



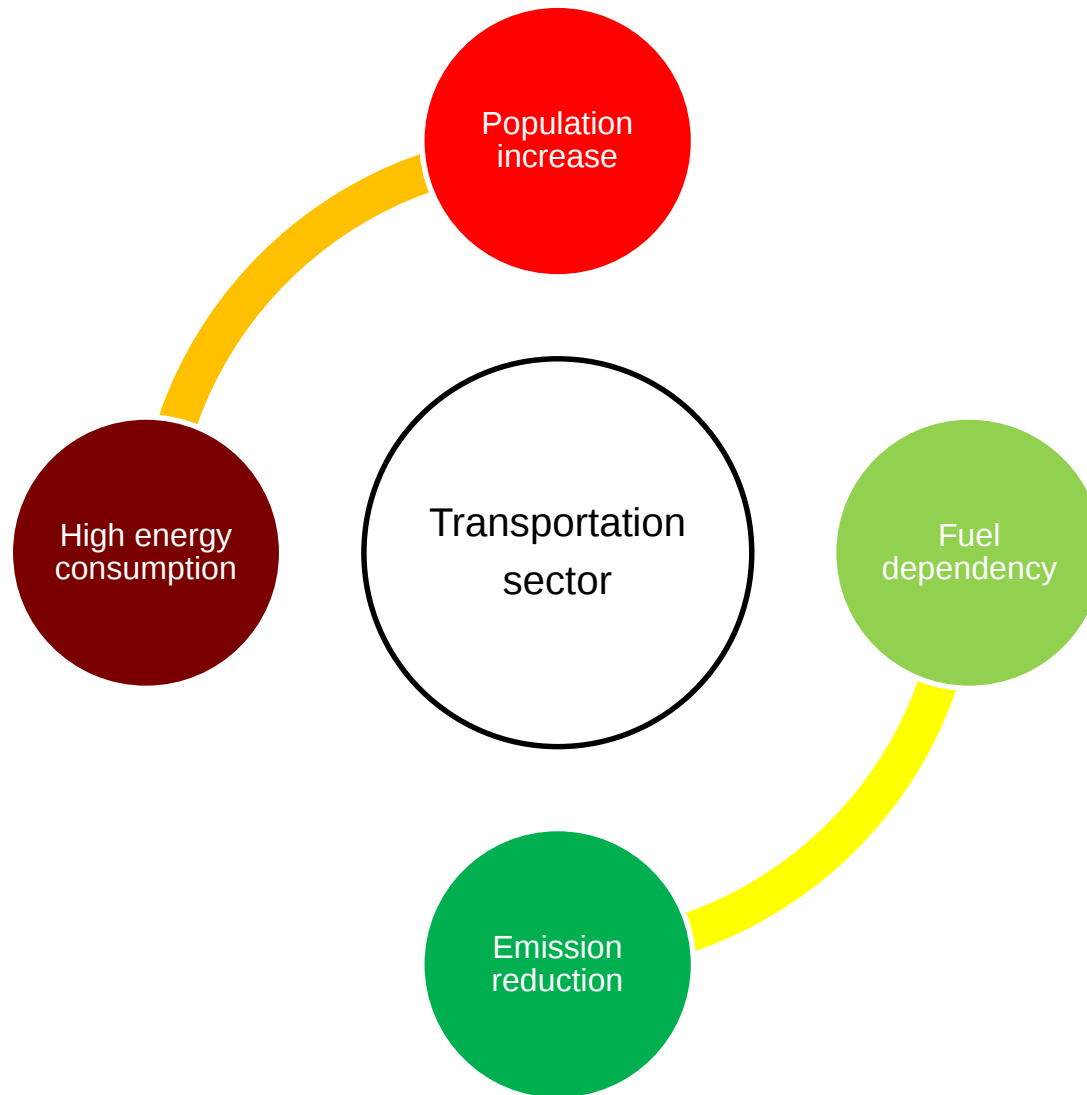
THE 7th WORLD HYDROGEN TECHNOLOGY CONVENTION

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

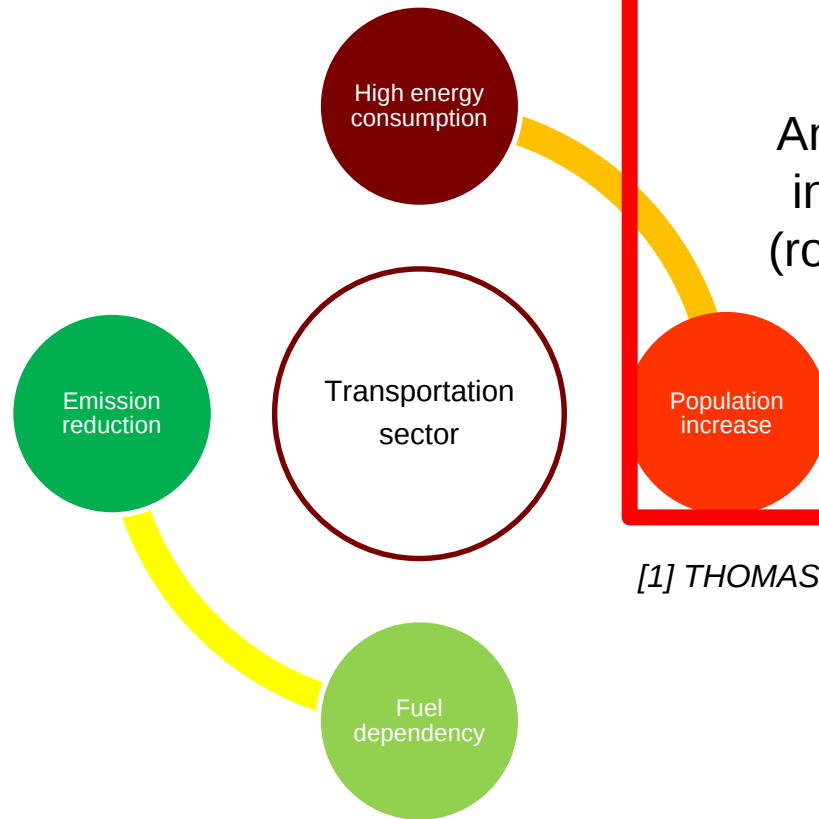
Institute of Energy and Climate Research, Systems Analysis and Technology Evaluation (IEK-STE)

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



Introduction, European context

Population increase



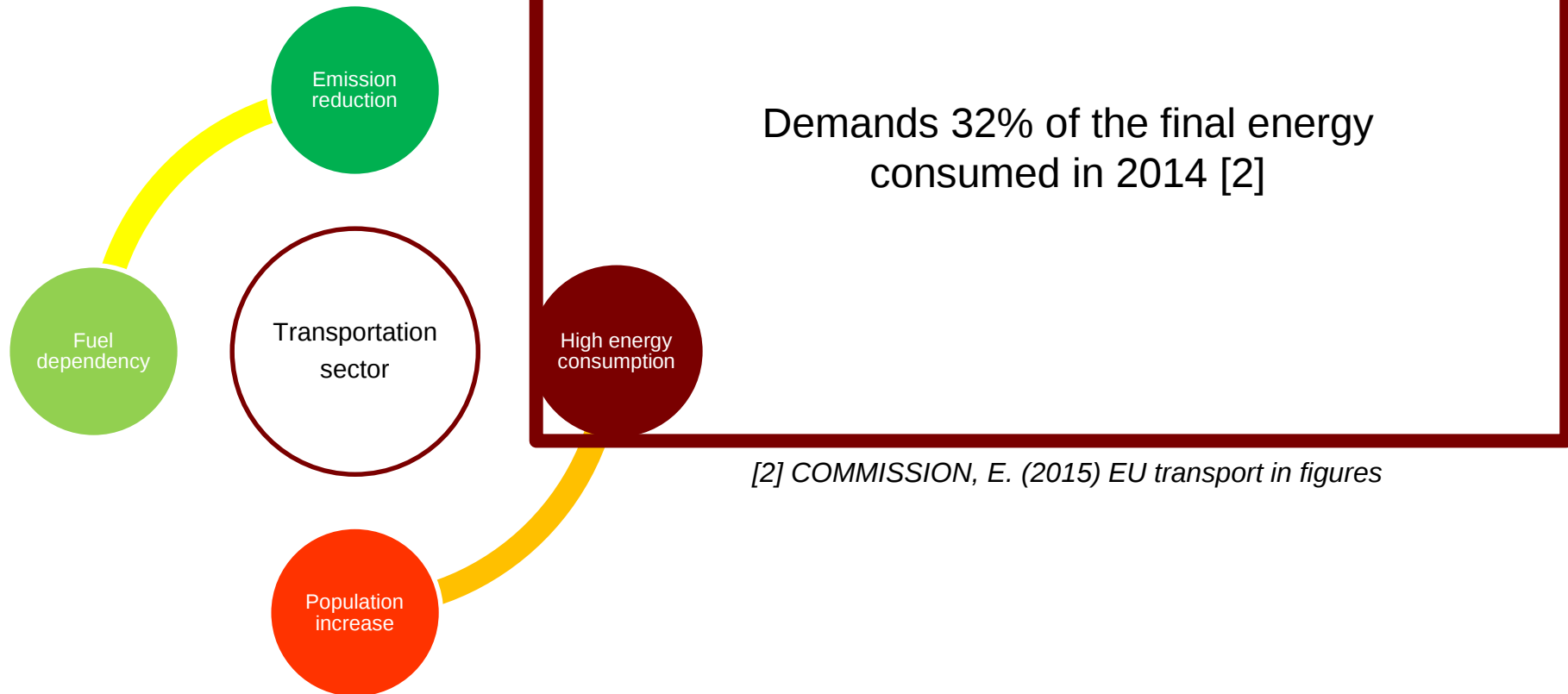
An increase of the population by 30 million in the last 25 years → increasing need of (road) transportation → 84 million new cars [1]

[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

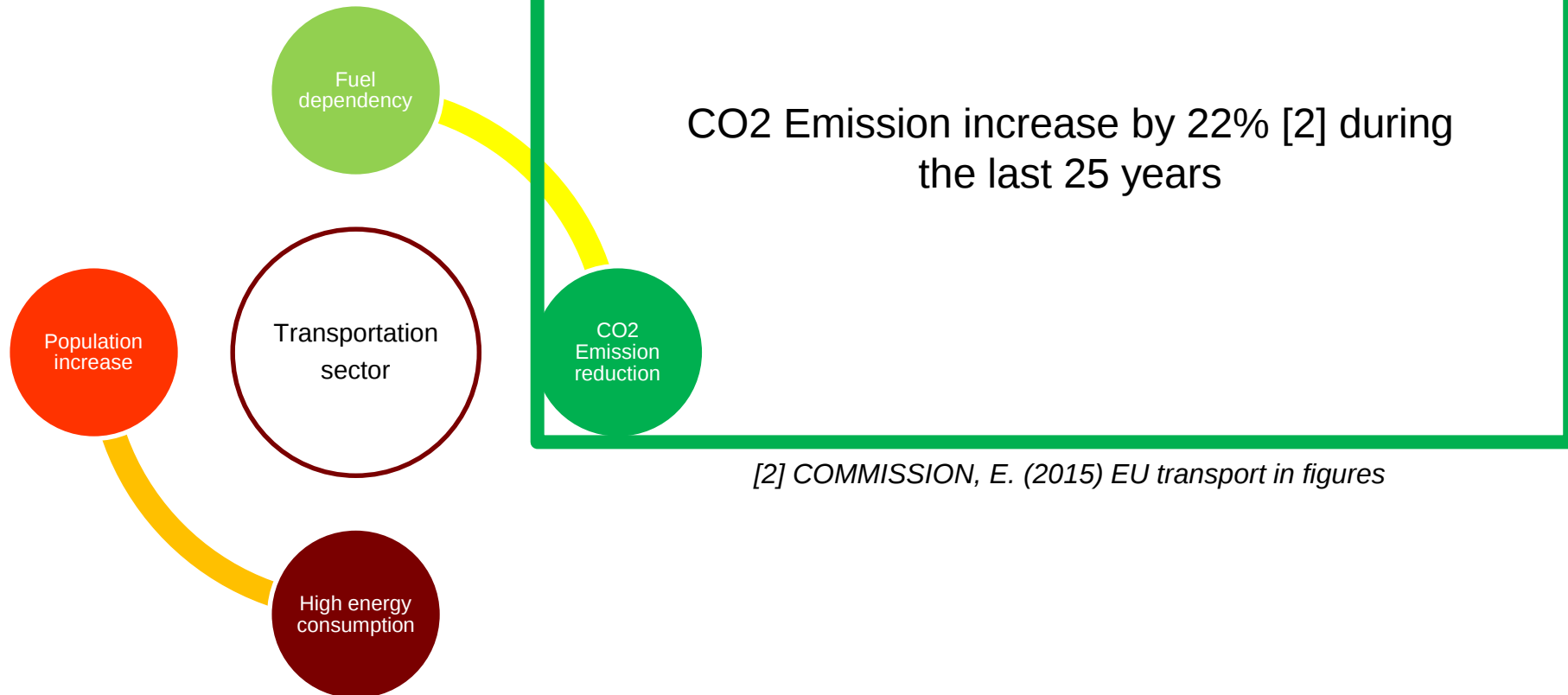


[2] COMMISSION, E. (2015) EU transport in figures

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

Introduction, European context

Emission reduction

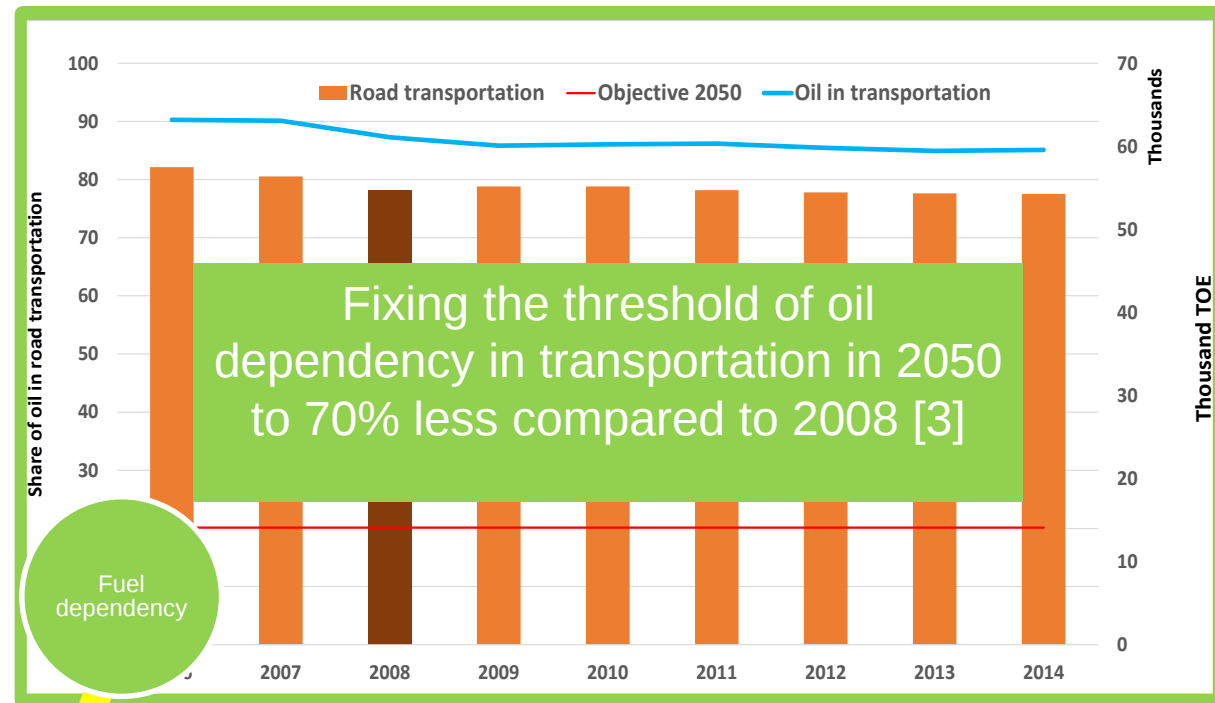
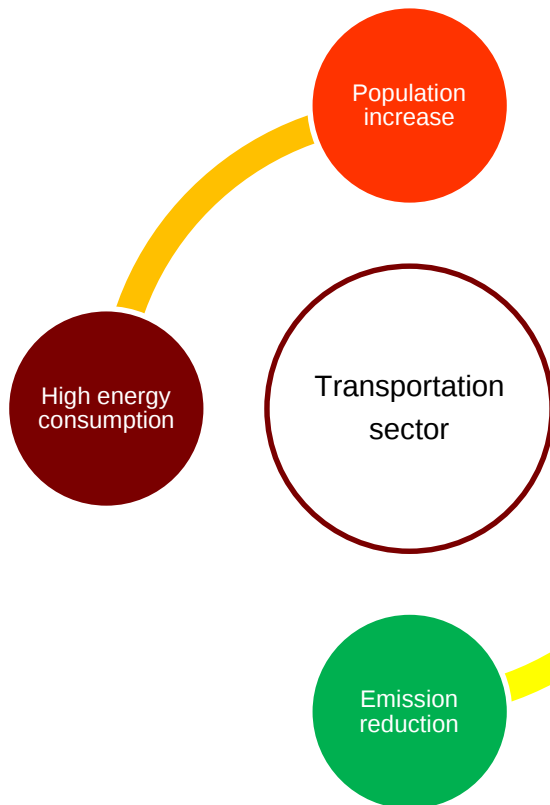


[2] COMMISSION, E. (2015) EU transport in figures

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Introduction, European context

Fuel dependency

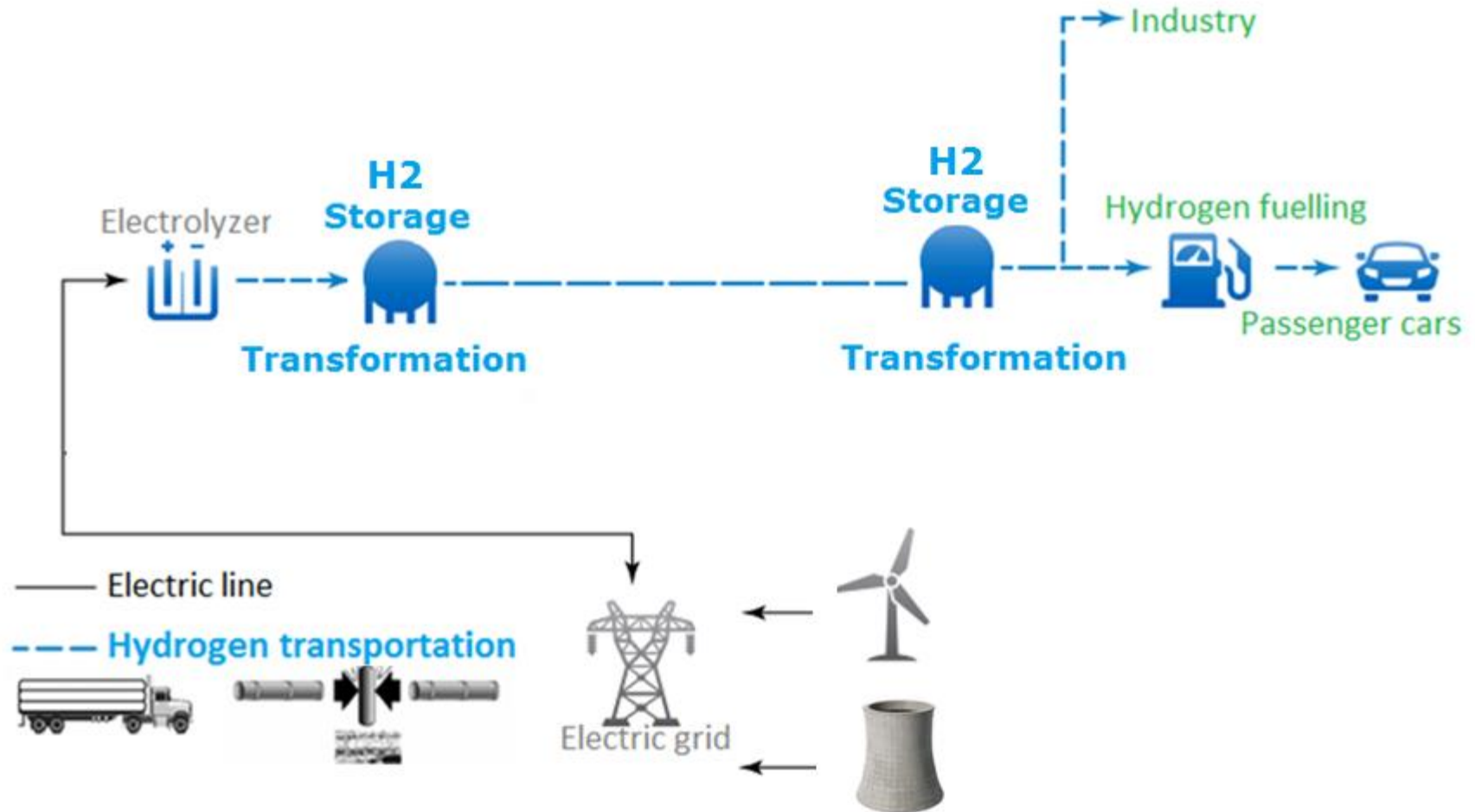


[EU transport in figures, EU commission 2015] and Own presentation

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

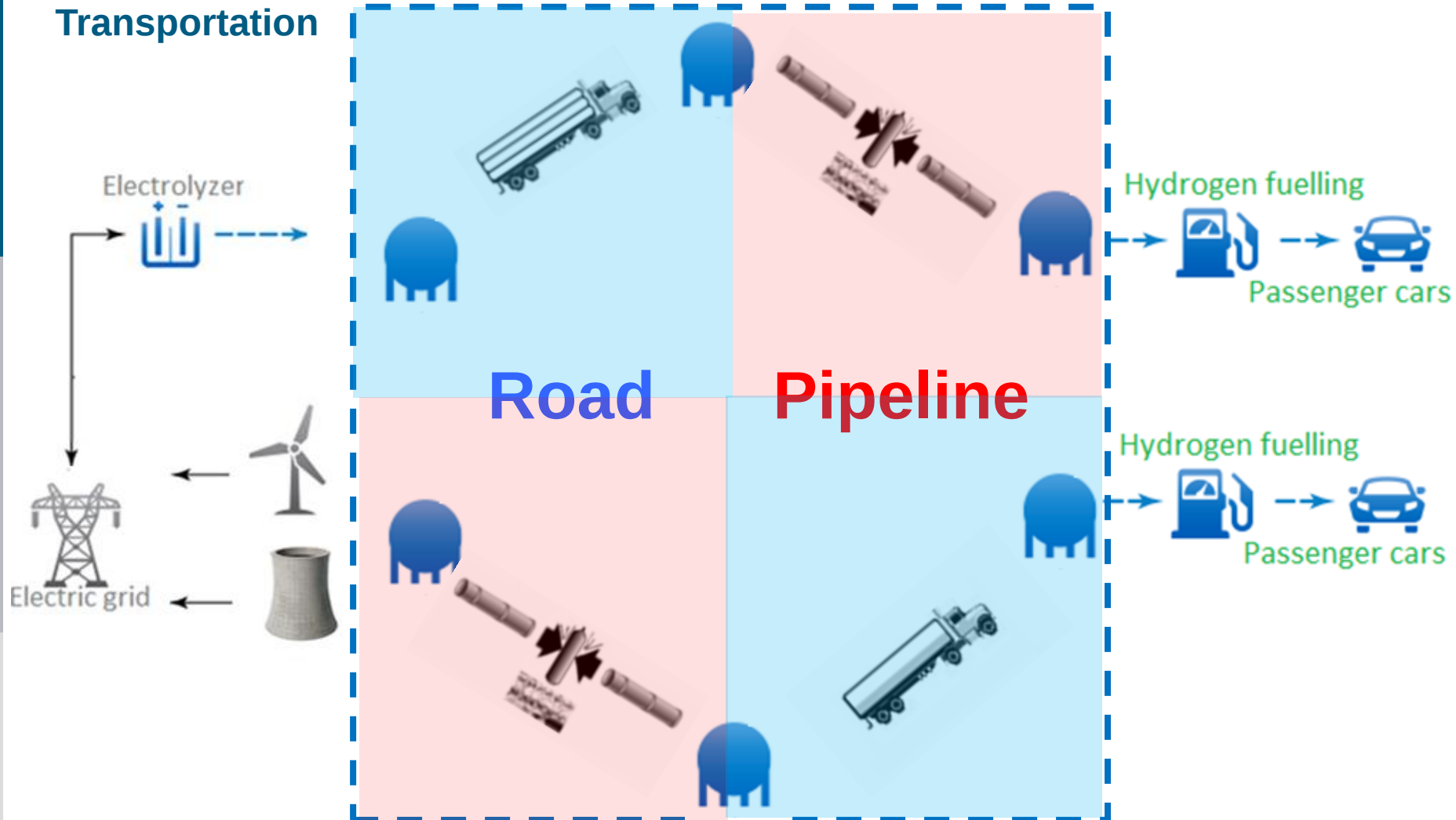
Hydrogen infrastructure

Hydrogen supply chain



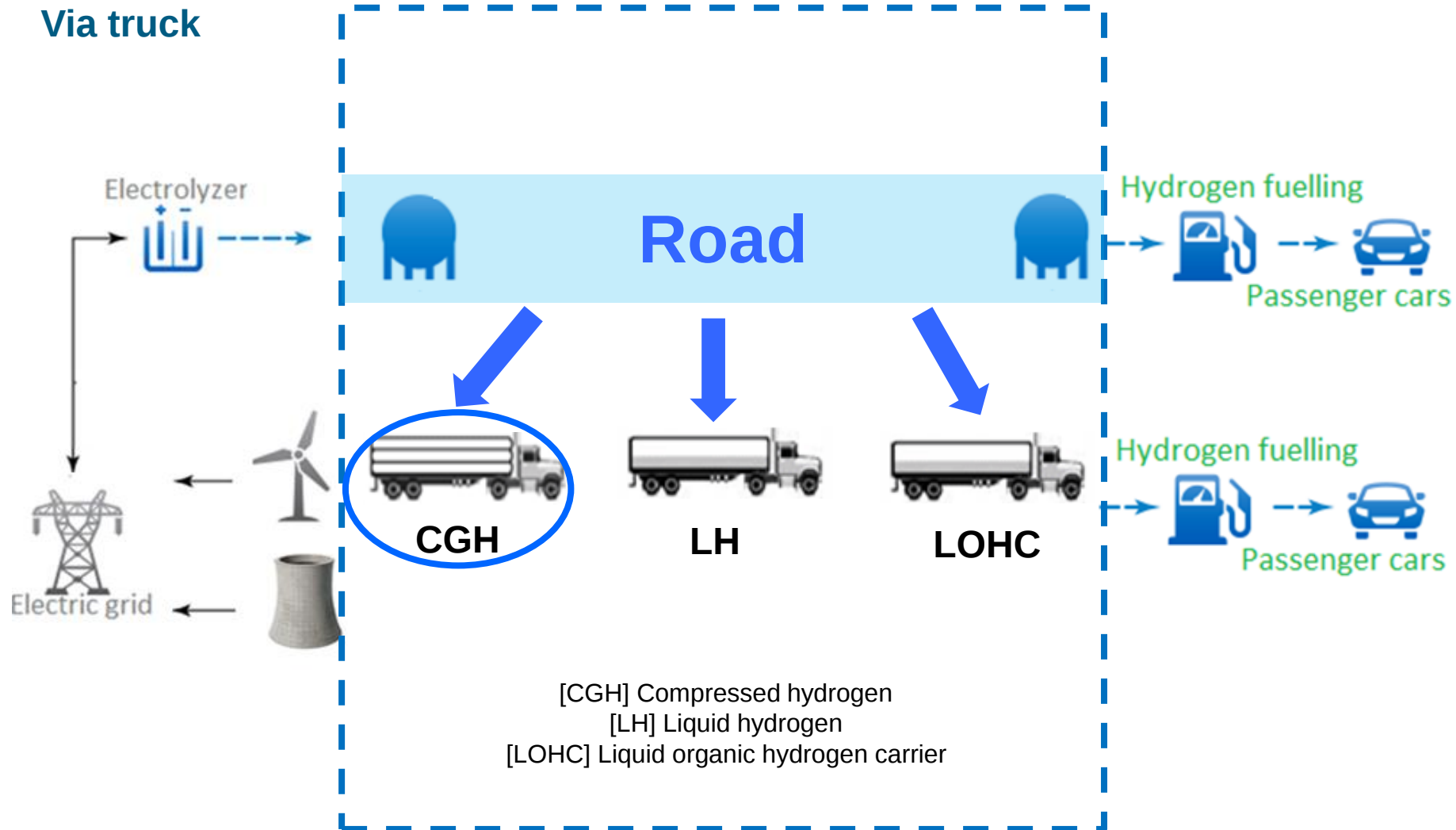
Hydrogen infrastructure

Transportation

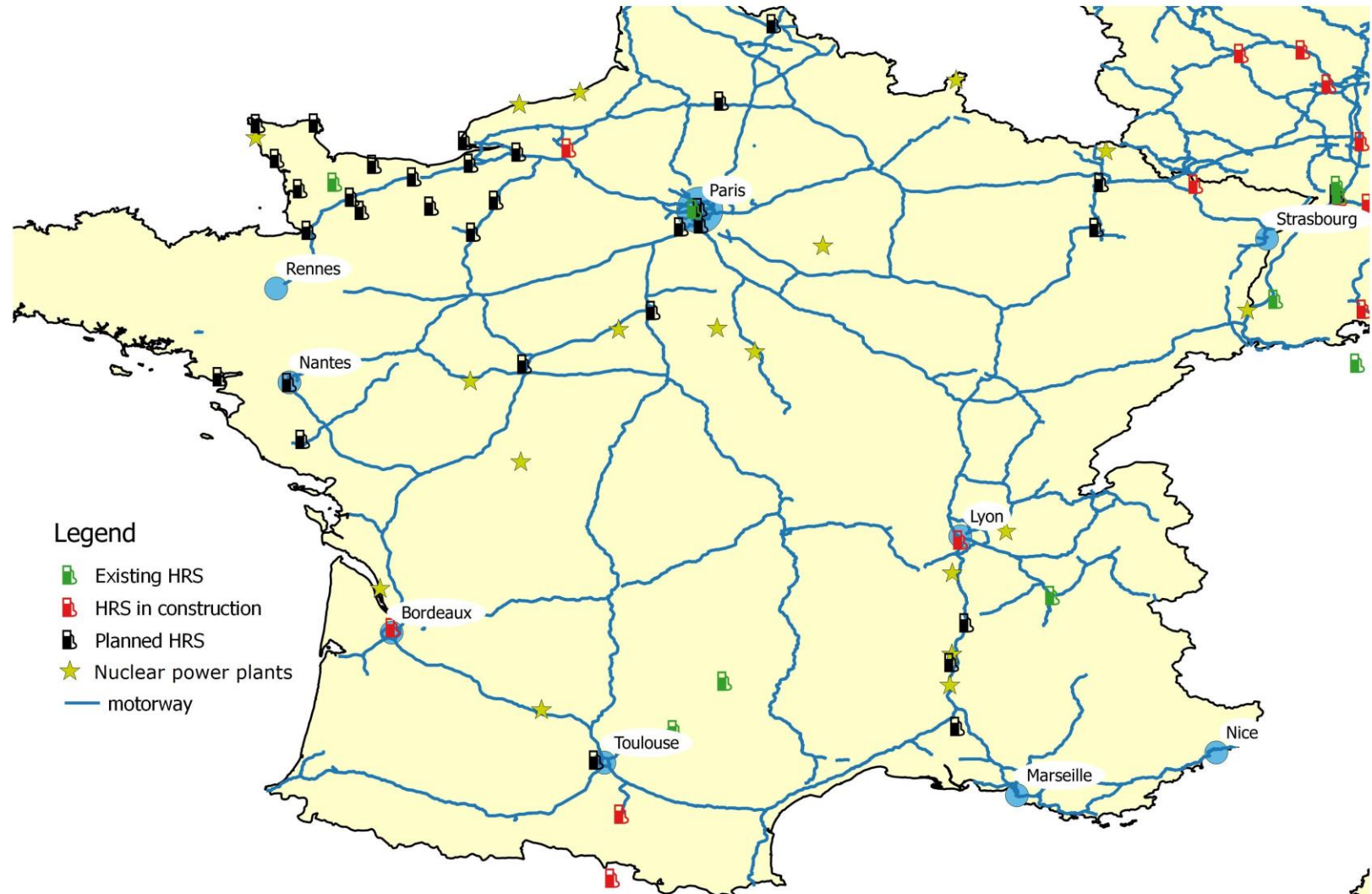


Hydrogen infrastructure

Via truck



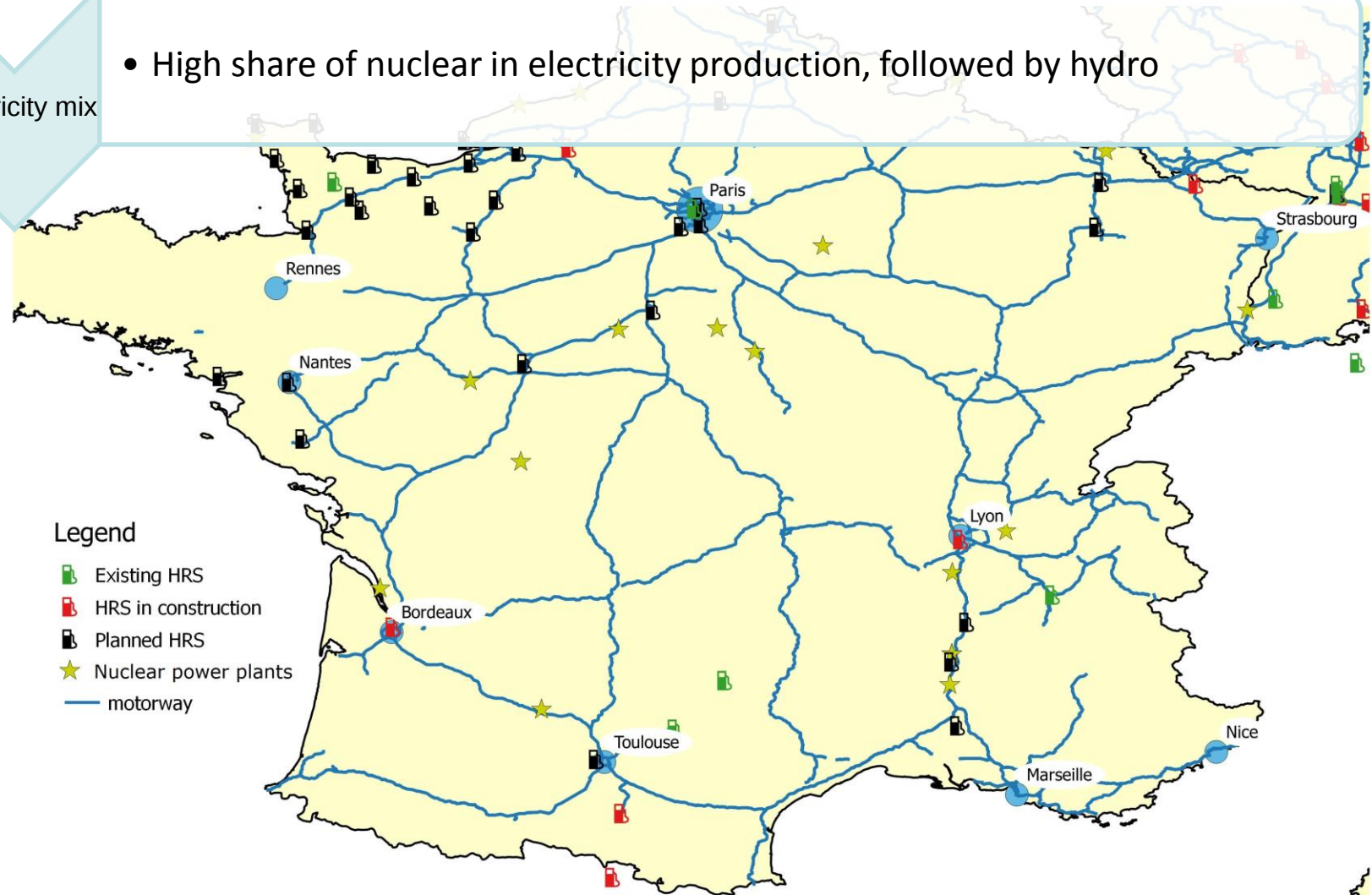
Modeling framework, France



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

Electricity mix

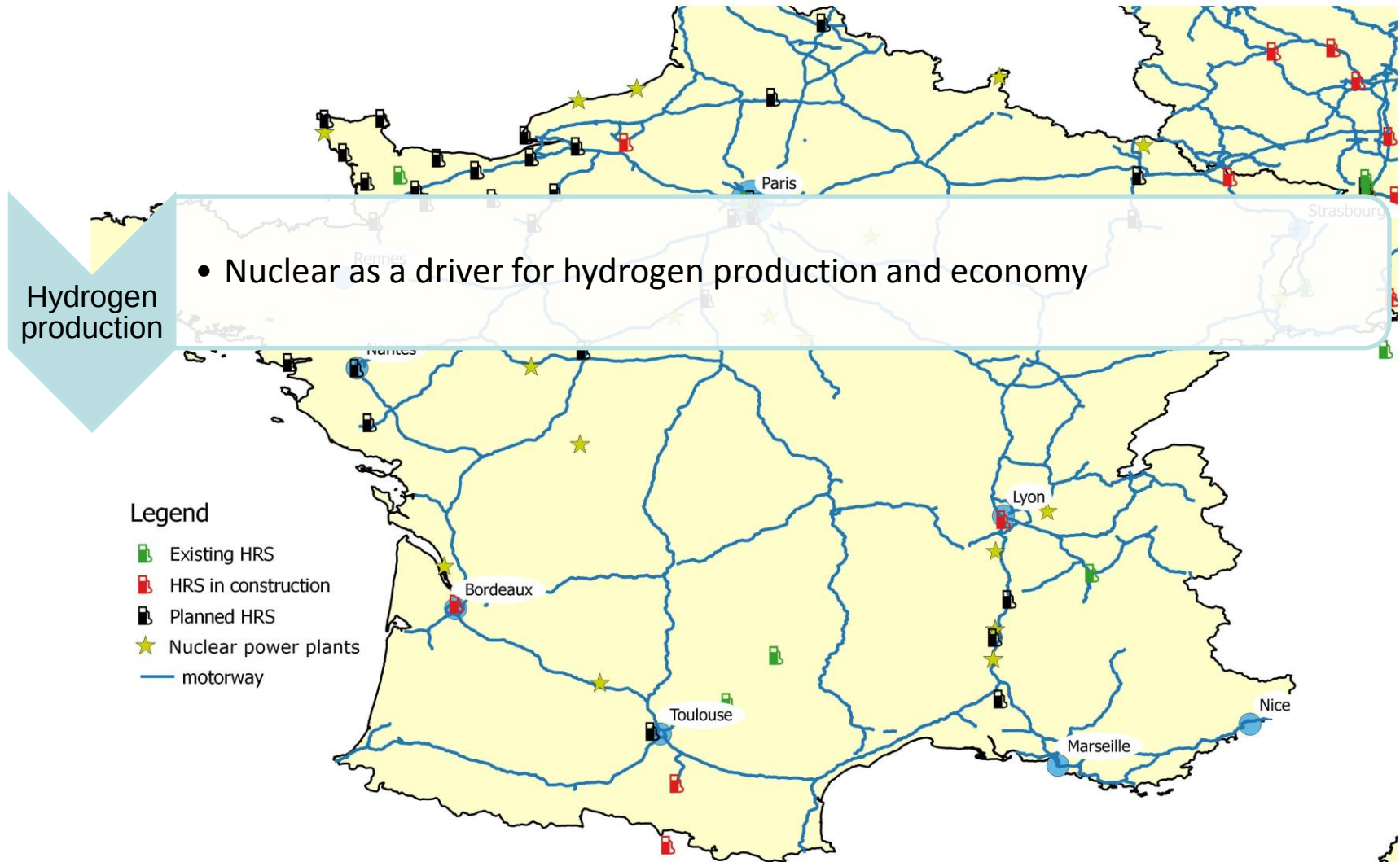
- High share of nuclear in electricity production, followed by hydro



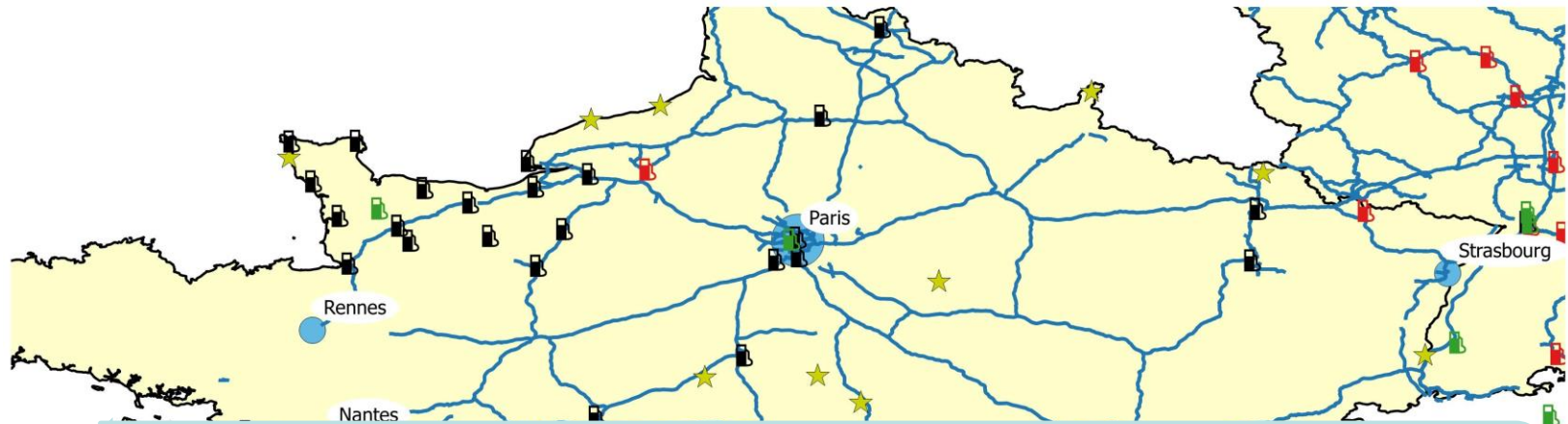
Legend

- Existing HRS
- HRS in construction
- Planned HRS
- Nuclear power plants
- motorway

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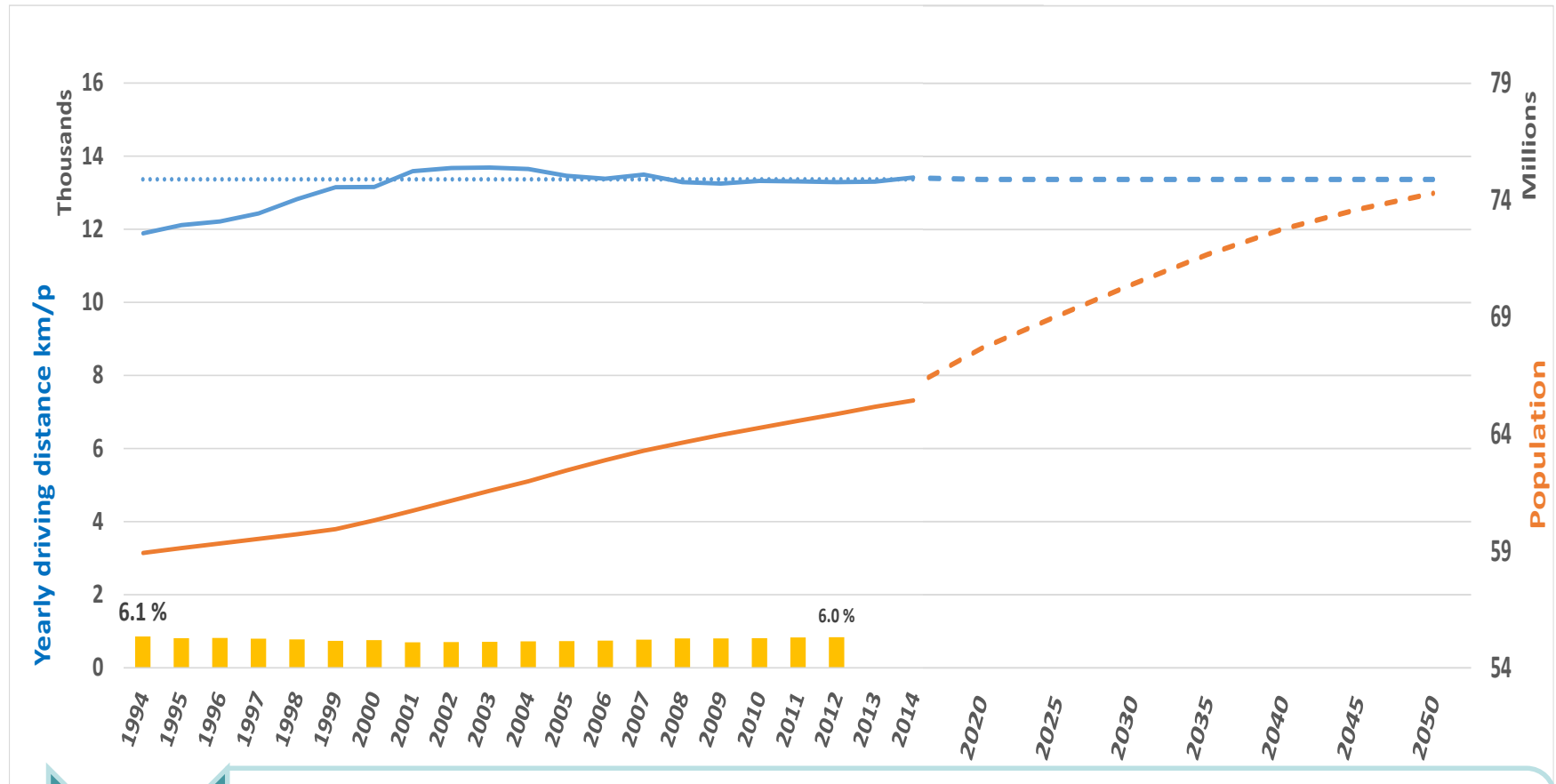
Infrastructure
deployment

- 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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Modeling framework, France



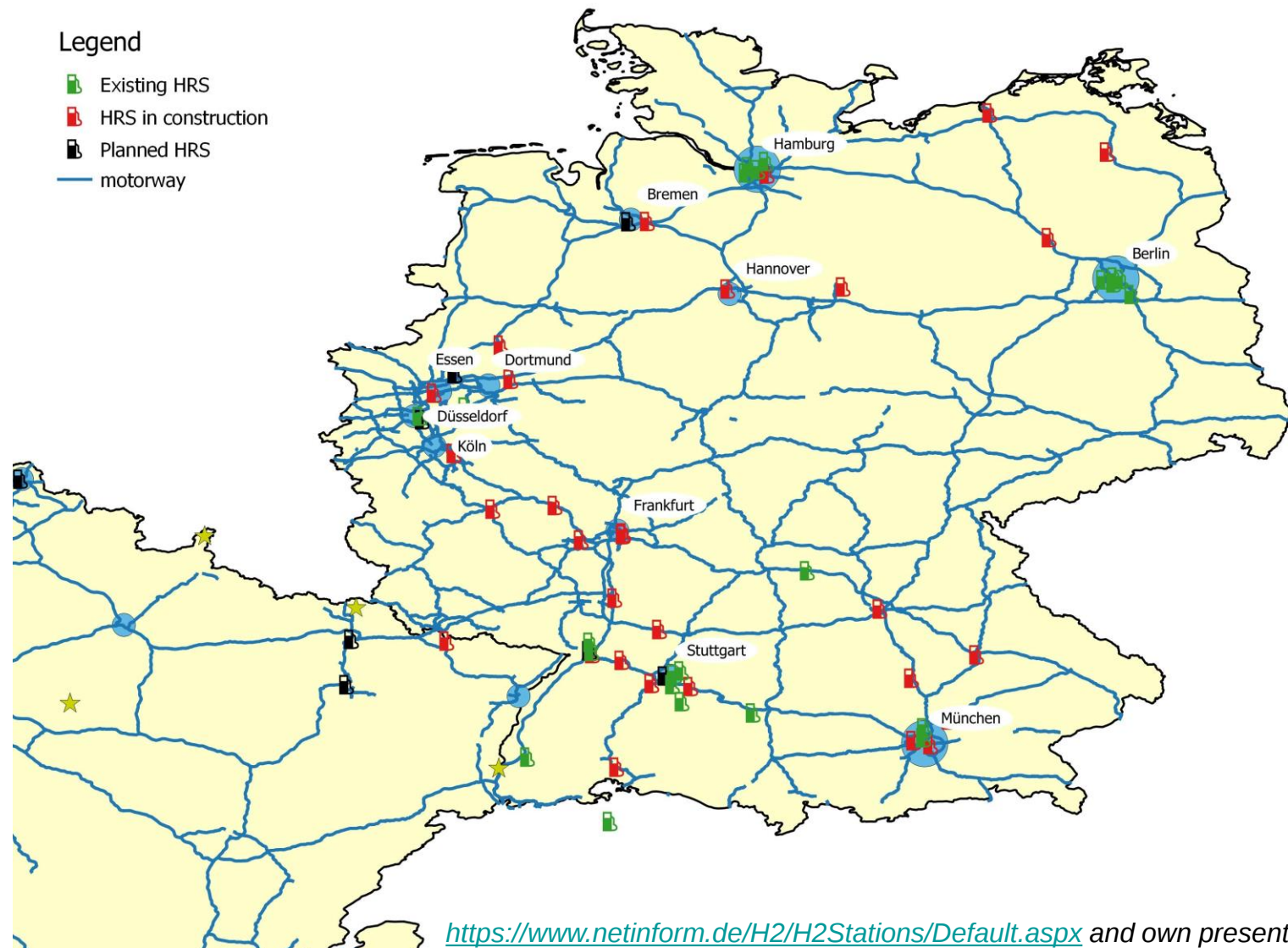
Hydrogen
demand

- 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*

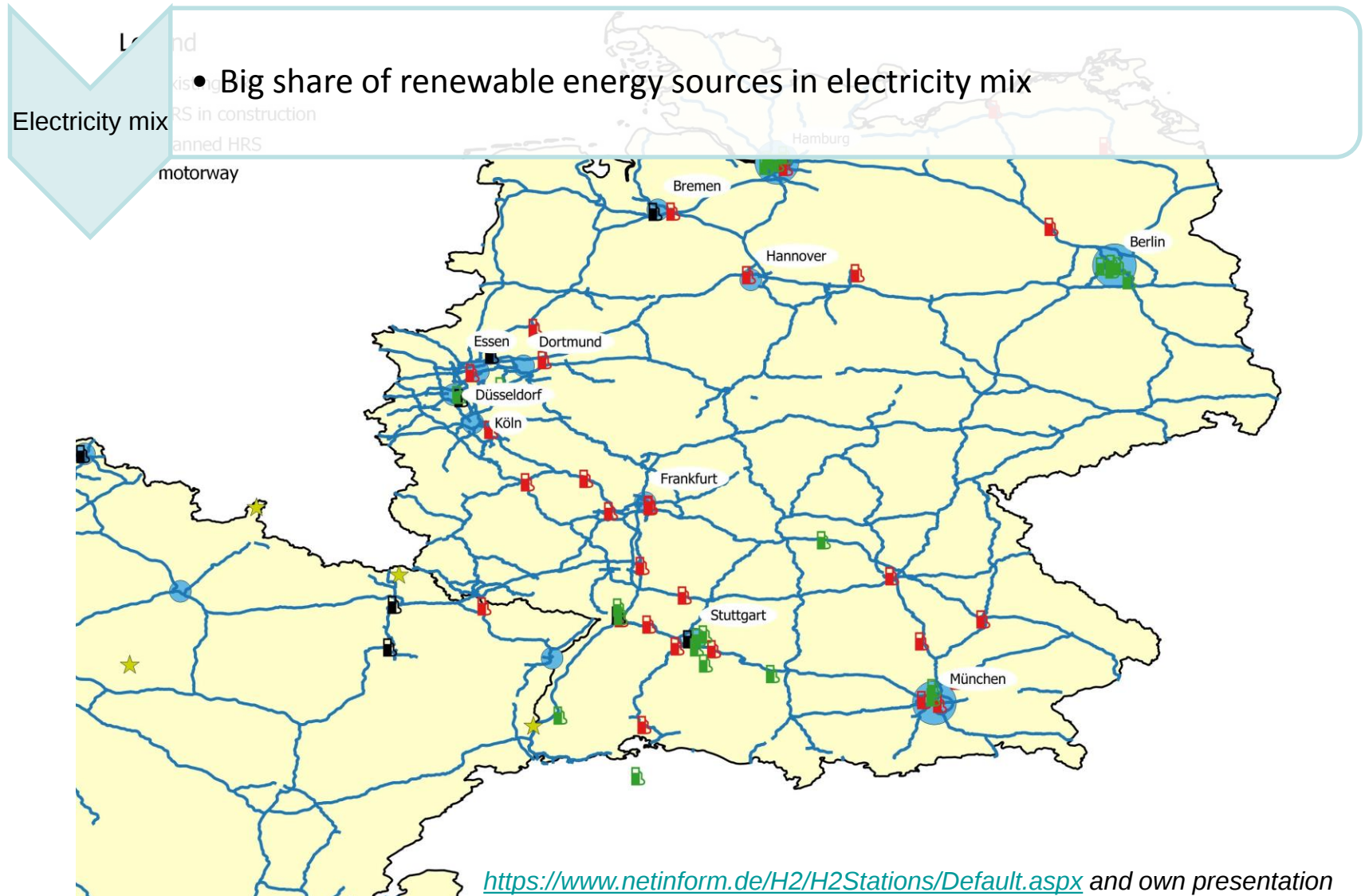
[5] EUROSTAT (2016) *Transport statistics*

Modeling framework, Germany



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

Modeling framework, Germany



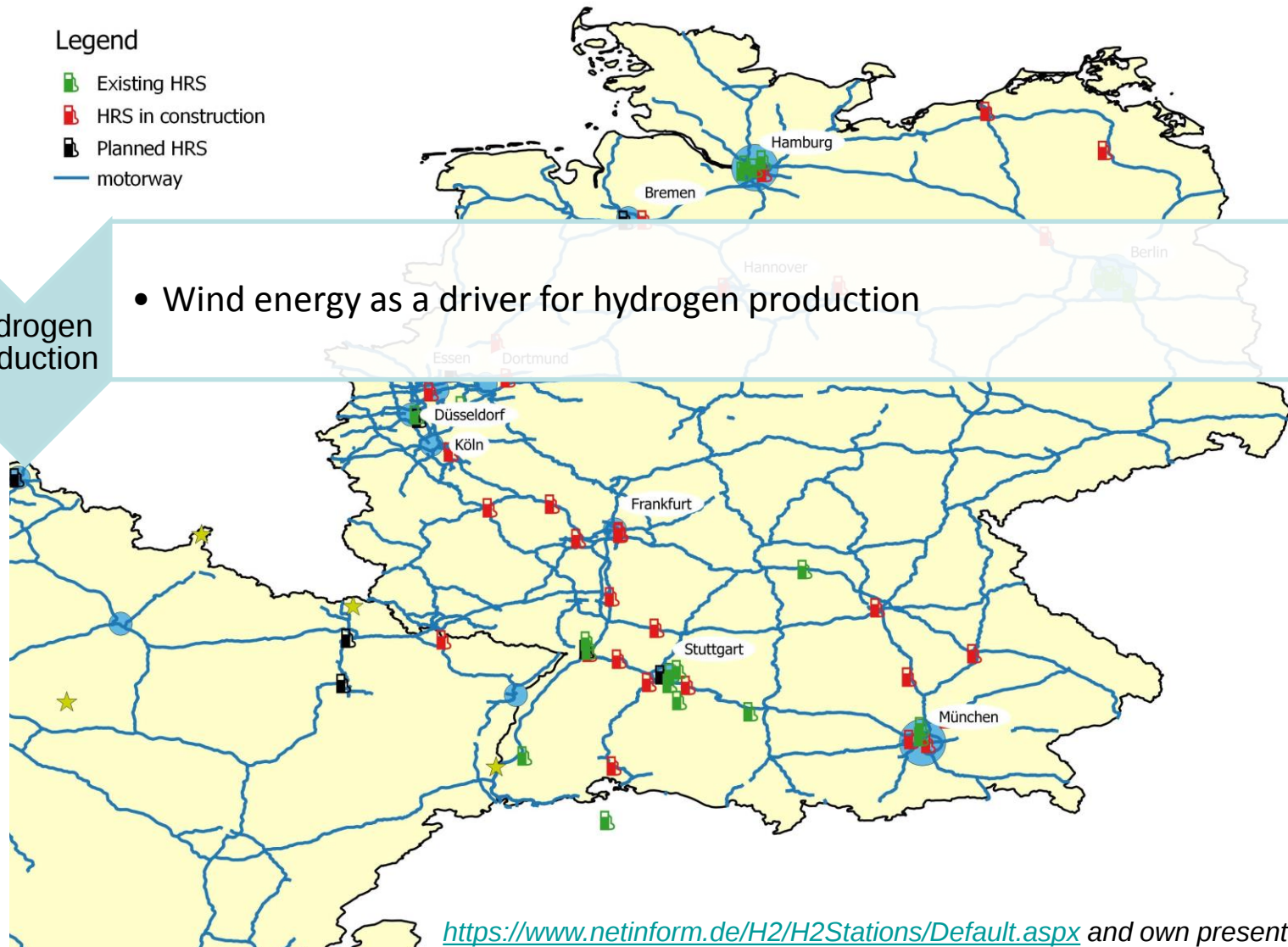
Modeling framework, Germany

Legend

-  Existing HRS
-  HRS in construction
-  Planned HRS
-  motorway

Hydrogen
production

- Wind energy as a driver for hydrogen production

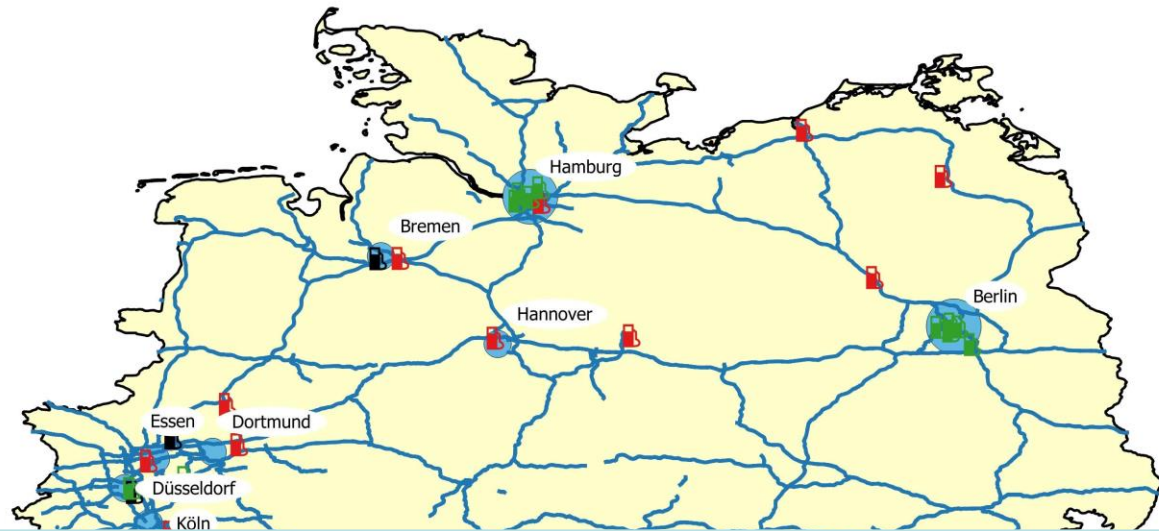


<https://www.netinform.de/H2/H2Stations/Default.aspx> and own presentation

Modeling framework, Germany

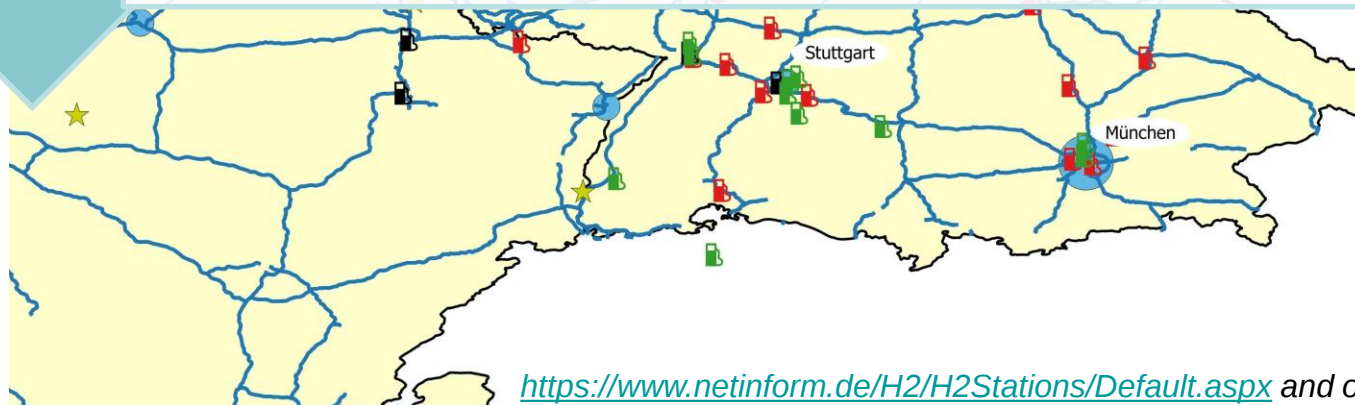
Legend

-  Existing HRS
-  HRS in construction
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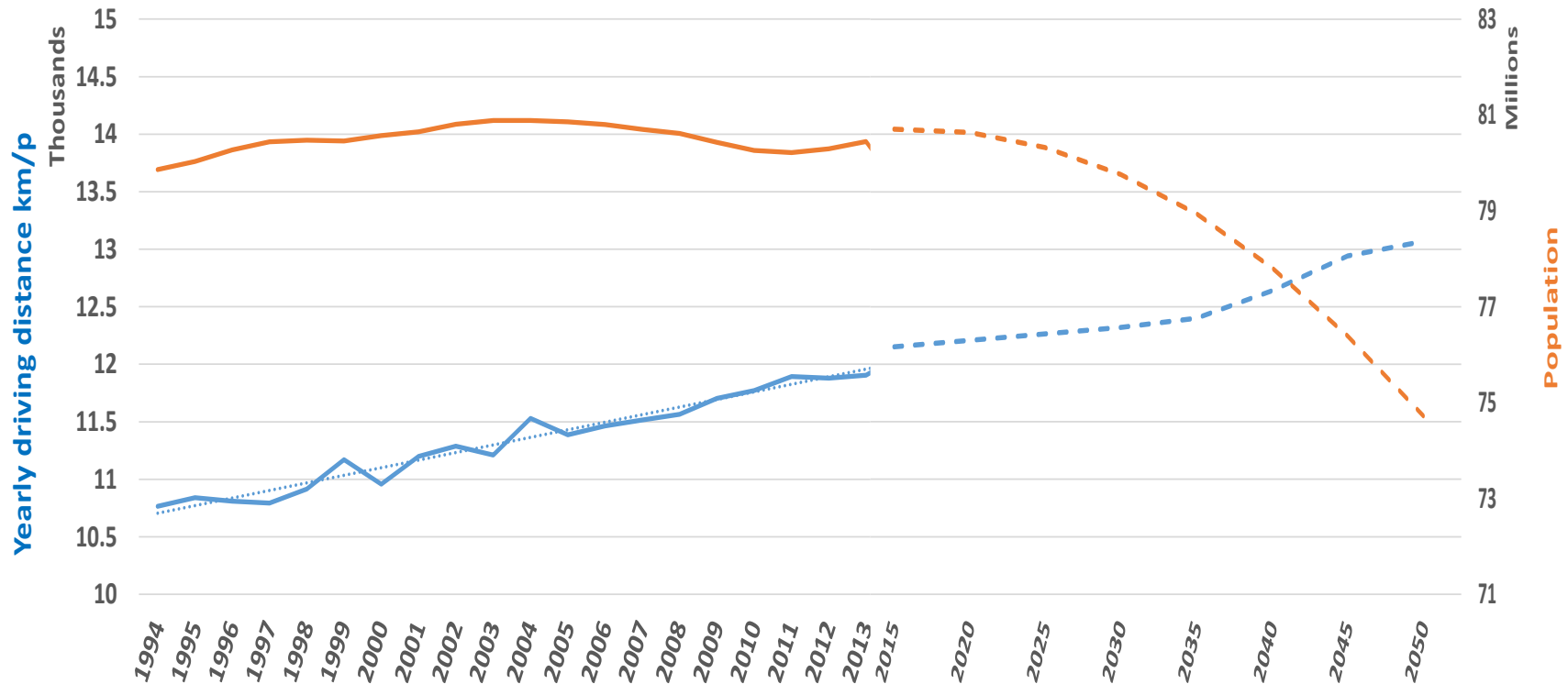
Infrastructure
deployment

- 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

Modeling framework, Germany



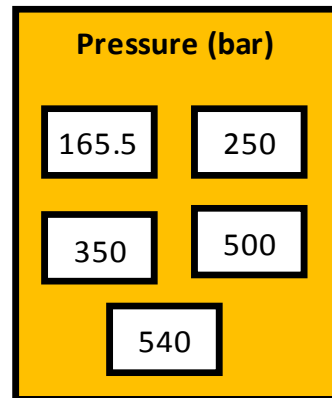
Hydrogen
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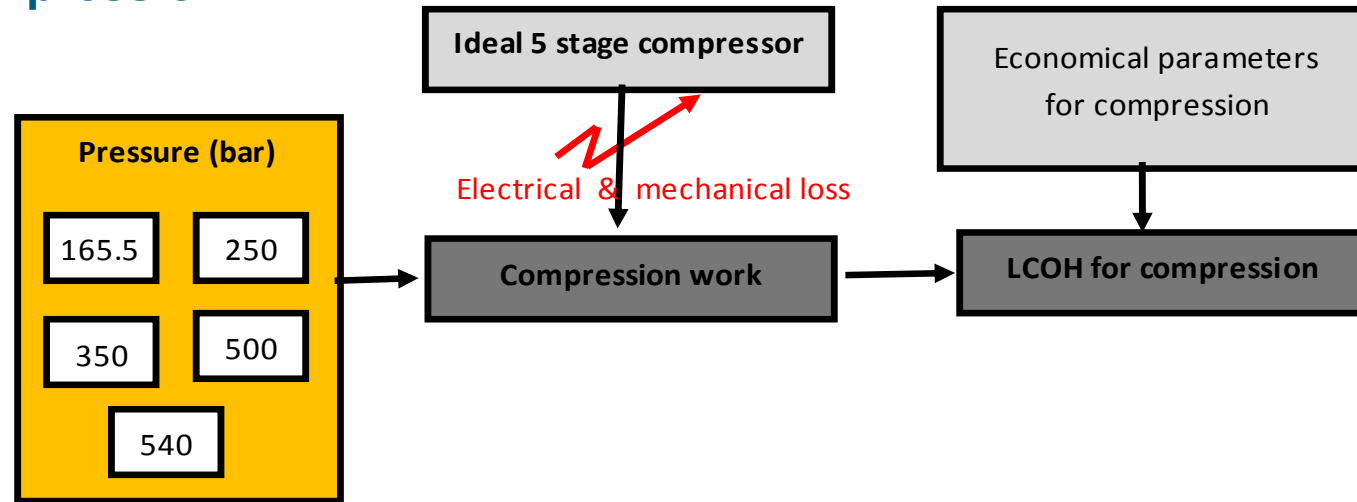
[4] IEA (2015) *Technology Roadmap, Hydrogen and Fuel Cells*

[5] EUROSTAT (2016) *Transport statistics*

Model Variables



Model Compression

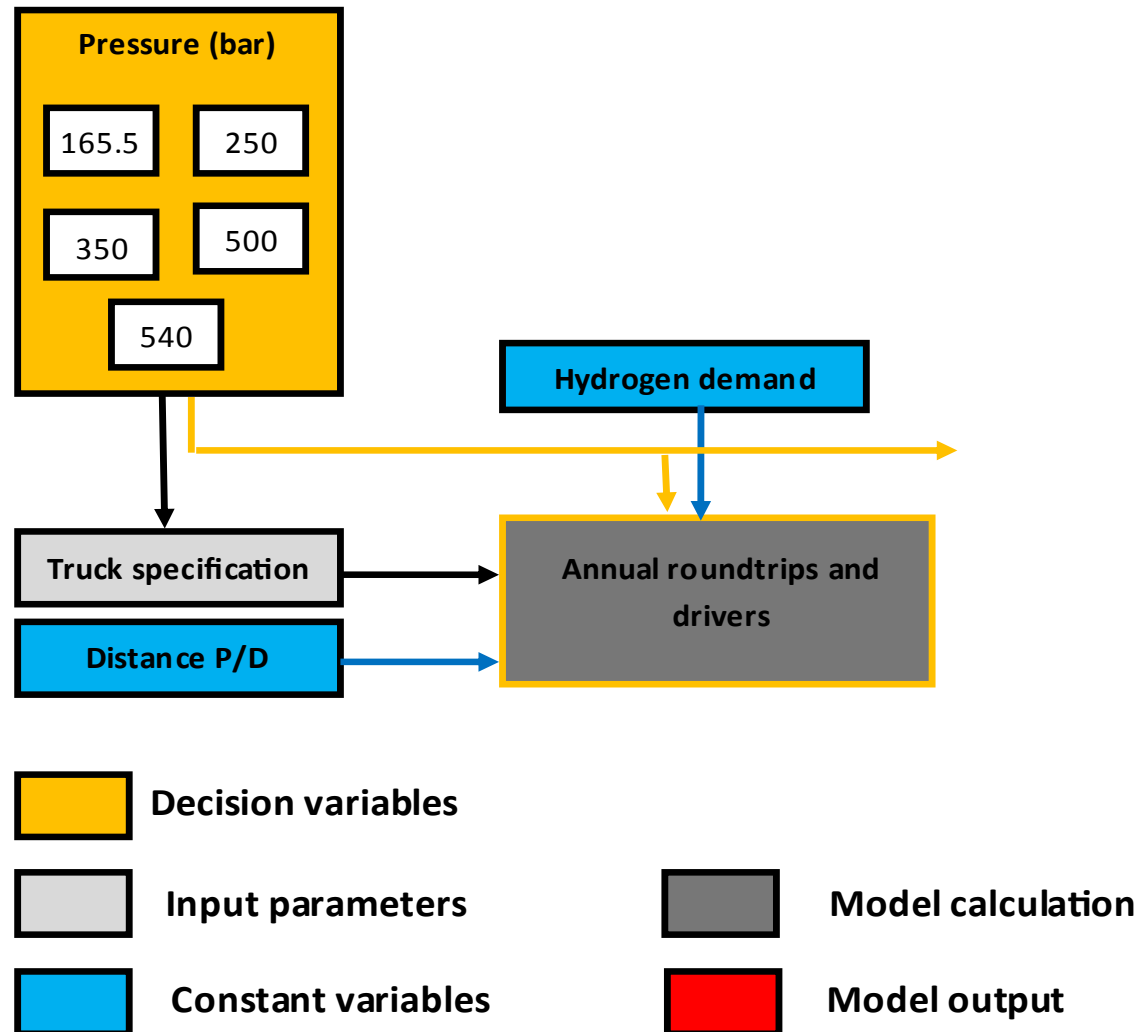


LCOH Levelized cost of hydrogen



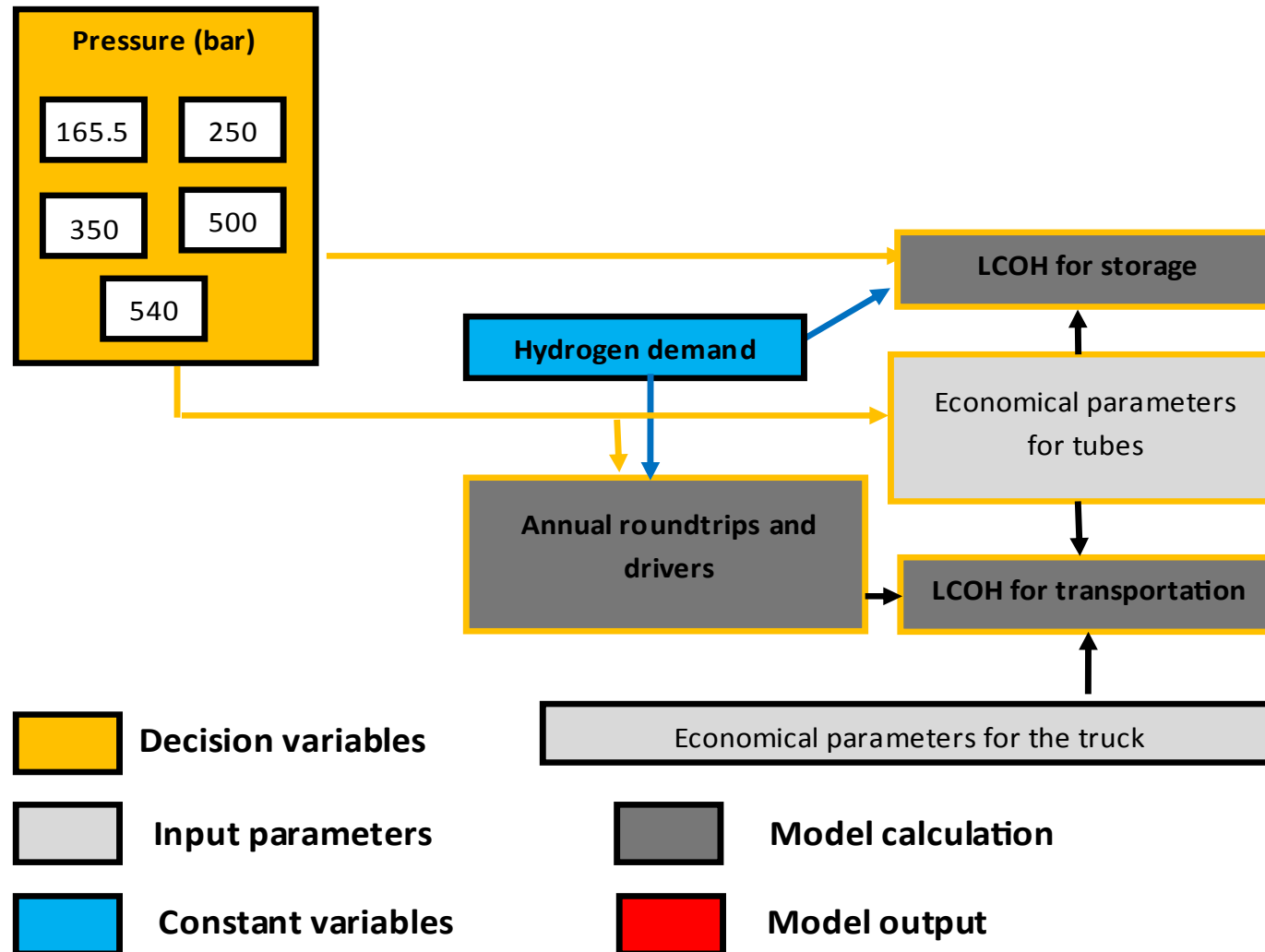
Model

Transportation and storage



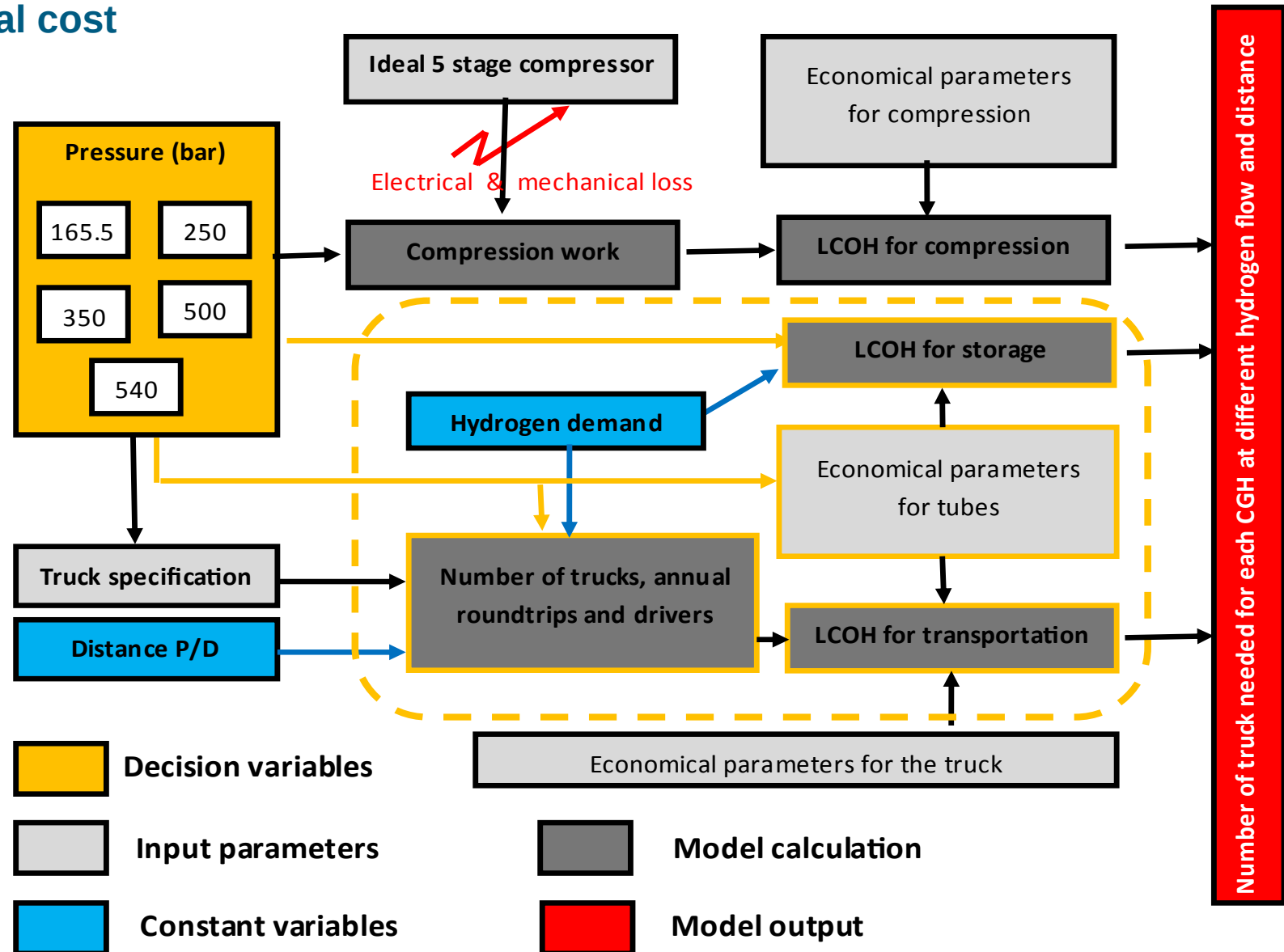
Model

Transportation and storage



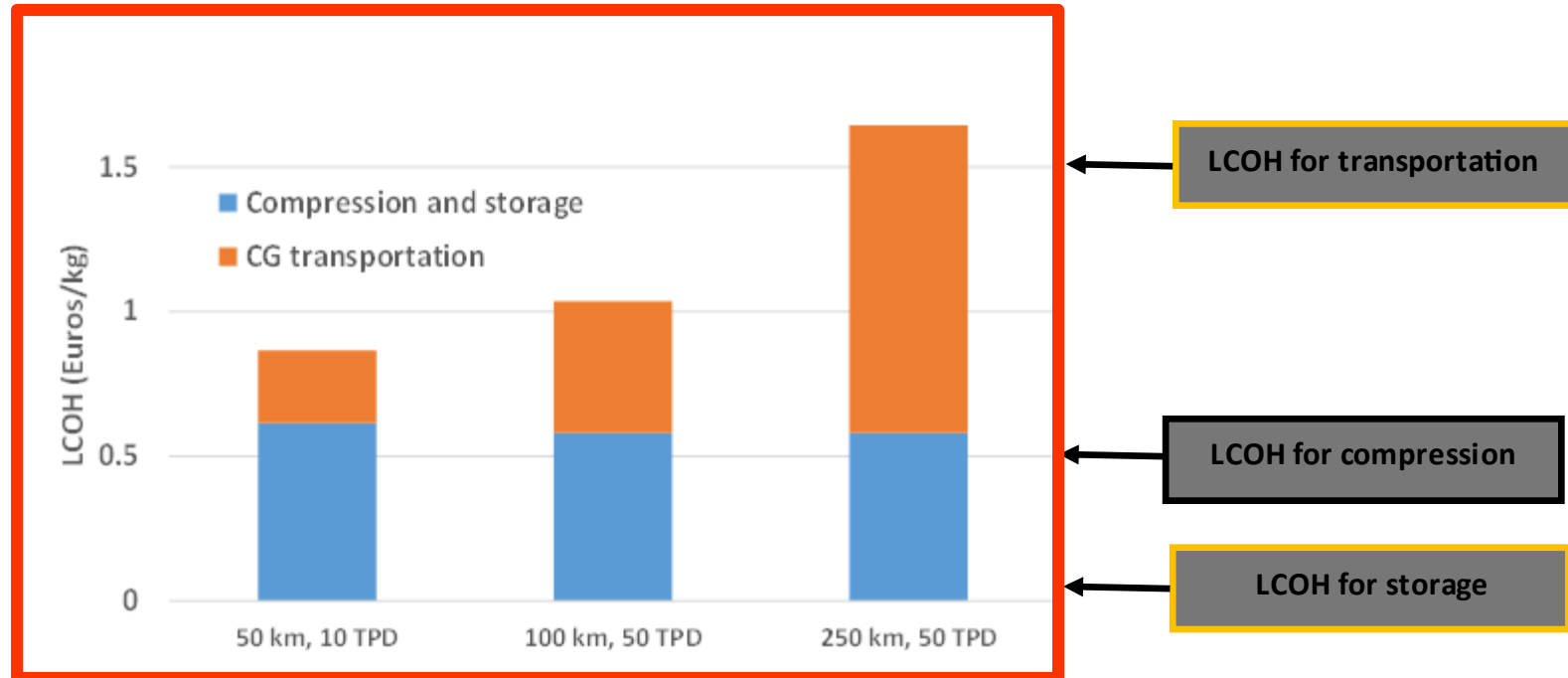
Model

Total cost



Model results

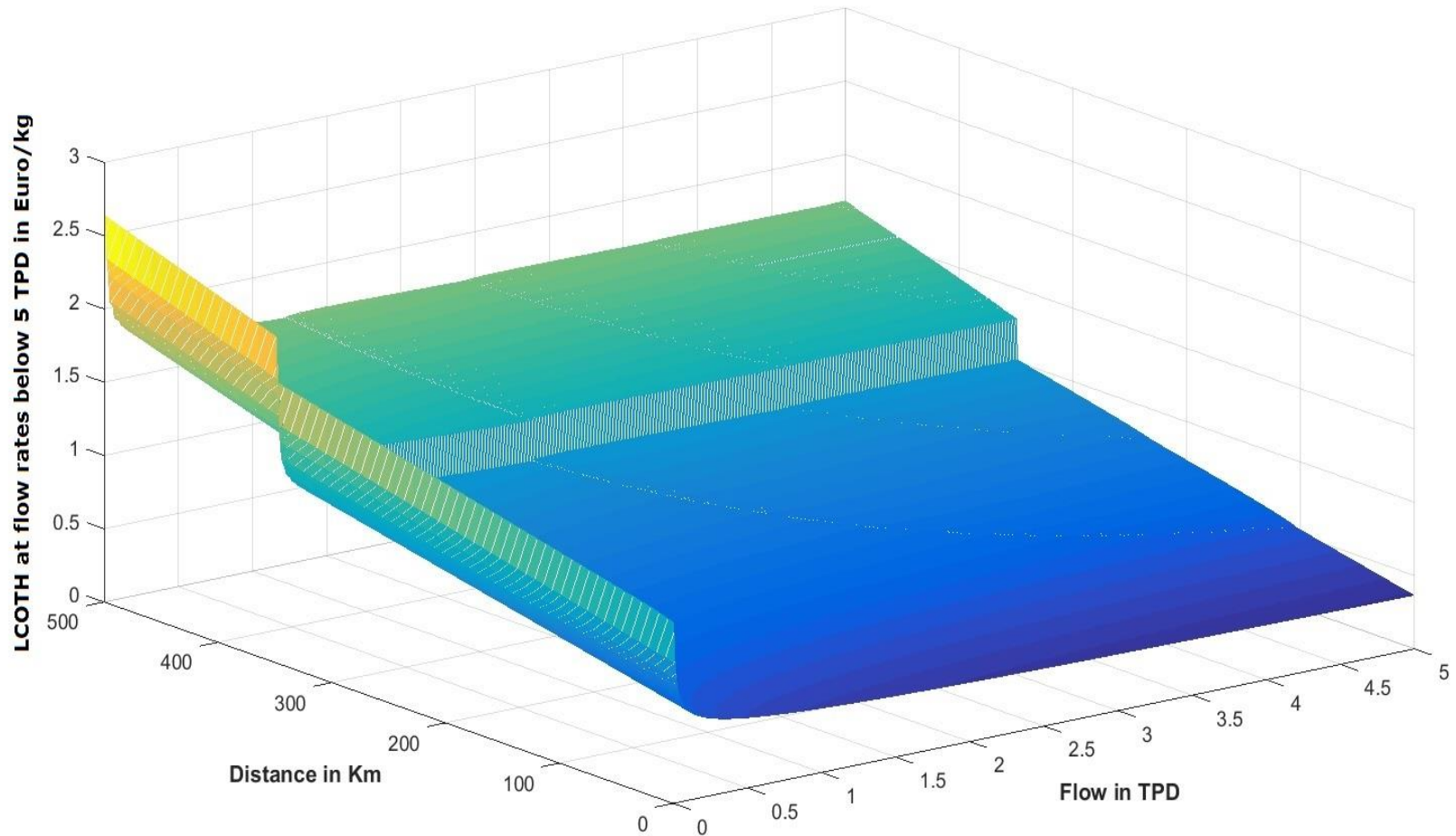
LCOH for transportation, storage and compression



TPD: Ton per day

Model results

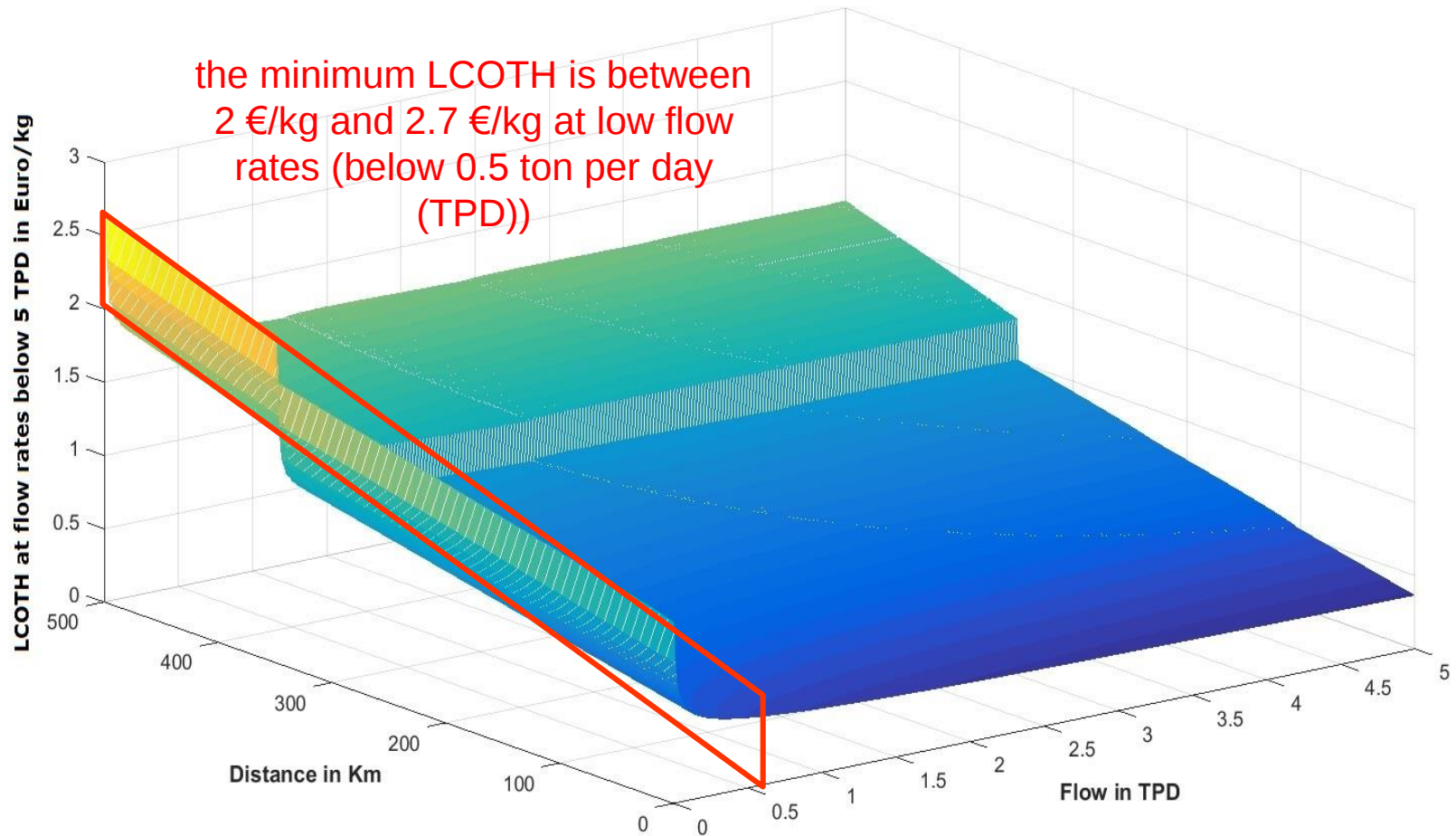
LCOTH



LCOTH Levelized cost of transporting hydrogen

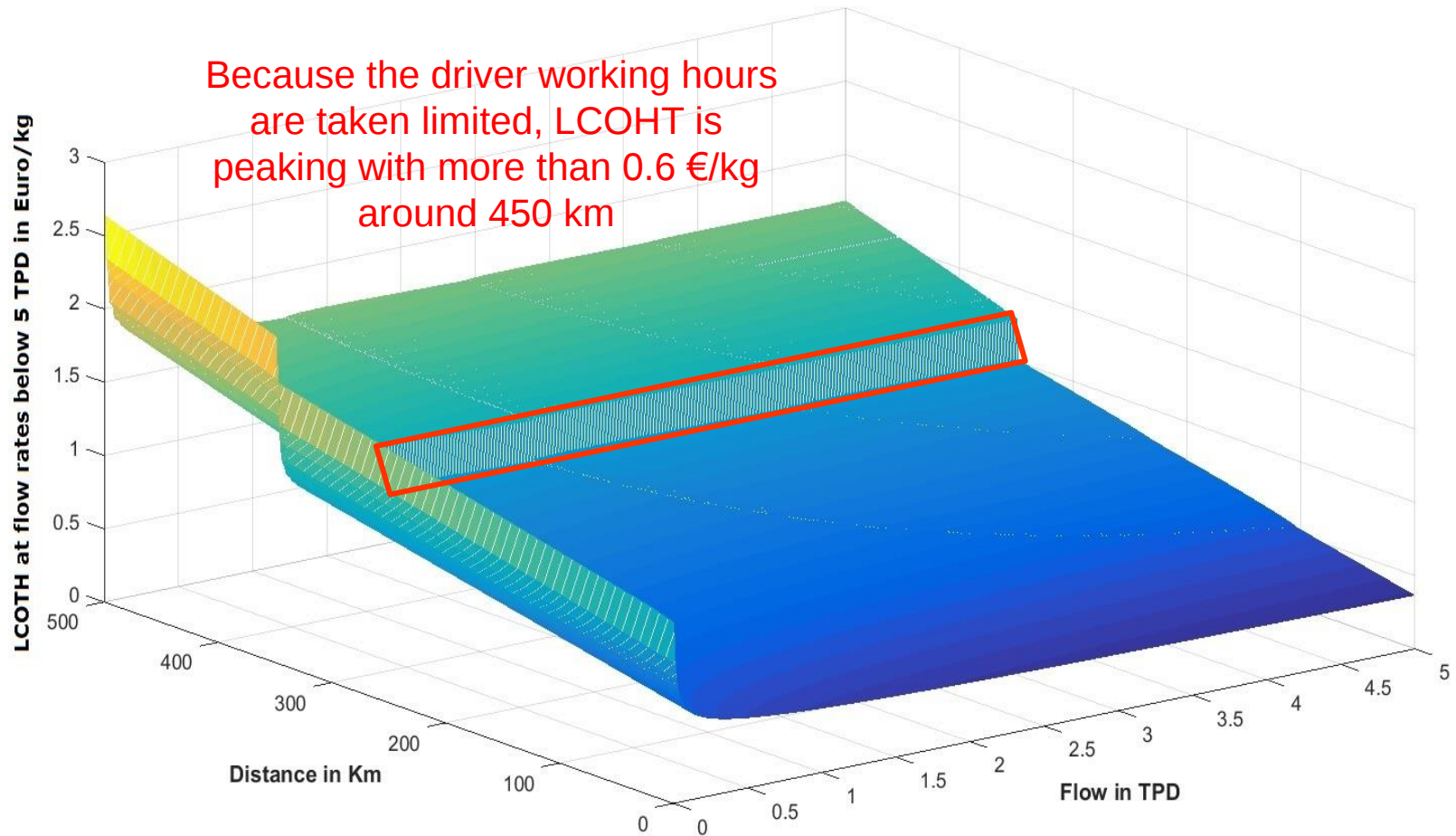
Model results

LCOTH



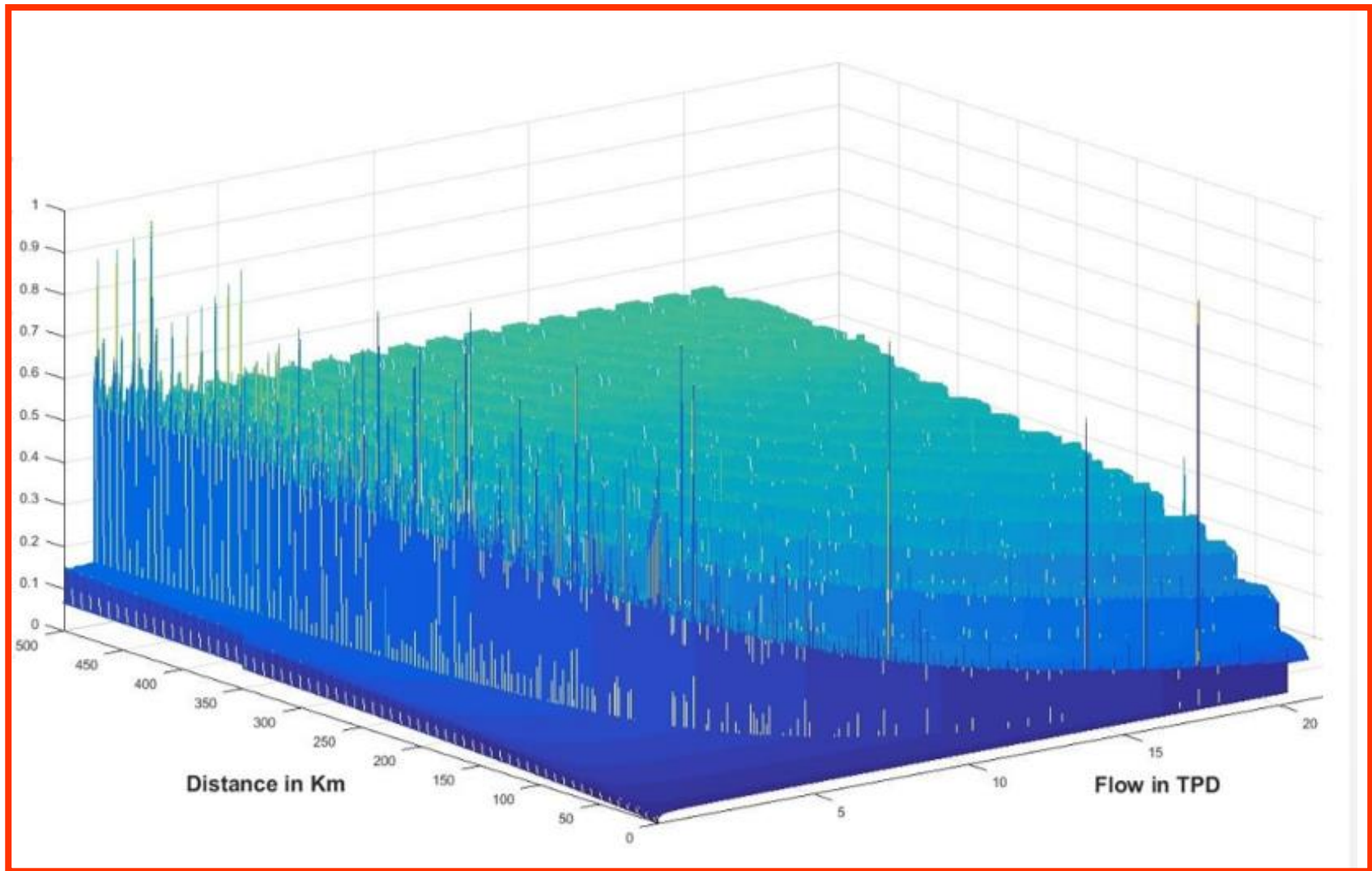
Model results

LCOTH



Model results

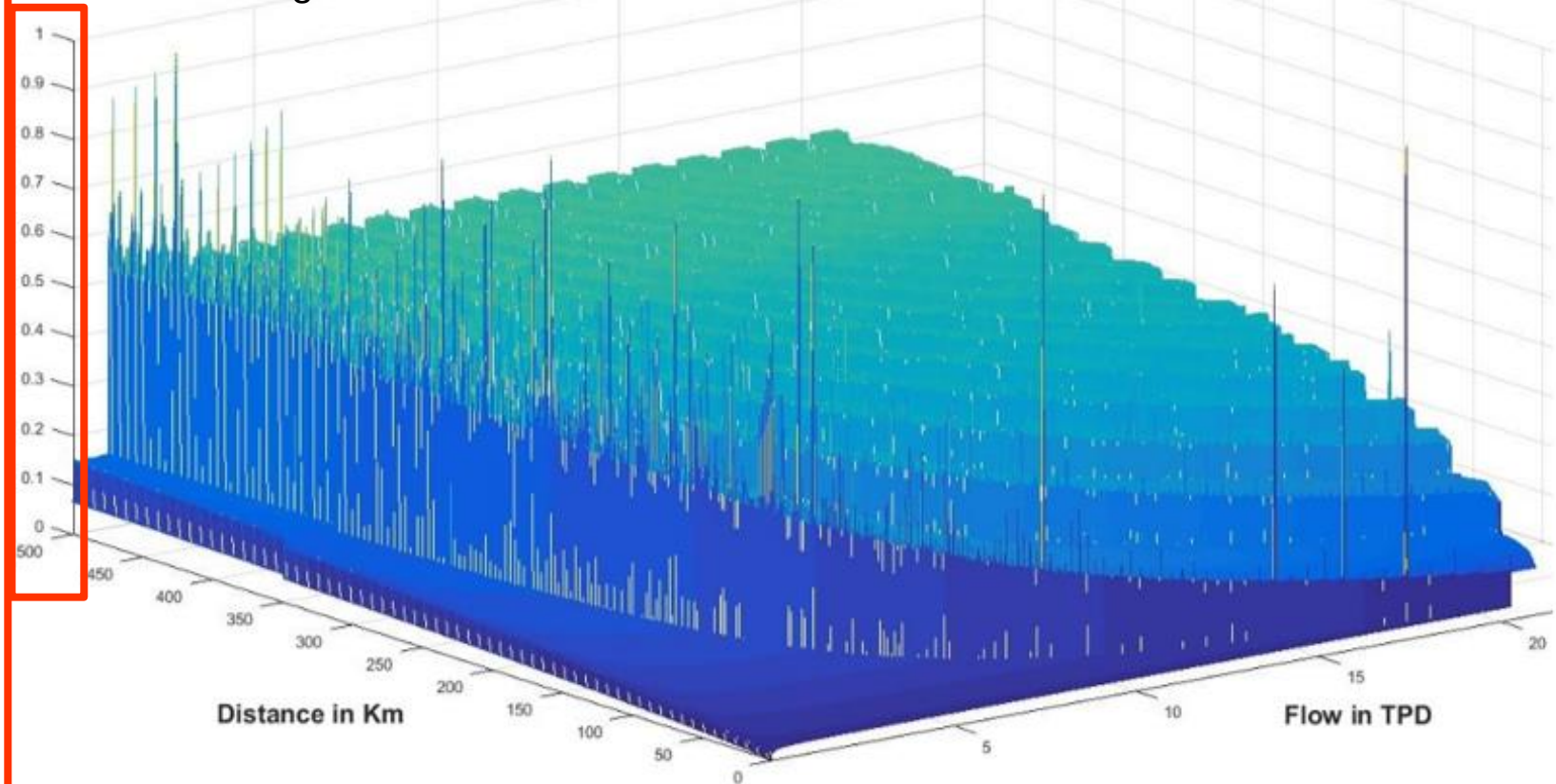
Share of transporting CGH at 540 bar



Model results

Share of transporting CGH at 540 bar

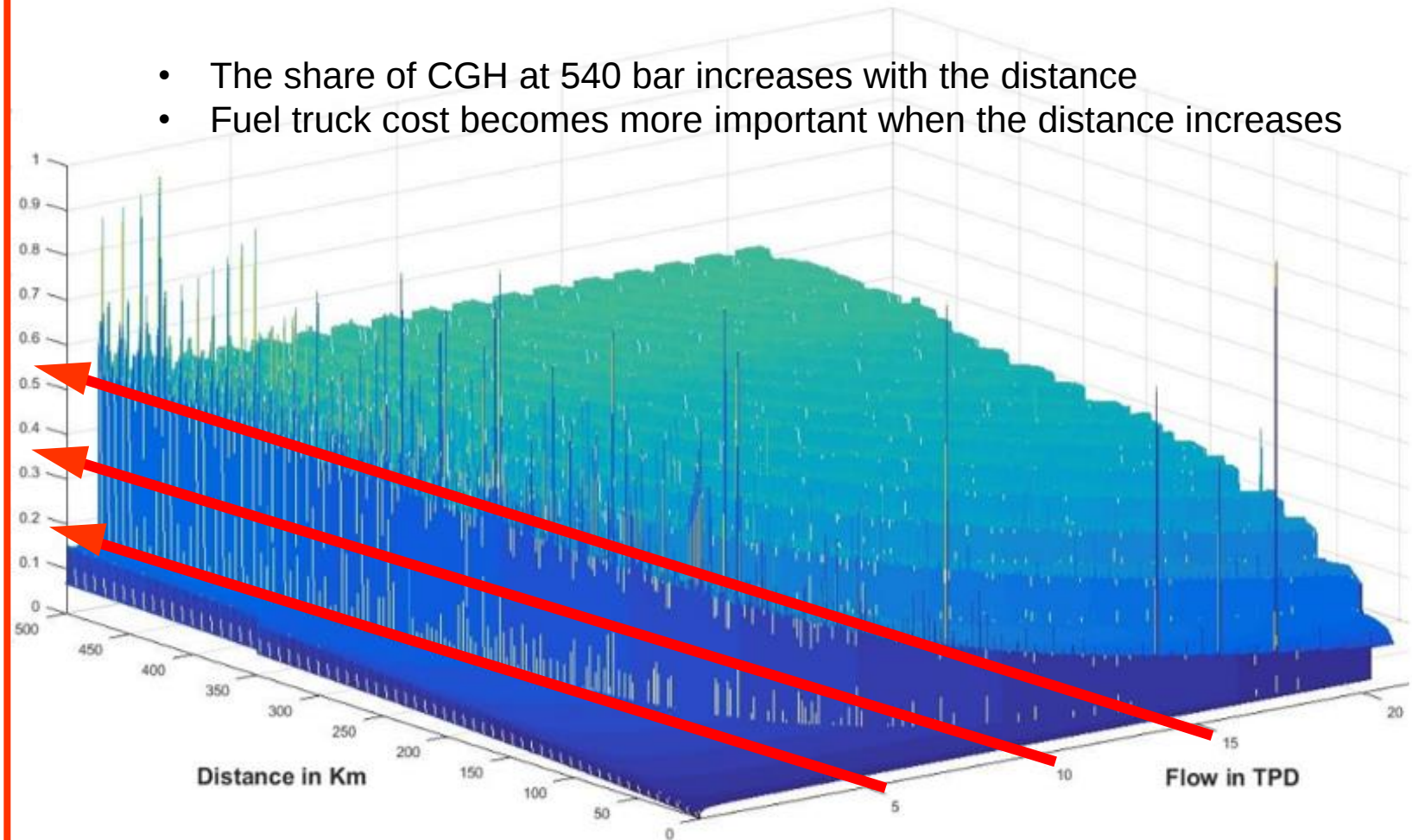
- **0** corresponds to the case where no CGH at 540 bar is used
- **1** corresponds to the case where 100 % of the capacity is transported using a CGH at 540 bar



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



- **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**

- 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 cost are important at low hydrogen flow
 - Fuel cost are important at long distance
- Driver costs impact on the total transportation cost

Thank you for your attention

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Dipl.-Ing. Amin Lahnaoui, MSc.
Institut für Energie- und Klimaforschung -
Systemforschung und Technologische Entwicklung (IEK-STE)

Telefon: [+49 2461 61-3275](tel:+492461613275)

Telefax: [+49 2461 61-2540](tel:+492461612540)

E-Mail: a.lahnaoui@fz-juelich.de