Fonds National de la Recherche Luxembourg

SIMULATING MULTIMODAL PASSENGER MOBILITY AND ITS ENVIRONMENTAL CONSEQUENCES AT A TERRITORIAL SCALE

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Smart City Symposium
5th March 2019

Smart cities Symposium international

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CROSS-BORDER COMMUTING

CURRENT SITUATION

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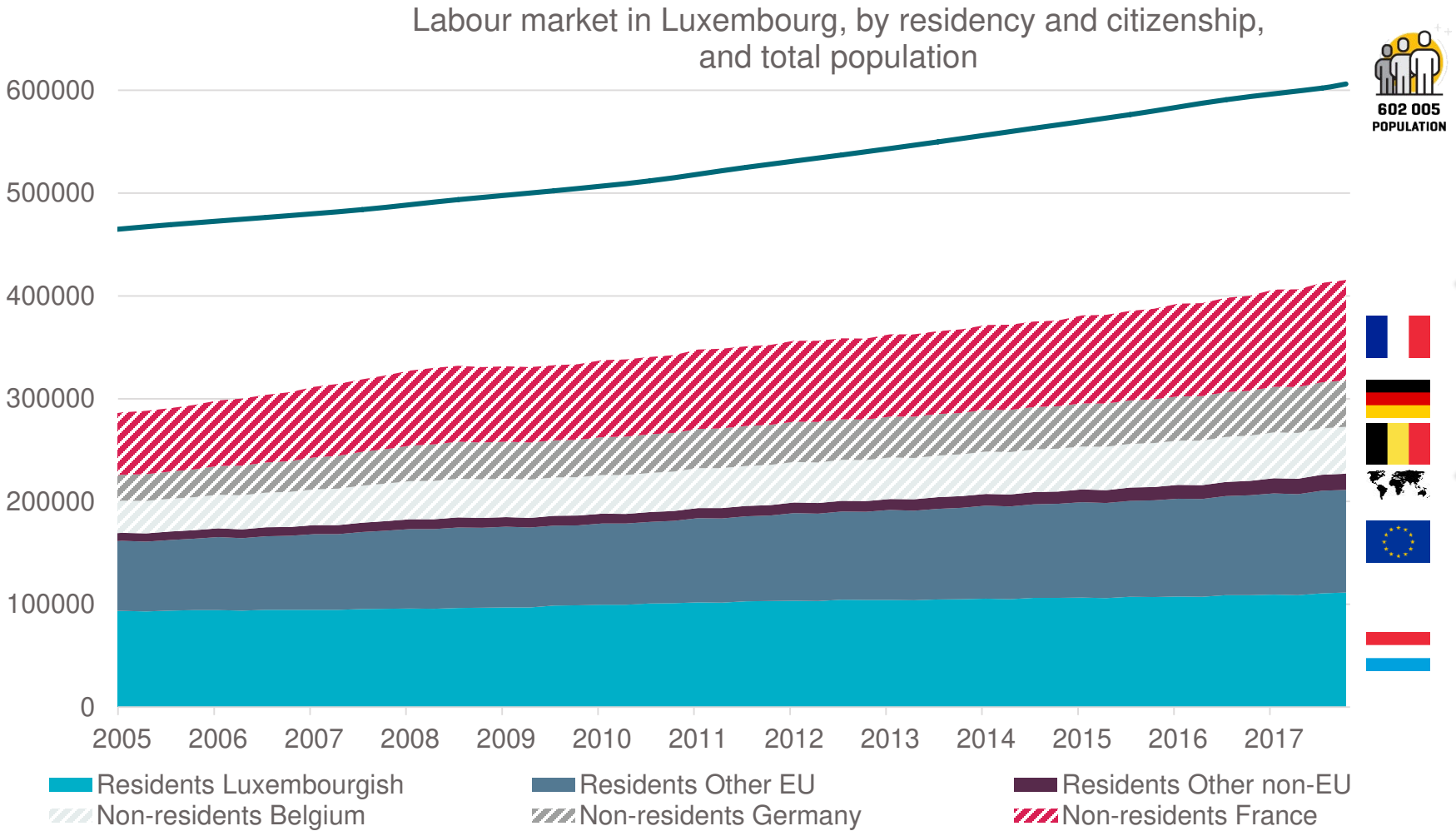

Cross border commuters

+ 4.3% annually

+ 2.7% for residents

+1.6% for Luxembourgers

- Context
- Framework
- Results
- Discussion

https://statistiques.public.lu

CROSS-BORDER COMMUTING

OUTLOOK

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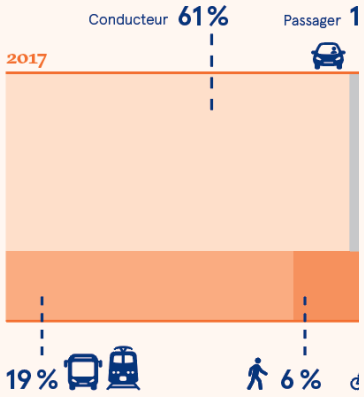
- Luxembourg's strategy to tackle the growing in-out of commuters (MODU2)

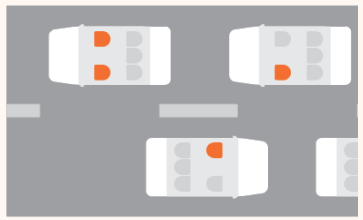
Objectif 1

Parts modales des déplacement



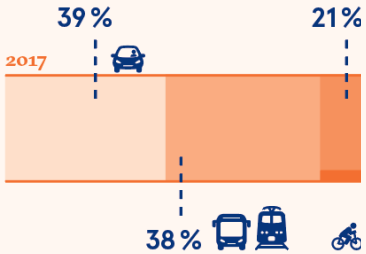
Objectif 2

Augmenter le taux d'occupation travail à au moins deux person



Objectif 3

Parts modales des déplacement



Objectif 4

Rendre les transports en commun plus attractifs.

1/100 *Supprimer moins de 1 train sur 100 (1 sur 40 en 2017).*

Réduire de 25 % la part des trains accusant un retard de 6 minutes ou plus (par rapport à 2017). **25%**

Express *Atteindre des temps de trajet inférieurs à ceux de la voiture pour les lignes de bus express aux heures de pointe entre le premier arrêt et le terminus.*

- Context
- Framework
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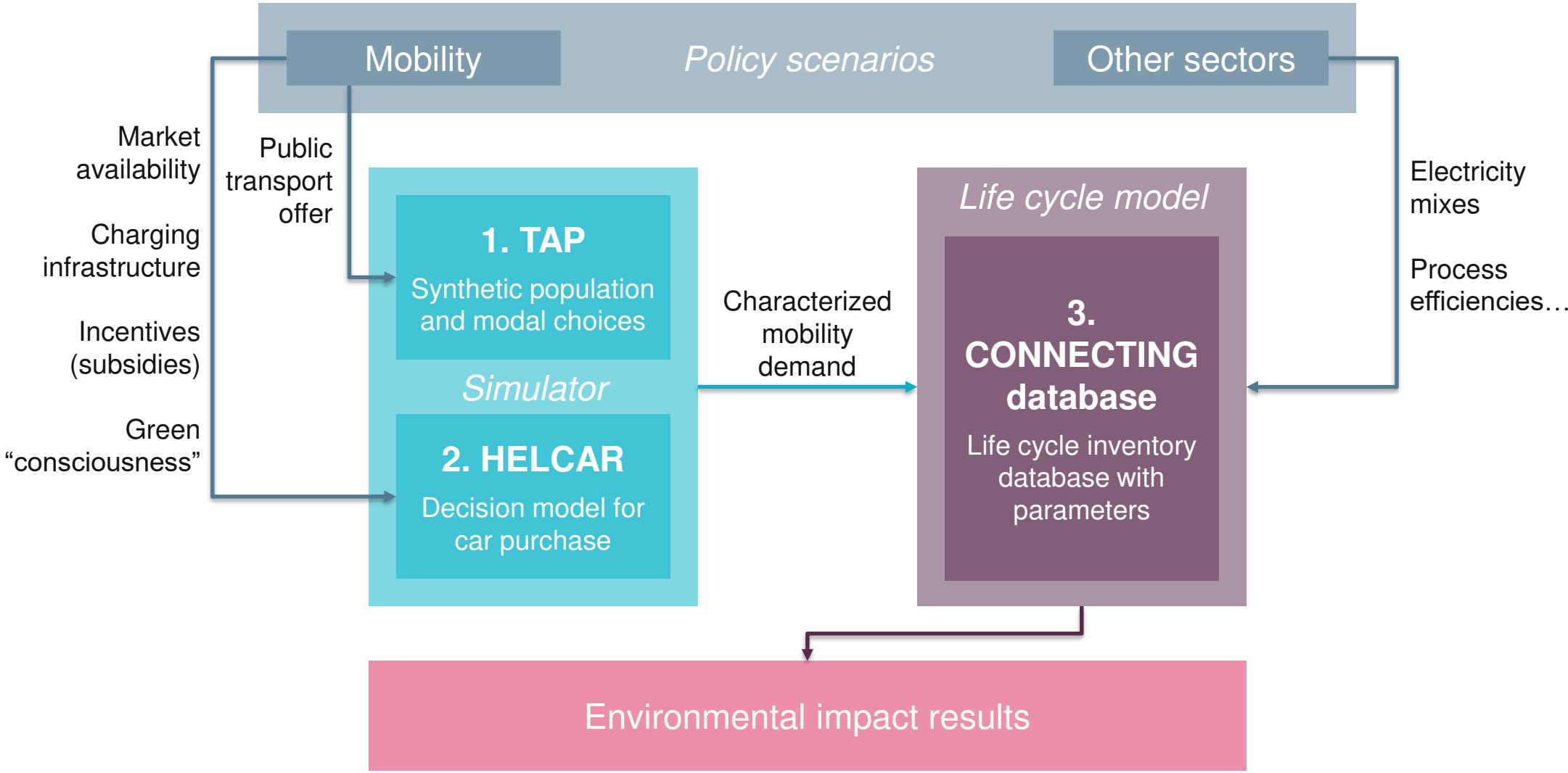
- Discussion

Modal shift | Occupancy | School transportation | Maintain existing infrastructure

http://www.developpement-durable-infrastructures.public.lu/fr/grands-dossiers/modu2/index.html

FRAMEWORK

METHODS OVERVIEW



Context
Framework
Results
Discussion

FRAMEWORK

SCENARIO DEFINITION

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Parameters	Scenarios			
	Business-as-usual	Economic Downturn	Green	Non-coherent policies
Incentives for electric cars	CAR-e Scheme unchanged	~~All incentives~~	follows unchanged	follows unchanged
Subsidies for public transport	Subsidies upheld	~~All subscription subsidies~~ Normal ticket prices	Subsidies ⇧ Prices ⇩	subsidies M-Pass prices ⇩ ~~subscription subsidies~~ Flexway prices ⇧
Teleworking legislation	No new legislation	No new legislation	New legislation allowing 24 days/year Employers promote teleworking	No new legislation

Context
Framework
Results
Discussion

FRAMEWORK

TAP – DEFINING A SYNTHETIC POPULATION

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1. TAP
Synthetic population and modal choices

- Context
- Framework
- Results
- Discussion

- A survey was sent out to ca. 5000 cross-border commuters (France-Luxembourg) to know 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 jours de travail ?**
ⓘ *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 question **A9***

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

Mode de transport principal	Caractéristiques
☐ voiture →	covoiturage → ☐ oui, toujours ou presque ☐ oui, parfois ☐ non
☐ 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 : ☐ vélo ☐ bus ☐ voiture passager ☐ voiture conducteur ☐ à pied ☐ autre
☐ vélo / marche à pied	
☐ cyclo / moto	
☐ autre (service de ramassage…)	

FRAMEWORK

TAP – DEFINING A SYNTHETIC POPULATION

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1. TAP
Synthetic population and modal choices

- The **Travel Activity Pattern** (TAP) model describes the commuting habits of a synthetic population depending on
  - daily **origins** and **destinations**,
  - daily activity chains by mode
    - **car (diesel, gas, electric),**
    - **bus**,
    - **tram**,
    - **train,**
    - **soft (walking, biking)**.

- **Data input**
  - origin-destination matrices per mode (in time and distances) for 2015, 2020, 2025
  - activity chains of agents (home, office, shopping, school, …)

- **Data output**
  - the distances covered for each **mode**
    for each **agent**
    for each **activity**

Context
Framework
Results
Discussion

TAP is adapted from Leite Mariante (2017) Econometric generation of individual daily travel and activity pattern: a case study with the cross-border workers in Luxembourg

FRAMEWORK

TAP – DEFINING A SYNTHETIC POPULATION

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Synthetic population and modal choices

Context
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- **Example of the MNL's *β* factors, providing "utilities" for the first trip**
  (~ correlation coefficients of the multivariate regression)

Relative to using car →

Relative to default commuter ↓

Factor	Bus	Train	Soft	Multimodal with car	Multimodal without car	*Interpretation*
default correlation (intercept)	*-14.8*	*3.5*	*-41.6*	*-29.8*	*-18.6*	*car is almost always preferred (ceteris paribus)*
age 30-39	19.2	-3.6	0.9	5.0	2.3	*young commuters will strongly prefer the bus*
age 40-49	9.9	-6.1	0.2	4.3	-4.9	*middle-age commuters still prefer the bus*
age 50-59	-2.6	-1.8	0.3	-25.8	-5.7	*less young commuters will almost always use the car*
is man	-5.3	-10.9	-0.3	0.5	3.1	*men have a tendency to prefer driving*
single	8.7	-12.6	-0.3	-2.5	-9.1	*single people prefer bus, and driving in other alternatives*
has children	-5.9	13.8	-0.3	-1.3	-5.9	*prefer driving or using P&R*
fixed working time	10.8	8.7	0.3	-0.1	-5.3	*having fixed hours encourages bus and train*
arranged working time	18.4	13.5	-0.2	1.8	-7.9	*...even better if the fixed hours are agreed with employer*
can park at work, for free	9.9	-6.3	1.2	3.6	2.8	
can park at work, not free	10.3	-7.2	0.5	4.8	-3.1	
hard to park	-26.0	-17.2	0.7	-3.6	6.6	*even if hard to park, car usually preferred, or multimodal with car*
impossible to park	21.6	2.7	-0.7	-1.0	-13.5	*bus is preferred in the impossibility to park*
has company car	-23.0	9.4	0.3	0.8	-9.8	
employer pays commuting expenses	16.1	-18.0	0.1	-0.1	0.4	
leaves home (first activity) by car	-6.1	-29.4	-1.7	-8.7	-17.7	*if you drive from home to work, you're driving to the next activity*

TAP is adapted from Leite Mariante (2017) Econometric generation of individual daily travel and activity pattern: a case study with the cross-border workers in Luxembourg

FRAMEWORK

HELCAR – SIMULATING A POPULATION'S CHOICES

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2. HELCAR

Decision model for car purchase

- Context
- Framework
- Results
- Discussion

Societal parameters

- Population (demography, car ownership, parking/charging availability),
- Behaviour (propension to switch to electric, car segment),
- Mobility (daily activity patterns, distances);

Economic parameters

- Fuel prices (gasoline, diesel, average and renewable electricity),
- Car prices (by segment/powertrain);

Technology parameters

- Car consumption (by segment/powertrain),
- Weights (by segment/powertrain),
- Full and plug-in hybrid electric market;

Policy parameters

- Economic incentives (subsidies)

Querini & Benetto (2015). Combining agent-based modeling and life cycle assessment for the evaluation of mobility policies. Environmental Science & Technology, 49(3), 1744-1751.

FRAMEWORK

CONNECTING DB – ENVIRONMENTAL IMPACTS

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3. CONNECTING database

LCI database with parameters

- Context
- Framework
- Results
- Discussion

- 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

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1. TAP
Synthetic population and modal choices

Context

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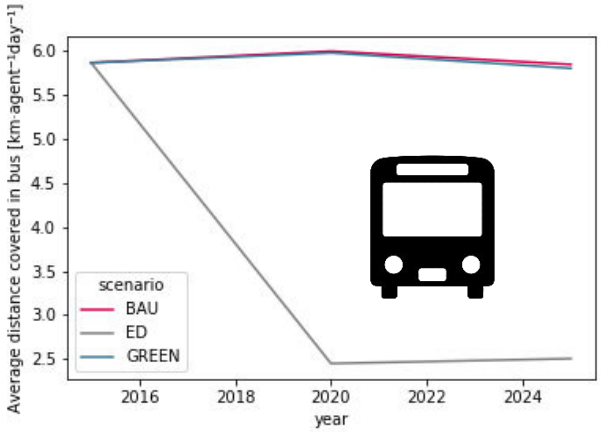
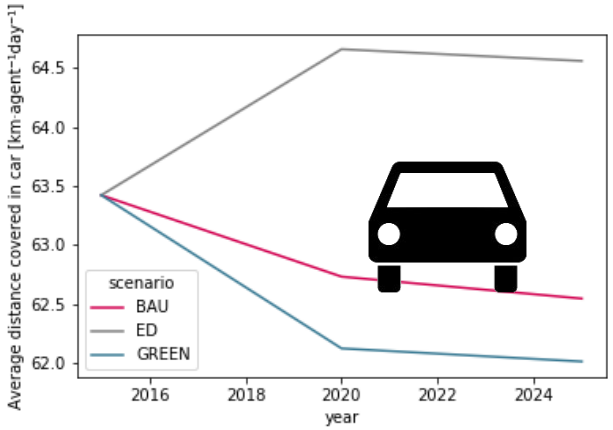
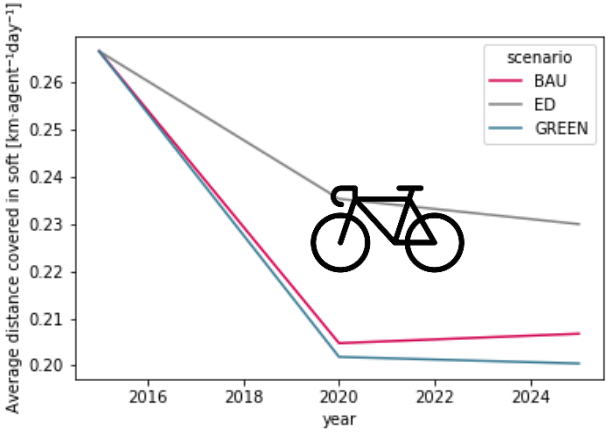
Results

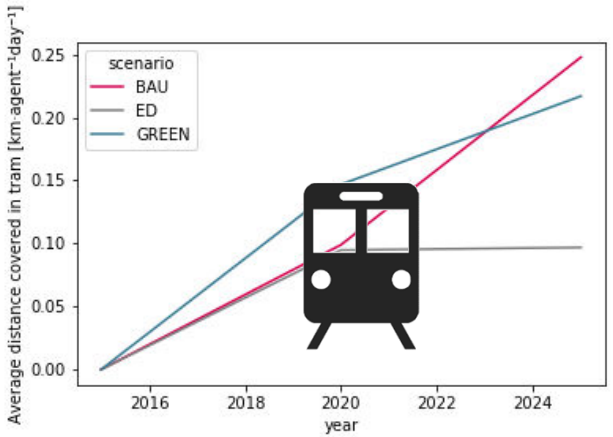
Discussion

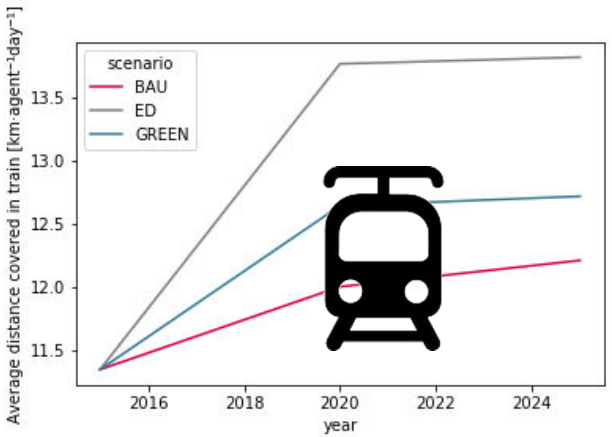
- A typical commuting day in 2015, 2020 and 2025











RESULTS

POPULATION MODAL CHOICES

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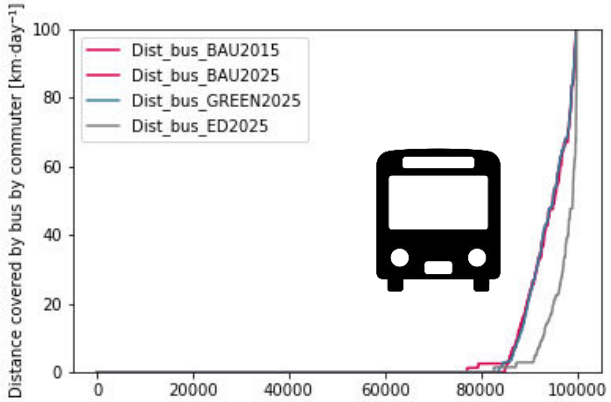
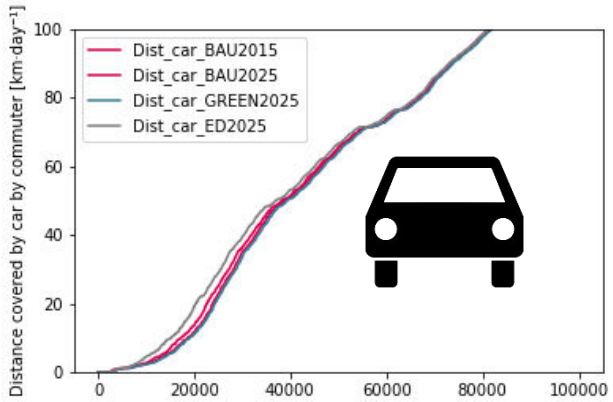
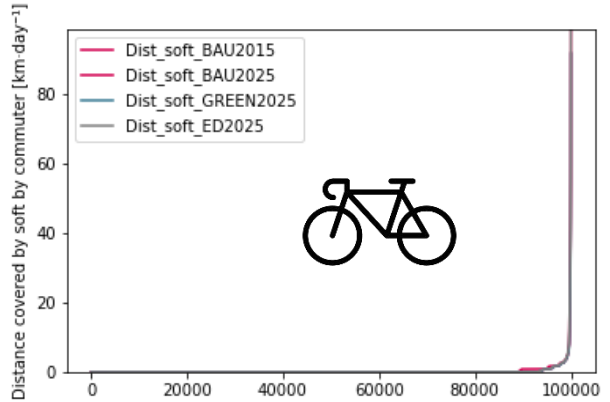
1. TAP
Synthetic population and modal choices

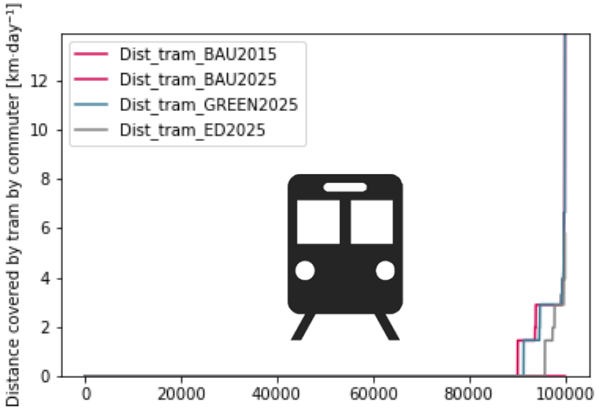
Context
Framework
Results
Discussion

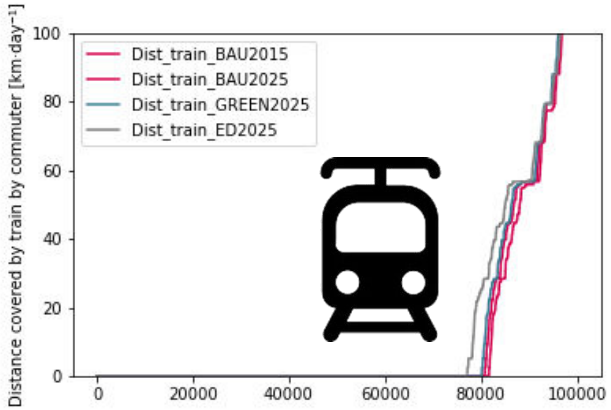
- So, do public transport policies influence car driving?





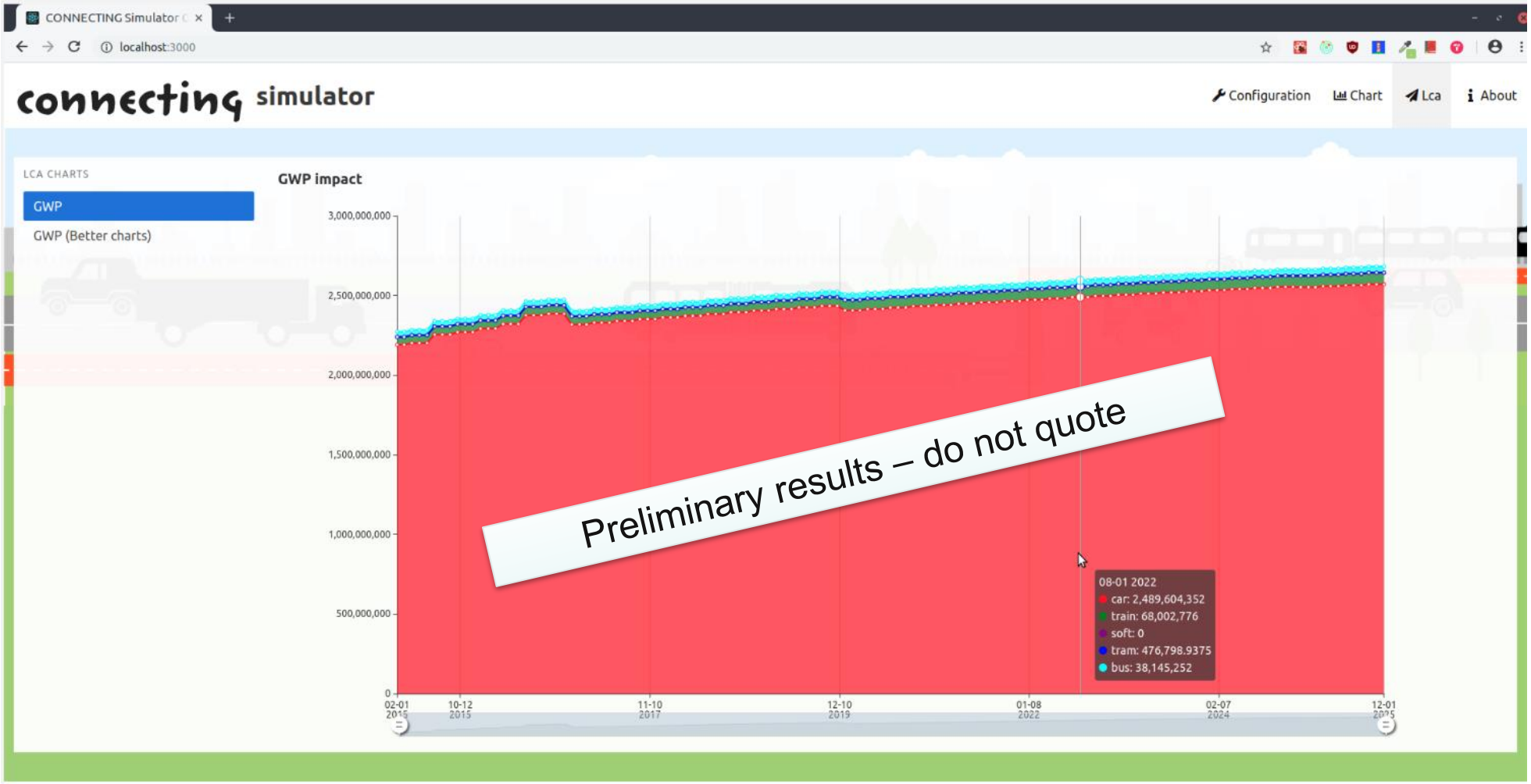






RESULTS

SCALED-UP IMPACTS



- Context
- Framework
- Results
- Discussion

RESULTS

ENVIRONMENTAL IMPACTS: GWP_{100} AND RESPIRATORY EFFECTS

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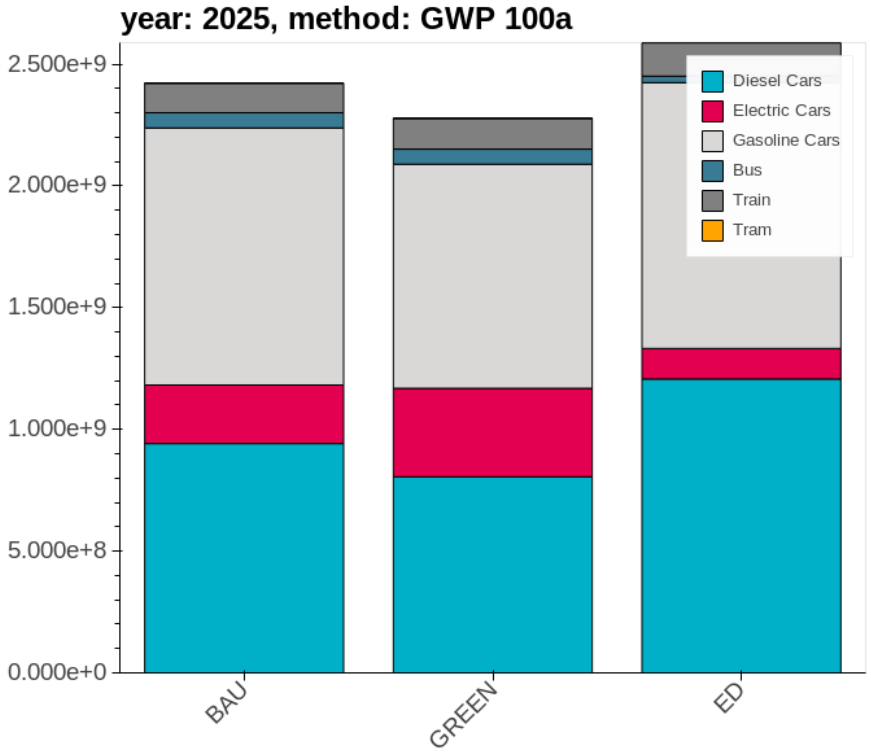
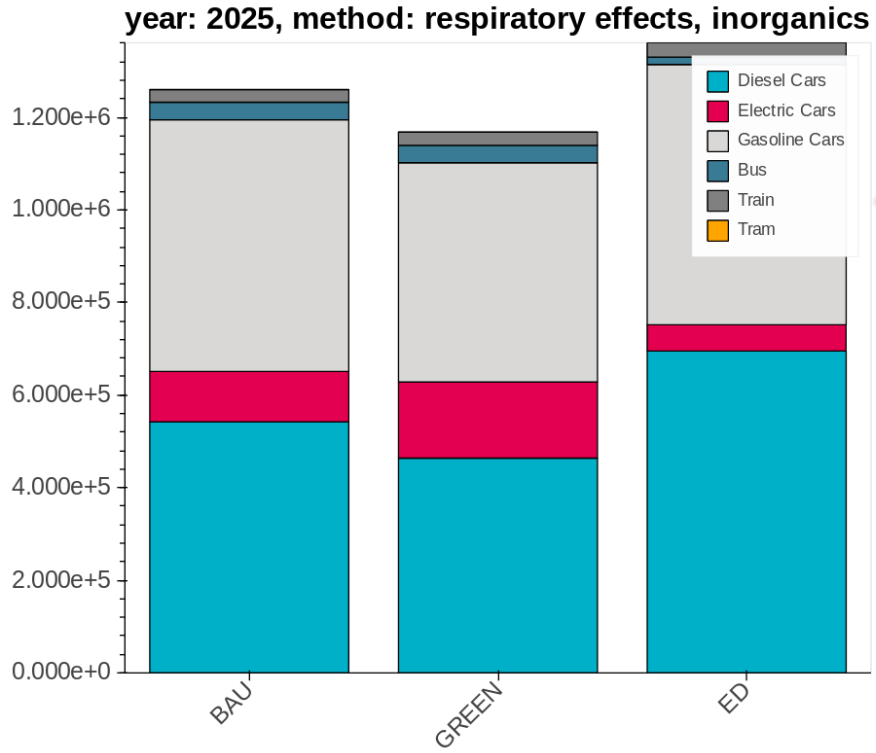
2.5 Mt CO_2 eq. per year



(in kg CO2 eq. per year)



1 kt $PM_{2.5}$ eq./year

(in kg PM2.5 equivalents per year)

*for comparison the whole road transport sector emitted **5.7 Mt CO_2 eq.** in 2018*

- Context
- Framework
- Results
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https://environnement.public.lu/fr/loft/air/inventaires-emissions/inventaire-polluants-atmospheriques.html

RESULTS

PROJECT OFFSHOOT: ONLINE COMPARATOR

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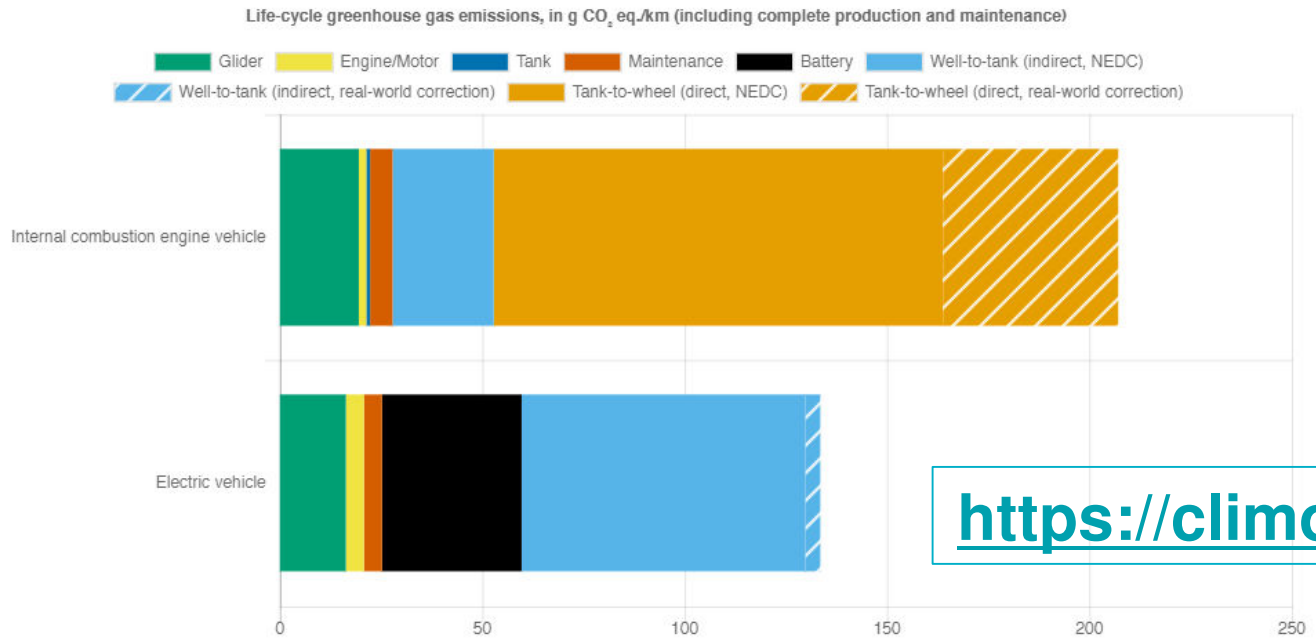
PARAMETERS

- Internal combustion engine vehicle: VOLKSWAGEN / Golf SW 2.0 TDI 150 (2017) — 1
- Electric vehicle: RENAULT / ZOE (2017) — 2
- Where/how are you charging your electric car?: Luxembourg — 3
- Annual mileage: 20000 km/year

RESULTS

Average range of the electric car	285 km
Electric car consumption	0.137 kWh/km
Greenhouse gas emissions due to electricity generation and distribution to the charging station per km	70.1 g CO_2 eq./km
Internal combustion engine vehicle (NEDC)	164 g CO_2 eq./km
Internal combustion engine vehicle (real world)	207 g CO_2 eq./km
Electric vehicle	134 g CO_2 eq./km

CHARTS



Parameters as csv | Bar chart as csv | Curves as csv

Parameters and results as CSV will be shown here

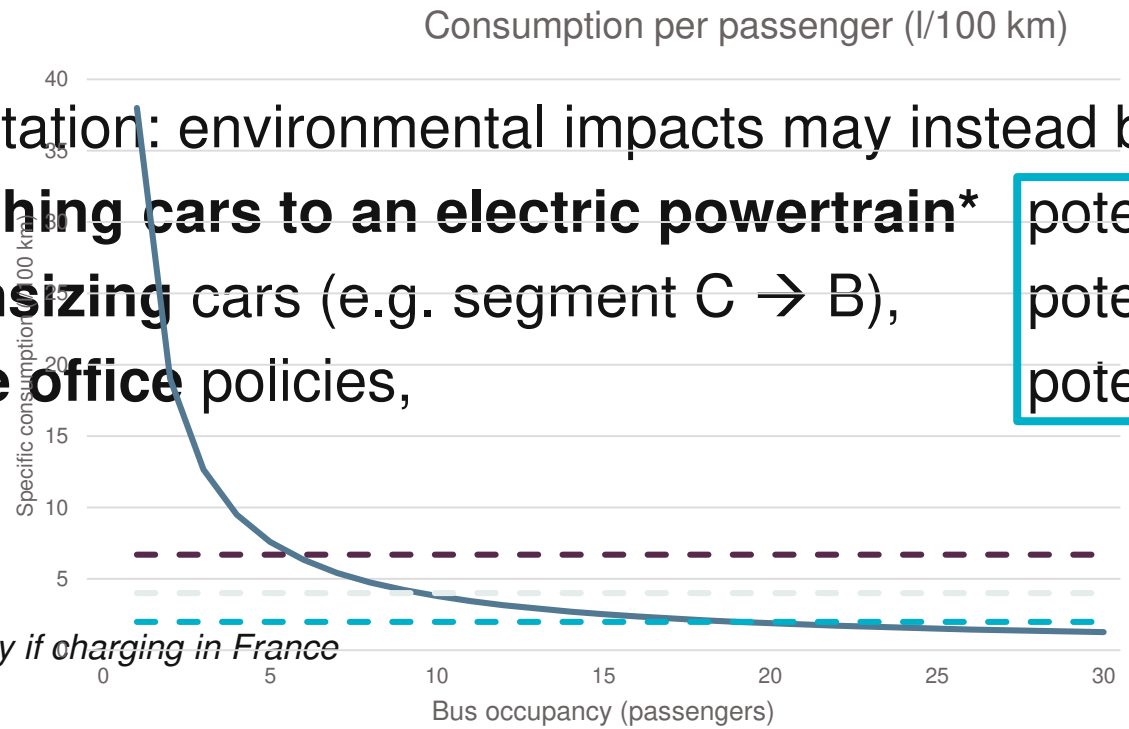
https://climobil.connecting-project.lu

- Context
- Framework
- Results
- Discussion

RESULTS

ENVIRONMENTAL IMPACTS

- The preliminary simulations shows that public transport policies **may not have as a significant effect** as expected
  - Many locations will **still not have** public transport offer in 2025,
  - High performance (occupancy) is **needed to mitigate** emissions,
  - Private vehicle usage remains high, virtually identical in 2025.



- Interpretation: environmental impacts may instead be reduced by
  - **Switching cars to an electric powertrain*** potential: **+++**, certainty: **++**
  - **Downsizing** cars (e.g. segment C → B), potential: **+**, certainty: **++**
  - **Home office** policies, potential: **+**, certainty: **-**

*especially if charging in France

Context → Framework → Results → Discussion

DISCUSSION

LIMITATIONS

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- **Simulator**
  - New origin-destination matrices every 5 year (i.e. 3 only over 2015-2025),
  - 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 (because only option), some ride their bicycle >100 km/day…

- **LCA data and methods**
  - Very rough coverage of infrastructure and its allocation (to cross-border commuters only, when the whole population uses it),
  - Should electricity consumption be treated as consequential? Monthly, annually, or over 10 years?

DISCUSSION

FURTHER WORK

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- Finalizing and validating the full scale framework
  - Interconnections between modules
  - Highlight influence of powertrain shifting vs. public transportation offer

- Introduce new powertrains!
  - Project “HERMES” (Hydrogen-Electric Road Mobility Environmental Scenarios)
    - Hydrogen fuel cell powertrains
    - Production and infrastructure modelling
    - Agents: fleet managers, companies, taxis
    - …started 2018

  - **POSTER AVAILABLE IF YOU ARE INTERESTED!**

THANKS!

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- Further questions? Feel free to write:
  - Travel Activity Pattern model: paul.baustert@list.lu
  - CONNECTING Simulator: tomas.navarrete@list.lu
  - CONNECTING DB and Climobil: thomas.gibon@list.lu
- Calculator URL:

Smart cities Symposium international

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https://climobil.connecting-project.lu

VEHICLE RESULT EXAMPLE
UNIT IMPACTS – PUBLIC TRANSPORT, E.G. TRAM

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- Context
- Framework
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Life cycle impacts of a tram type CAF Urbos as used by Luxembourg, per pkm