LCA OF AUTOMOTIVE TECHNOLOGIES AND MOBILITY SCENARIOS

A journey through four scales of LCA applications

AUTOMOTIVE DAY IN GRANDE REGION •
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Enrico Benetto

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LCA is a a matter of scale of analysis

Policies: *What are the environmental consequences of mobility scenarios on a territorial level ?*

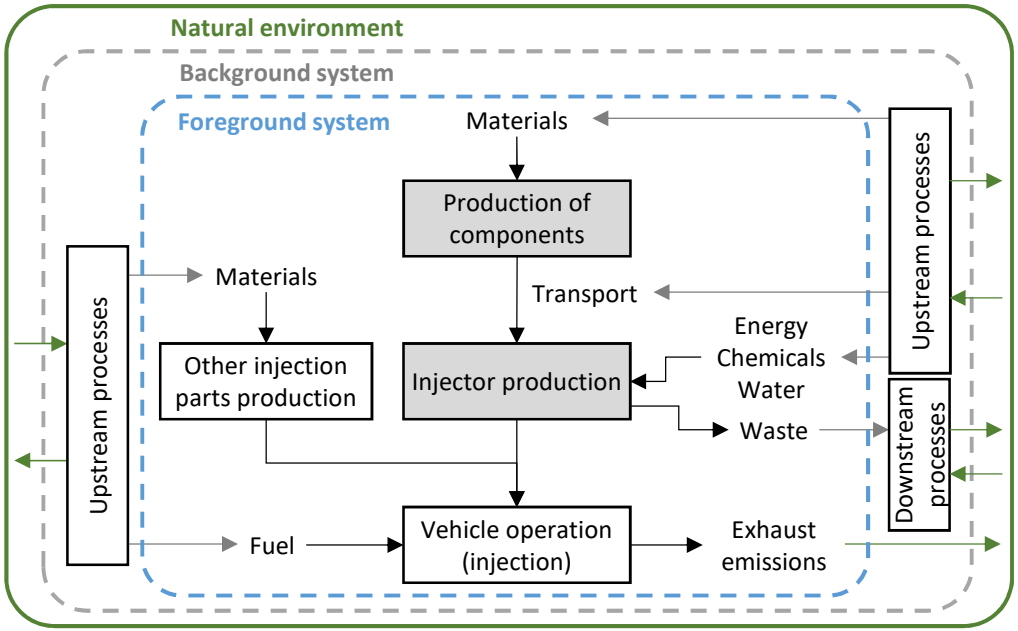
Vehicles*: What are the environmental impacts of an electric vehicle as compared to a thermal engine one ?*

Components: *What are the environmental impacts associated to a newly developed component (technology) as compared to status quo?*

Component scale:

What are the environmental impacts associated to a newly developed component (technology) as compared to status quo?

Direct injection (DI) of compressed natural gas (CNG) developed at pilot scale

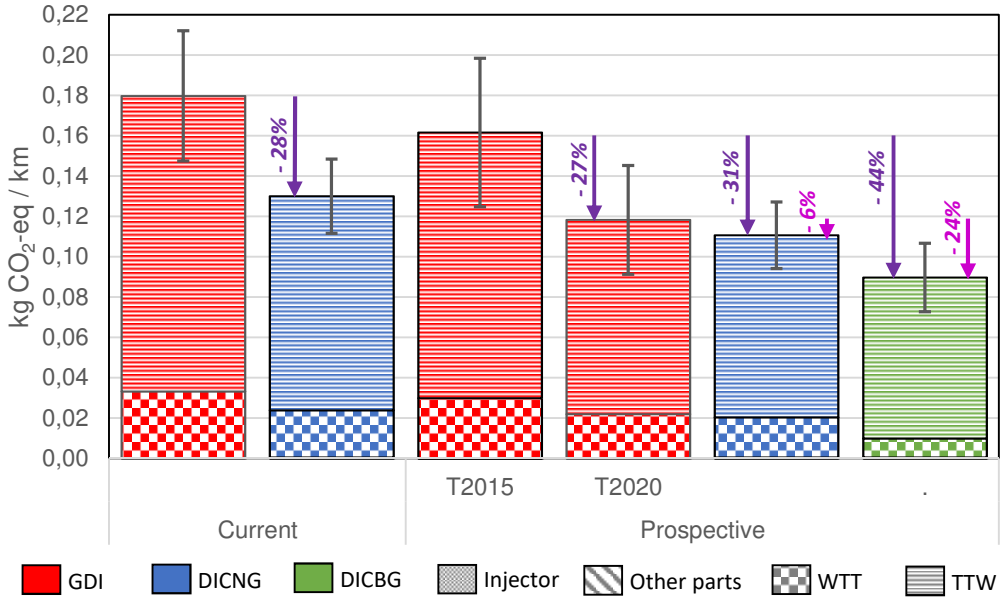


Functional unit:

- Production of one injector (Poland)
- Injection of fuel to drive a medium-size passenger car over one kilometre in average European conditions, based on engine efficiency of 2015 and on prospective efficiency between 2015 and 2020

Carbon footprint: lifecycle impacts

- DI-CNG system generate less GHGs (lower TTW CO_2 emissions) than GDI but no significant difference with *GDI_T2020* scenario
- The use of biogas improves the carbon footprint (carbon balance between CO_2 intake and emissions)
- Main contribution WTT and TTW phases (CO_2 emissions from fuel combustion, CH_4 emissions from biogas purification for DI-CBG)
- Negligible impacts from the production of injectors and other engine parts



Comparison	Probability	Conclusion
DICNG_NoImprv better than GDI_current	92%	Very likely advantage
DICNG_Imprv better than GDI_T2015	91%	Very likely advantage
DICNG_Imprv better than GDI_T2020	58%	No significant difference
DICBG_Imprv better than GDI_T2015	98%	Very likely advantage
DICBG_Imprv better than GDI_T2020	82%	Likely advantage
DICBG_Imprv better than DICNG_Imprv	94%	Very likely advantage

Other impacts: lifecycle impacts

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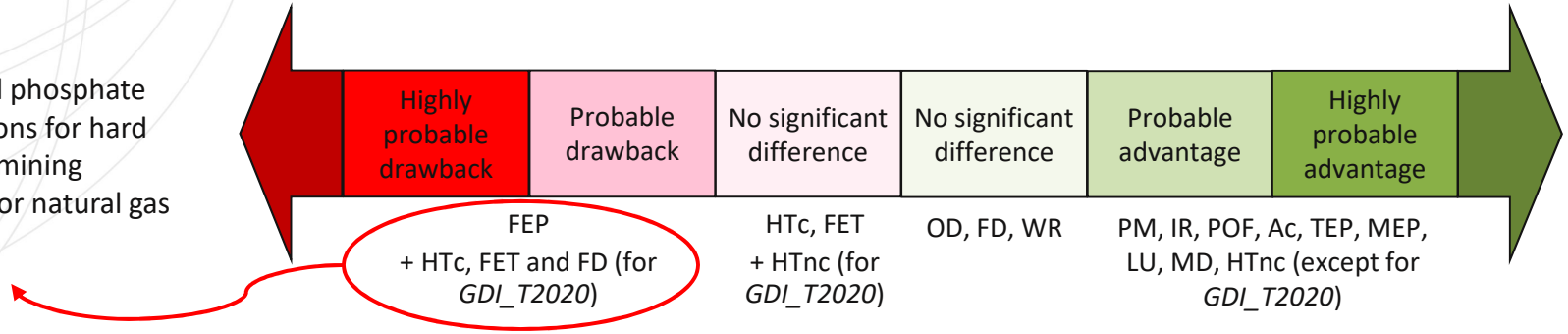
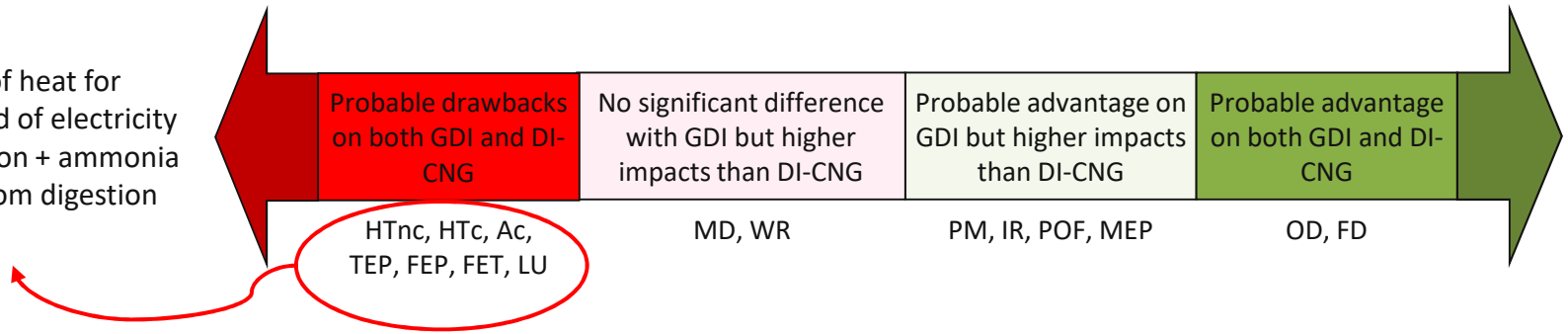
DI-CNG effects compared to GDI:

Metallic and phosphate spoil emissions for hard coal/lignite mining (electricity for natural gas transport)



DI-CBG impacts:

Production of heat for digestion and of electricity for purification + ammonia emissions from digestion (TEP)



Challenges

- Consequences of new technology on background processes ?
- Foreground data representativeness ? Validation with up-scaled production for DI-CNG ? (in particular electricity consumption)
- Background processes representativeness ? (EU average, several old data, some proxies)
- End-of-life of injectors ? (negligible?)
- Uncertainty from LCIA methods ?

Inventory data	Reliability	Comple-teness	Temporal correlation	Geographical correlation	Technological correlation
Injector components	1	4	1	1	1
Injector assembly (GDI)	3	4	1	5	1
Injector assembly (DI-CNG)	4	4	1	5	4
Other engine parts (Delphi data)	4	4	1	1	1
Other engine parts (estimated)	4	5	1	2	2
Fuel consumption (current)	2	3	1	2	2
Fuel consumption (prospective)	4	5	1	2	3
TTW emissions	3	3	1	1	2

Vehicle scale:

What are the environmental impacts of an electric vehicle as compared to a thermal engine one ?

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Website: climobil.connecting-project.lu

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Territorial policy scale:

What are the environmental consequences of mobility scenarios on a territorial level ?

Cross-border commuting

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order
uters

bs:

annually

.7% for
sidents

+1.6% for
Luxembourgers

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Complementary visions

…at the decision making level

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François Bausch	Claude Turmes
• Minister of **Transportation** • All public transport free from 2020 • 2 G€ investment in rail • 300 M€ in tram	• Minister of **Energy** • 800 EV charging points in 2020 • Car-sharing • Green electricity, GOs, …

Framework
Methods overview

Fonds National de la Recherche Luxembourg

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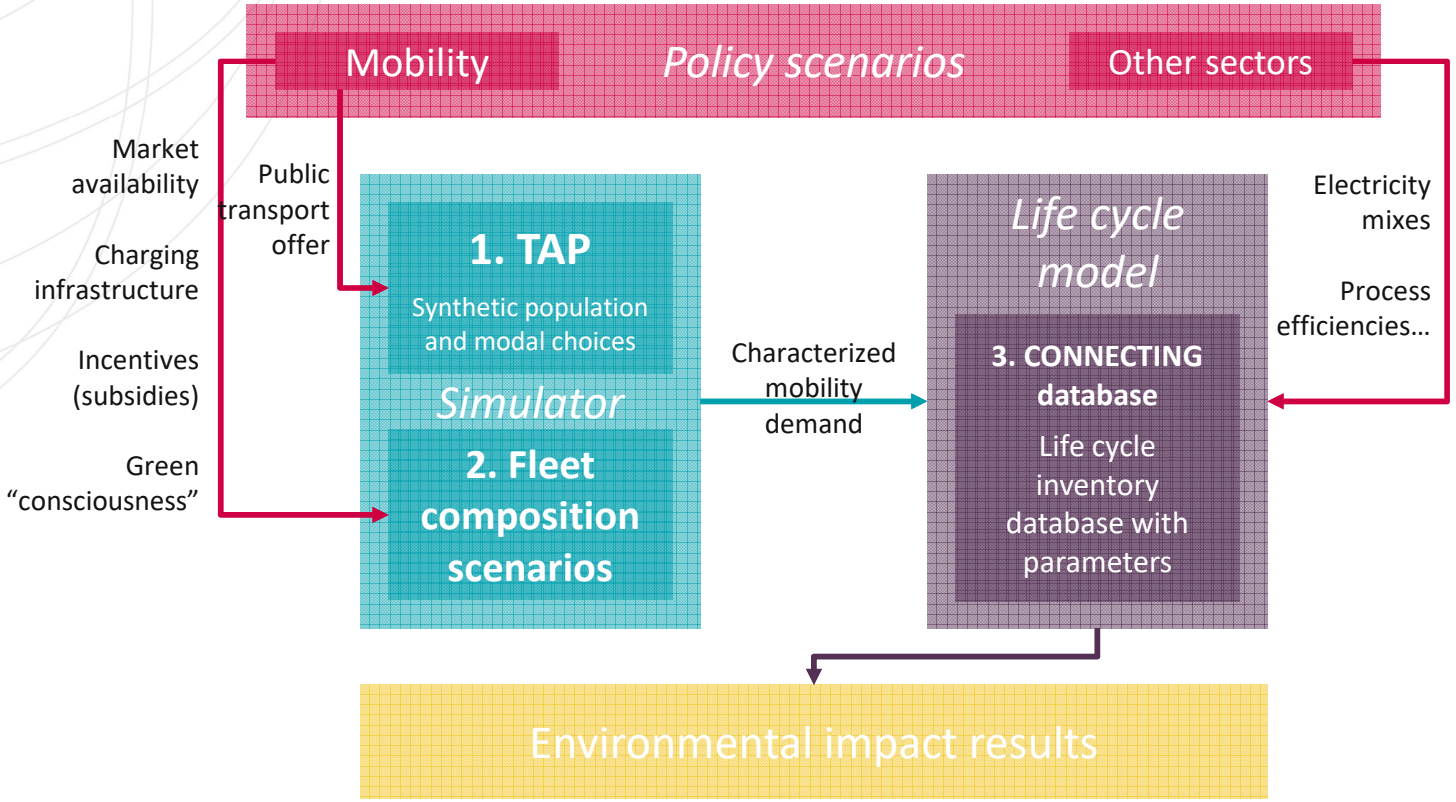
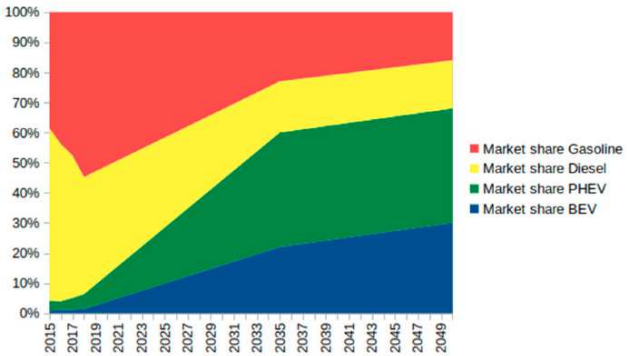


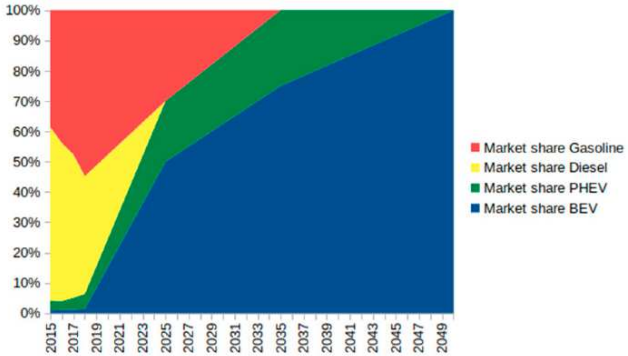
Policy scenarios

Business-as-usual (BAU)	• "moderate" yearly changes regarding coverage and speed of the study region
GREEN	• ambitious environmental measures reflecting "high" yearly changes regarding coverage and speed of the study region.

Two powertrain mix scenarios: ADEME (FR) and TIR (LU)



(a)



(b)

Combet, E.; Marchal, D.; Vincent, I.; Mairet, N.; Briand, V.; Cals, G.; Sidat, P.; Bellini, R.; Guenard, V.; Berthomieu, N. *Update of the ADEME 2035–2050 Energy-Climate Scenario*; **ADEME**: Angers, France, 2017
TIR Consulting Group LLC. The 3rd Industrial Revolution Strategy Study; TIR Consulting Group LLC: Luxembourg, 2016; p. 475

TAP – Defining a synthetic population

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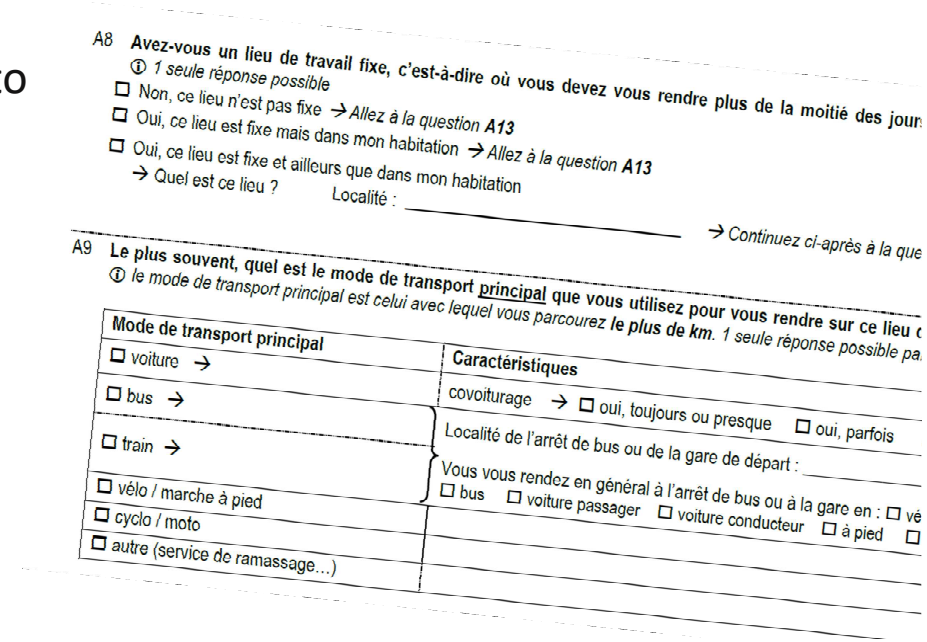
1. TAP
Synthetic population and modal choices

- A survey was answered by ca. 5000 cross-border commuters (France-Luxembourg), on their transportation habits and what influenced them
- Answers were treated to feed a **multinomial logit** (MNL) model
- The MNL model links agents' properties with **modal choices** in a probabilistic way.



A8 **Avez-vous un lieu de travail fixe, c'est-à-dire où vous devez vous rendre plus de la moitié des jour**
ⓘ *1 seule réponse possible*
☐ Non, ce lieu n'est pas fixe → *Allez à la question **A13***
☐ Oui, ce lieu est fixe mais dans mon habitation → *Allez à la question **A13***
☐ Oui, ce lieu est fixe et ailleurs que dans mon habitation
→ Quel est ce lieu ? Localité : _____ → *Continuez ci-après à la que*

A9 **Le plus souvent, quel est le mode de transport principal que vous utilisez pour vous rendre sur ce lieu**
ⓘ *le mode de transport principal est celui avec lequel vous parcourez **le plus de km**. 1 seule réponse possible pa*

Mode de transport principal	Caractéristiques
☐ voiture →	covoiturage → ☐ oui, toujours ou presque ☐ oui, parfois
☐ bus →	Localité de l'arrêt de bus ou de la gare de départ : _____
☐ train →	Vous vous rendez en général à l'arrêt de bus ou à la gare en : ☐ vé ☐ bus ☐ voiture passager ☐ voiture conducteur ☐ à pied ☐
☐ vélo / marche à pied	
☐ cyclo / moto	
☐ autre (service de ramassage…)	

Two trends for private cars

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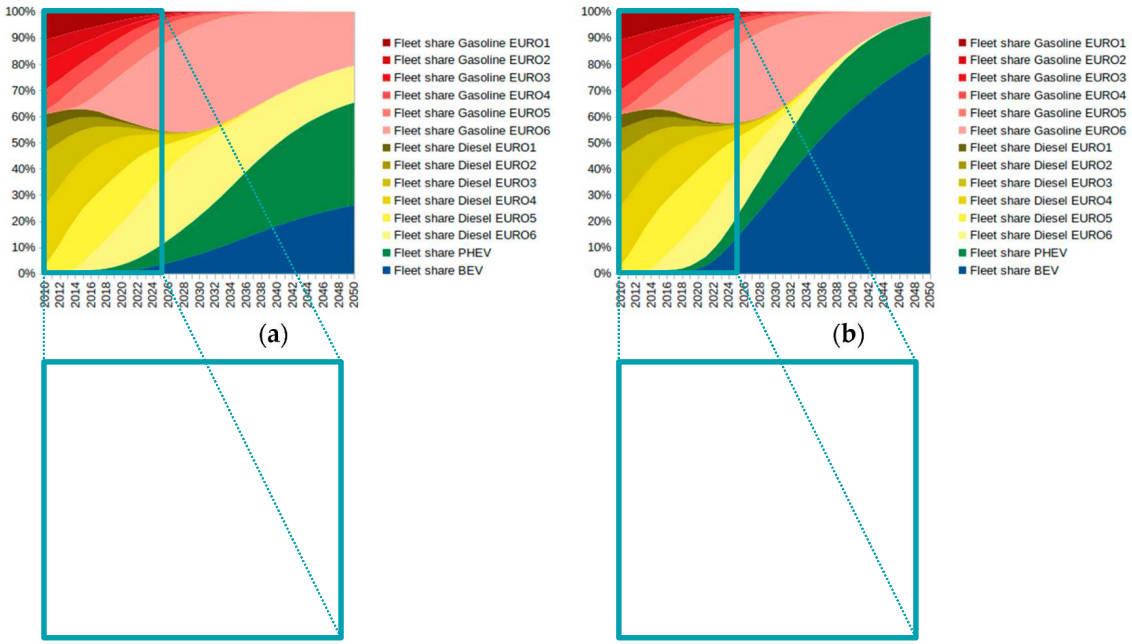
2. Fleet compositi on scenarios



ADEME (FR)

TIR (LU)

CONNECTING DB – Environmental impacts

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3. CONNECTING database

LCI database with parameters

- Life cycle inventories have been built for
  - **Private vehicles** (electric, diesel, gasoline),
  - **Buses** (electric, diesel),
  - **Train**,
  - **Tram**.
- Fully parameterized to take into account
  - **Cars**: curb weight (kg), lifetime (km), battery size (kWh), consumption (l/100 km), emissions (g xxx/km) – use in conjunction with real car fleet data
  - **Buses, train, tram**: occupancy rates.

Database for vehicles

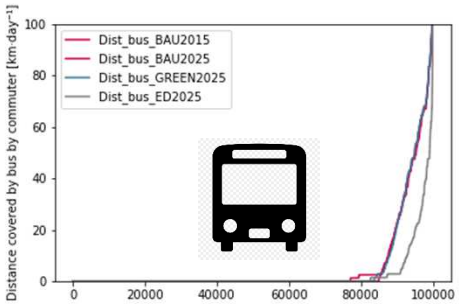
Average mass from database (n = 23097), in kg	Powertrain						
Segment	Gasoline	Diesel	Diesel hybrid	Electric	Gasoline LPG	Gasoline hybrid	LPG
A	1057	1147	-	1001	1072	1174	1000
B	1150	1349	1806	1158	1072	1174	1022
C	1306	1352	-	1489	-	1468	1285
D	1469	1608	1660	1539	1319	1497	1157
E	1495	1523	1700	1989	-	1682	-
F	1627	1620	2025	1281	-	1805	-
J	1885	1971	2322	-	1210	2175	1285
M	1594	1642	1660	2413	1160	1991	1454
S	1588	1765	-	1640	-	1589	-

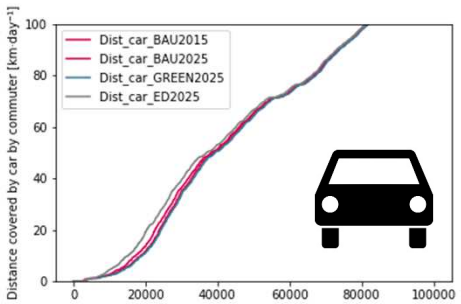
Average NEDC consumption from database (n = 23038), in l/100 km	Powertrain						
Segment	Gasoline	Diesel	Diesel hybrid	Electric	Gasoline LPG	Gasoline hybrid	LPG
A	5.6	4.2	-	0.0	6.8	3.7	5.7
B	5.5	4.4	-	-	-	-	-
C	6.2	4.6	-	0.0	-	4.2	7.8
D	6.9	5.5	3.7	0.0	6.5	3.7	6.7
E	7.9	5.3	3.8	0.0	-	5.2	-
F	8.8	5.5	4.3	0.0	-	6.0	-
J	10.6	7.6	6.1	-	12.4	6.3	9.5
M	7.7	5.5	3.6	0.0	7.5	5.7	7.4
S	12.7	6.8	-	0.0	-	8.6	-

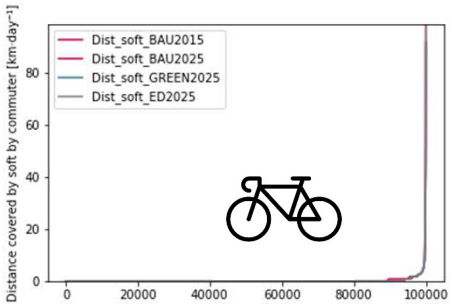
RESULTS

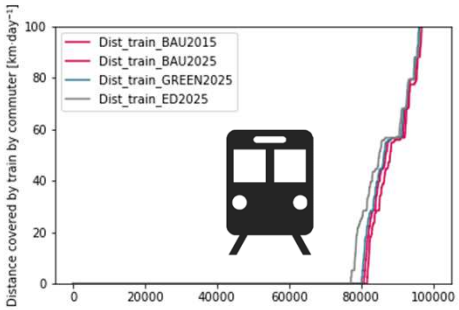
Population modal choices

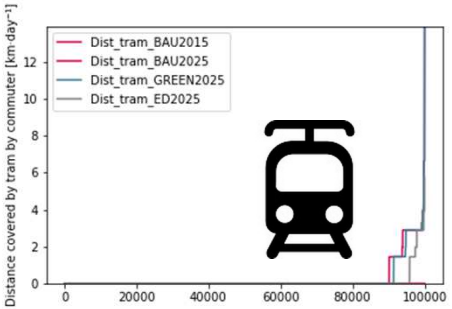
- *So, do public transport policies influence car driving?*







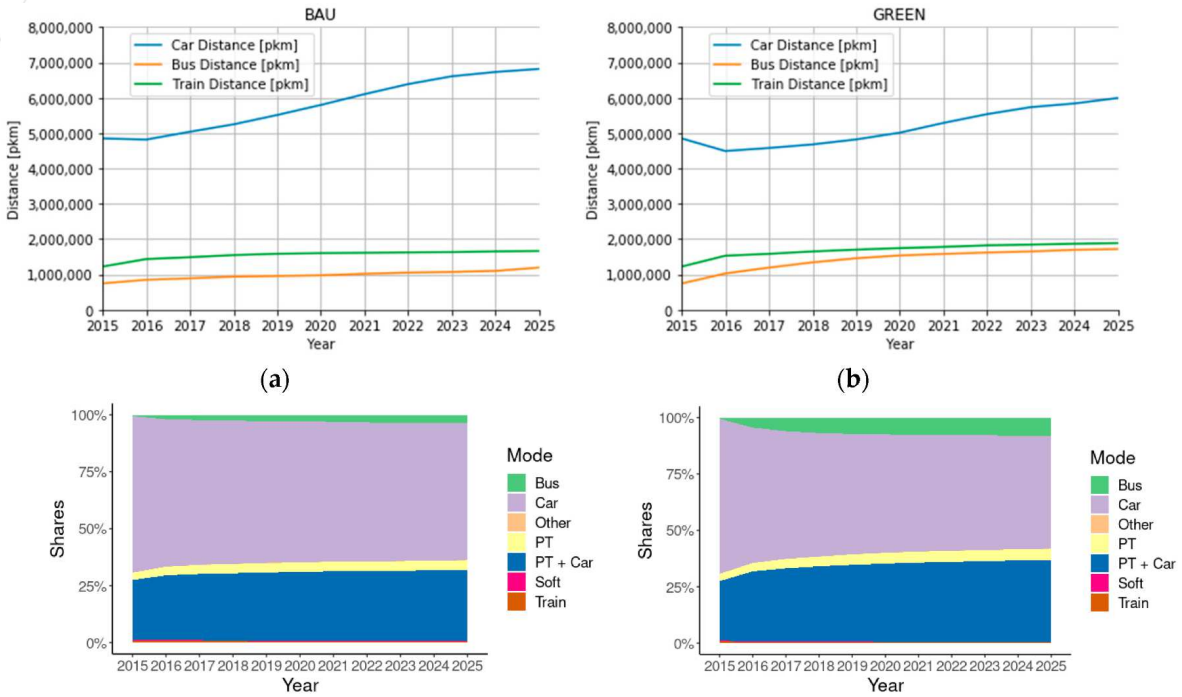




RESULTS

Aggregate modal choices

- *Total distance driven per mode, and modal shares*



RESULTS

Life cycle assessment – climate change

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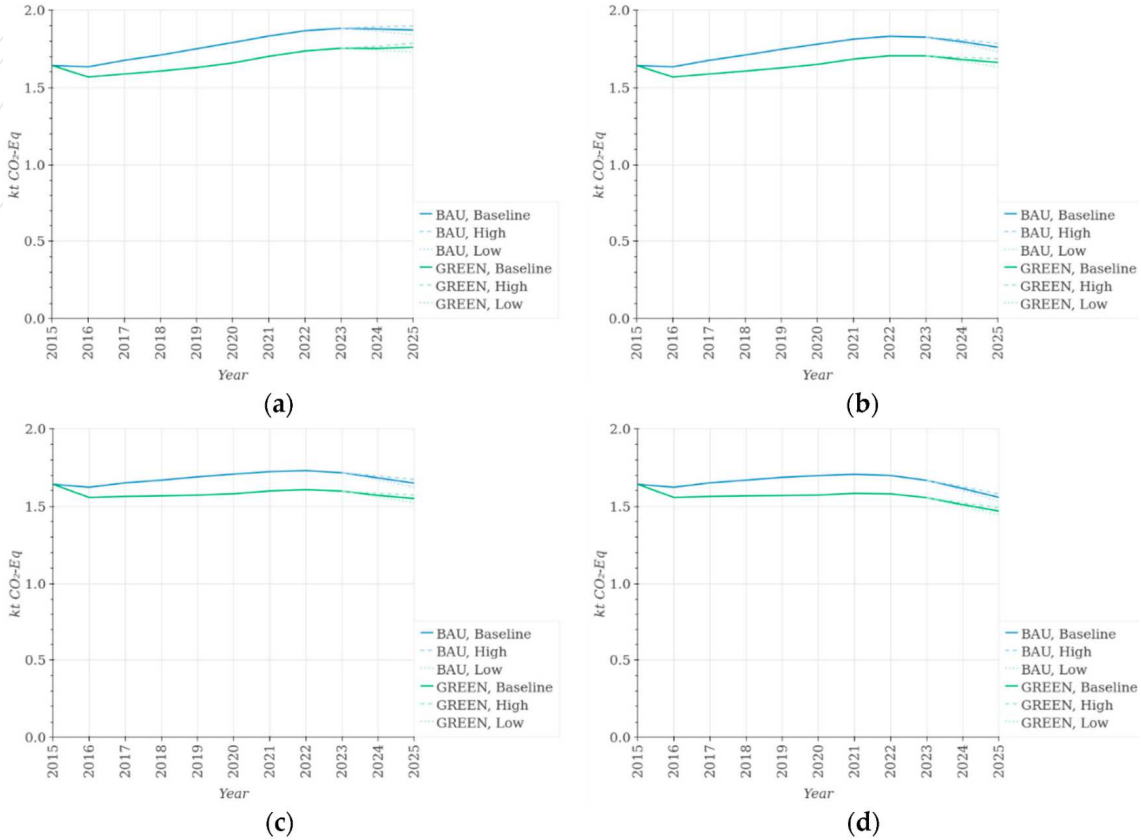
Fixed LCA background

Changing LCA background

(decrease in fuel consumption, decarbonization of electricity)



(c) ADEME fleet mix (mild elec.)

(d) TIR fleet mix (ambitious elec.)

RESULTS

Life cycle assessment – Mineral depletion

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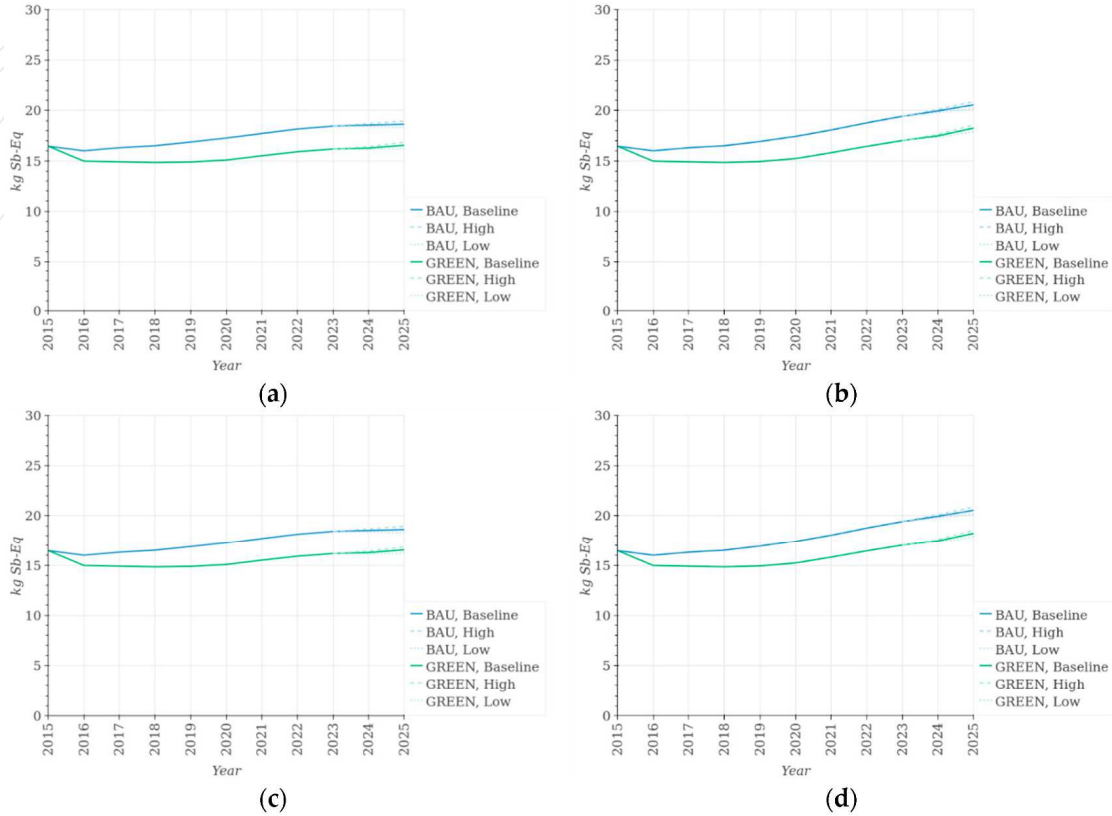
Fixed LCA background

Changing LCA background

(decrease in fuel consumption, decarbonization of electricity)



ADEME fleet mix (mild elec.)

TIR fleet mix (ambitious elec.)

RESULTS

Environmental impacts

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Simulations shows that transportation policies **may not have such a significant effect** as expected

- Many locations will **still not have** public transport offer in 2025
- Public transport for cross-border commuters means **bus** (with low occupancy) or electric train with a ~500 g CO2/kWh electricity
- Private vehicle usage remains **high**, virtually identical in 2025
- Fuel combustion dominates most impacts – **banning** certain powertrains most effective solution (but not tested (yet))

Interpretation: environmental impacts may instead be reduced by a combination of

- **Public transport offer**
- **Electricity decarbonization**

DISCUSSION

Challenges

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Simulator

- New origin-destination matrices **every 5 year** (i.e. 3 only over 2015-2025) instead of yearly
- Agents are **not spread over** their town of residency but are all assumed to live at the centroid thereof
- How to treat outliers? Some agents still use the bus when unavailable (and a few ride their bicycle >100 km/day…)

LCA data and methods

- Very rough coverage of infrastructure and its **allocation** (cross-border commuters only, but the whole population uses it)
- Should electricity consumption be treated as **consequential**, i.e. new vehicles entering use the marginal electricity? Monthly, annually? (comparison to be done)

Simulating hydrogen-based mobility and its environmental consequences at a territorial scale

2018 - 2030

Agents	Vehicles	Gasoline	Diesel	Electricity	Hydrogen	Compressed natural gas	Hybrid (gasoline)	Plug-in Hybrid. (gasoline)	Plug-in Hybrid (diesel)
Independant taxi Taxi company Entity with company cars (attributed or shared)		✓	✓	✓	✓		✓	✓	
Large company with utility vehicles Small company (<50 employ.) with utility vehicles		✓	✓	✓	✓	✓			
Local authority managing 12m urban buses			✓	✓	✓	✓			✓
Local authority managing 18m urban buses			✓	✓	✓	✓			✓
Local authority managing garbage trucks			✓	✓	✓	✓			

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Main stakeholders: Fleet managers

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Number of agents and number of vehicles per agent
Distance demand (km/day)
Number of days worked per year
Threshold for renewing vehicle and vehicle fleet
Desire to choose greener technologies

Price of vehicles
Autonomy range (km)
Fuel consumption
Loss of value when reselling

Price of fuels

Subsidies and carbon tax
Ban on fuels

Usage of the vehicles

1. Choice of whether to renew vehicle fleet or not

2. Choice of fuel type for each vehicle

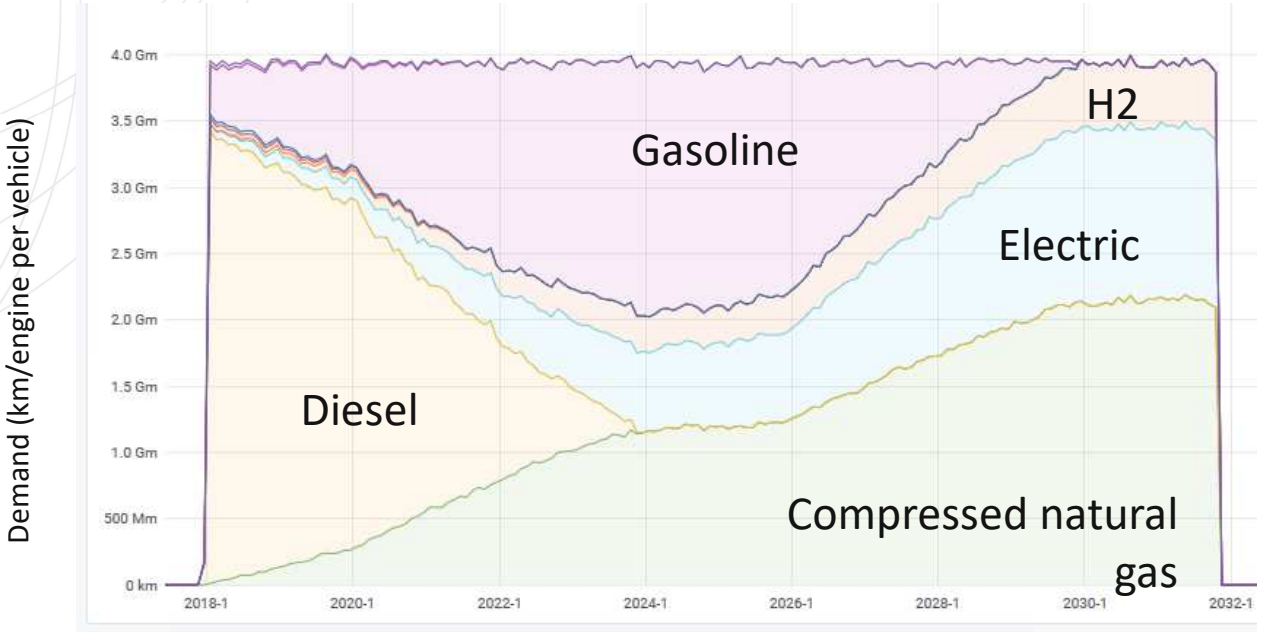
Score calculated for each option:

$$S_i = avail_i \times TCO_i^{\beta_{TCO}} \times range_i^{\beta_r} \times green_i^{\beta_g}$$

→ Probability to choose each option

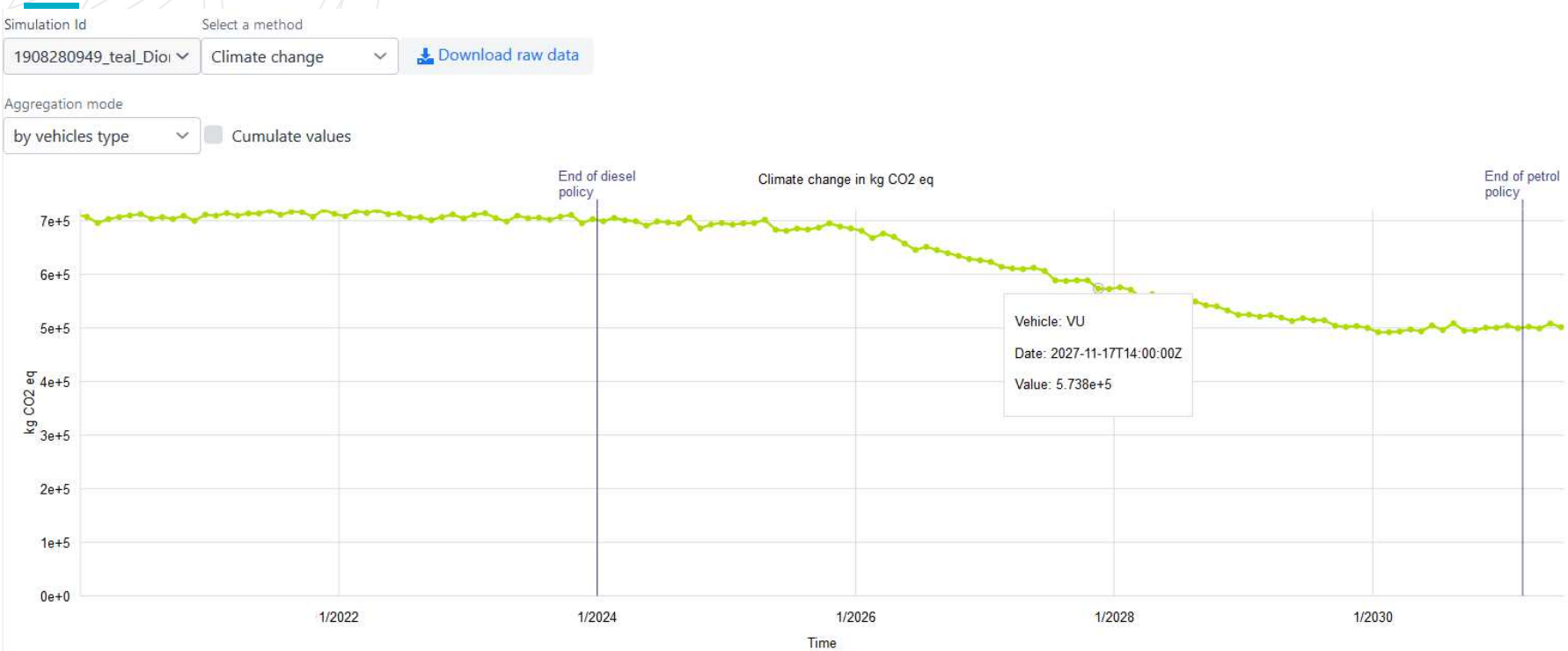
LCA: Assessing environmental impacts

Modelling 150 companies of 20 utility vehicles each



Extracted from the HERMES simulation tool

Climate change results



Extracted from the HERMES simulation tool

Conclusions and outlook

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- **“Goals and scope” counts!** Technology assessment and policy assessment require different LCA modelling frameworks

- **Good data are still missing (in the era of data mining...)**
  - Upscaled technological data
  - Market information
  - Social behaviour

- **LCA is more than an accounting tool:**
  - Prospective and dynamic modelling of supply chains
  - Modelling of feedback loops (foreground vs. background)