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Energy Modelling Initiative
Bringing the Tools to Support Canada's Energy Transition

A comprehensive method for assessing energy and emissions for future mobility scenarios

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EMI Final Presentation
April 1st 2021

The challenge

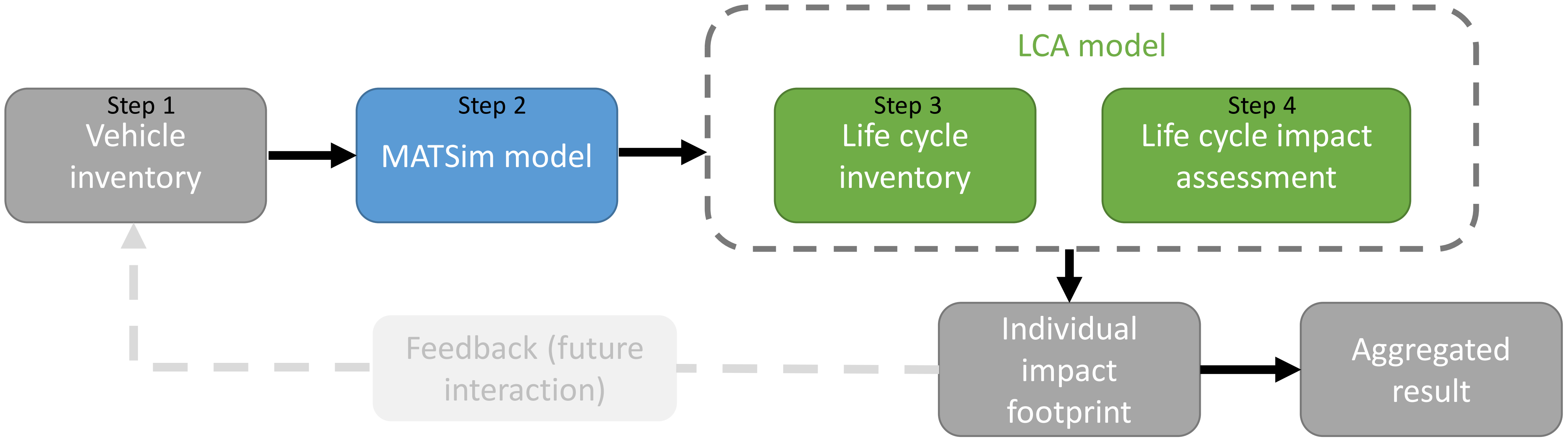
- Transportation has been dominated by automobile → Flexible and relatively affordable but huge negative externalities
- Novelties introduced recently are expected to substantially change the status quo:
  - Technological: Electrification and Automation
  - Technology enabled: Servicization (Shared mobility, Mobility as a Service)
- Expectations: Less energy intensive vehicles (ZEV), Reduced global fleet
- Issues:
  - Energy and climate change impact substantially different for different power trains over production/use phases
  - Shared vehicles are used more intensively and need a quicker turnaround

- Transportation planning neglects such issues
- Life Cycle Assessment is an answer but typical applications do not take into account the impact of changes in the transportation system on travel behavior

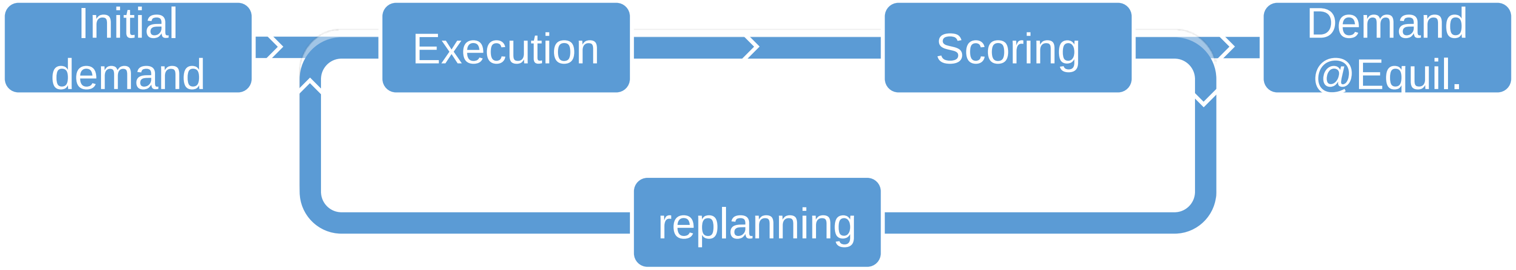
→ Combining a model that offer realistic, self-consistent mobility scenarios with LCA

Methodology

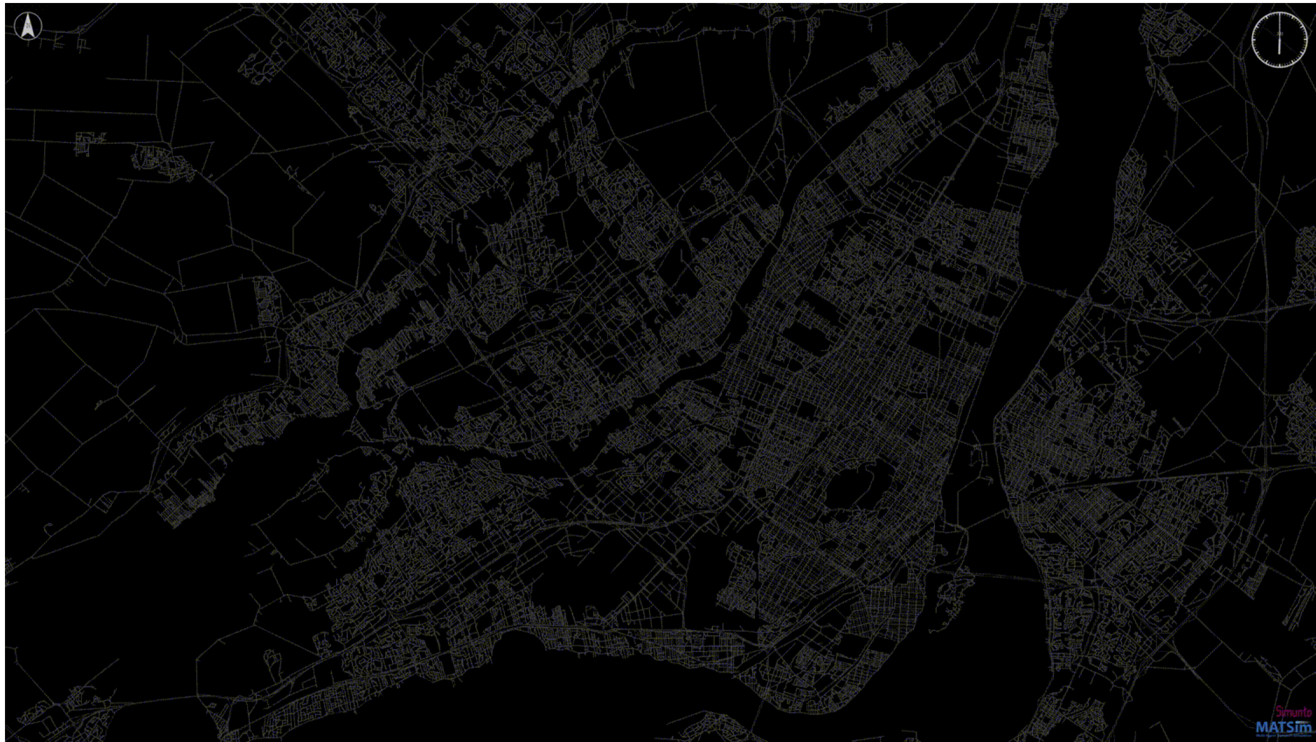
Coupling ABS with life cycle assessment



MATSim: Multi-Agent Transport Simulation

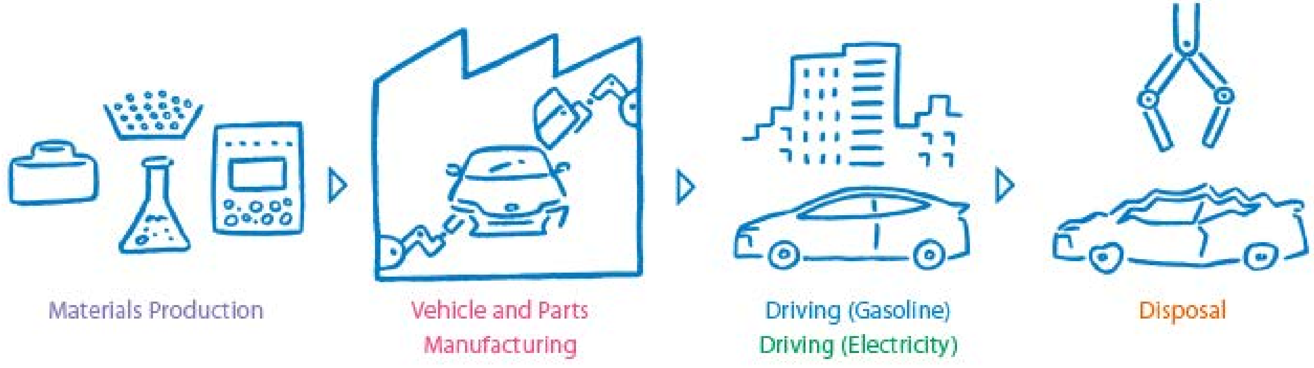


- Open source framework written in java (GNU License)
- Started 15+ years ago, large community of users
- Developed by Teams at ETH Zurich, TU Berlin
- www.matsim.org



Life Cycle Assessment

- LCA quantifies the environmental impacts of a product based on a cradle-to-grave concept.
- This may include emissions, energy use, water use, impact on ecosystems and and human life, among others.
- Such assessment is made throughout the product lifetime stages, from raw material extraction to operation, and to disposal as described in ISO 14040 and ISO 14044



[Source:Toyota Environmental Challenge 2050]

MATSim and LCA

- ABM-LCA Simulation Steps
- *Step 1*: A vehicle inventory is built (weight, aerodynamic force, drivetrain efficiency, rolling drag coefficient, etc.) based on existing car models.
- *Step 2*: Agents perform activities and decide optimal mode, route, and time. Travel behavior is constrained by the traffic conditions, (for EVs range and charging).Information of charging time and energy use at the vehicle level → TtW Energy (Use phase)
- Step 3: Other life cycle stages (i.e., manufacturing, maintenance, energy storage, road, end-of-life) are added based on ***ecoinvent***.
- Step 4: LCIA calculation provides the impact factor (i.e., emission factor) and the energy consumption factor. Calculated values are multiplied by the kilometer-travelled distance of all individual agents and aggregated to determine impacts equivalent per day.

Simulation Scenarios

Scenarios

Isle of Montréal

- Current situation Scenario (2013 data)
- EV Scenario
- SEV Scenario

EV Scenario

- ***Penetration rate of EVs***
  - The EV scenario assumes that all car owners of the CMA of Montreal who travel less than **150 km a day own an electric vehicle (EV)**. Given this 150 km threshold, 1,559,560 Montrealese car users are assigned an EV.
- ***EV fleet characteristics***
  - Only one EV model was considered, however, the approach naturally allows accounting for different models as every single vehicle is simulated.
- ***Charging stations***
  - **14,680 charging stations** are introduced in the CMA of Montreal, most of them are located in the island of Montreal (fig. 3). All charging stations deliver the same power of **100 kW** and have **5 charging plugs.**
  - For the auxiliary energy consumption of EVs, an outdoor temperature of 15 degrees Celsius is assumed. **The methodology allows to set this parameter to any other outdoor temperature.**

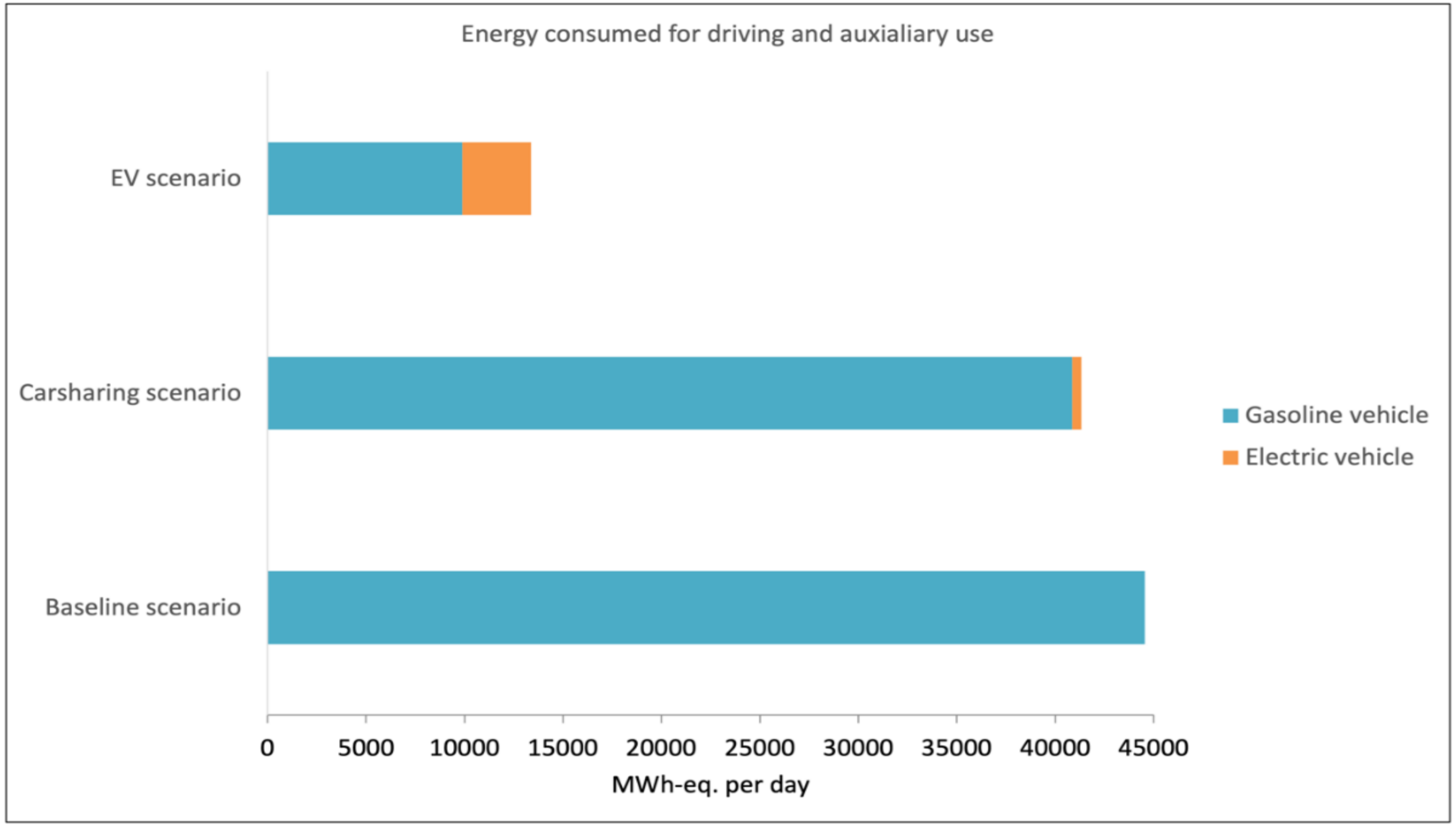
CS Scenario

- ***Carsharing membership***
  - In the e-carsharing scenario, **10% of the population of driving licence holders is given a carsharing membership**. This share is to be compared with 4%: the actual share of carsharing members in the CMA of Montreal. The selected agents are randomly drawn from the total population of the island of Montreal.
  - The methodology allows for other membership assignment strategies to be used.

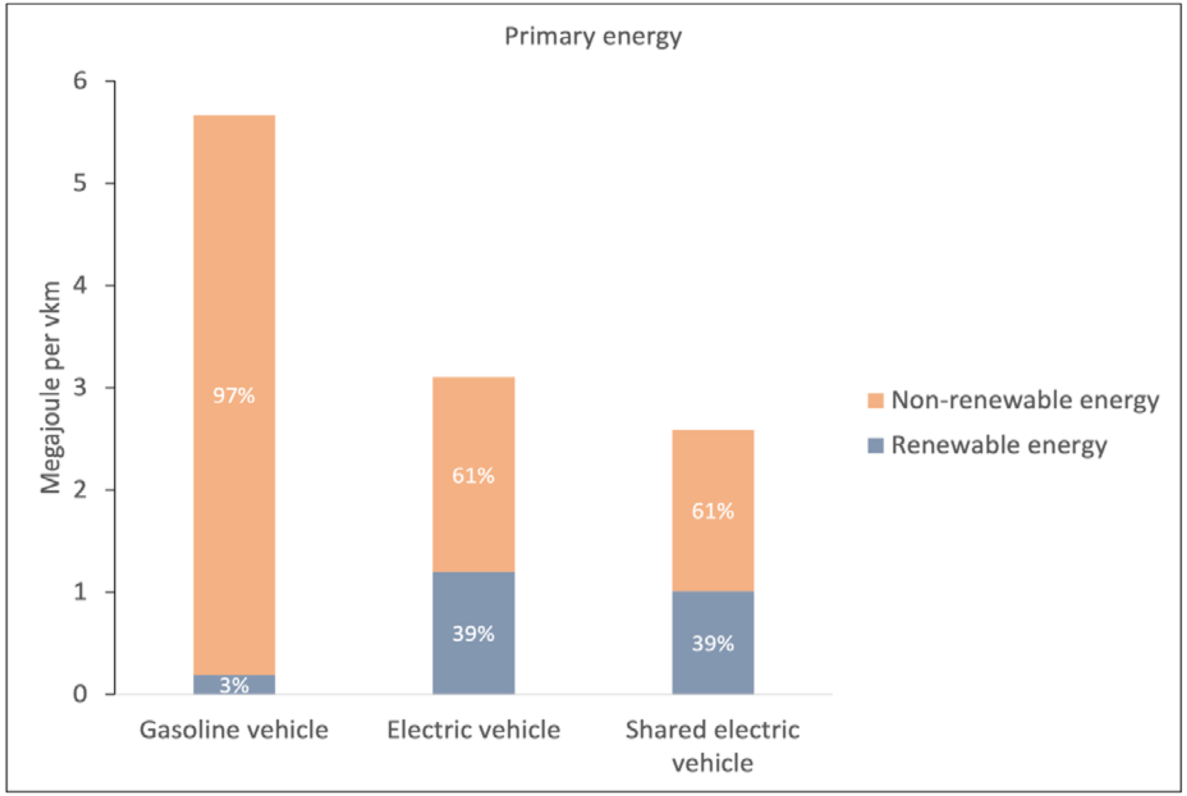
- ***Carsharing supply***
  - **11,460 carsharing stations** are introduced in the CMA of Montreal (fig. 4). **Each station offers 6 vehicles for reservation**: 3 two-way EVs and 3 one-way fuel-powered cars. This results in 68,760 shared vehicles, of which 34,380 are EVs. Shared EVs are assumed to have a **battery capacity of 100 kWh**. This capacity is greater than that of personal EVs (60 kWh).
  - ***Communato*** data are used to infer the spatial location of carsharing stations. Each station contains 6 charging plugs delivering a power of **25 kW**. **The recharging of shared EVs is only allowed at carsharing stations.**

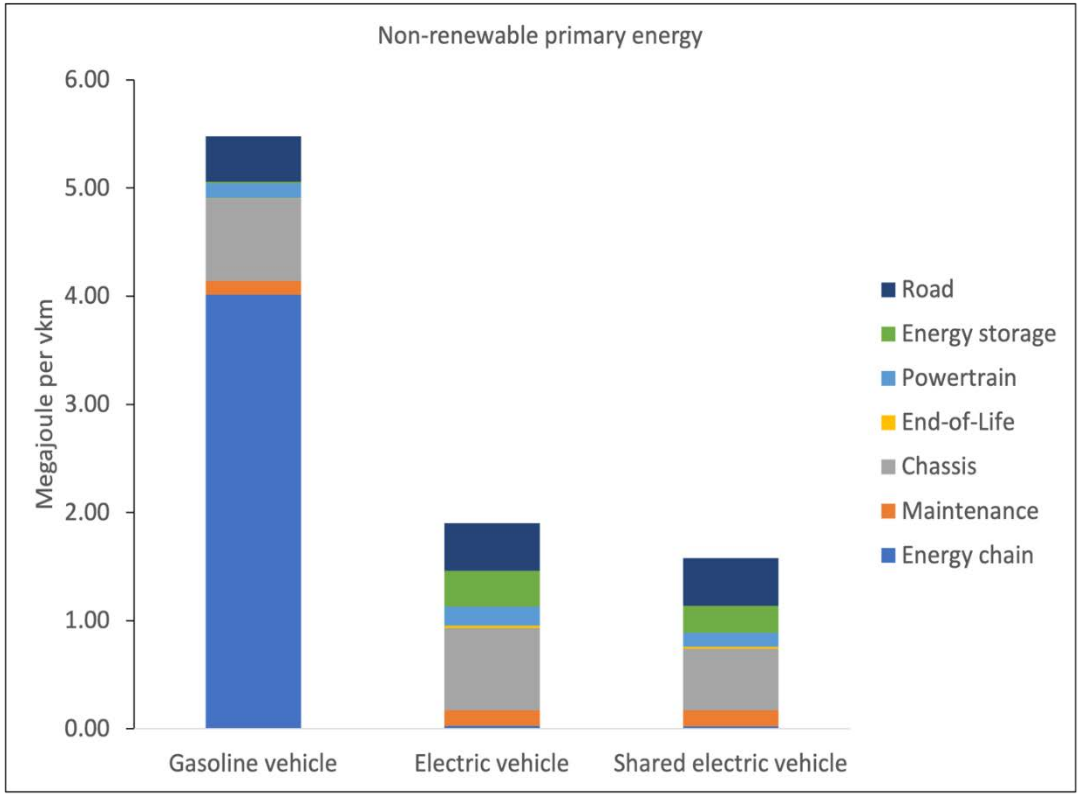
Modelling results

Scenarios' total energy consumption



Energy consumption over the life-cycle





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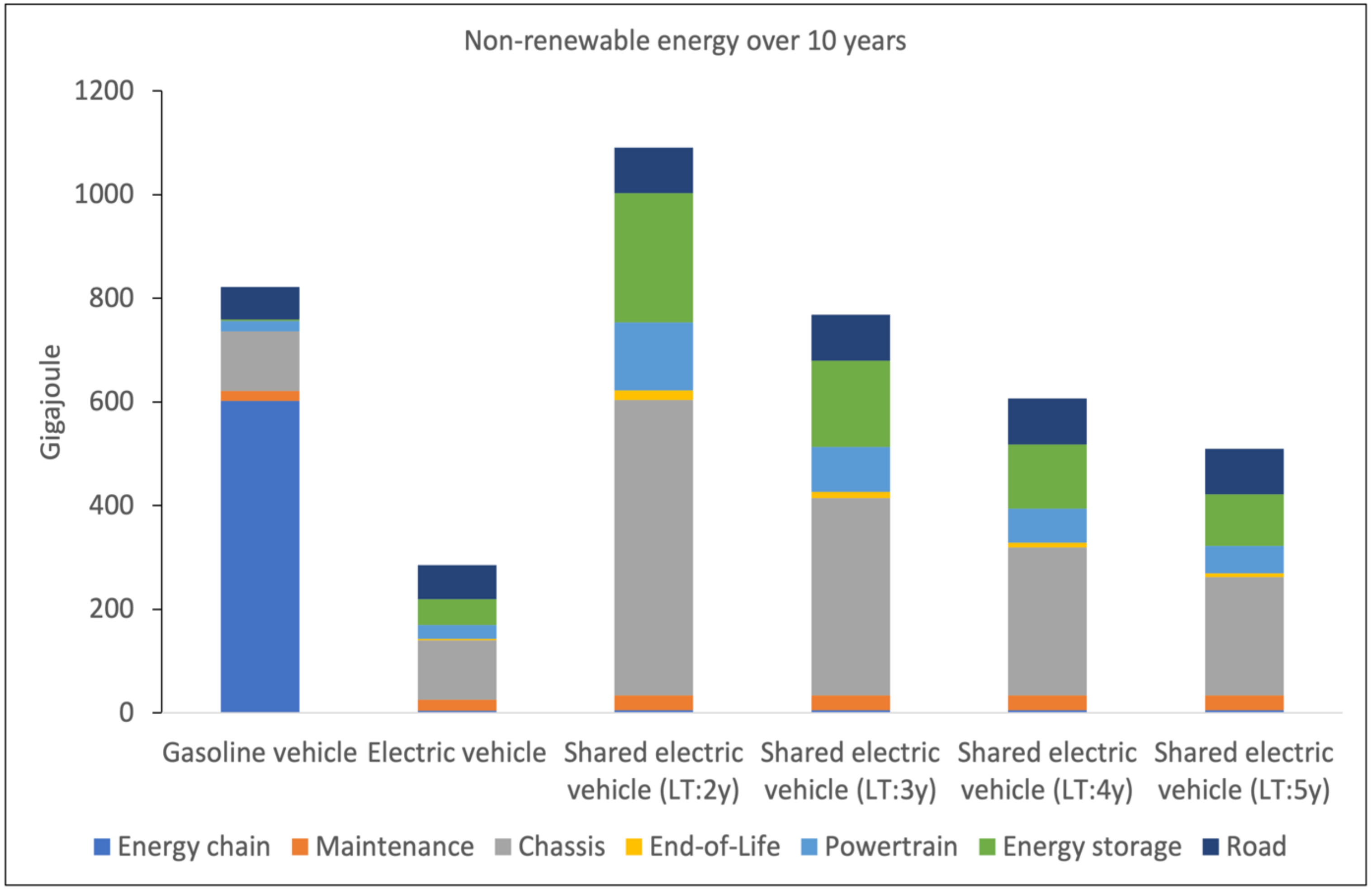
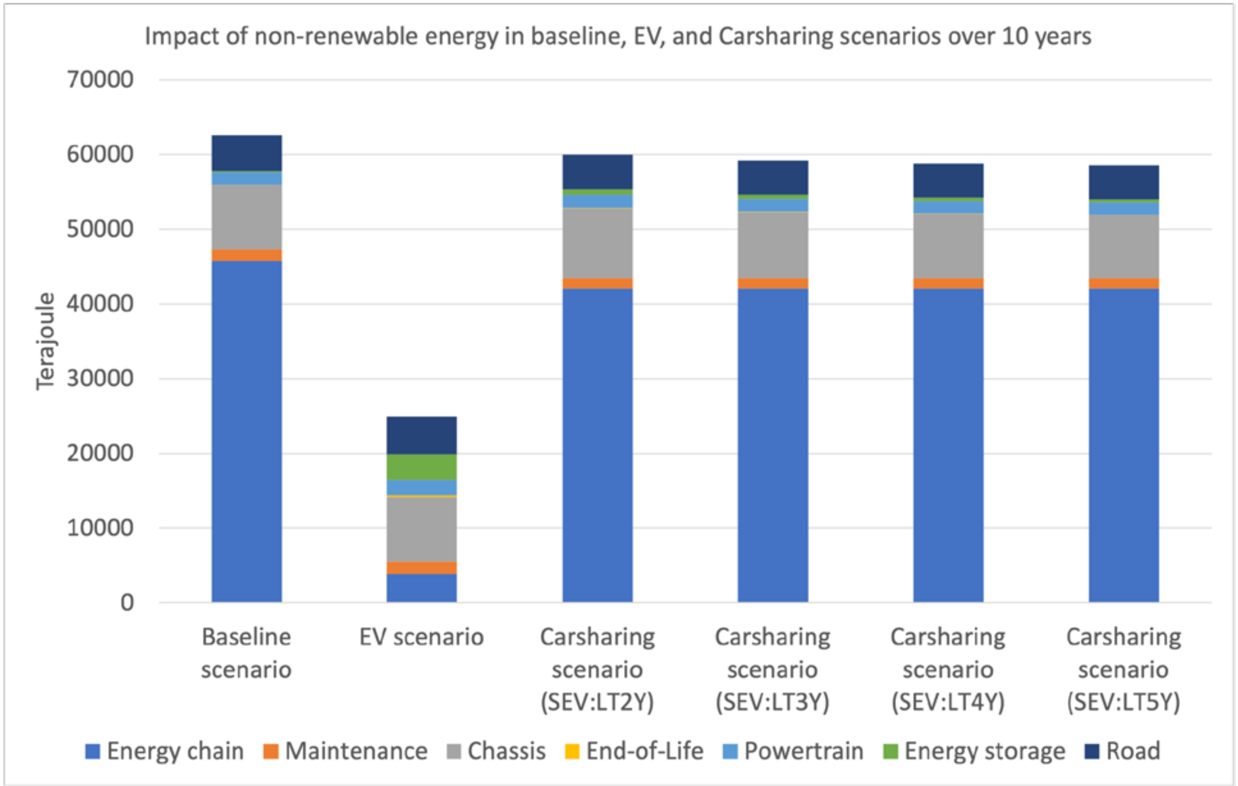
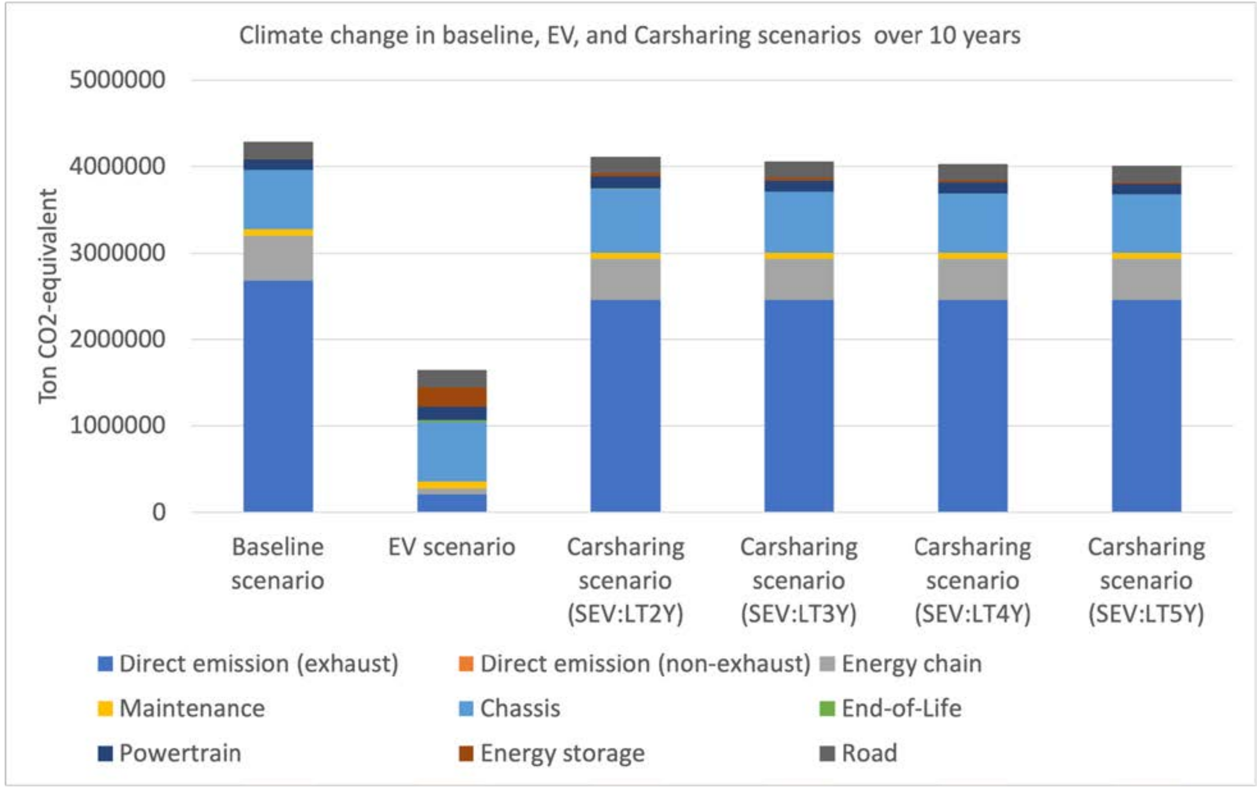
LC Energy consumption: different life lengths



Scenario LC Energy consumption





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Discussion (I)

- Between the scenarios with large EV fleet and EV carsharing, the EV scenario is the one that performs better.
- The CS scenario is not extreme enough to have a larger impact, as an even larger system would substitute more private cars and then, from a certain size on, perform even better than the EV scenario. However, it possibly limits the mobility of individuals. This aspect can be directly observed and measured in the transportation side of the model (MATSim).
- This shows, therefore, that the methodology proposed represents all possible trade-offs and provide the information necessary in order to decide how to deal with them.

Discussion (II)

- The results presented are a demonstration of how the combined ABM-LCA framework works and offers a **fair** and **comprehensive** assessment of future transportation scenarios.
  - Fair because it takes into account the implication of a possible larger diffusion of shared vehicles and the intensity of use
  - Comprehensive because LCA accounts for all the phases of the life cycle of the vehicles and not only for operations.
- It is based on realistic, behaviorally sound transportation scenarios as it allows explicitly representation of individual constraints and preferences and of all transportation modes, and the trade-offs among them given their specific implementations
- Such a tool should, therefore, play a crucial role in designing and evaluating transformation pathways in the transportation sector. Here, specifically, it provides a complete picture of impacts of different systems and help defining the most desirable futures.

Summary (I)

- We need an holistic approach to assess emissions (and externalities in general) in an ever transforming transportation sector, especially as several different parts of the system might change

- We won't find a single model that will capture all

- Integrating LCA to tools like MATSim looks like an important step in the right direction to have an approach that is holistic and at the same time guarantees systemic consistency (plausible solutions from a transportation standpoint) and fair comparison of different systems (takes into account different life spans of the systems)

Summary (II)

ABM →

Does:

- Produce consistent mobility scenarios (individual constraints)

But:

- Only represents direct emissions
- Doesn’t account for demand variability over time (i.e. weekly, seasonal, weather related, system changes)

LCA →

Does:

- Look at emissions over the whole life-cycle (and by this offers a fair comparison of systems with different life spans, and of emissions for diffent kind of vehicles)

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Future work

- What we can already do:
  - Use MATSim output (travel details of the whole vehicles fleet for an « average day) and feed an LCA calculation tool
- What we are planning to do in the future:
  - Create several MATSim scenarios for different situations (days of the week, seasons, transformation path of the transportation system) and modify the tool in order to have a more accurate LCA
  - Extend the model to energy consumption related to other human activities as MATSim provides daily plans for each individual