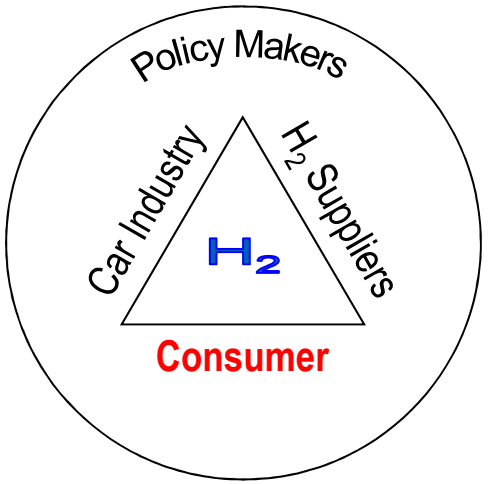
DAIMLER, THE LINDE GROUP, NOW, EnBW, OMV, L'Air Liquide, Air Products, TOTAL, VATTENFALL

Founding members:
Daimler, Linde, Total, Shell, Vattenfall, EnBW, OMV, NoW (Moderator)

THRIVE: Study of hydrogen roll-out scenarios

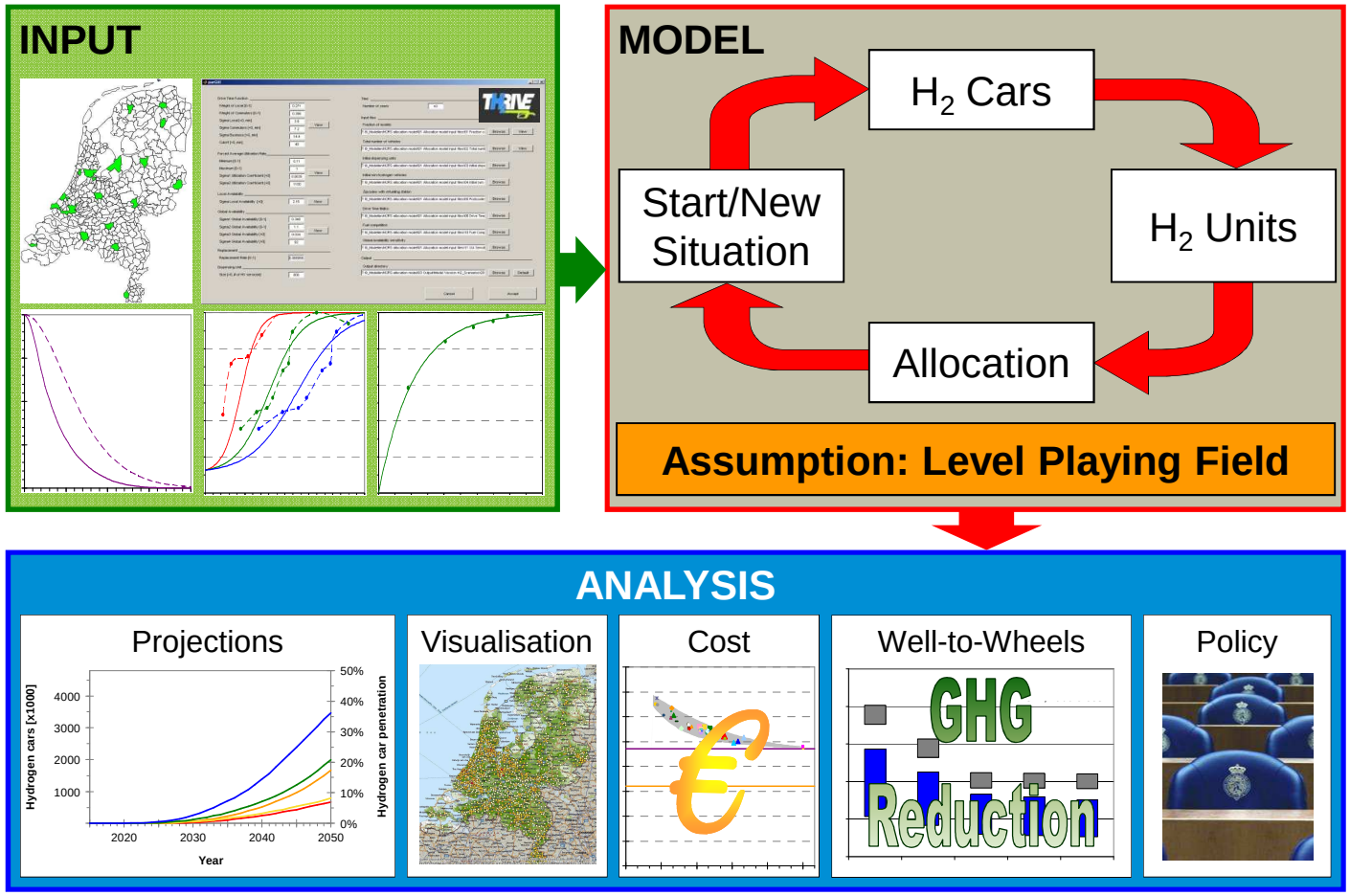
Towards a **H**ydrogen **R**efuelling **I**nfrastructure for **VE**hicles

- Dynamic simulation consumer-driven, interdependent roll-out of a FCEV fleet and corresponding hydrogen refuelling infrastructure
- Cost analysis
- Analysis impact on GHG emissions



- Focus:
  - Hydrogen as fuel for passenger cars
  - Commercialisation phase
  - The Netherlands

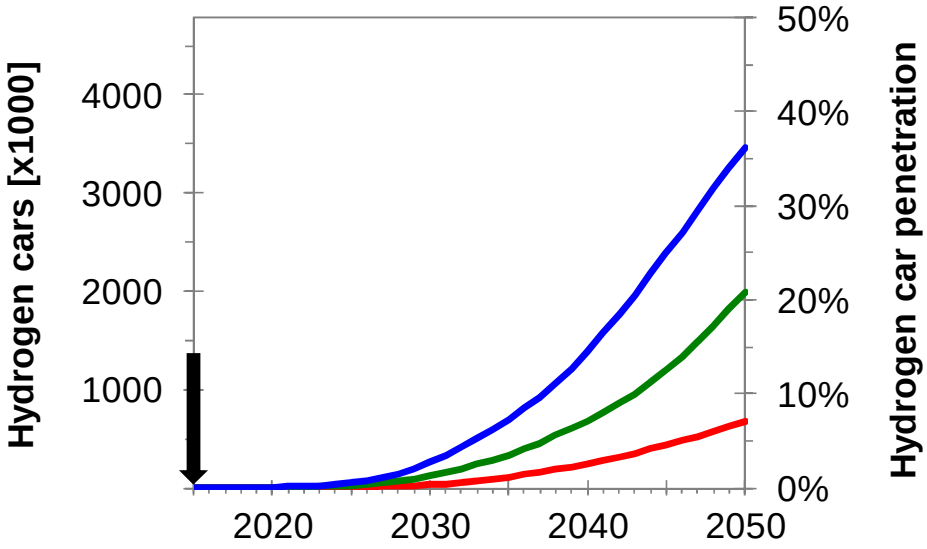
Project approach



Coherent scenarios

Policy **ambition** level	**Low**	**Medium**	**High**
Fuel supplier strategy	Careful	Reactive	Proactive
Car industry strategy	Careful	Reactive	Proactive
Consumer attractiveness	Low	Medium	High

High Scenario

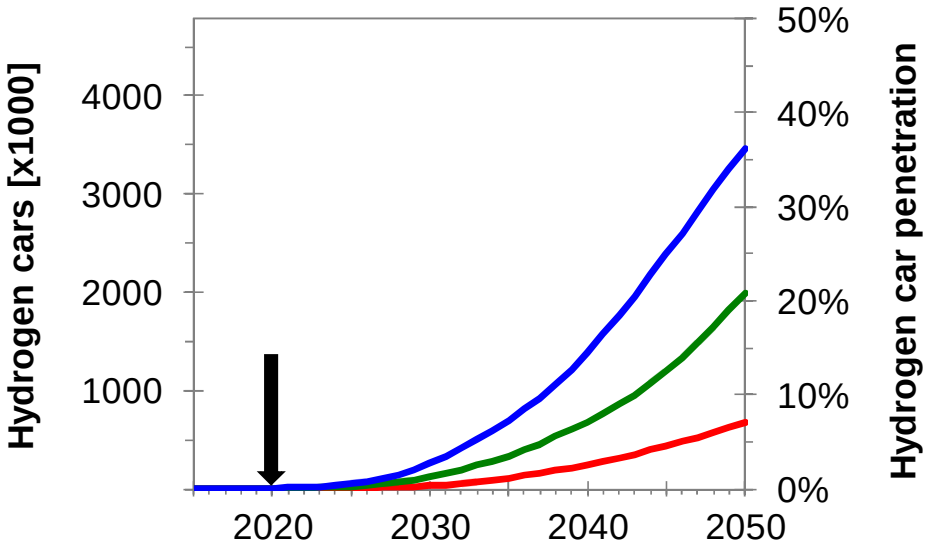


Scenario	Low	Medium	High

Increasing number of H2 refuelling units

Increasing H2 car penetration

High Scenario



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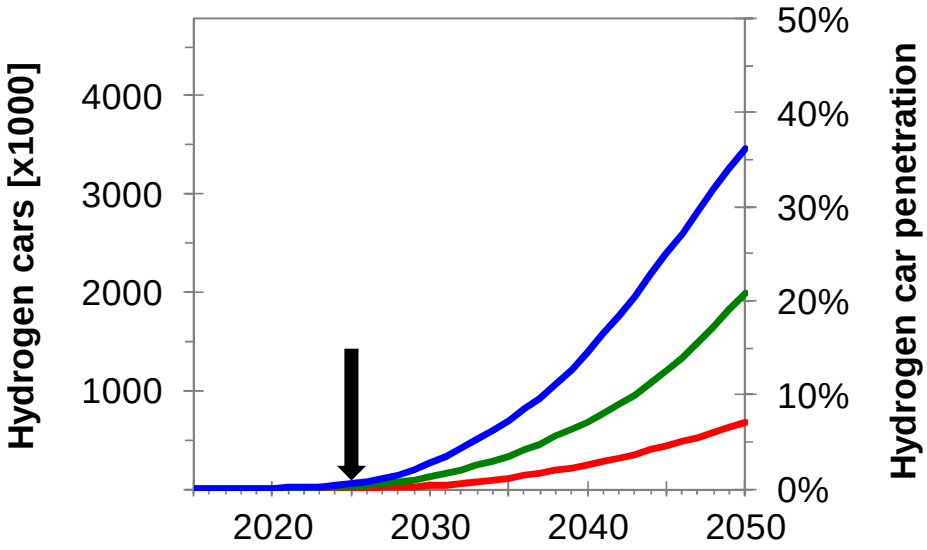

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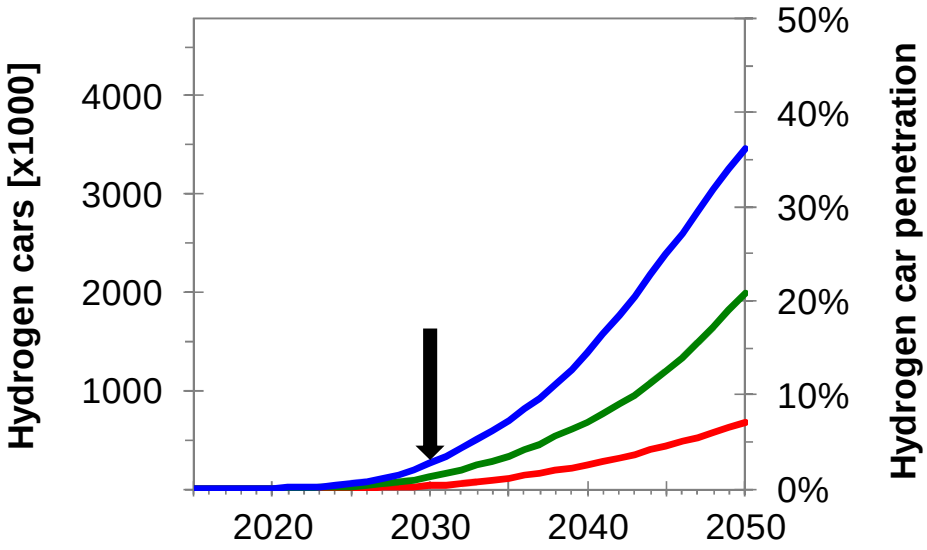

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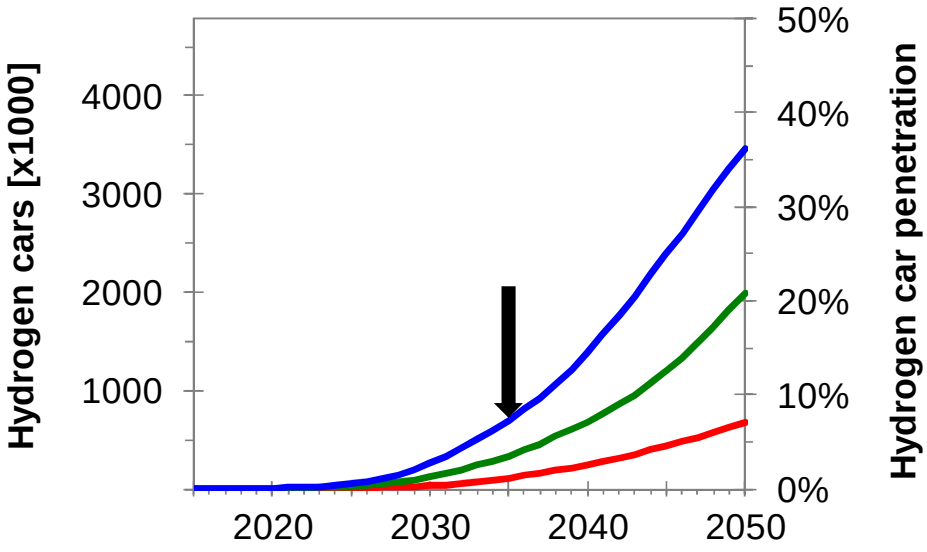

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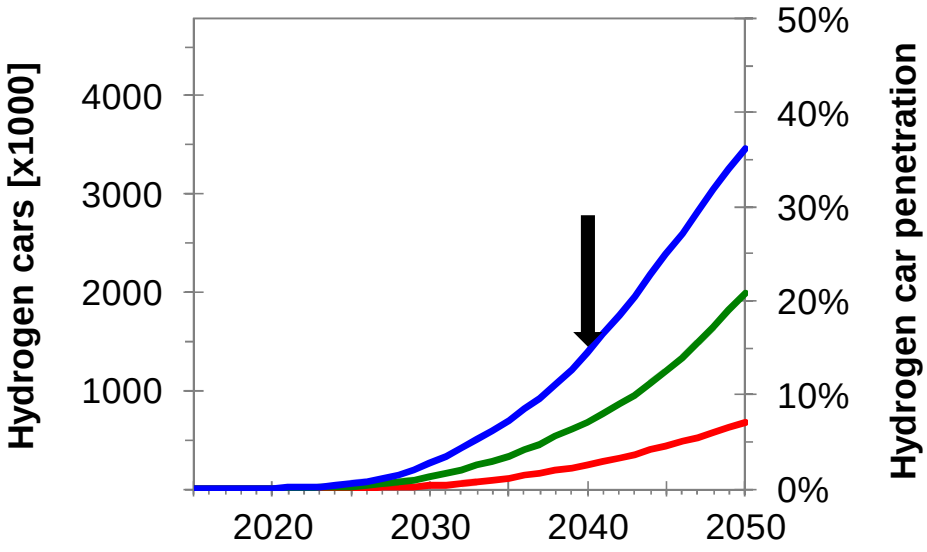

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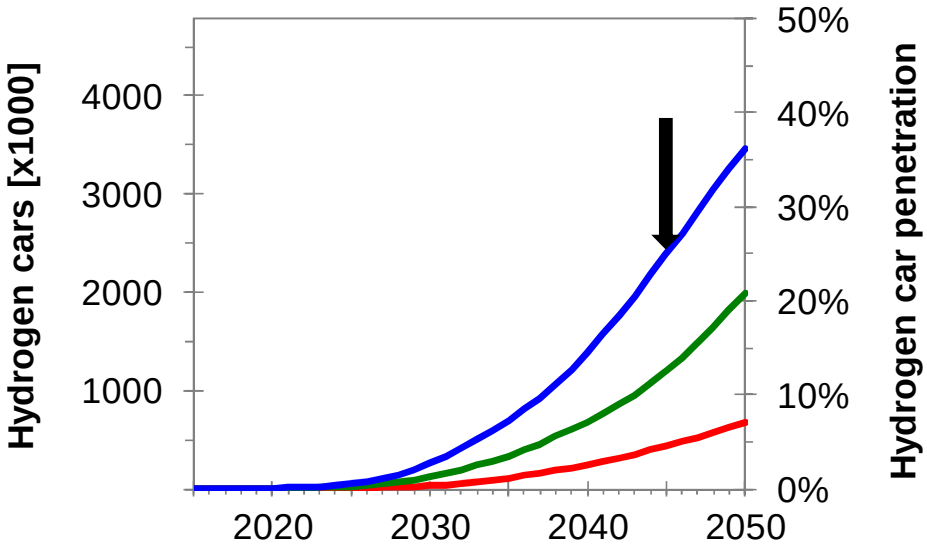

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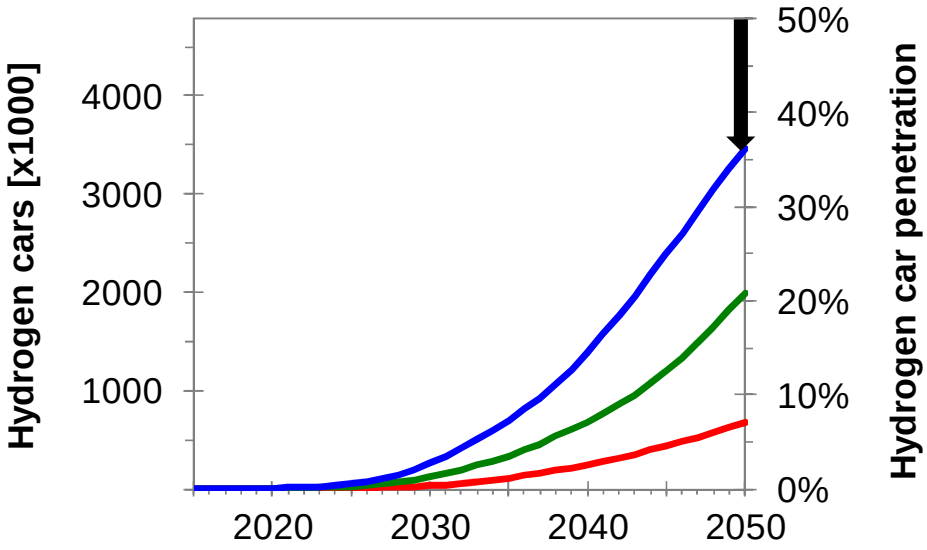

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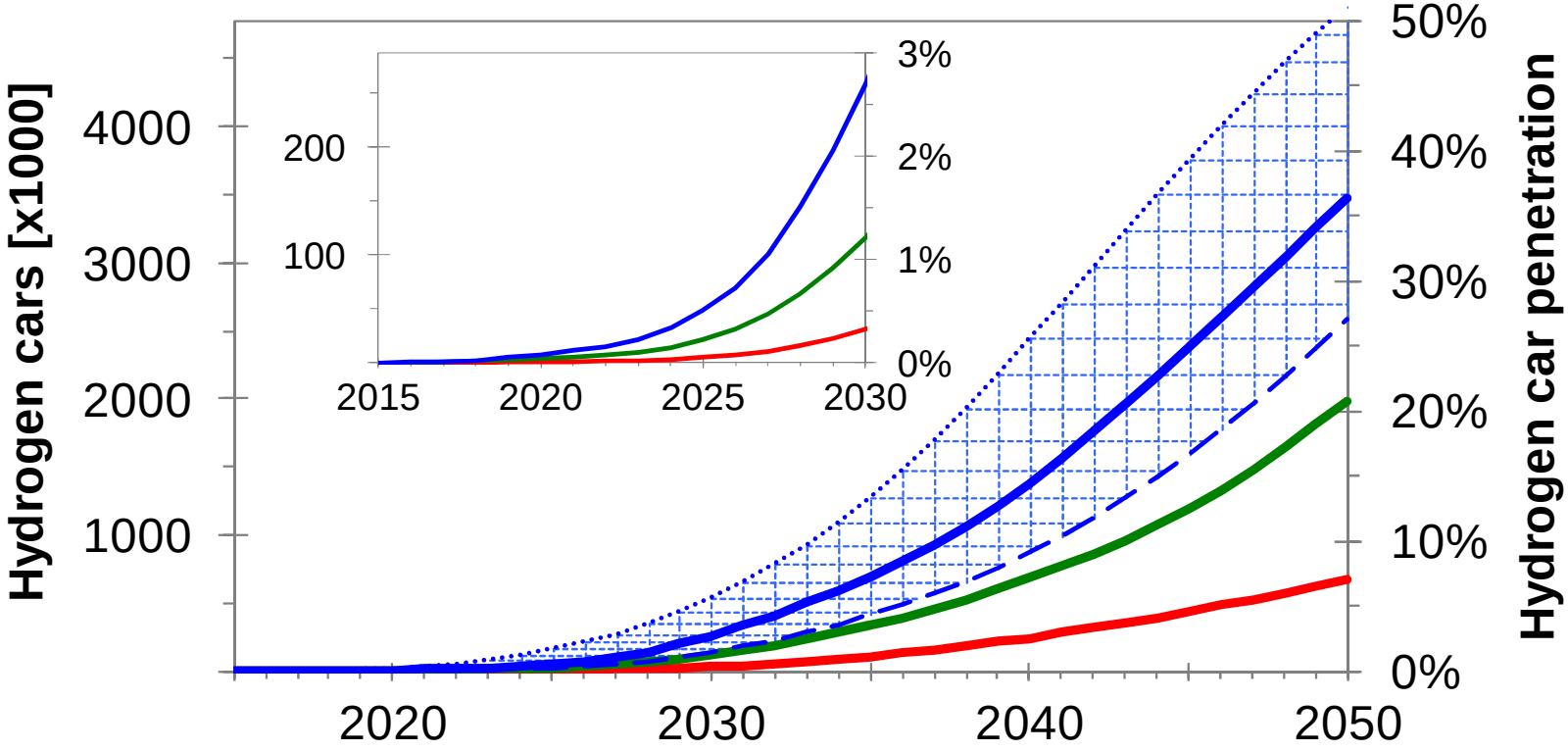
Increasing number of H2 refuelling units

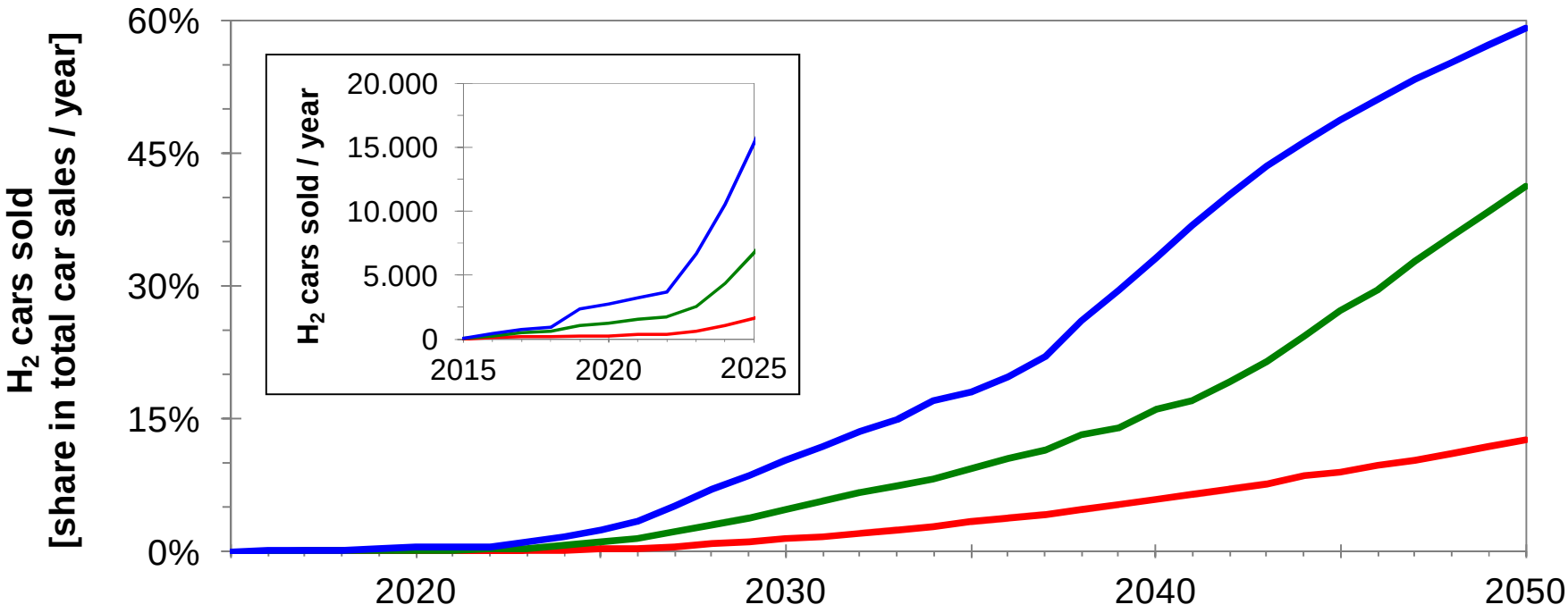
Increasing H2 car penetration

Results – car penetration per scenario



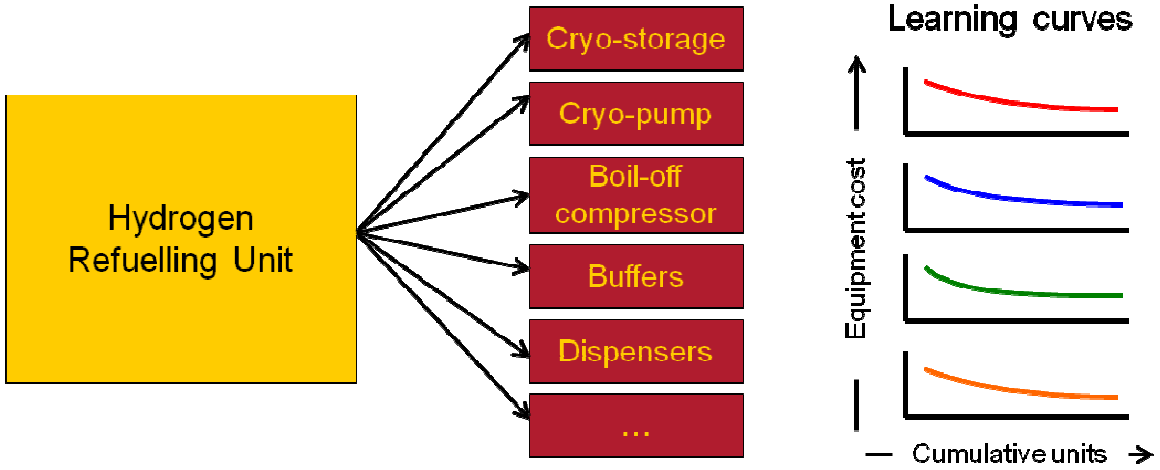
Scenario	Low	Medium	High

Results – Share of H_2 cars in total car sales



Scenario	Low	Medium	High

Considered refuelling station concept

- Integration in existing refuelling stations
  - Central production and liquefaction of hydrogen
  - Truck-delivery and cryo-storage of liquid hydrogen
  - Dispensing of gaseous hydrogen at 350 – 700 bar in <3 min
  - Pressurisation of hydrogen using cryo-pump
  - Expansion capacity with standardized modules
- 

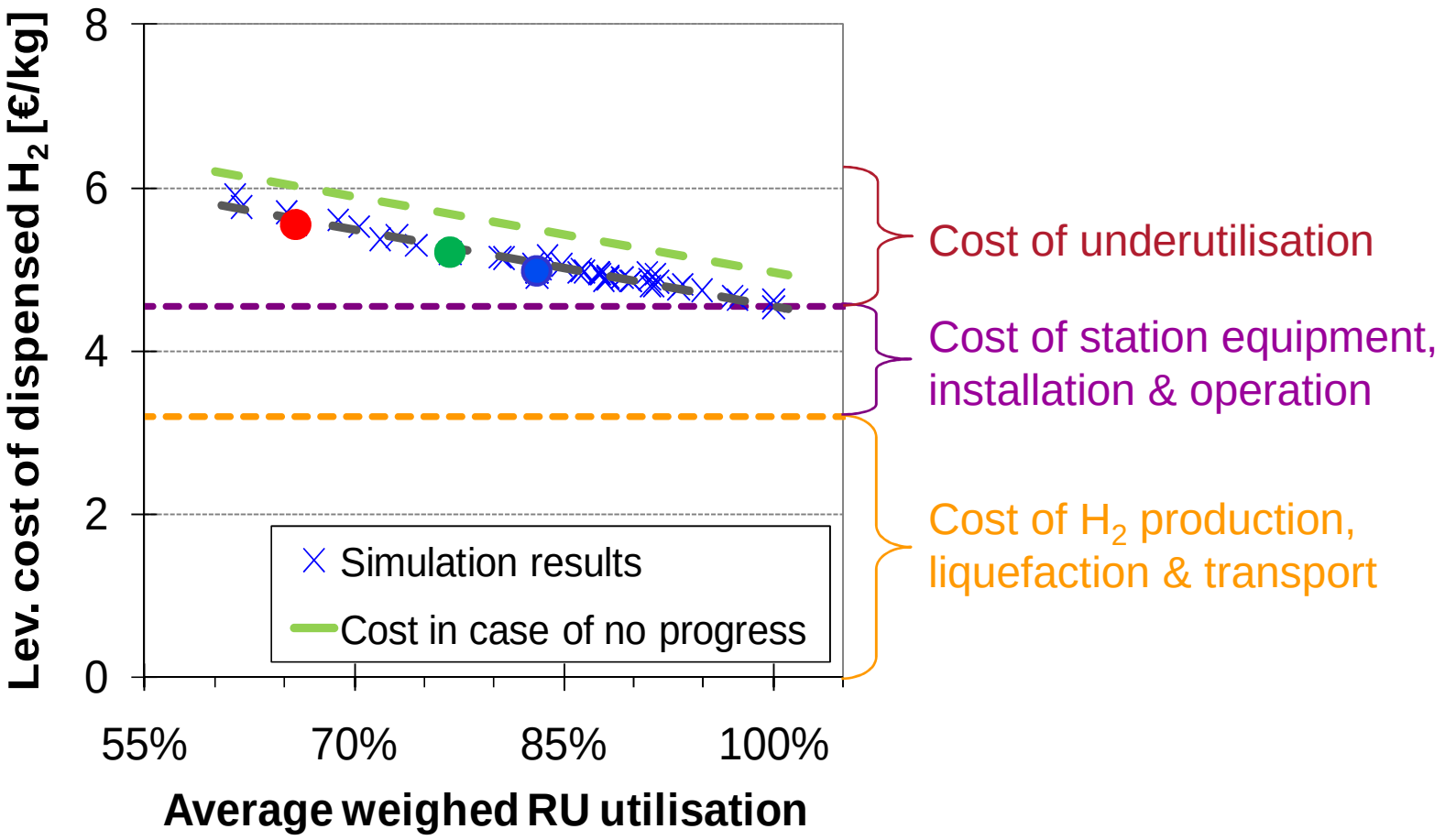
Investment Cost Analysis

- Discounted Cash Flow (DCF) analysis
- Levelised cost of dispensed H_2 (in $€_{2010}$)
  - Cost for which project NPV = 0 after economic lifetime
  - Minimum price (excl. VAT) to be charged at the pump
  - 2 perspectives:
    - <u>Whole infrastructure perspective (one big project):</u>

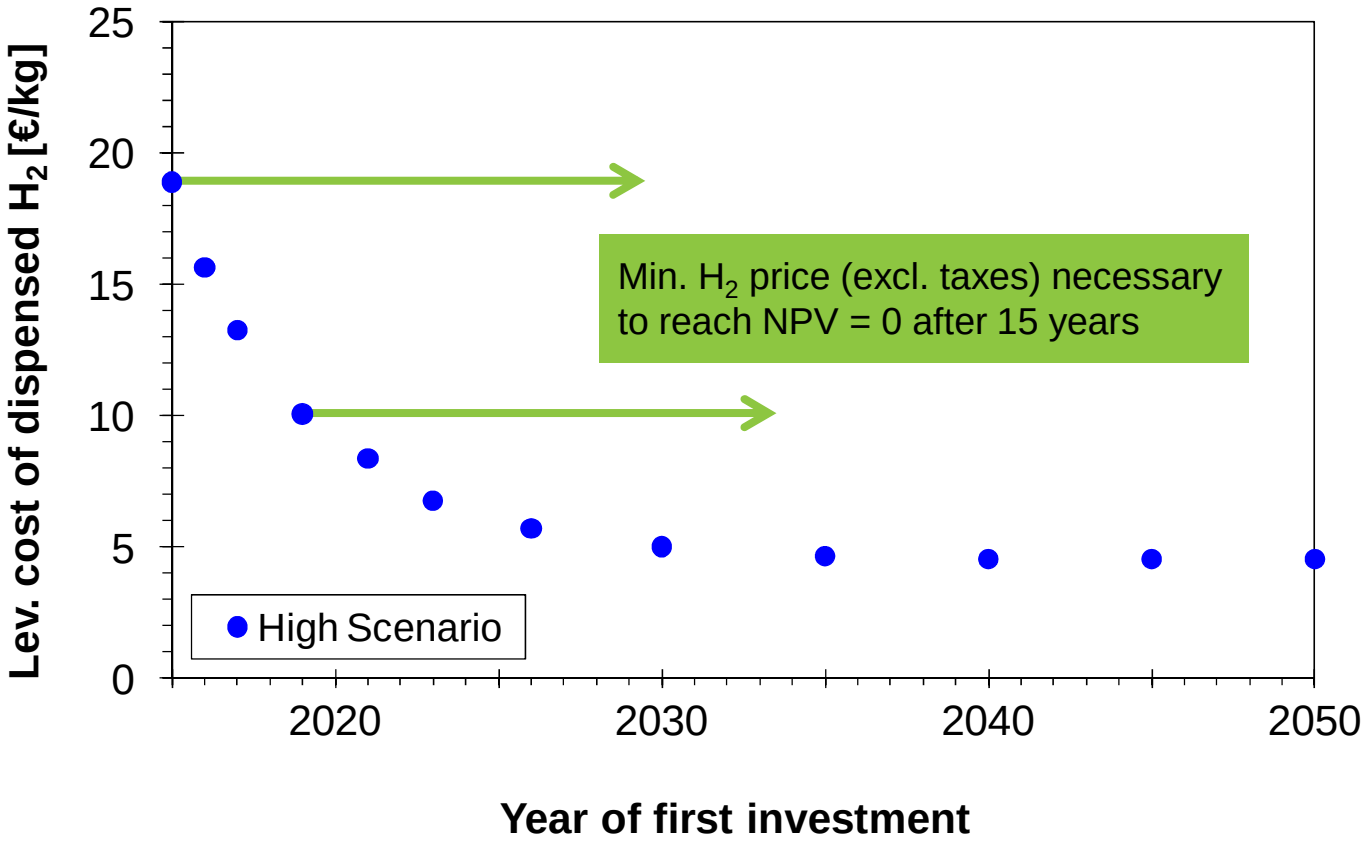
      Cumulative Net Present Value = 0 for investments until 2050
    - <u>Single investor perspective (individual projects):</u>

      Net Present Value = 0 after economic lifetime

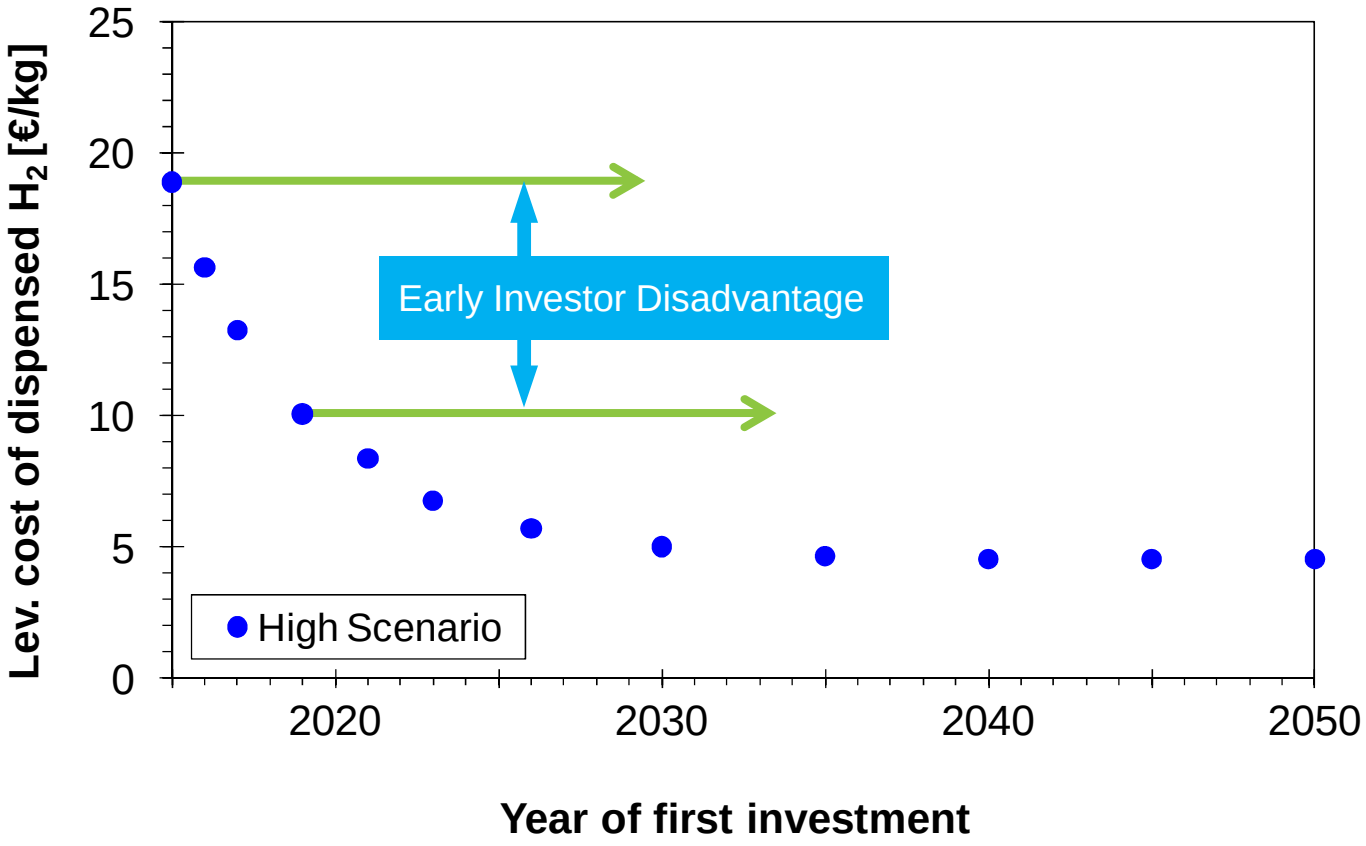
Whole Infrastructure Perspective



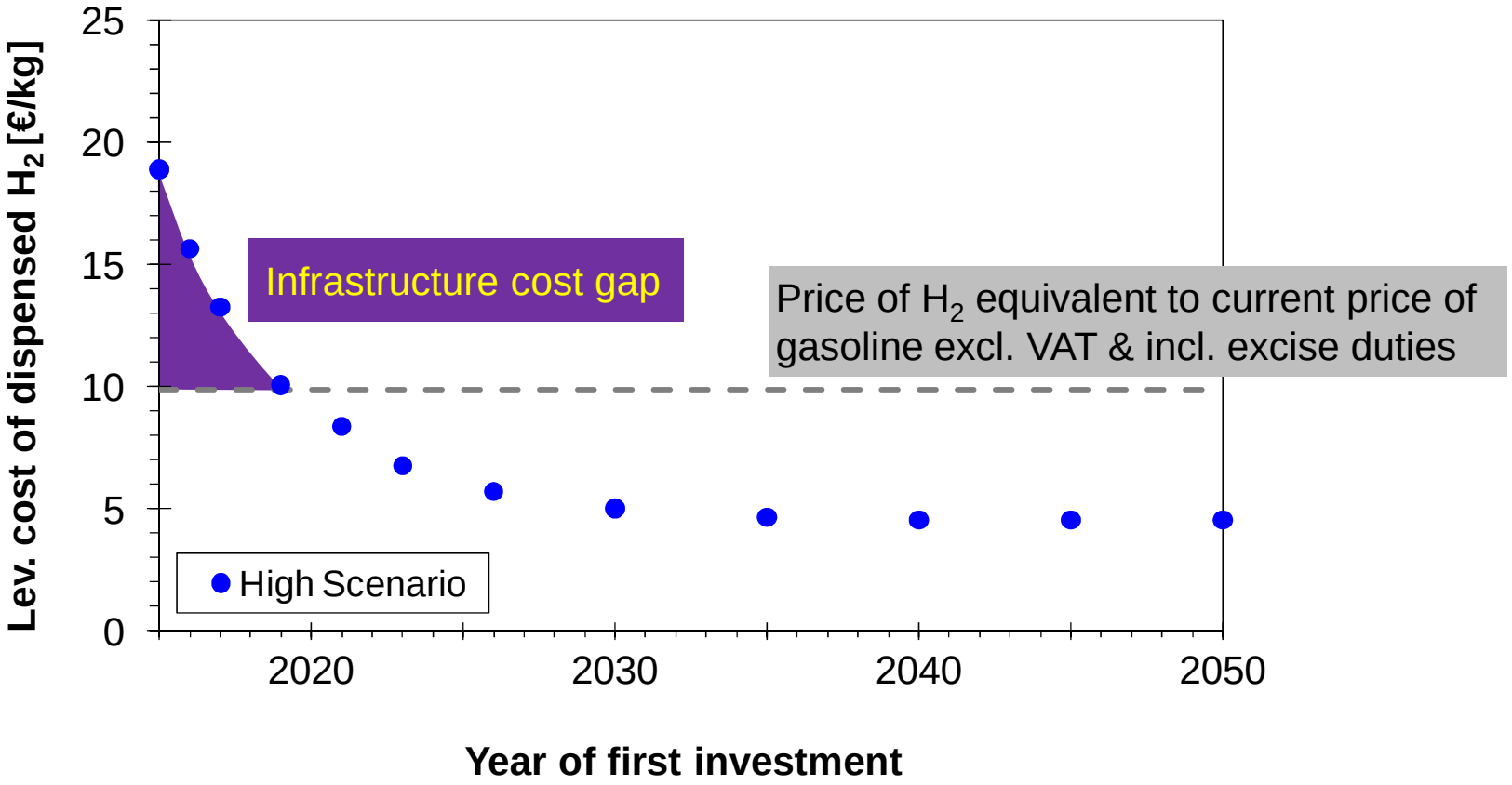
Single Investor Perspective



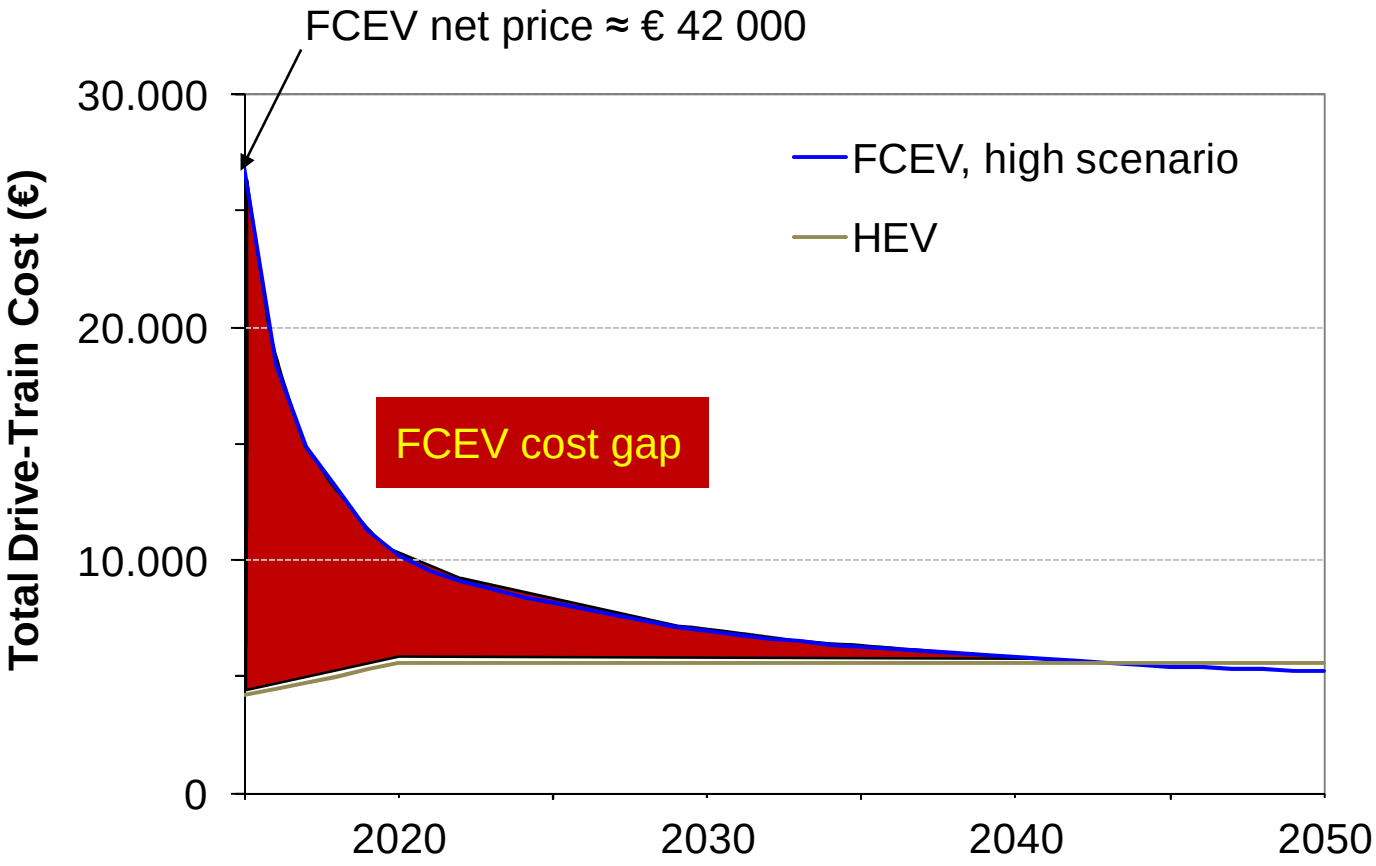
Early Investor Disadvantage



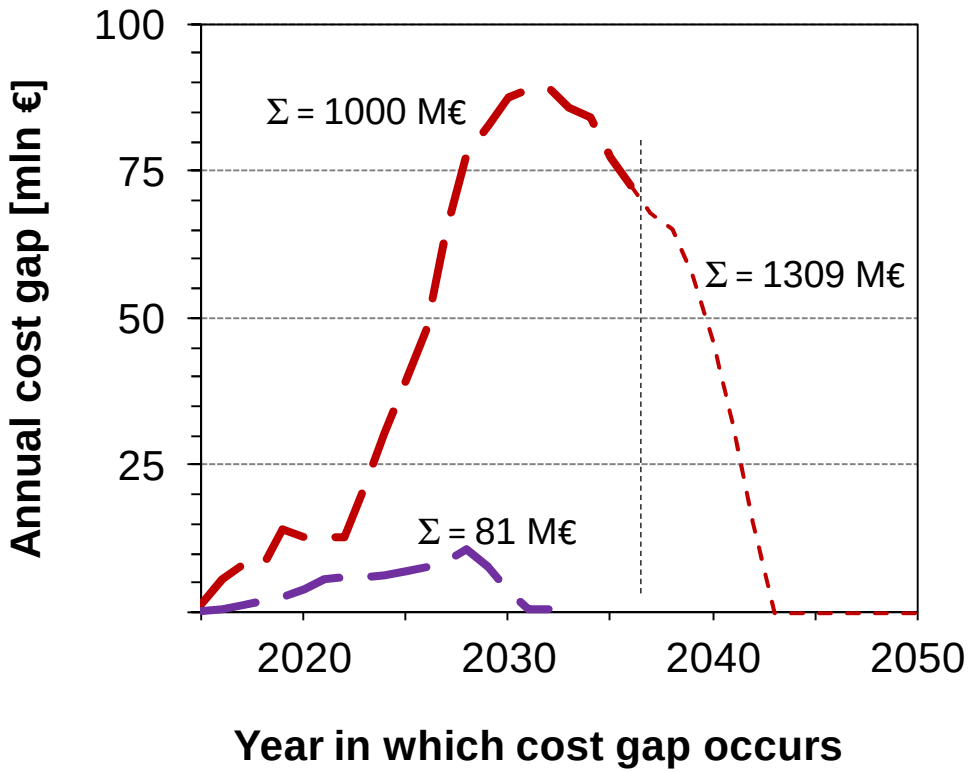
Definition “Infrastructure Cost Gap”



Definition “FCEV Cost Gap”



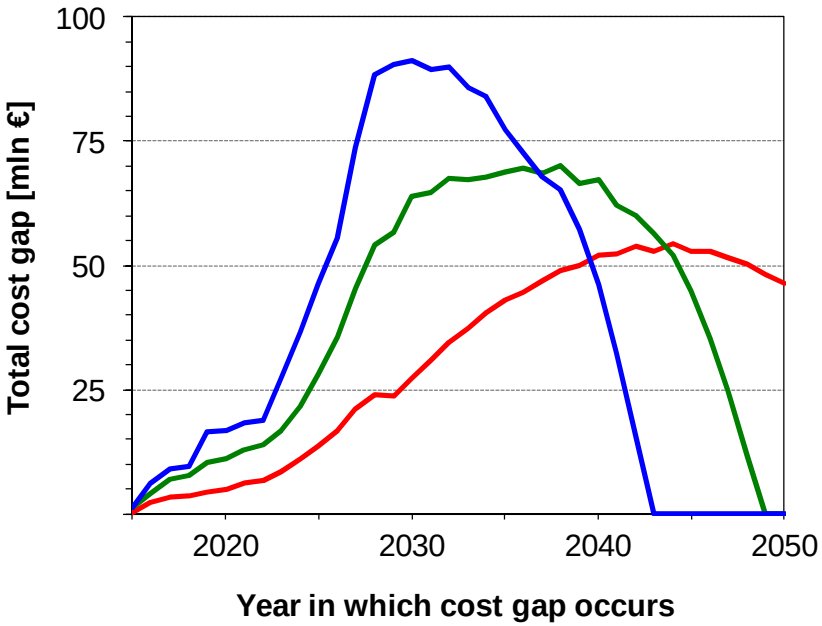
Cost Gap Analysis
– High Scenario –

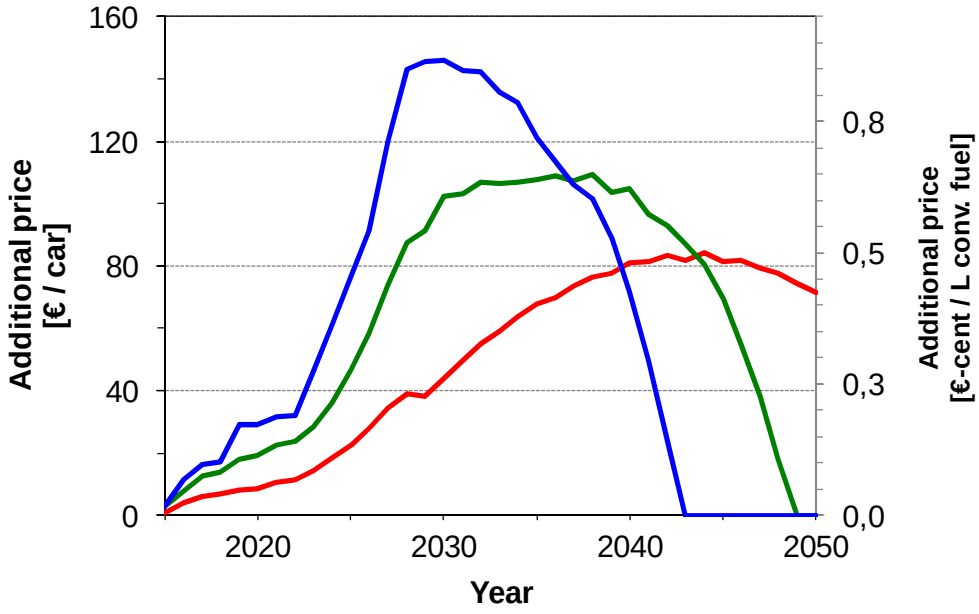


Acceptable extra cost [€]	Cum. gap [M€]	Extra cost till [yr]
0	1309	2042
500	636	2036
1000	266	2031
2000	76	2026

FCEV cost gap
difference to HEV < 10%
Infrastructure cost gap

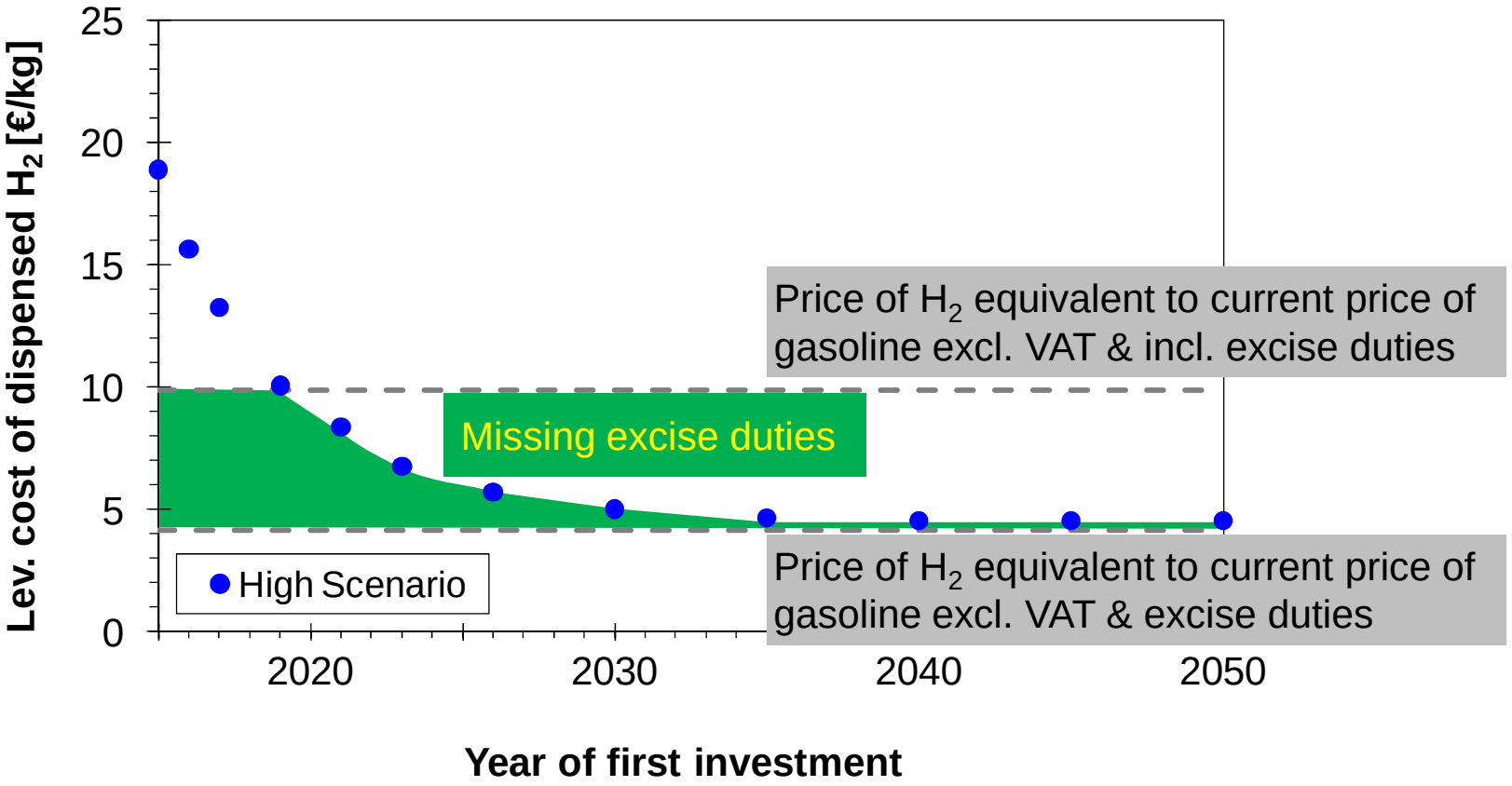
Cost Gap Analysis
– Comparison of Scenarios –



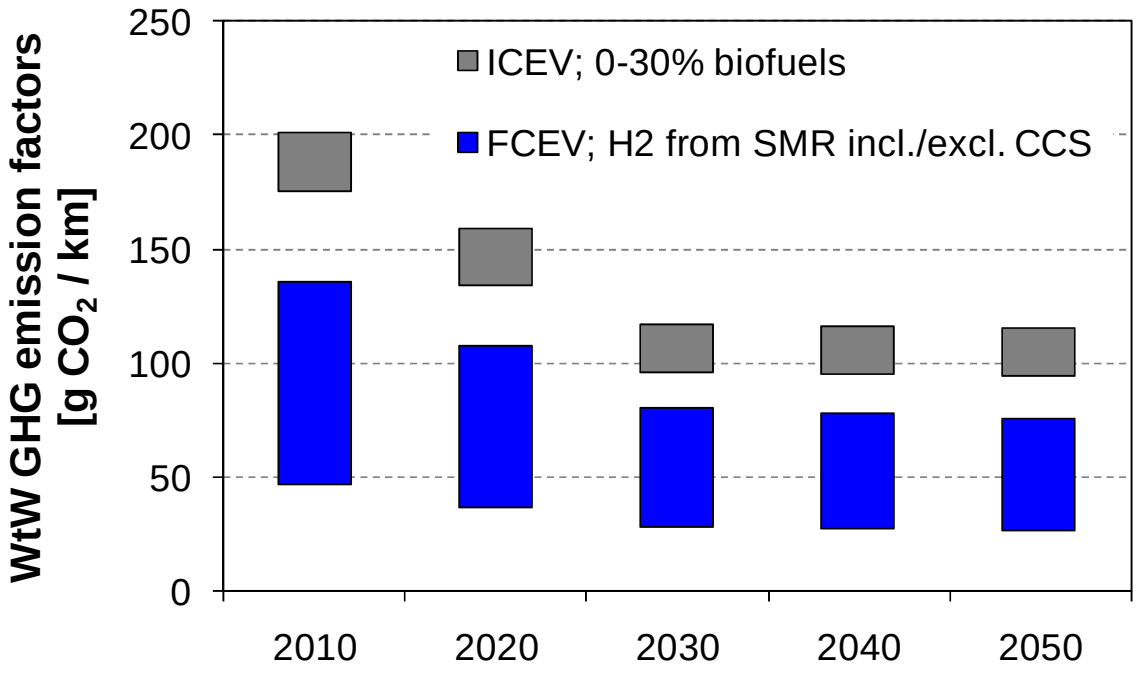


Scenario	Low	Medium	High

Cost Gap Analysis – Missing Excise Duties

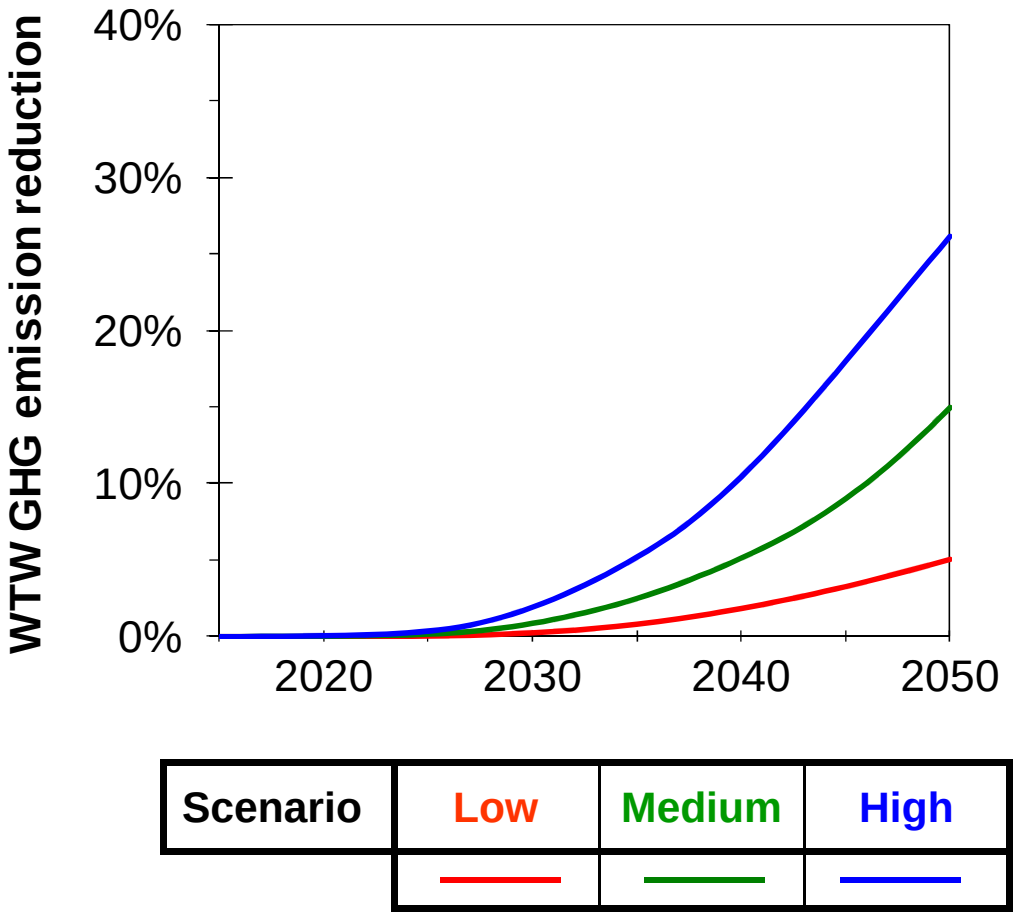


WTW GHG Emission Factors



- ICEV-fleet's energy consumption: 40% gasoline, 60% diesel
- Bandwidth dependent on % biofuels (ICEV) and CCS (H_2)
- FCEV offer 30% to 70% lower WTW GHG emission factors

Environmental impact of FCEV (Example)



- Diesel and gasoline are replaced by 30% with biofuels (ICE)
- H_2 is produced from natural gas via SMR including CCS

Conclusions

- THRIVE scenarios indicate that by 2050, up to 35% of all cars in the Netherlands could run on hydrogen
- Meaningful penetration requires large upfront investments in refuelling infrastructure, initially suffering from underutilisation and thus leading to high initial cost
- First movers require stimulation to overcome first mover uncertainties and disadvantages
- THRIVE evaluated that hydrogen is doable and affordable; cost gaps that need to be bridged cumulate to about 1 - 2 billion € (excl. missed excise duty), to be bridged in 2 – 3 decades
- Good prospects for significant Well-to-Wheel GHG emission reduction, especially if proper incentives are introduced for ‘clean and green’ hydrogen

Acknowledgement

- The THRIVE consortium gratefully acknowledges the Ministry of Economic Affairs and Agentschap NL for their financial support

- Report: ECN-E--11-005
- Link: www.ecn.nl/publicaties
- Contact: weeda@ecn.nl

THANK YOU

World’s first draft beer powered by a hydrogen fuel cell at the Dutch Pavilion WHEC 2010