THE 7th WORLD HYDROGEN TECHNOLOGY CONVENTION

# Building an optimal hydrogen transportation system for mobility in France and Germany,

## Example of transportation via compressed hydrogen trucks

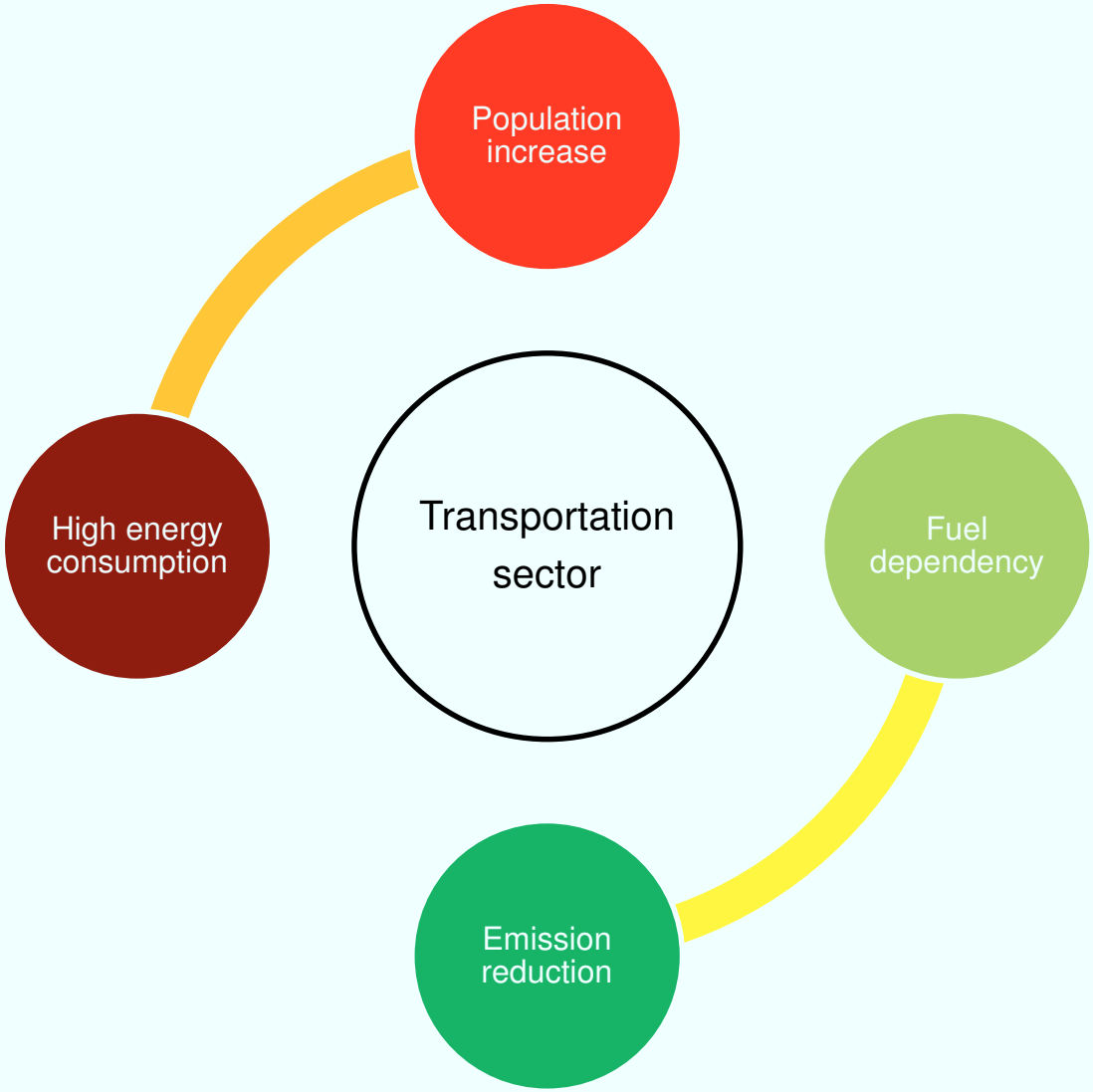
July 11th , 2017 | Amin Lahnaoui, Christina Wulf, Didier Dalmazzone

Institute of Energy and Climate Research, Systems Analysis and Technology Evaluation (IEK-STE)

# Outline

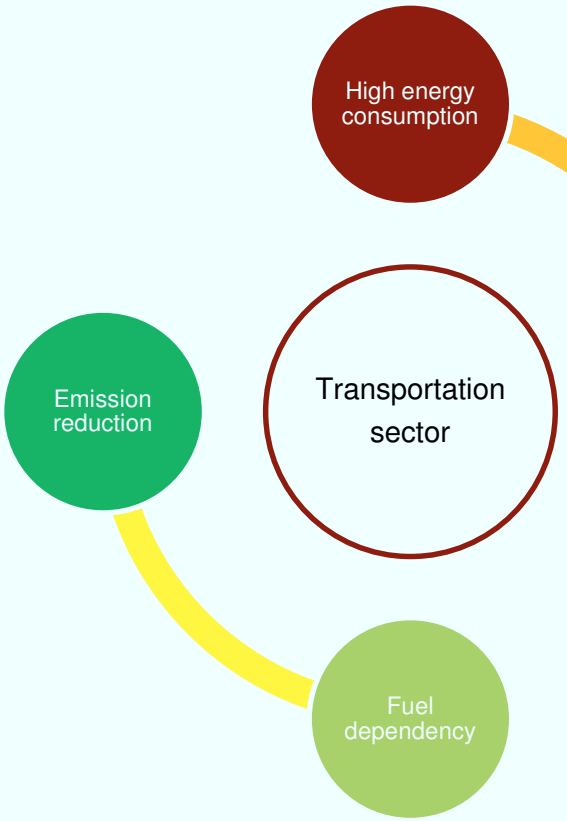
- Introduction, European context
- Hydrogen infrastructure
- Modeling framework
- Model
- Model results

# Introduction, European context



# Introduction, European context

## Population increase



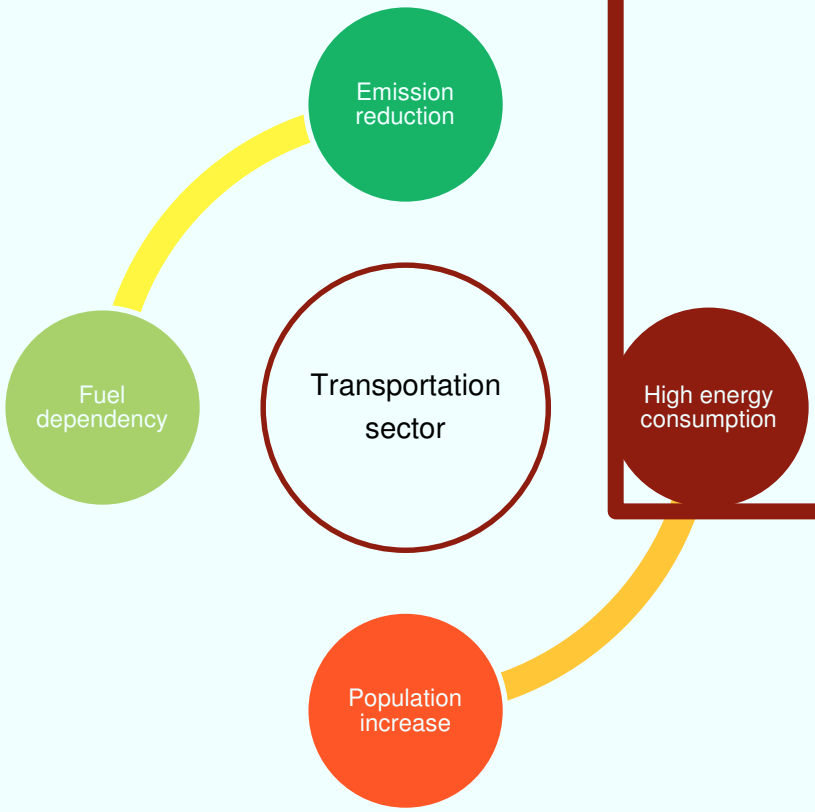

An increase of the population by 30 million in the last 25 years → increasing need of (road) transportation → 84 million new cars [1]

*[1] THOMAS, M. (2016) TRAN COMMITTEE – The world is changing, transport too*

*[EU transport in figures, EU commission 2015] and Own presentation*

# Introduction, European context

## Energy consumption



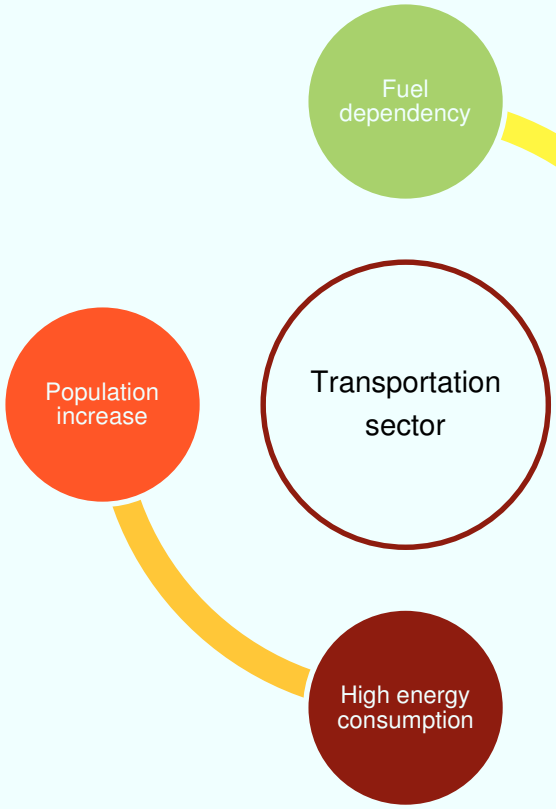

Demands 32% of the final energy consumed in 2014 [2]

*[2] COMMISSION, E. (2015) EU transport in figures*

*[EU transport in figures, EU commission 2015] and Own presentation*

# Introduction, European context

## Emission reduction



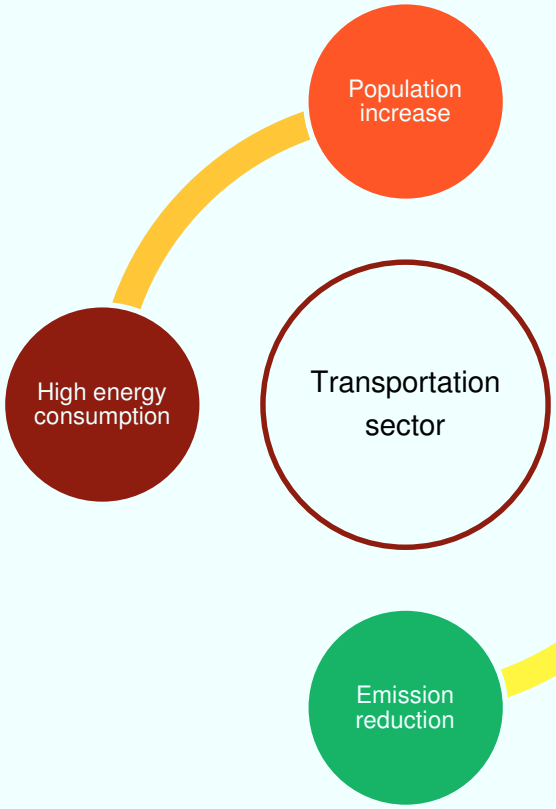

CO2 Emission increase by 22% [2] during the last 25 years

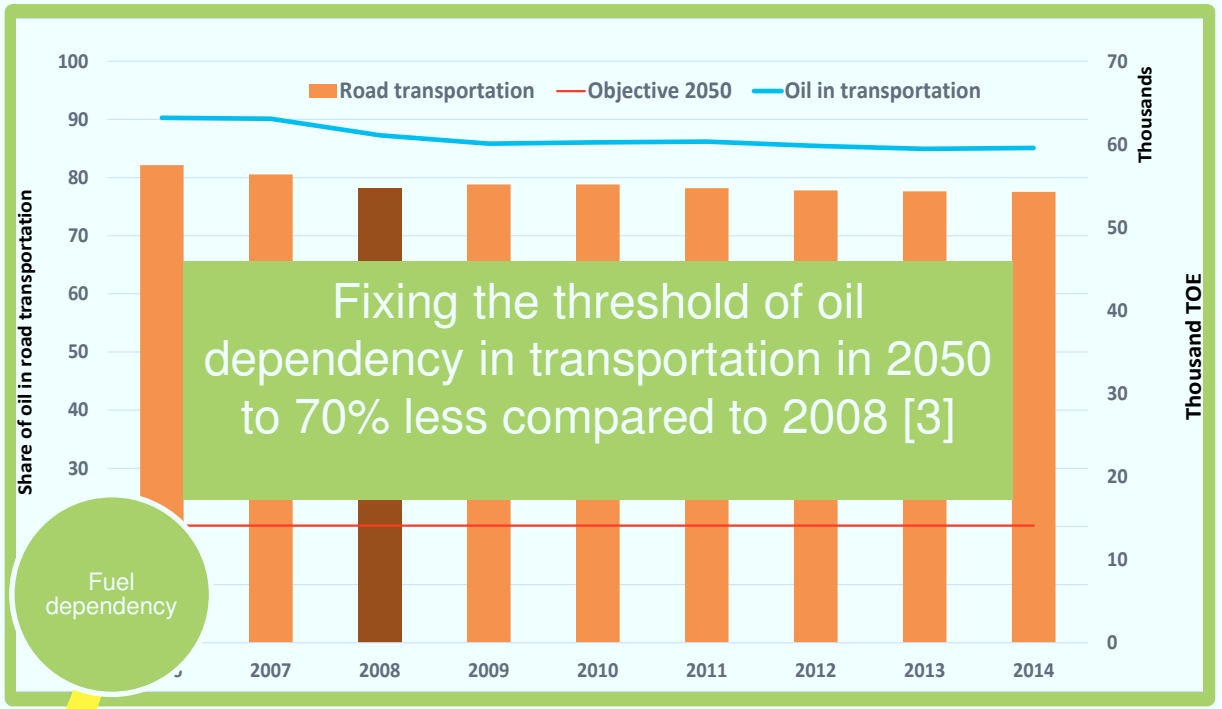
*[2] COMMISSION, E. (2015) EU transport in figures*

*[EU transport in figures, EU commission 2015] and Own presentation*

# Introduction, European context

## Fuel dependency



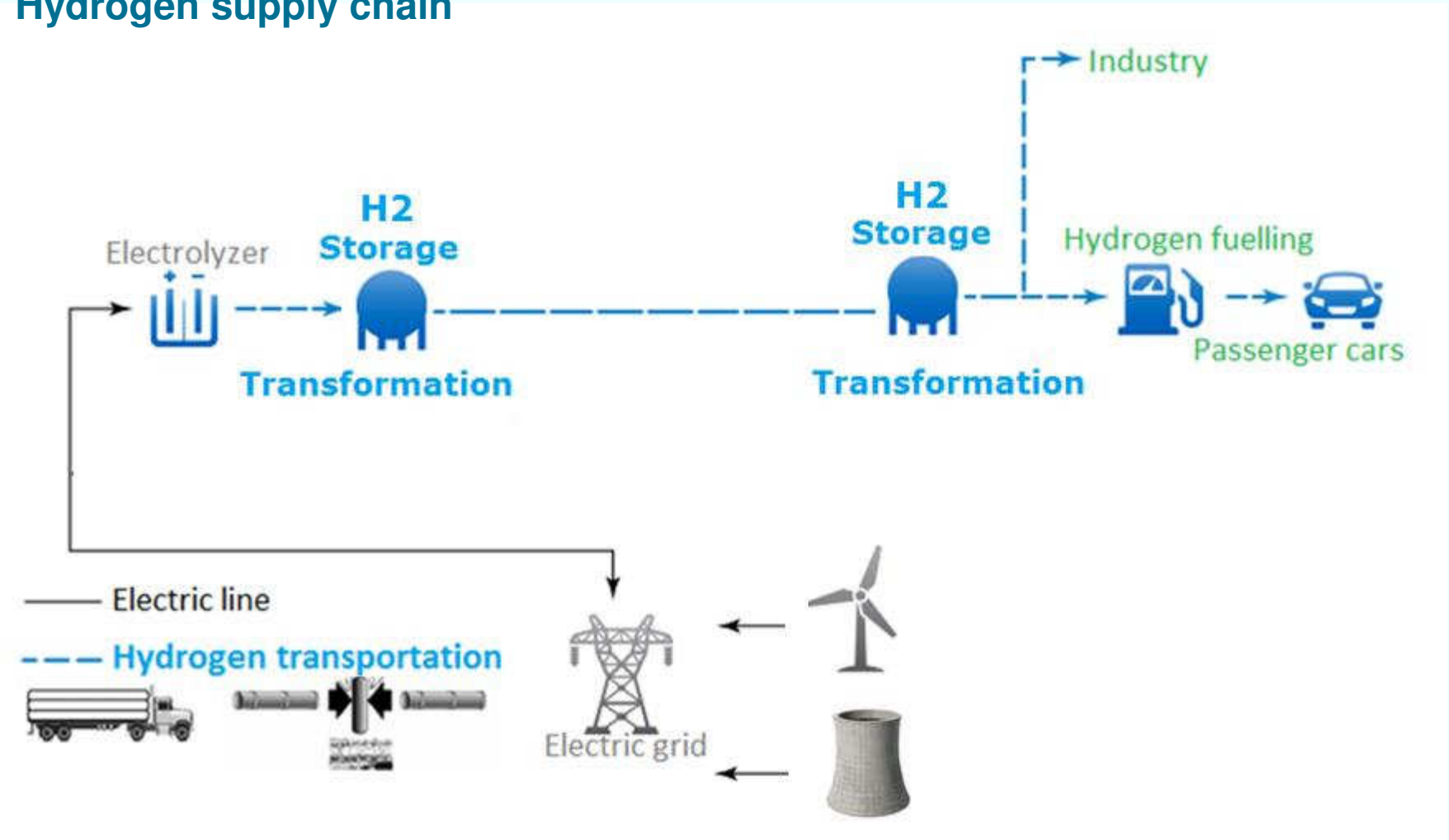




*[EU transport in figures, EU commission 2015] and Own presentation*

*[3] Union E. WHITE PAPER Roadmap to a Single European Transport Area. 2011*

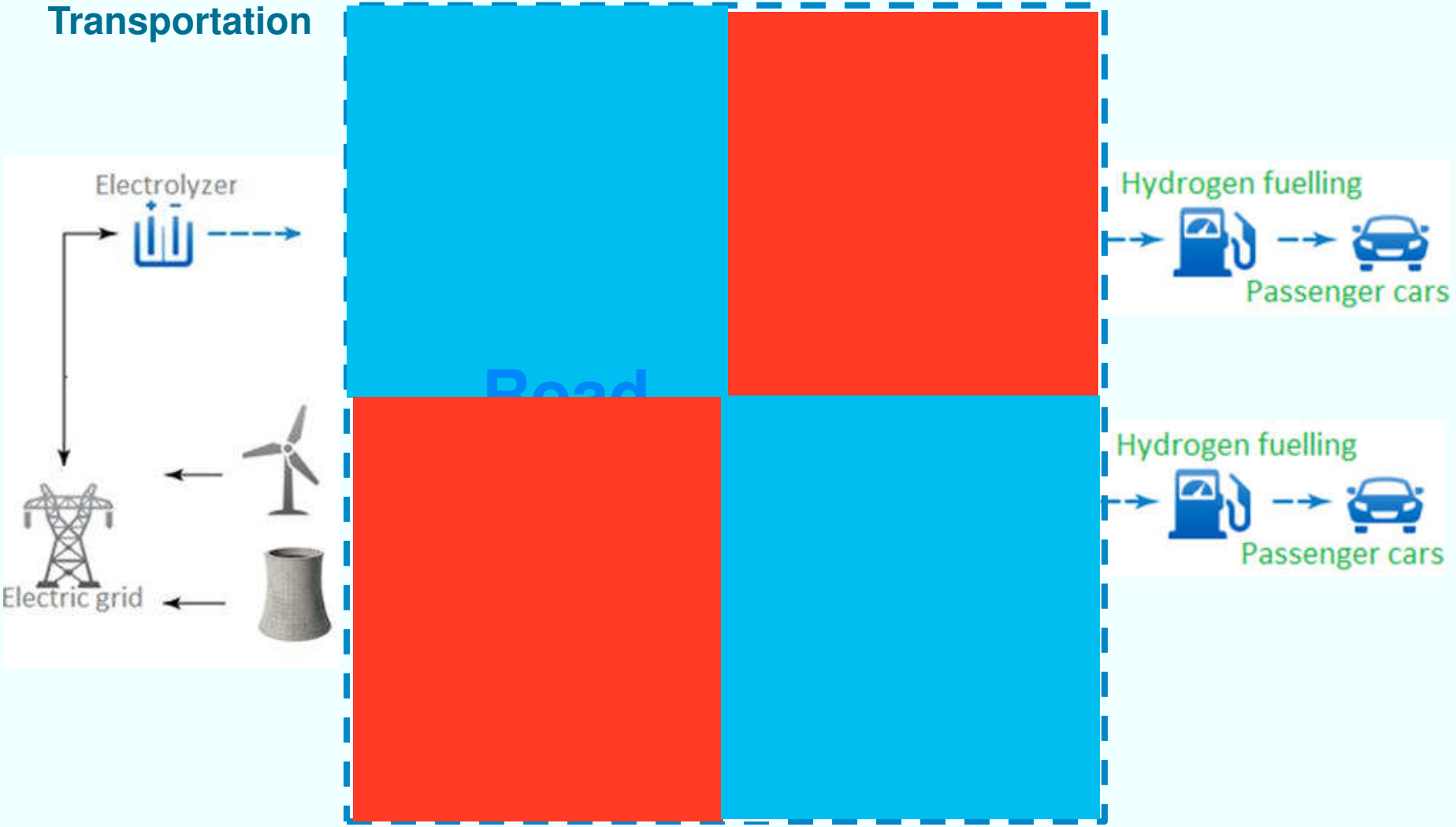
# Hydrogen infrastructure

## Hydrogen supply chain



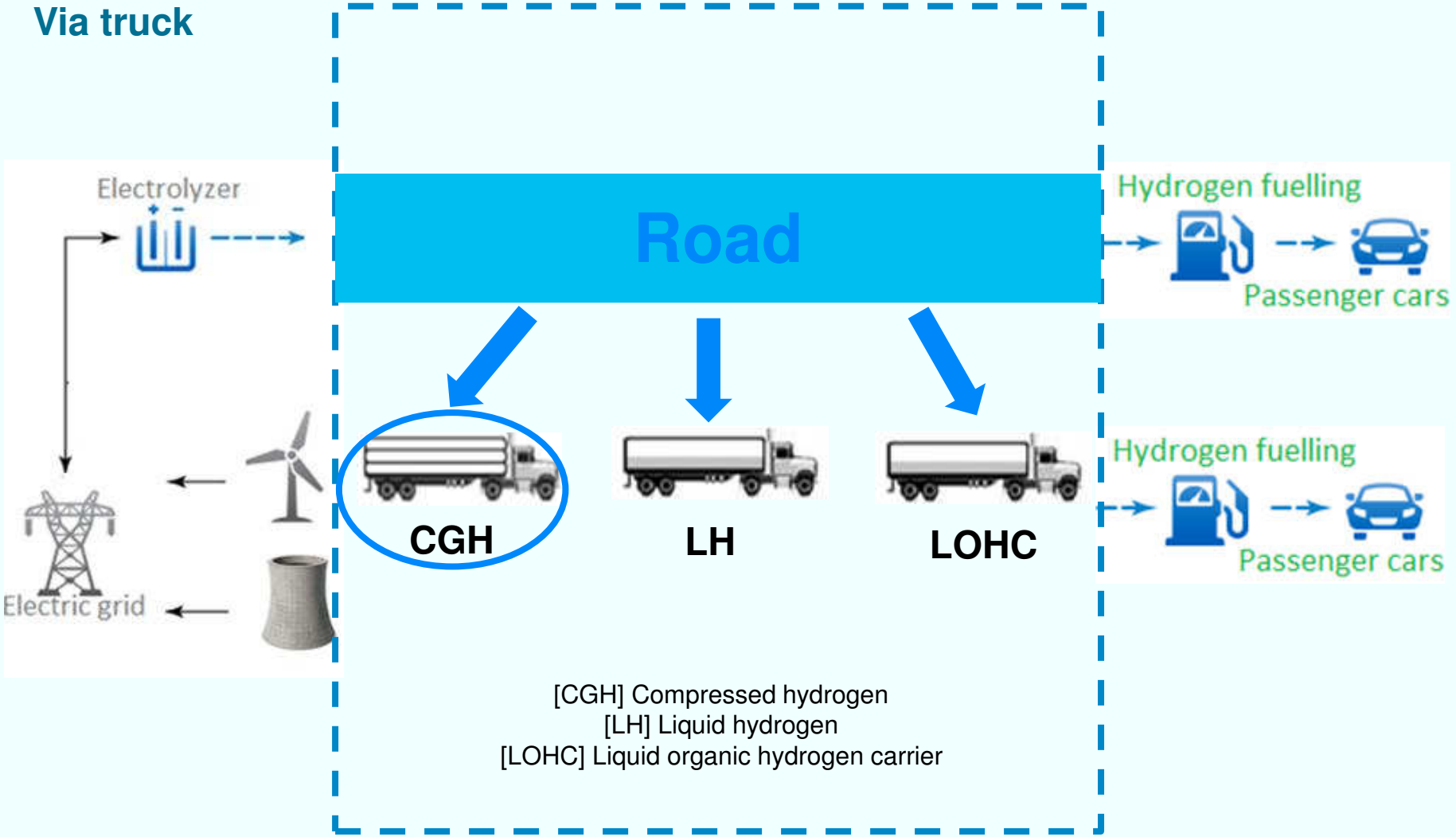
# Hydrogen infrastructure

## Transportation



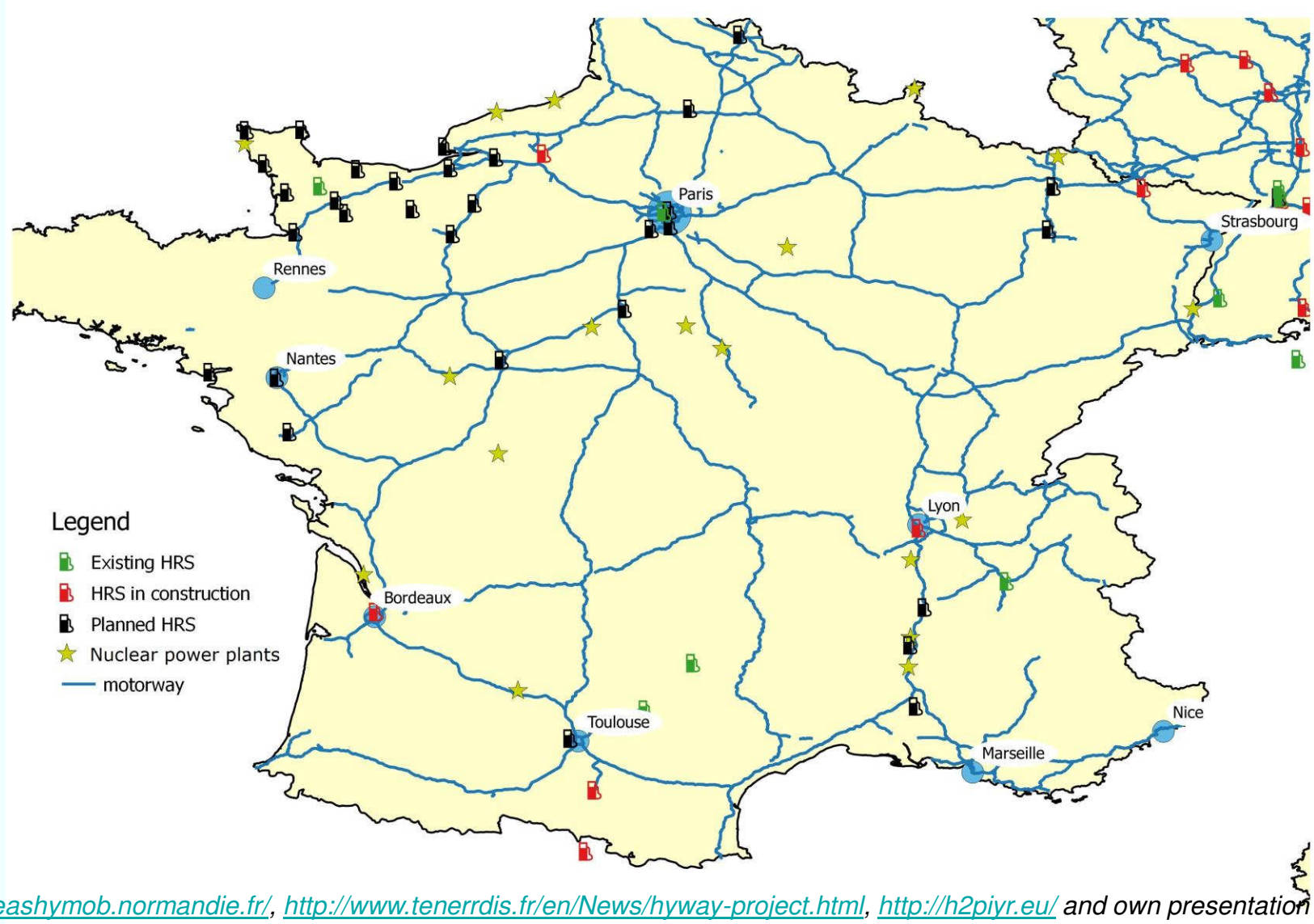
# Hydrogen infrastructure

## Via truck




[CGH] Compressed hydrogen
[LH] Liquid hydrogen
[LOHC] Liquid organic hydrogen carrier

# Modeling framework, France

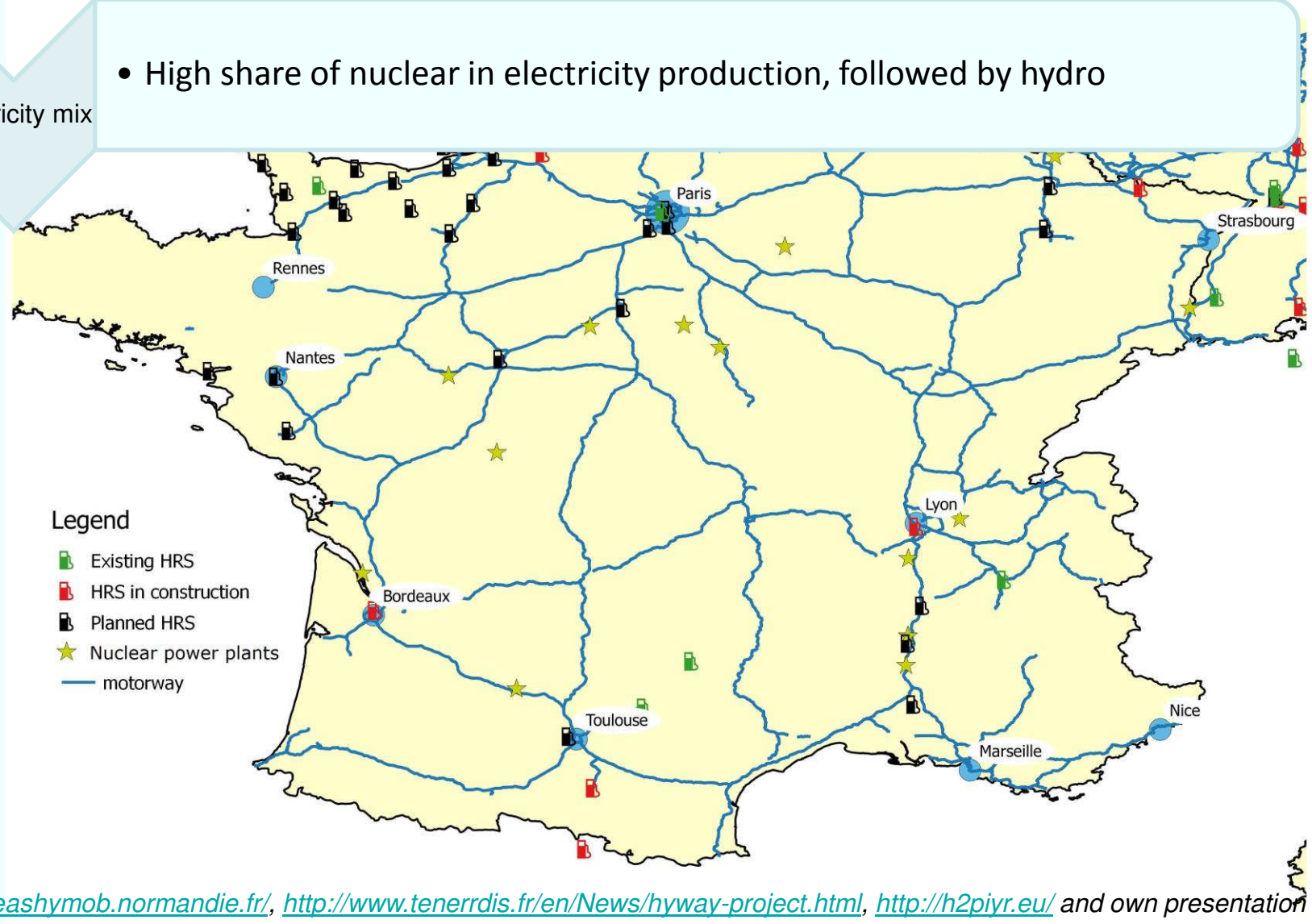



http://eashymob.normandie.fr/, http://www.tenerrdis.fr/en/News/hyway-project.html, http://h2piyr.eu/ *and own presentation*

# Modeling framework, France

Electricity mix

- High share of nuclear in electricity production, followed by hydro

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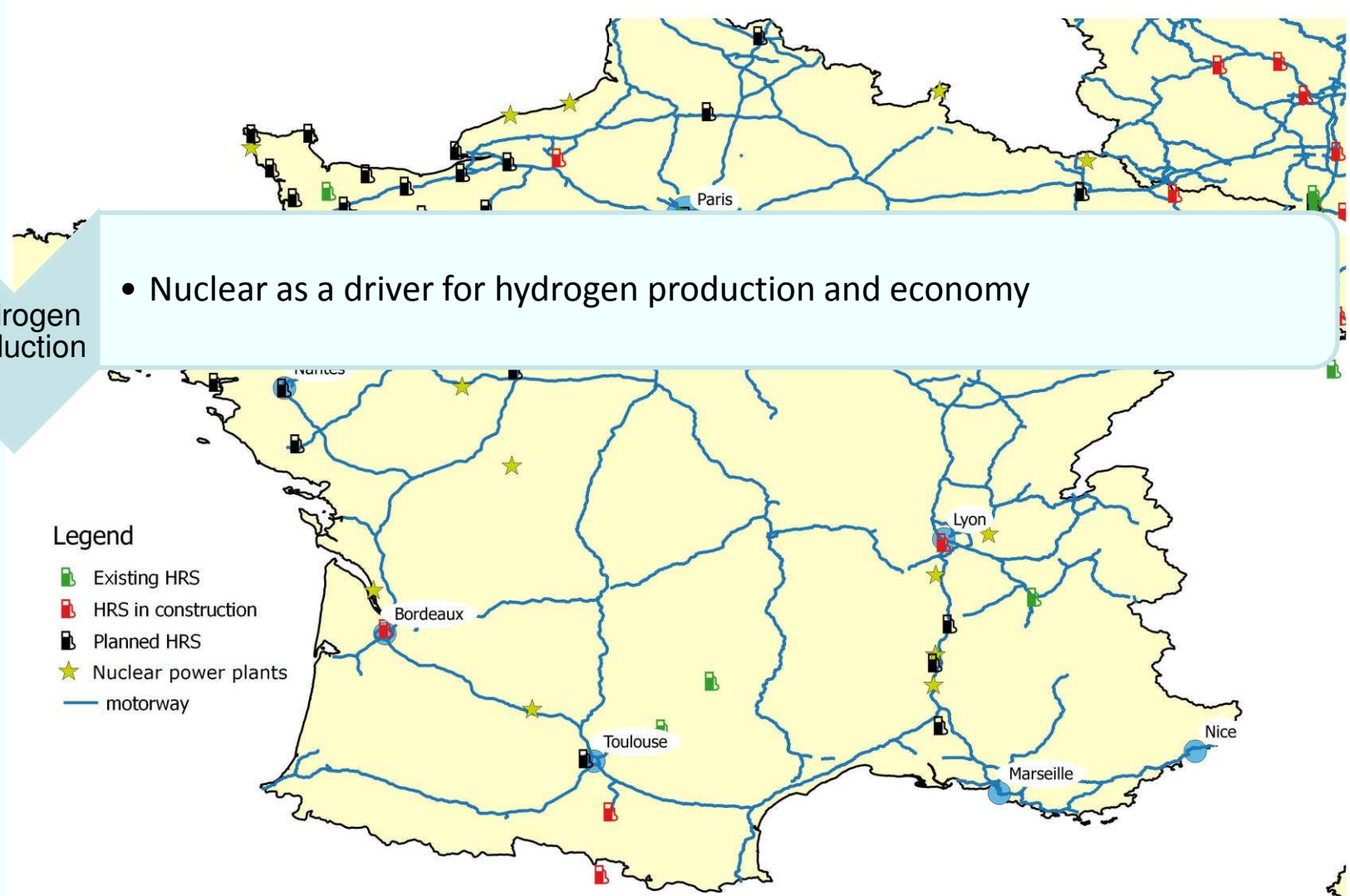
# Modeling framework, France

Hydrogen production

- Nuclear as a driver for hydrogen production and economy

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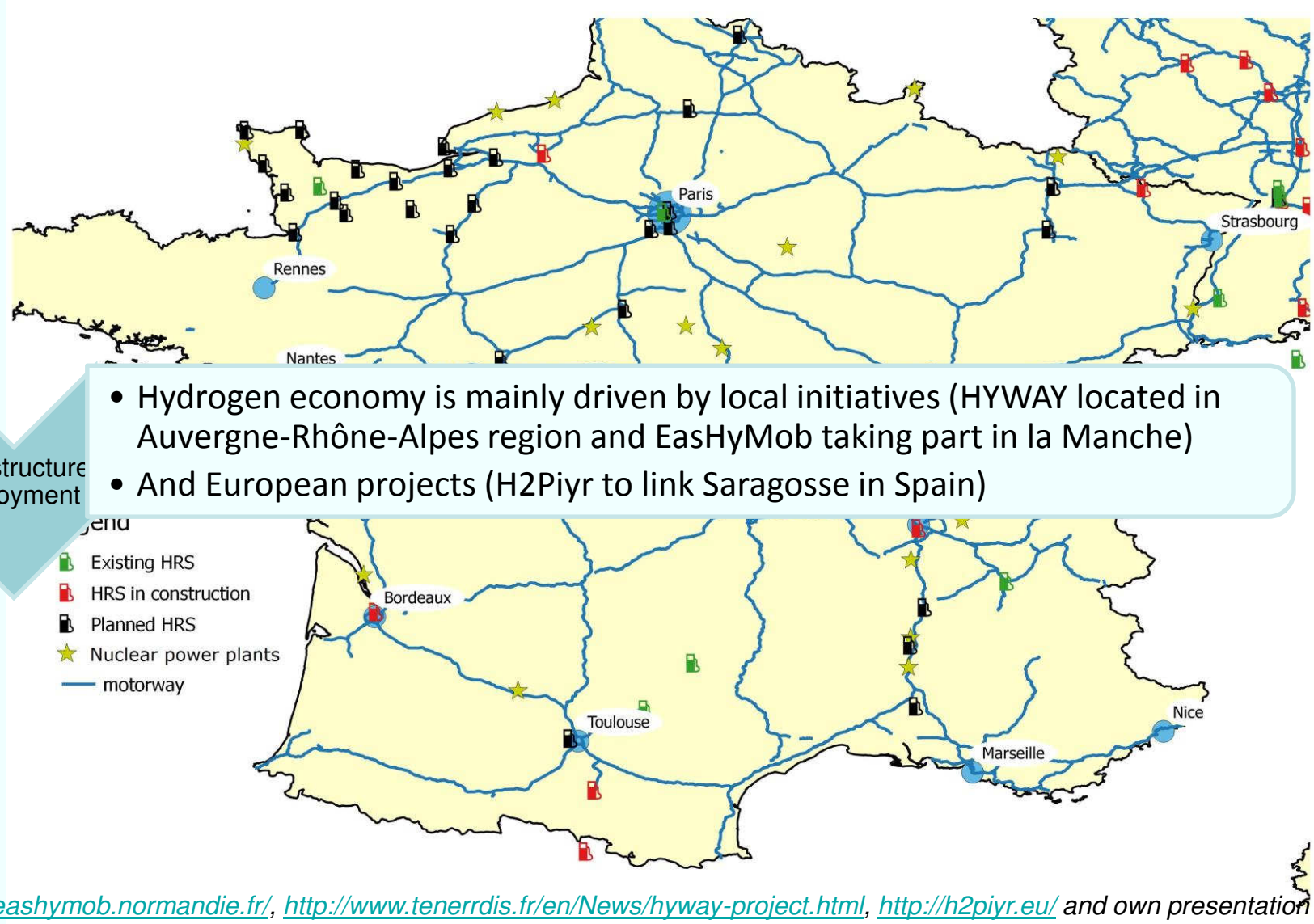


Infrastructure deployment

- Hydrogen economy is mainly driven by local initiatives (HYWAY located in Auvergne-Rhône-Alpes region and EasHyMob taking part in la Manche)
- And European projects (H2Piyr to link Saragosse in Spain)

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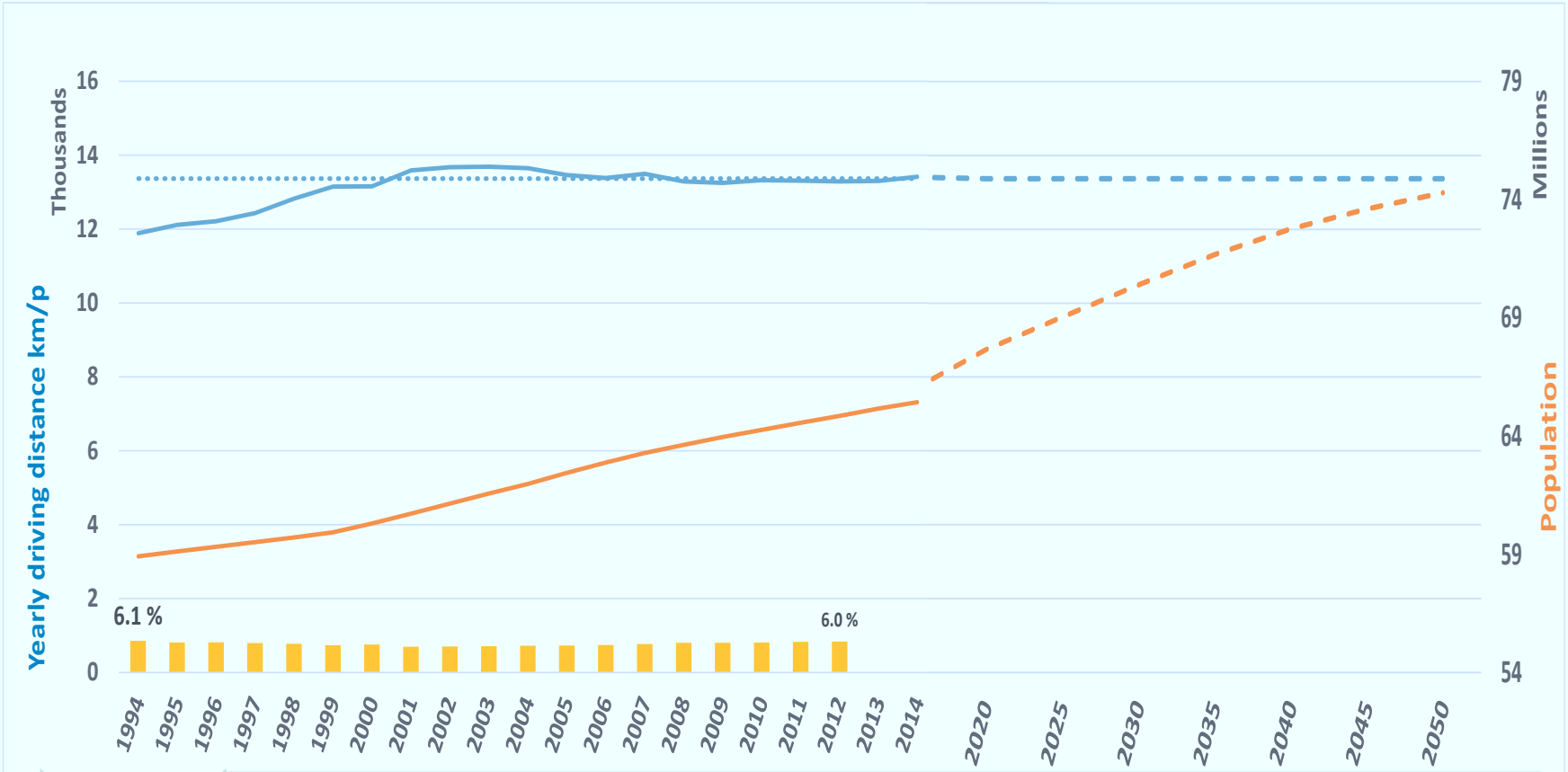
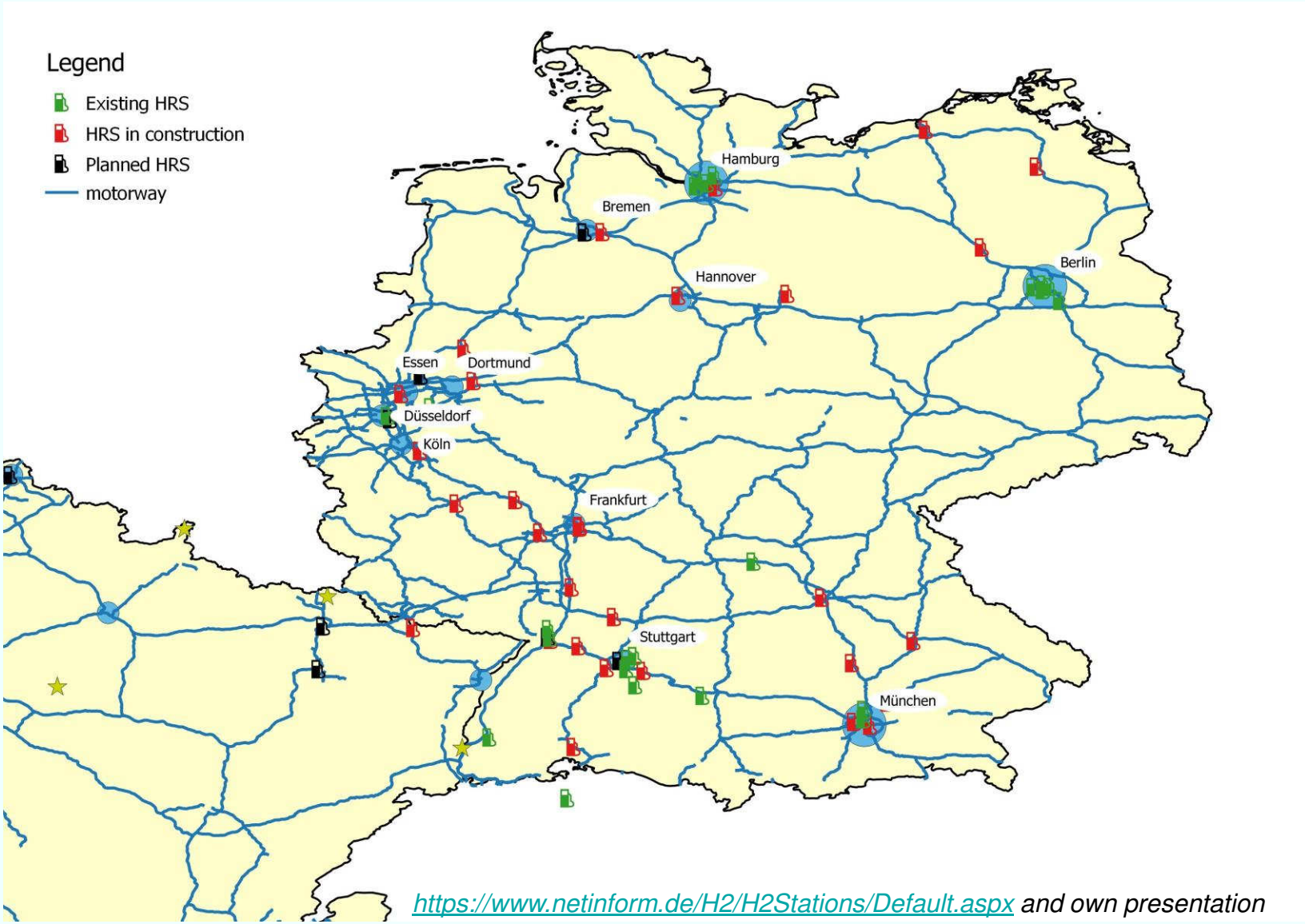



Hydrogen demand

- A share of 2.4% by 2030 and 28.5% by 2050 in passenger car(high penetration of hydrogen) [4]
- Constant need of transportation with a population growth [5]


[4] IEA (2015) *Technology Roadmap, Hydrogen and Fuel Cells*
[5] EUROSTAT (2016) *Transport statistics*

# Modeling framework, Germany

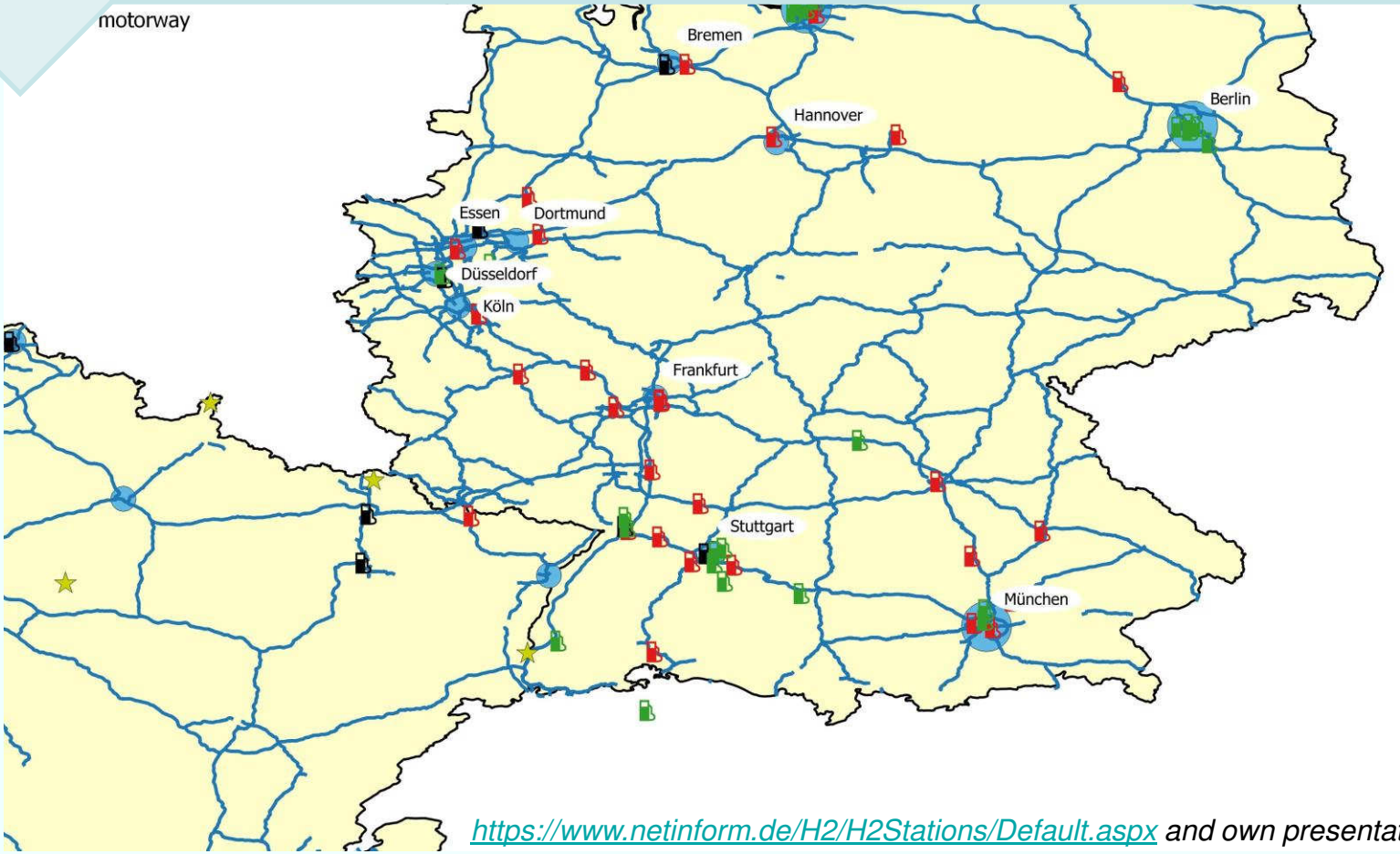



https://www.netinform.de/H2/H2Stations/Default.aspx *and own presentation*

# Modeling framework, Germany

Electricity mix

- Big share of renewable energy sources in electricity mix

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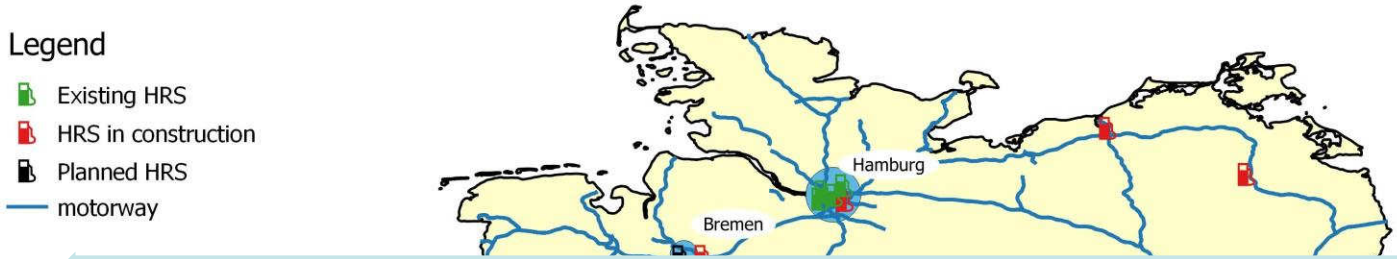


Hydrogen production

- Wind energy as a driver for hydrogen production


https://www.netinform.de/H2/H2Stations/Default.aspx *and own presentation*

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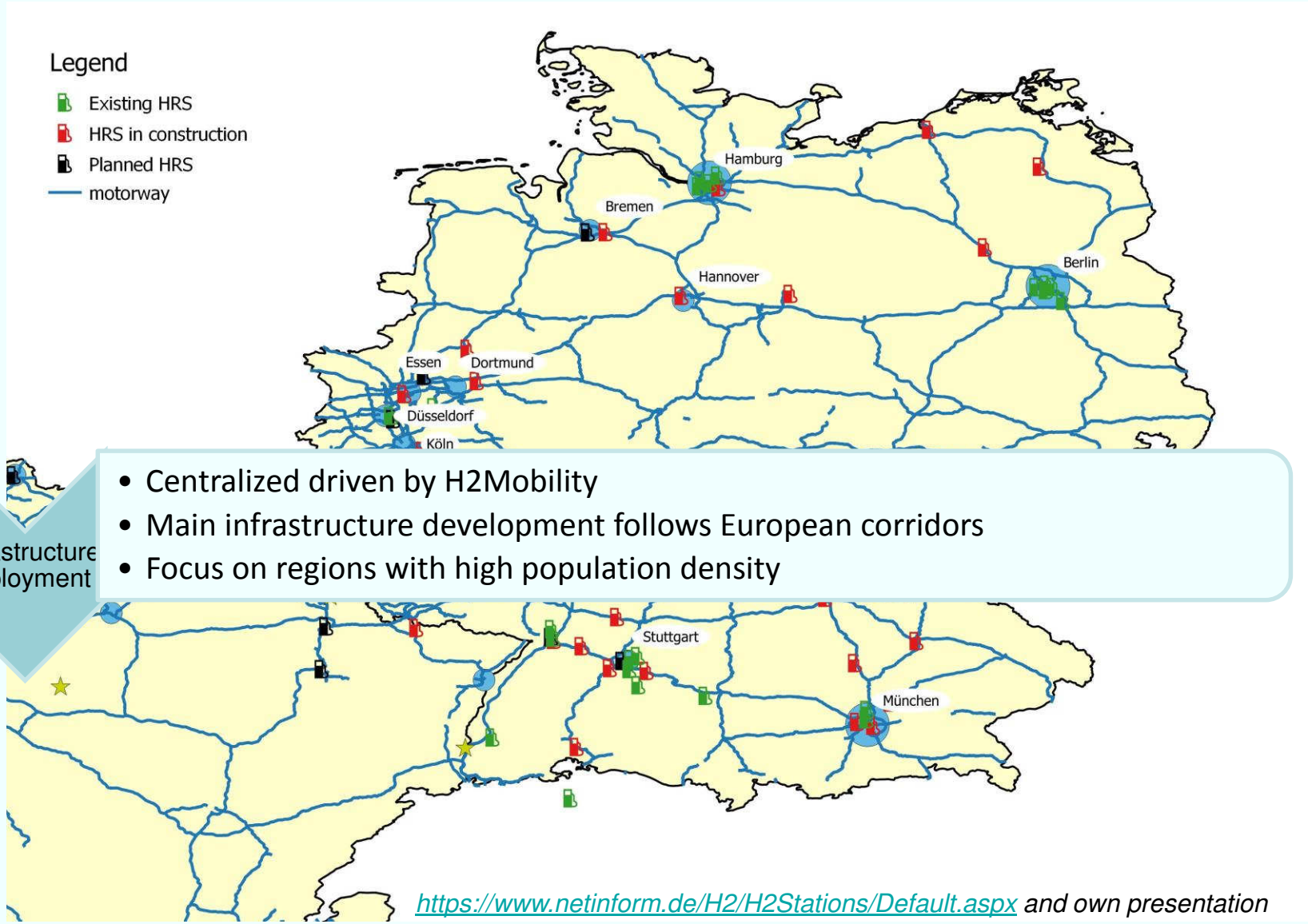


Infrastructure deployment

- Centralized driven by H2Mobility
- Main infrastructure development follows European corridors
- Focus on regions with high population density

*https://www.netinform.de/H2/H2Stations/Default.aspx and own presentation*

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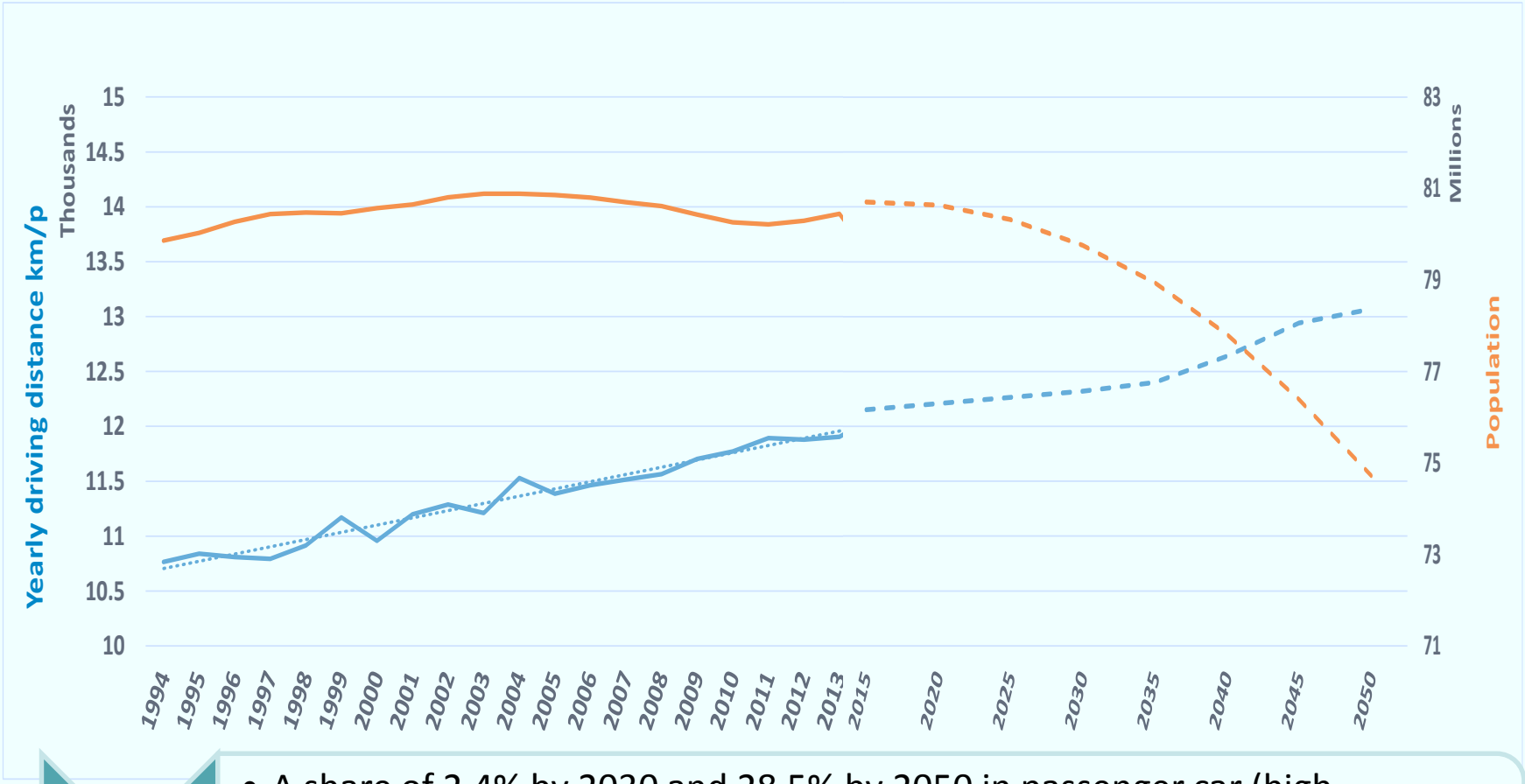


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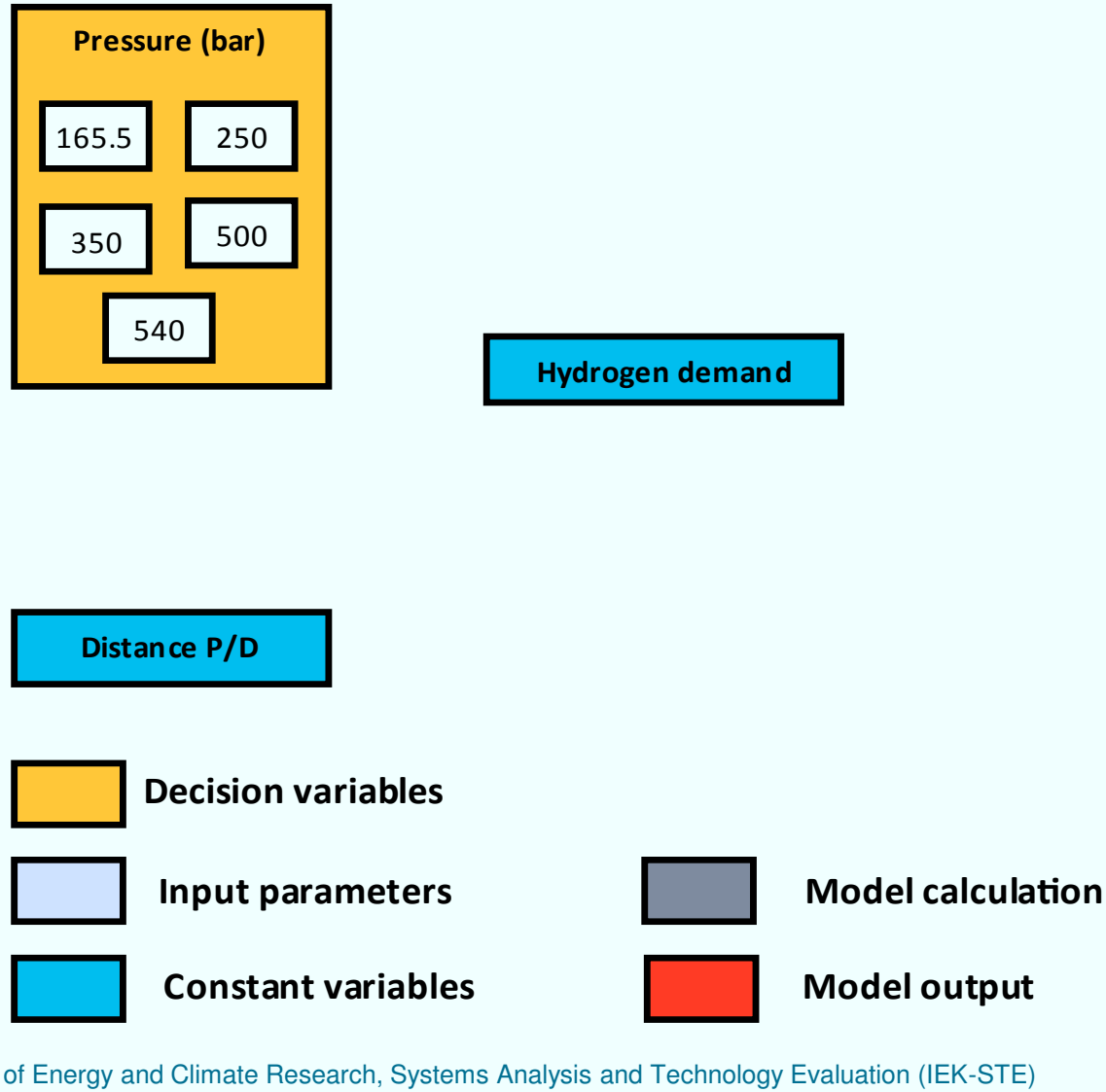
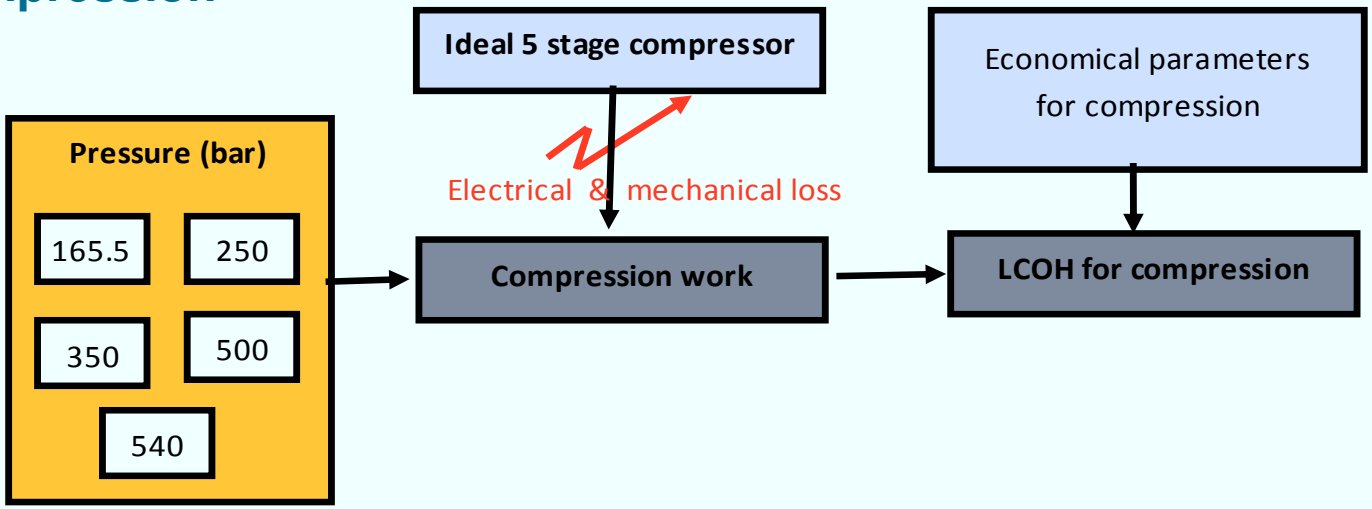
# Model
## Variables



# Model
## Compression




LCOH Levelized cost of hydrogen

Decision variables

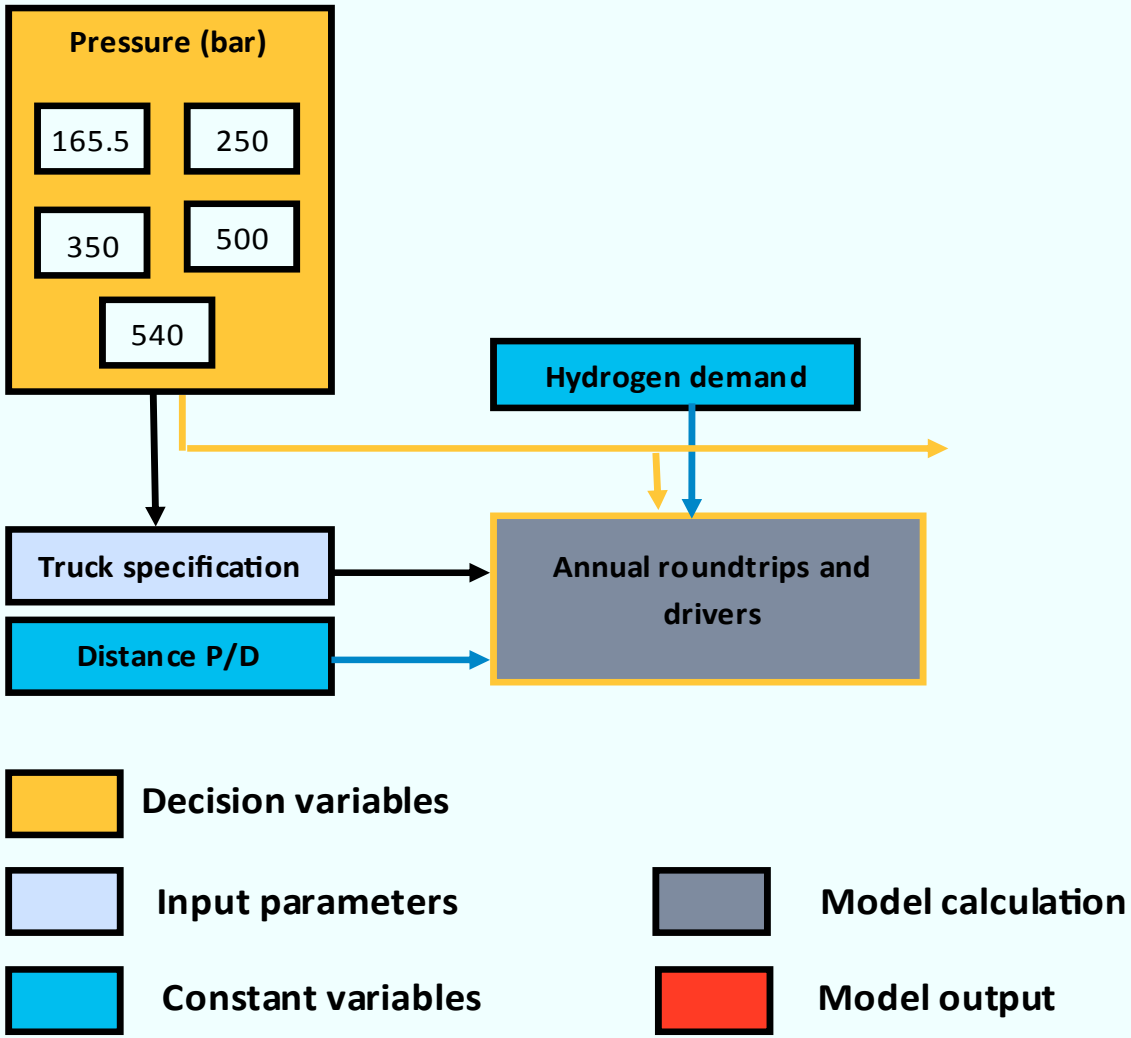
Input parameters

Constant variables

Model calculation

Model output

# Model
## Transportation and storage



# Model
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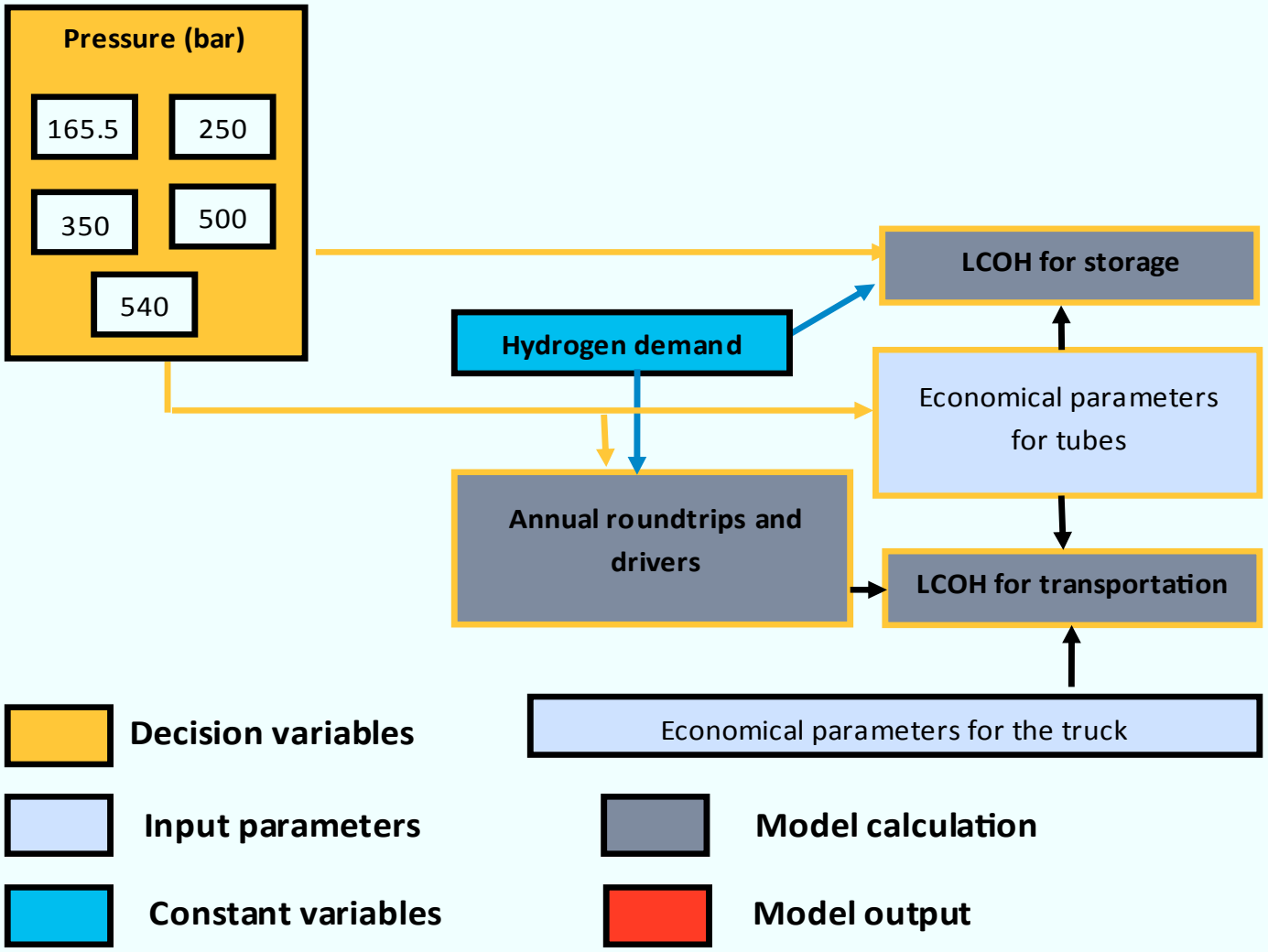
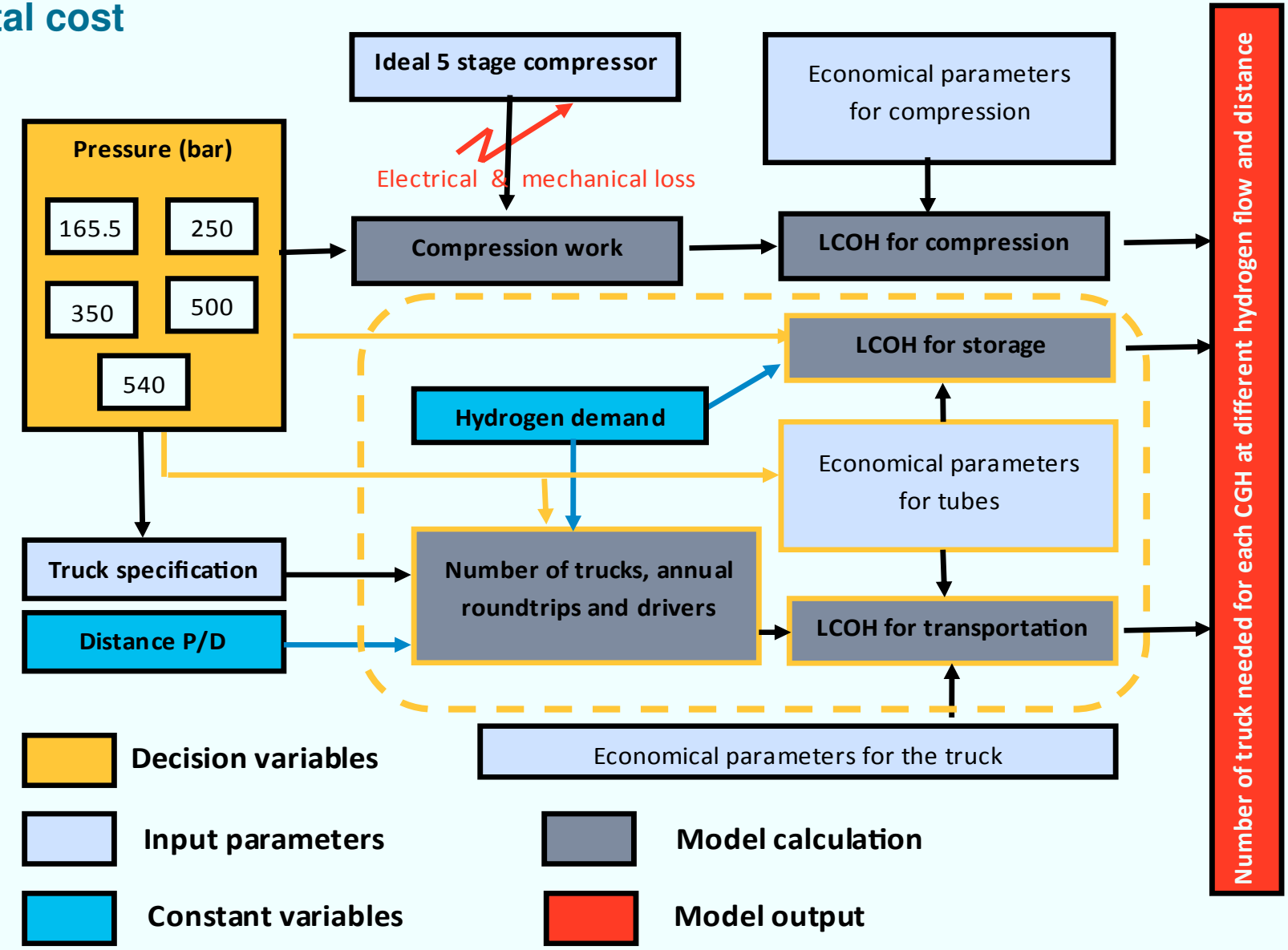
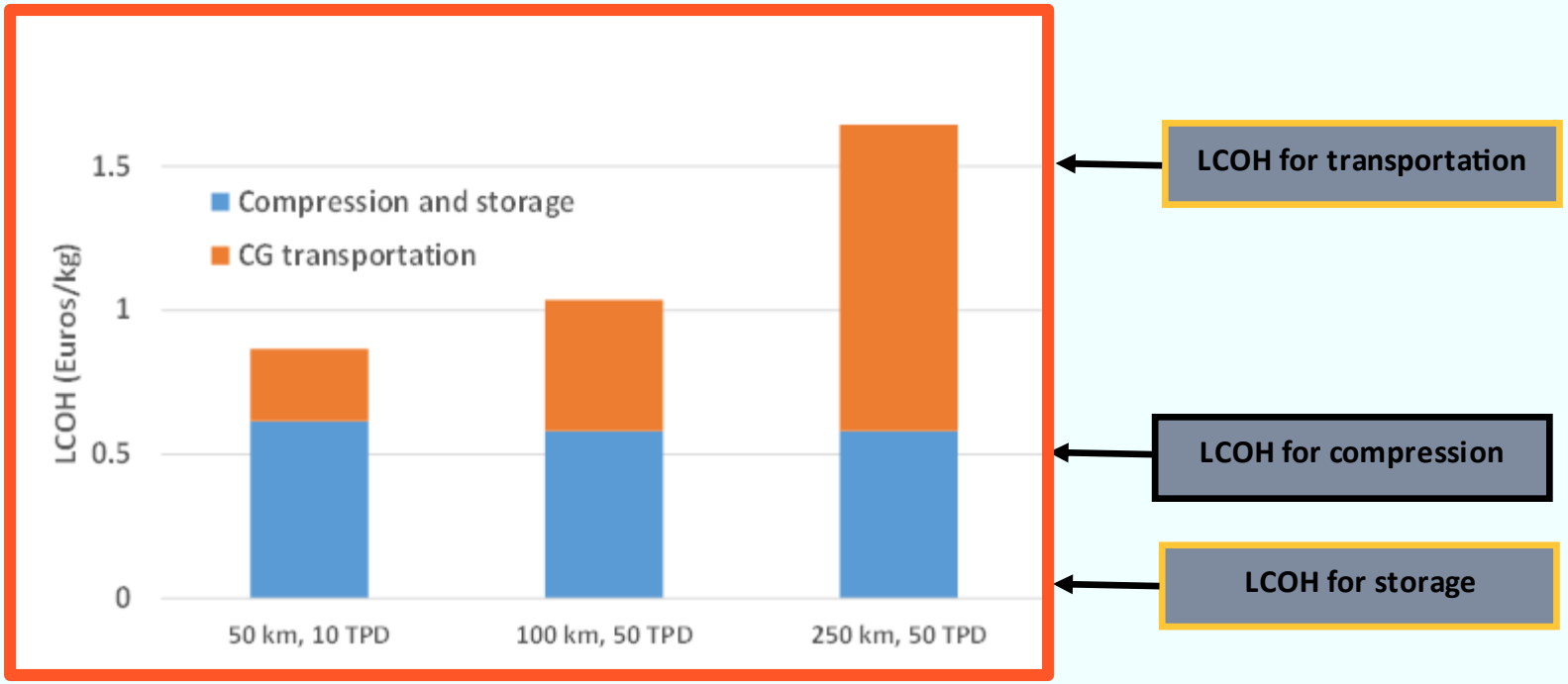


# Model
## Total cost



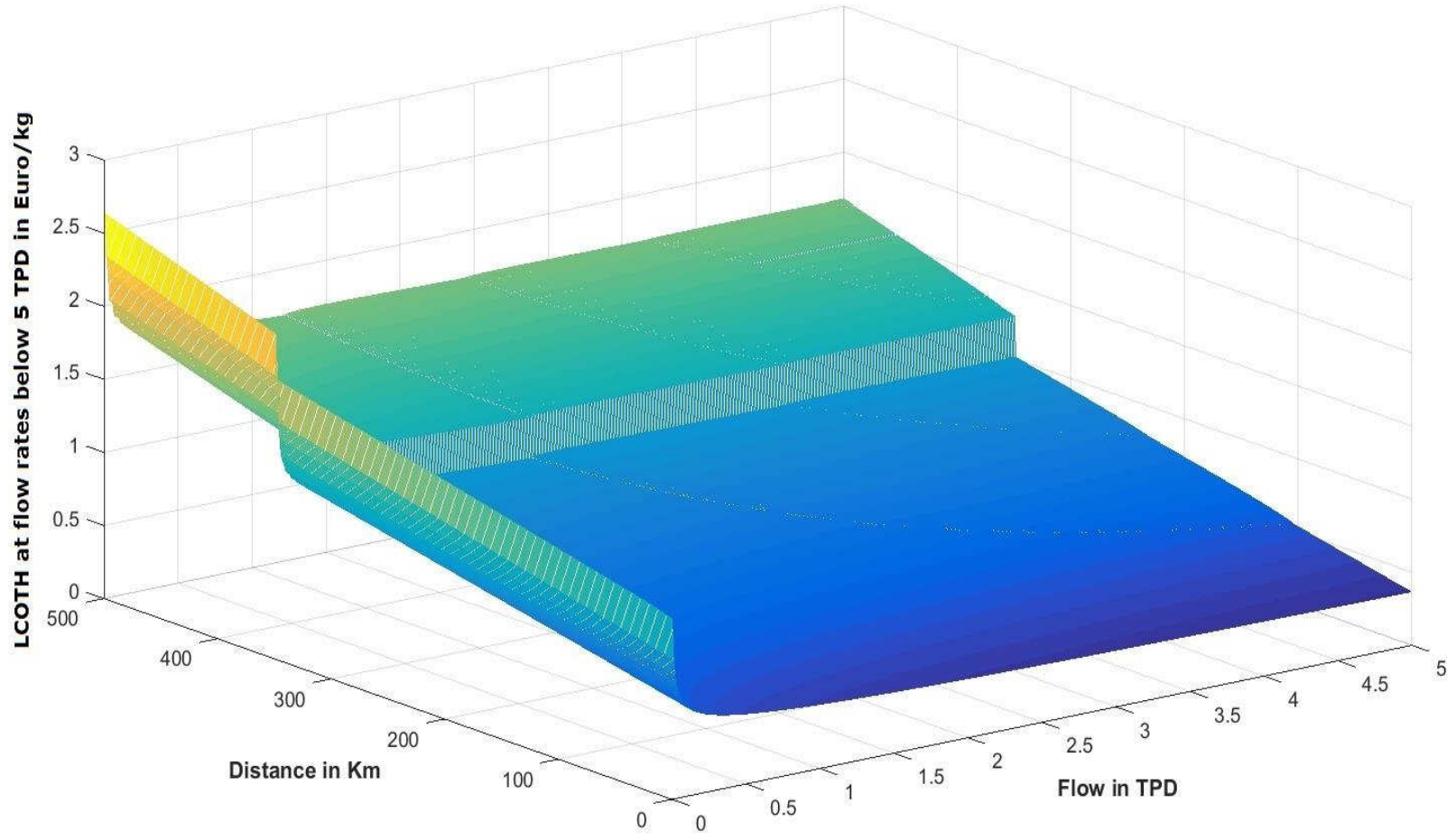
# Model results

## LCOH for transportation, storage and compression



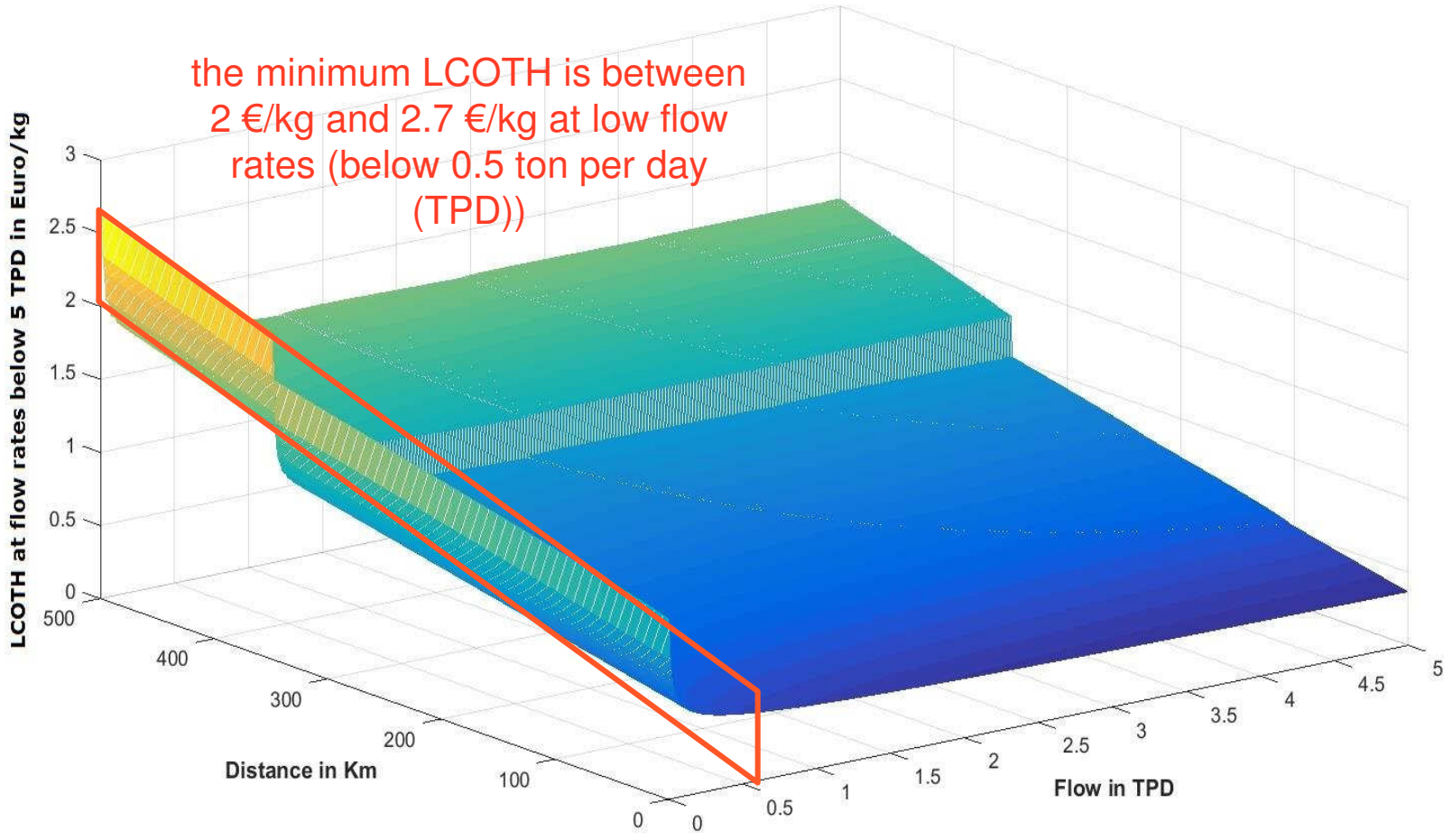

*TPD: Ton per day*

# Model results
## LCOTH




LCOTH Levelized cost of transporting hydrogen

# Model results
## LCOTH



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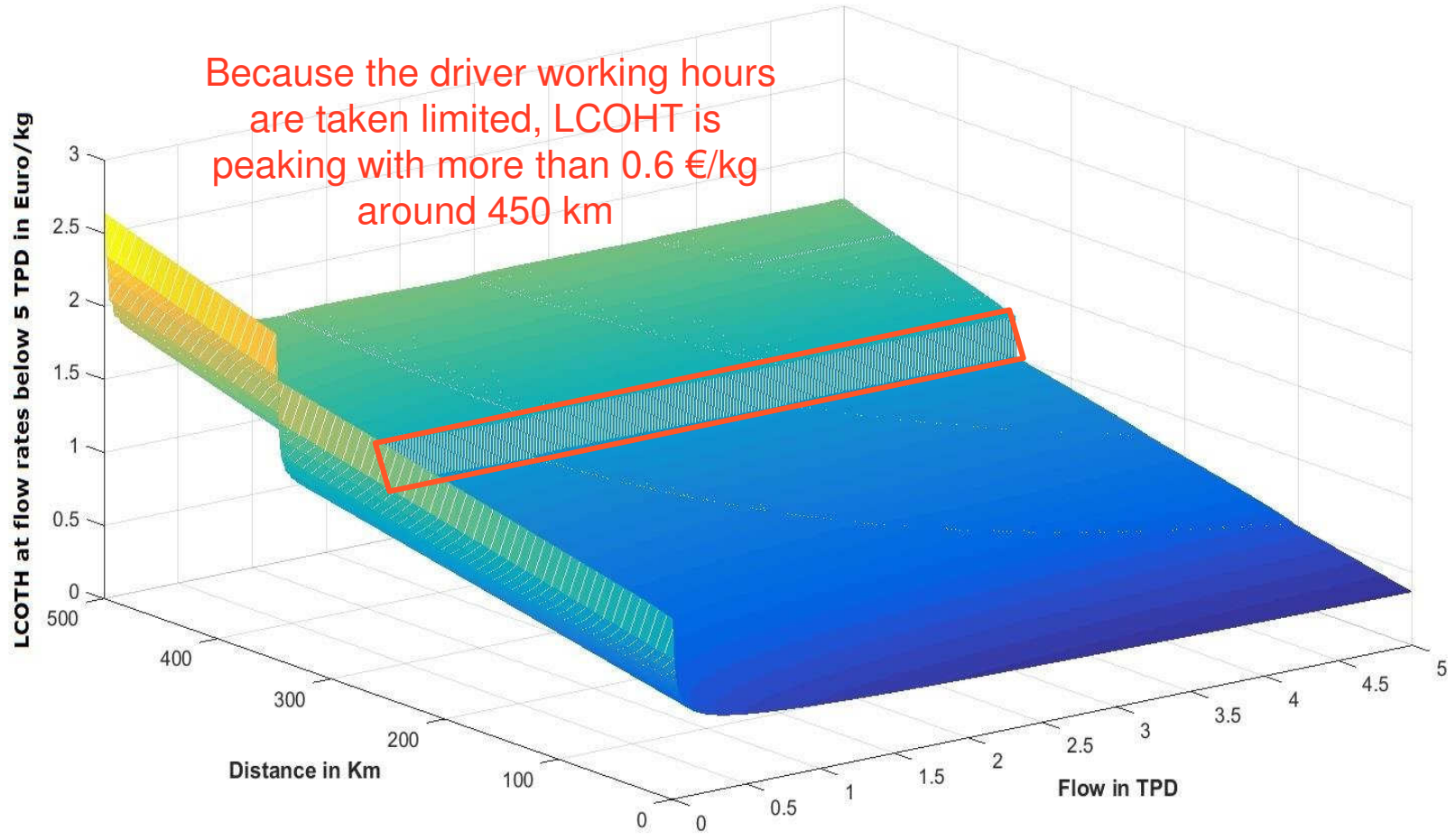
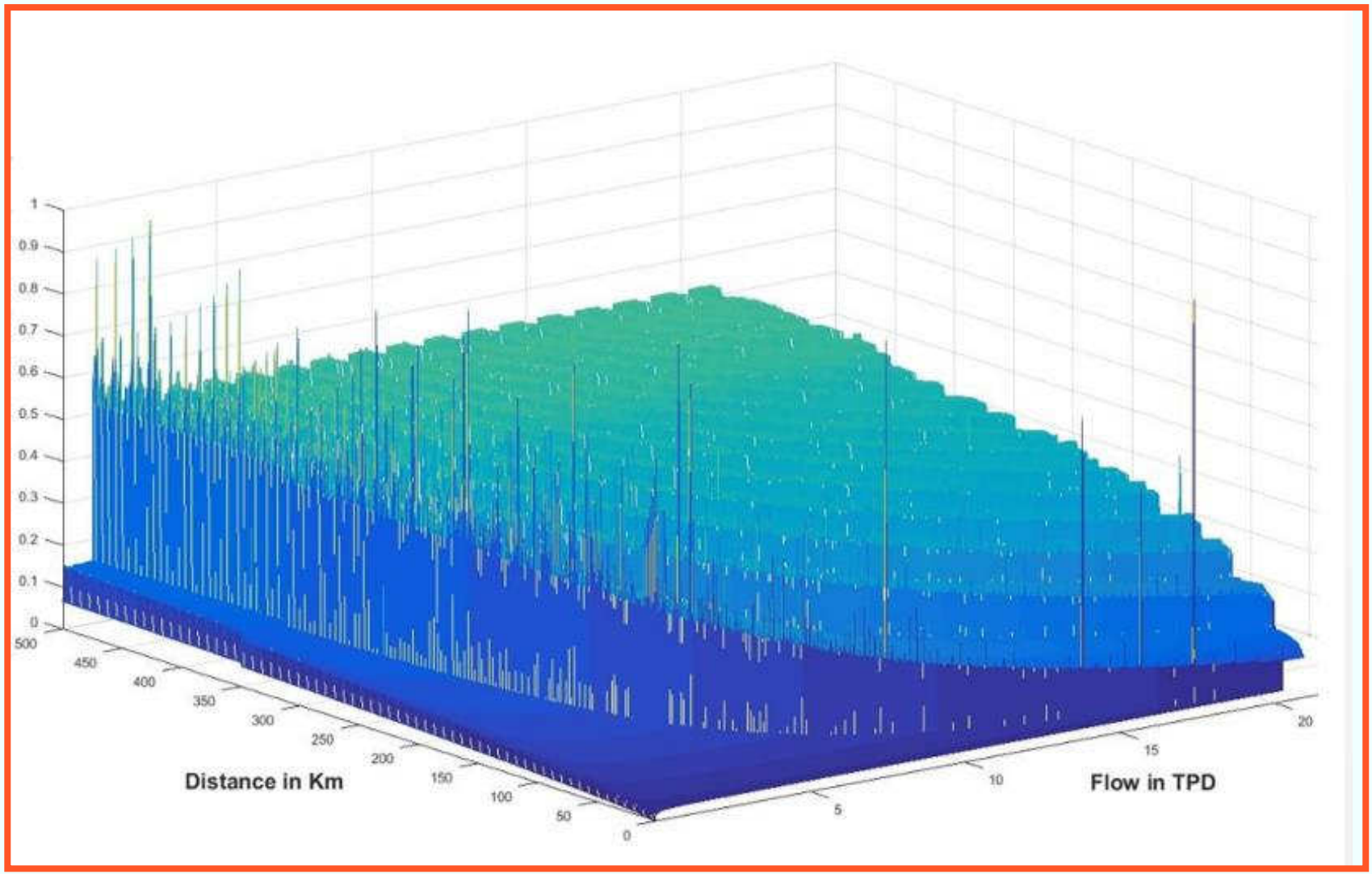
## LCOTH



# Model results

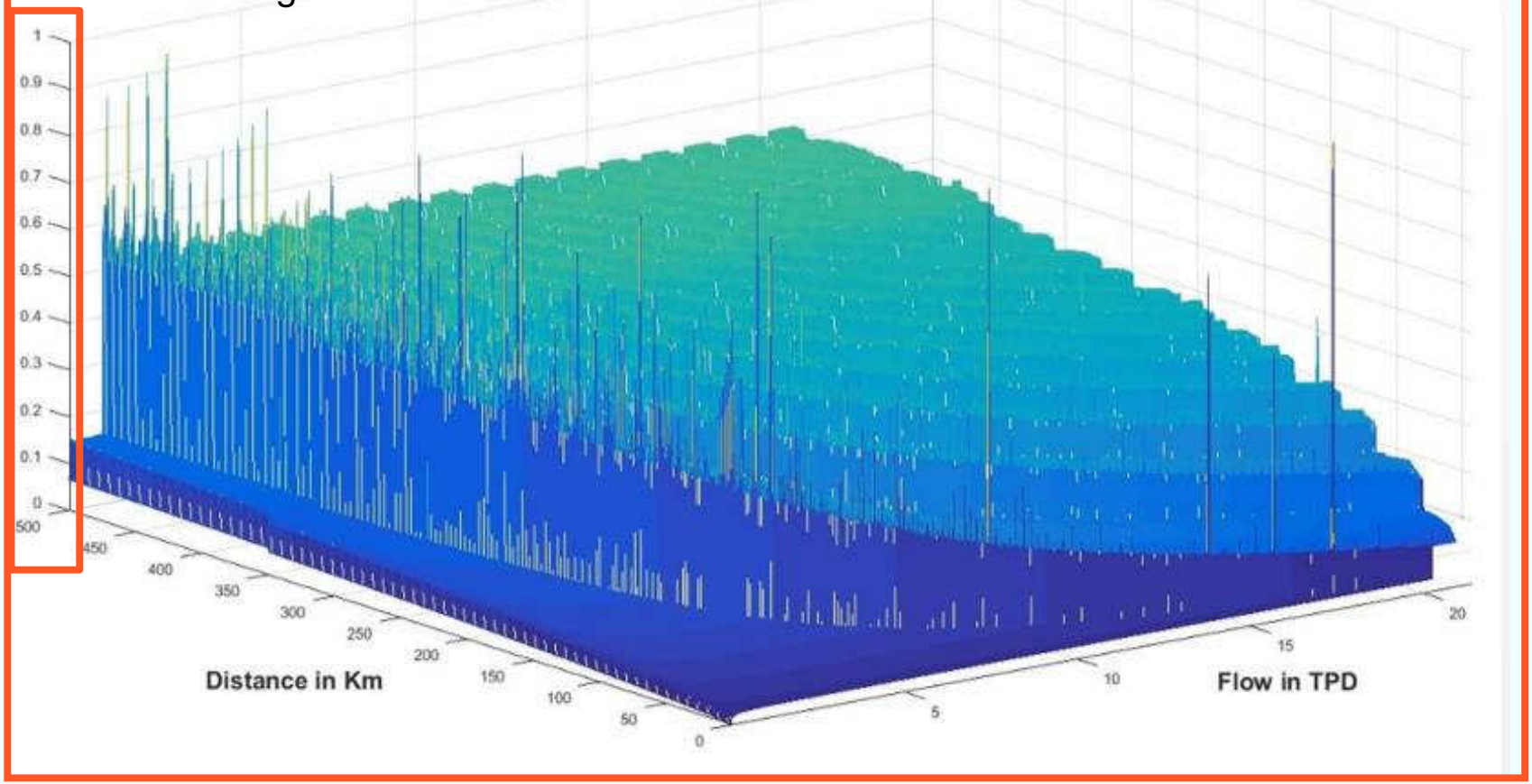
## Share of transporting CGH at 540 bar



# Model results

## Share of transporting CGH at 540 bar

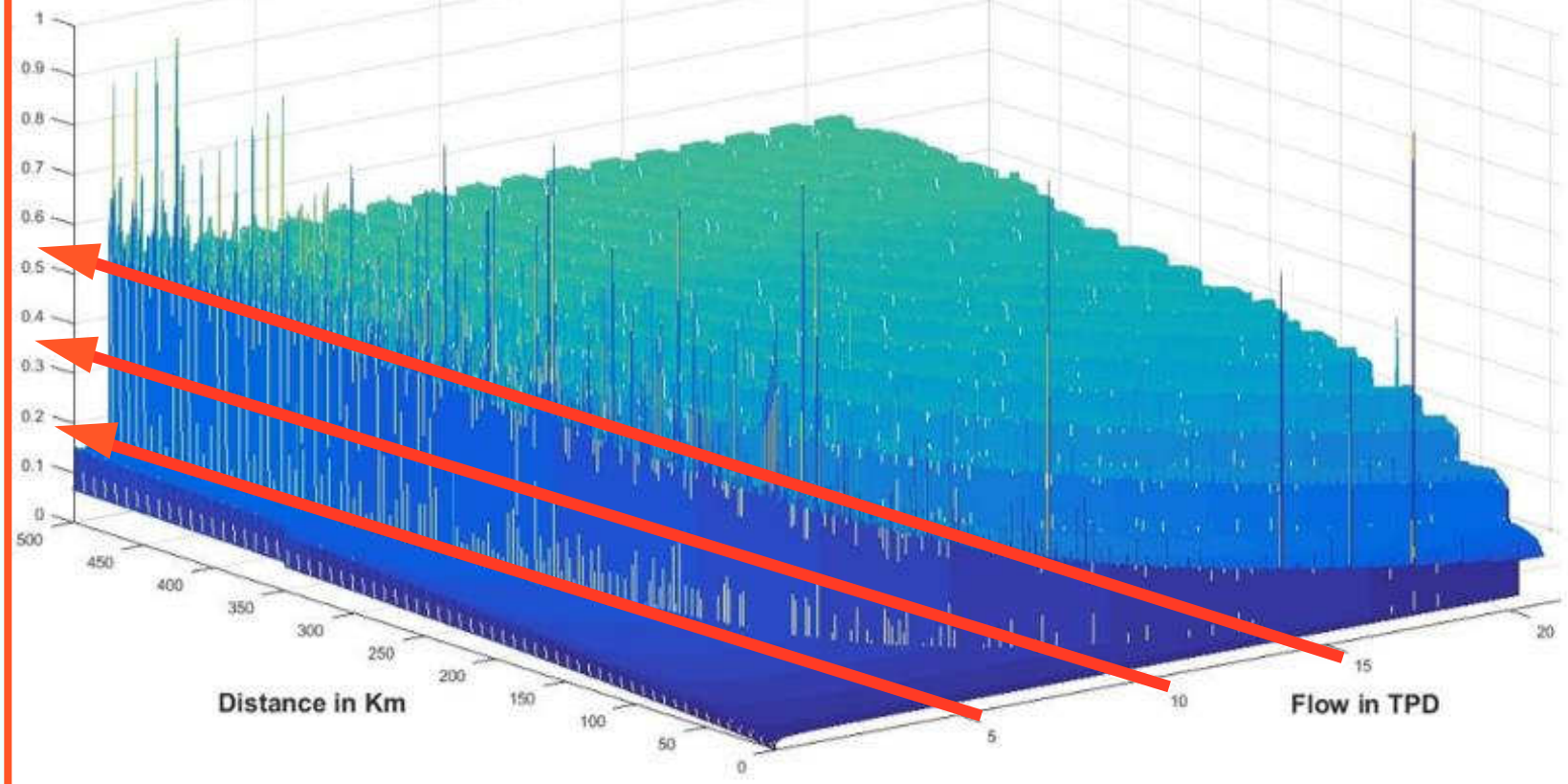
- **0** corresponds to the case where no CGH at 540 bar is used
- **1** corresponds to the case where 100 % of the capacity is transported using a CGH at 540 bar



# Model results

## Share of transporting CGH at 540 bar

- The share of CGH at 540 bar increases with the distance
- Fuel truck cost becomes more important when the distance increases



# Conclusion

- Not only truck at the highest compression are used even in case of high demand
- An average of a maximum of 52% of total capacity is transported at high compression level
- Capital costs are important at low hydrogen flow
- Fuel costs are important at long distance
- Driver costs impact on the total transportation cost

# Conclusion

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- Fuel cost are important at long distance
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## Thank you for your attention

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