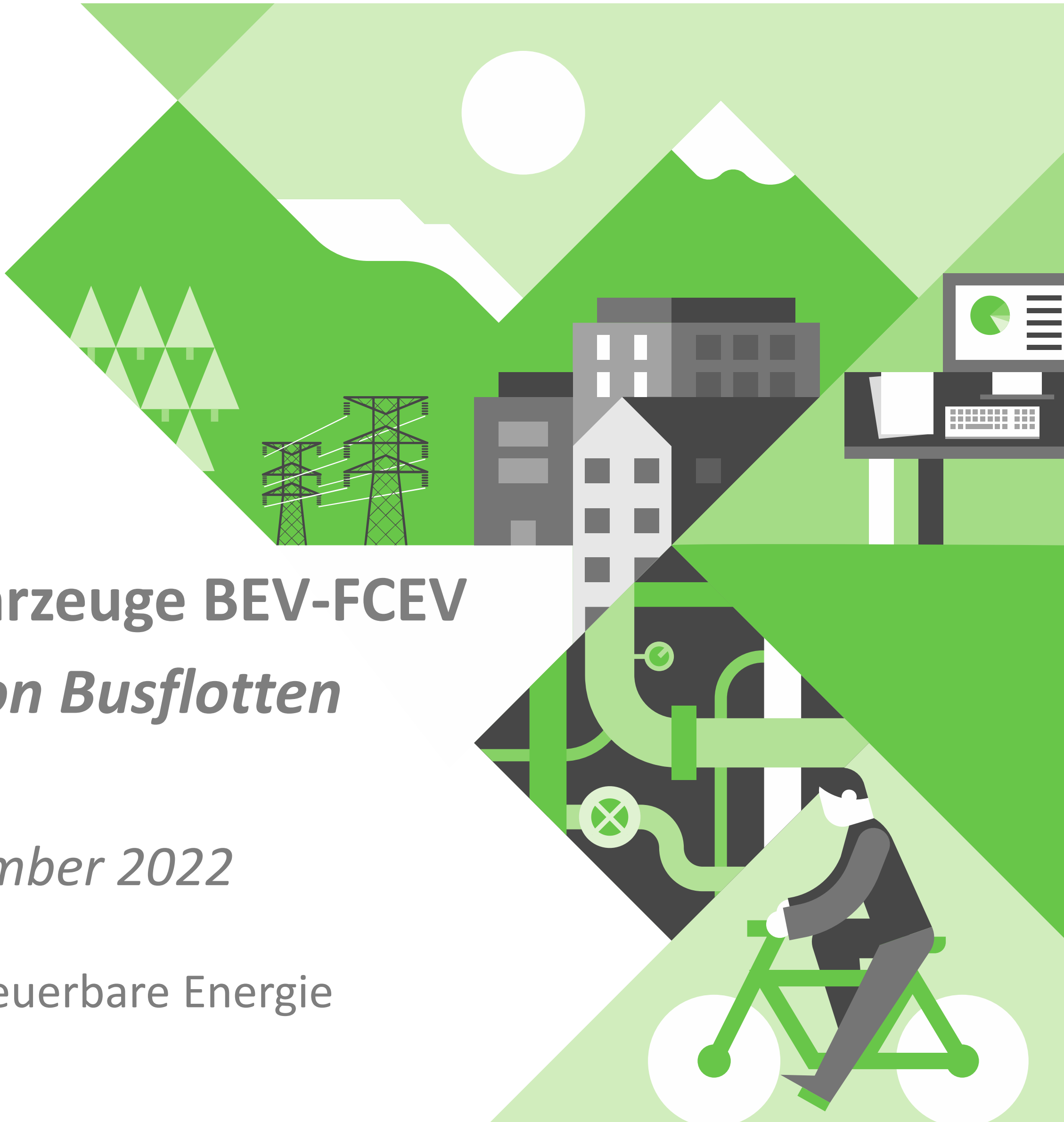

Aktuelle Feldstudie Nutzfahrzeuge BEV-FCEV

Simulation & Monitoring von Busflotten

E-Mobilitätstag Tirol – 13. Dezember 2022

Wolfram Sparber – Leiter Institut Erneuerbare Energie

Eurac Research – Institute for Renewable Energy

Eurac Research is an applied research centre located in Bolzano - Italy.
Within the Institute for Renewable Energy ~140 collaborators are working on different topics of the energy transition.

Credits: I. Corrà/NOI Spa - NOI Techpark in Bolzano, hosting offices and labs of Eurac Research

Background – simulation

This work has been presented in June in Oslo at the European E-Mobility Conference and the publication is available on Eurac's website

35th International Electric Vehicle Symposium and Exhibition (EVS35)
Oslo, Norway, June 11-15, 2022

Evaluation of different scenarios to switch the whole regional bus fleet of an Italian Alpine region to zero-emission buses

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Source: https://webassets.eurac.edu/31538/1655114255-2022_paper-evs35_busmodelling.pdf

Background – monitoring

This work has been submitted to a scientific peer reviewed journal. Publication is pending. Content will be available one's published.

Battery electric and hydrogen buses: real-world monitored data and social perceptions analysis

Aaron Estrada Poggio[a], Jessica Balest[a], Alyona Zubaryeva[a]*, Wolfram Sparber[a]

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*corresponding author

Source: Scientific work has been submitted to a scientific peer reviewed Journal. Publication pending

Project framework and partners

The simulation activities have been done in cooperation with STA Südtiroler Transport Betriebe

The monitoring activities have been carried out within the European project LifeAlps in cooperation with the public transport company SASA

schaffT Bewegung - crea movimento

The authors would like to thank the partners for the cooperation and the EU for the project framework and funding

Source: www.sta.bz.it/de/; www.sasabz.it/; www.life-alps.eu/en/

Busses in South Tyrol

South Tyrol has an extensive public transport system consisting of buses, trains and ropeways. There are **~ 700 buses in public service** covering bus lines with a **length of** up to **55 km** and an **elevation difference of up to 1780 hm**.

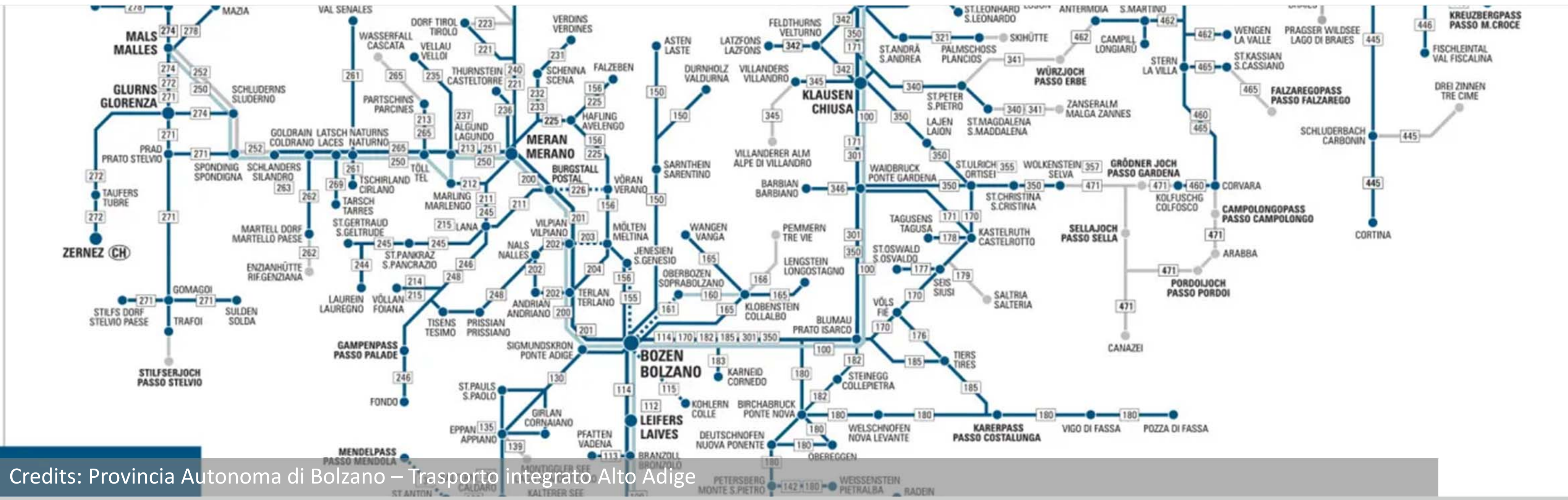
Credits: https://www.altoadigemobilita.info

Part A) Research question – simulation

Is it possible to transfer **100% of the bus service to zero emission** buses?

Is this possible **with battery electric buses**, with **fuel cell hydrogen buses** or both?

What kind of **charging infrastructure** is needed and **has the number of buses to increase**?



Credits: Provincia Autonoma di Bolzano – Trasporto integrato Alto Adige

1) Elaboration of the digitised map of the bus lines in 3D

Photo: asawin, Pxhere

Why a 3D map of the bus routes

The aim of the analysis is to reconstruct the height profiles of the **235 bus routes (4559 trips)** in order to define:

- **Distance**
- **Elevation difference**
- Maximum slope

These parameters are then **used to calculate the energy required by the buses (e-bus and H_2) to travel them**.

Photo: Viktor, Picjumbo

Input data

1. **Bus routes** and trips from the **General Transit Feed Specification** (GTFS) file (source: STA)
2. **Vector with the roads** (source: Provincia Autonoma di Bolzano – PAB)
3. **Digital Terrain Model** at 2.5m (DTM), from LIDAR (source: PAB)
4. Table with the synthesis **of the zero emission buses available on the market** (collected in a desk research upfront)

Photo: TruShotz, Pexels

Metodology: assess roads elevation

Extract the elevation of each points on the roads:

1. Select **tunnels, bridge, and subway infrastructures** that differ from the ground
2. Make a buffer of 10m around the infrastructures
3. Assign the elevation to the points outside the buffer, using the DTM data
4. **Lineraly interpolate the elevation for the points within the buffer** using the pointsfrom outside

Photo: J. Schmer, Pexels

Results chapter 1) Calssification of routes by elevation diff. and distance

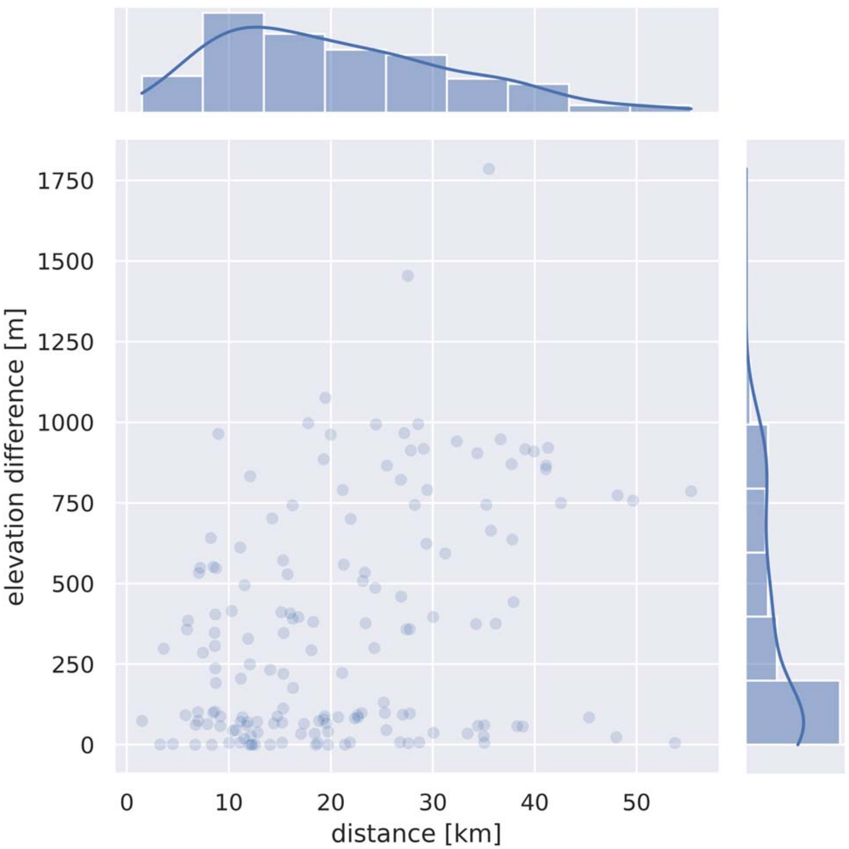
44'679 *roads have been:*

- *Transformed from 2D to 3D*
- *Checked and cleaned of abnormal gradients*

3'252'568 *points of the* ***4'594*** *bus trips in South Tirol* ***were metched to the official provincial roads data****.*

The mean ***distance*** *is* ***17.3 km*** *with a* ***maximum*** *value of* ***55.2 km.***

The mean ***height difference*** *is* ***300 m*** *with a* ***maximum*** *vaue of* ***1786 m****.*



2) Quantification of electricity or H_2 consumption for each bus route

Photo: L. Quintero, Pexels

Bus analysis and quantification of bus energy consumption

The energy required to travel the different routes/trips is calculated as a function of:

- ***altitude profile*** *and* ***distance***
- ***climatic*** *and* ***load conditions***

The energy require is compared with the capacity of the batteries and H_2 tanks of different buses' models.

Battery capacity range: **150 – 650 kWh**

H_2 tank range: **30 – 38 kg**

Photos: 741510, Pxhere

Cautionary assumptions of simulations

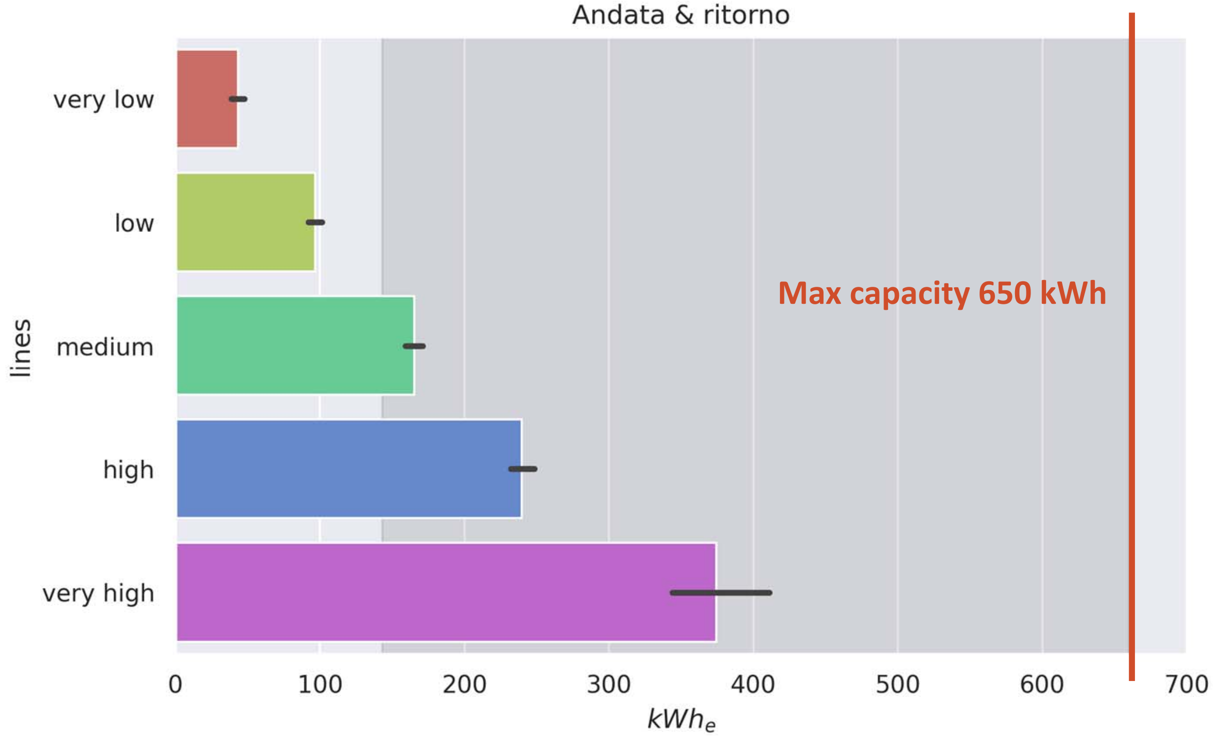
All the simulation were carried out under the most unfavourable energy conditions:

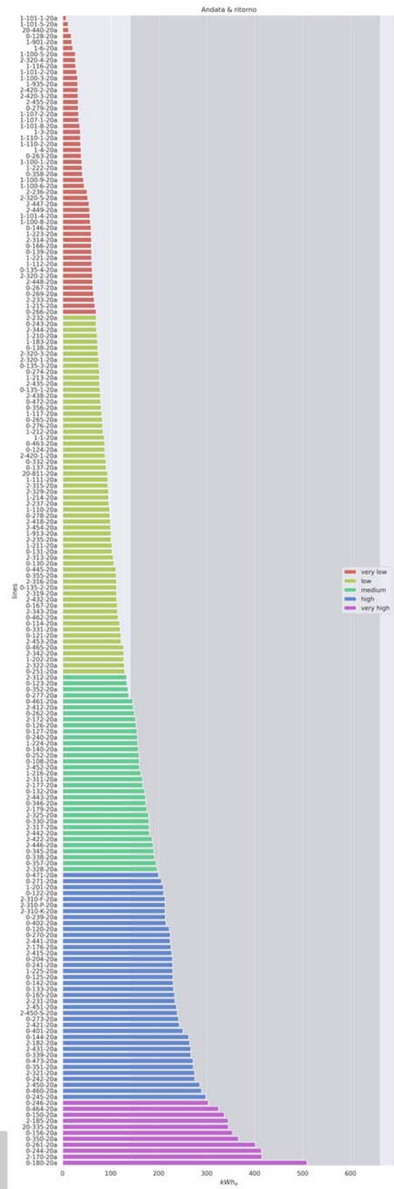
- ***Fully loaded bus uphill*** *and* ***unloaded bus downhill***
- ***Winter conditions for electric buses*** *and* ***summer conditions for hydrogen buses***

Photos: A. Grishin, Pixabay / Semvatac, Flickr

Battery electric bus: energy demand round trip

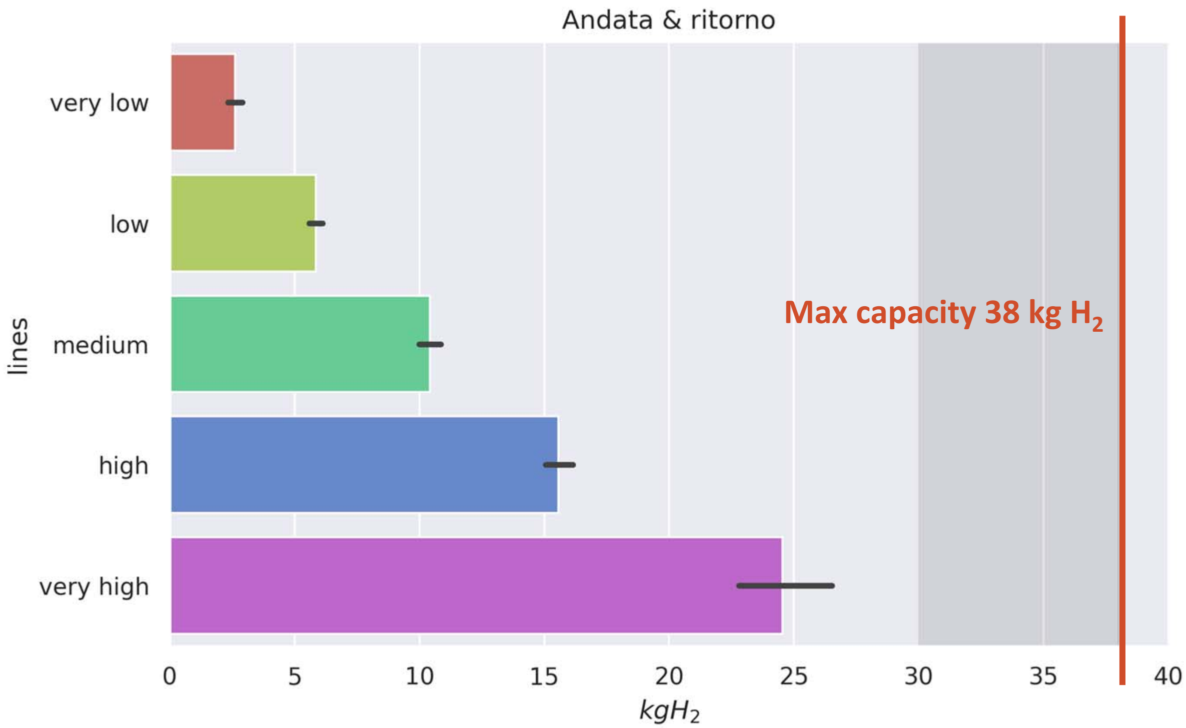
Energy required in kWh_e by the bus in order to execute one round trip under unfavorable climate and load conditions.

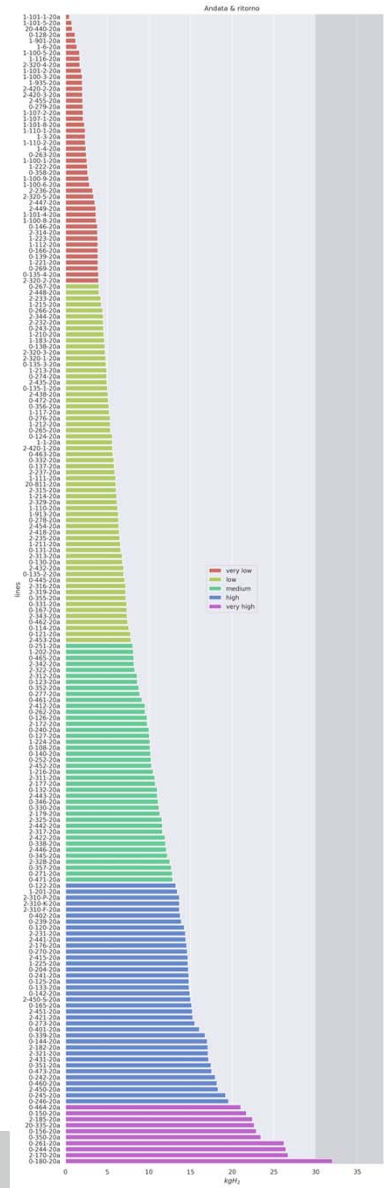




Fuel cell electric bus: hydrogen demand round trip

Energy required in kg H_2 by the bus in order to execute one round trip under unfavorable climate and load conditions.





3) Temporal analysis of the lines and practicability

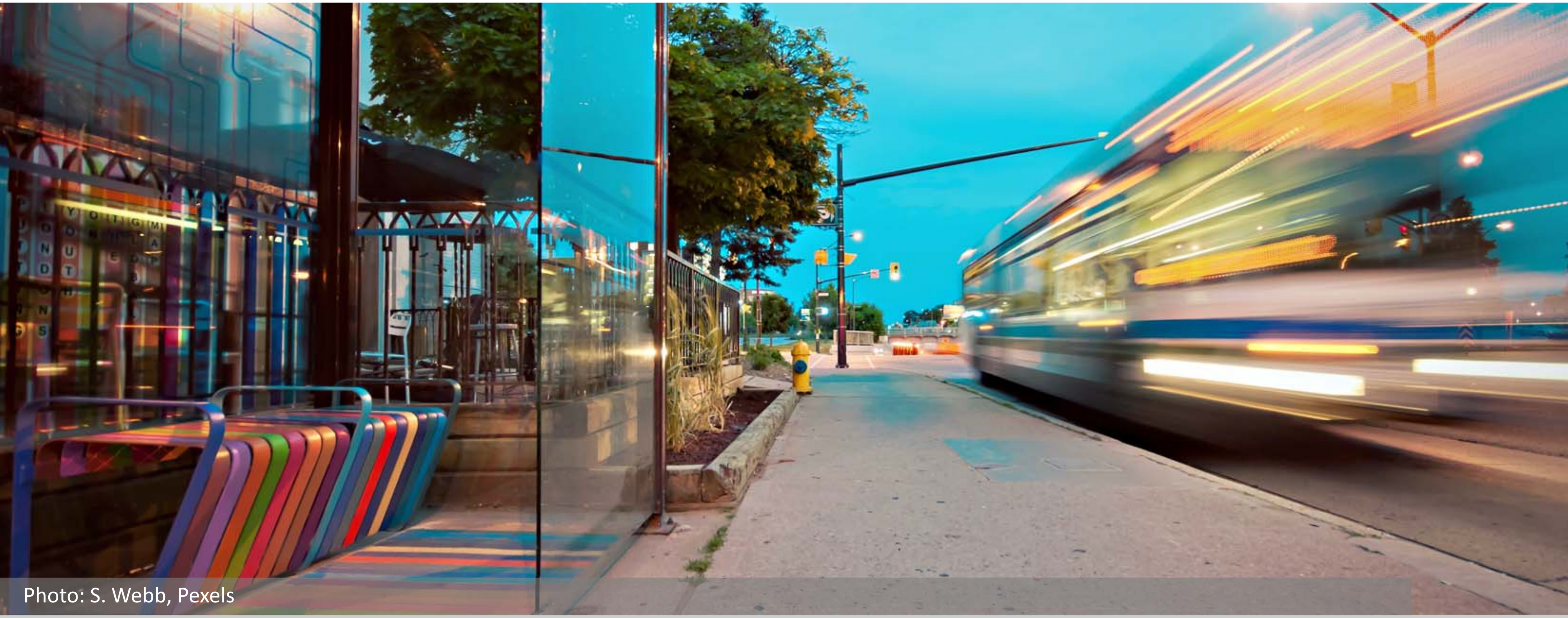


Photo: S. Webb, Pexels

Aims of the temporal analyses of the bus routes

For all the lines we estimated, for a particular day of the year, the number of buses and energy required to guarantee the service on a specific route. The main variable considered are:

- ***the energy required for the bus trip***
- ***the capacity of batteries or tanks***
- ***the charging times of the buses***
- ***the route timetable and the main breaks***

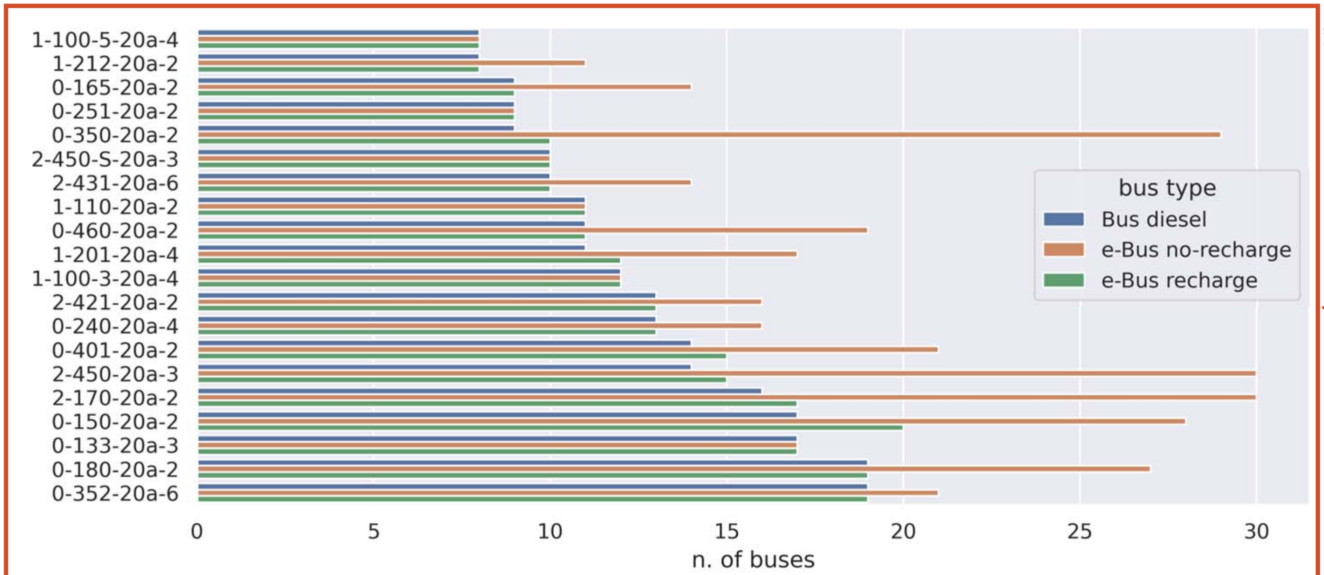
Each single route si considered separately and therefore the buses are not shared among the different bus routes.

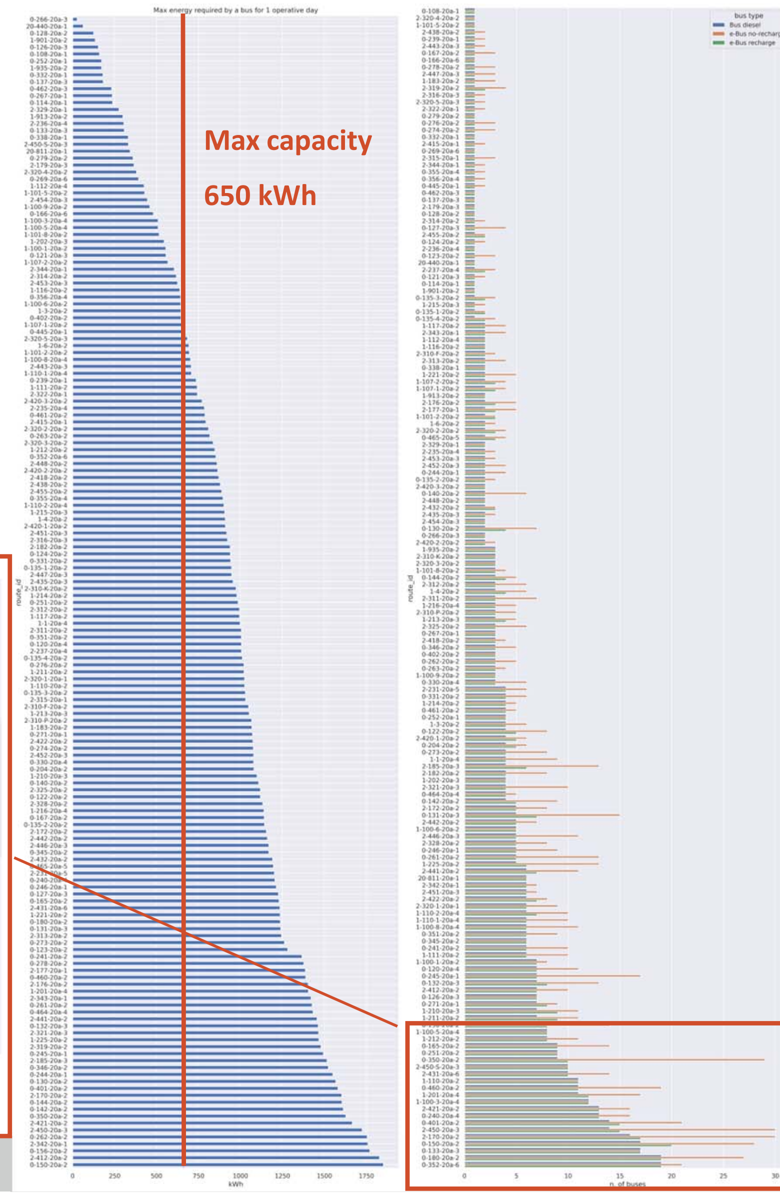
Therefore, the total sum of buses for all the routes is higher than the real value.

Photo: A. Morandarte, Wikimedia Commons

Bus routes classified by bus configuration

For each route we calculate the maximum energy required by the bus and the number of buses required





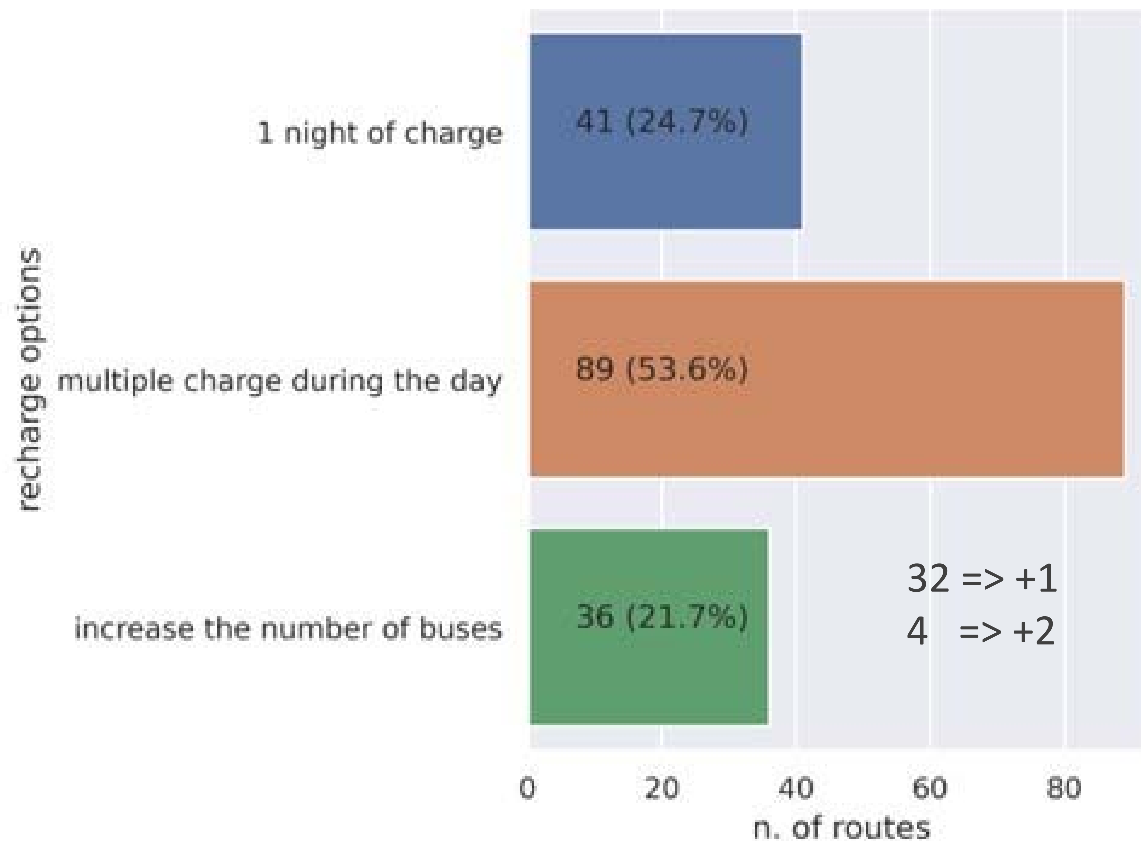
Results chapter 3) Routes sorted by battery electric bus charging options

More than 78% of the routes can be covered with the same number of buses.

Slightly more than 21% require more buses to guarantee the service.

The number of needed buses raises by 6%, if no interchange of buses between the single bus lines is considered!

Charging capacity: 150 kW

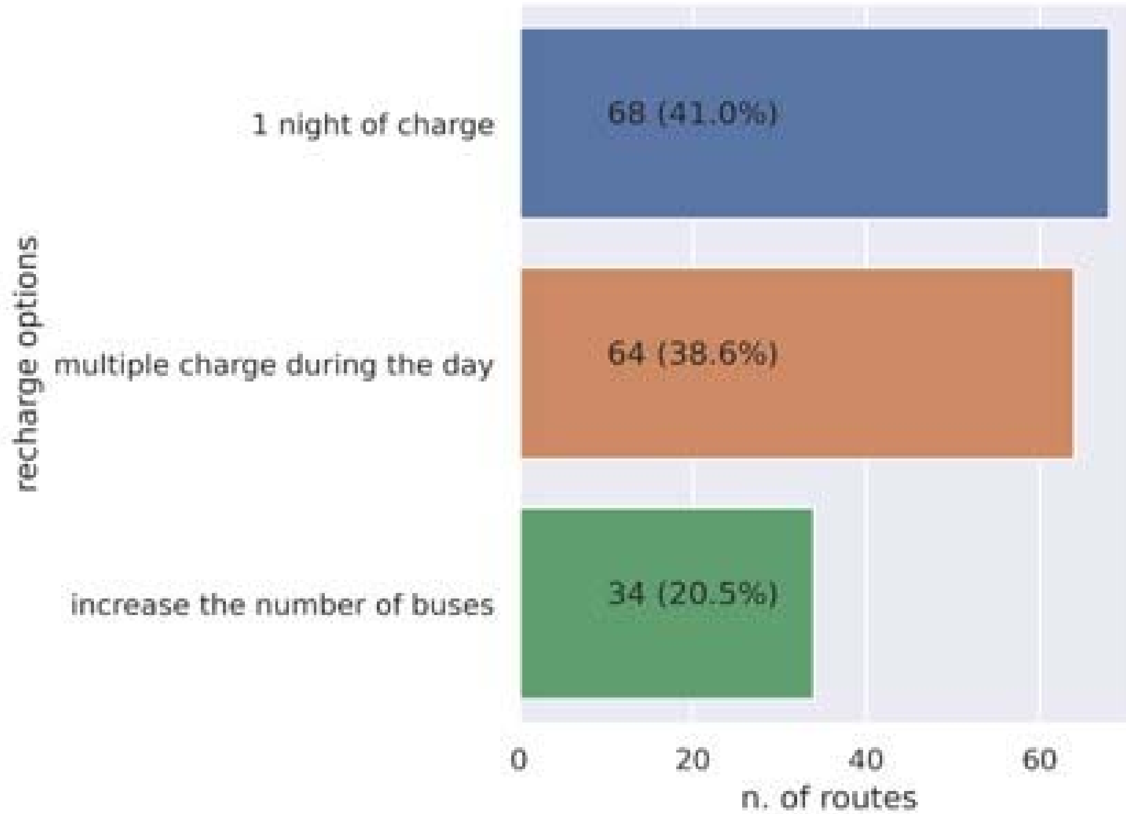


Results chapter 3) Routes sorted by fuel cell electric bus recharging options

More than 79% of the routes can be covered with the same number of buses.

Slightly more than 20% require more buses to guarantee the service.

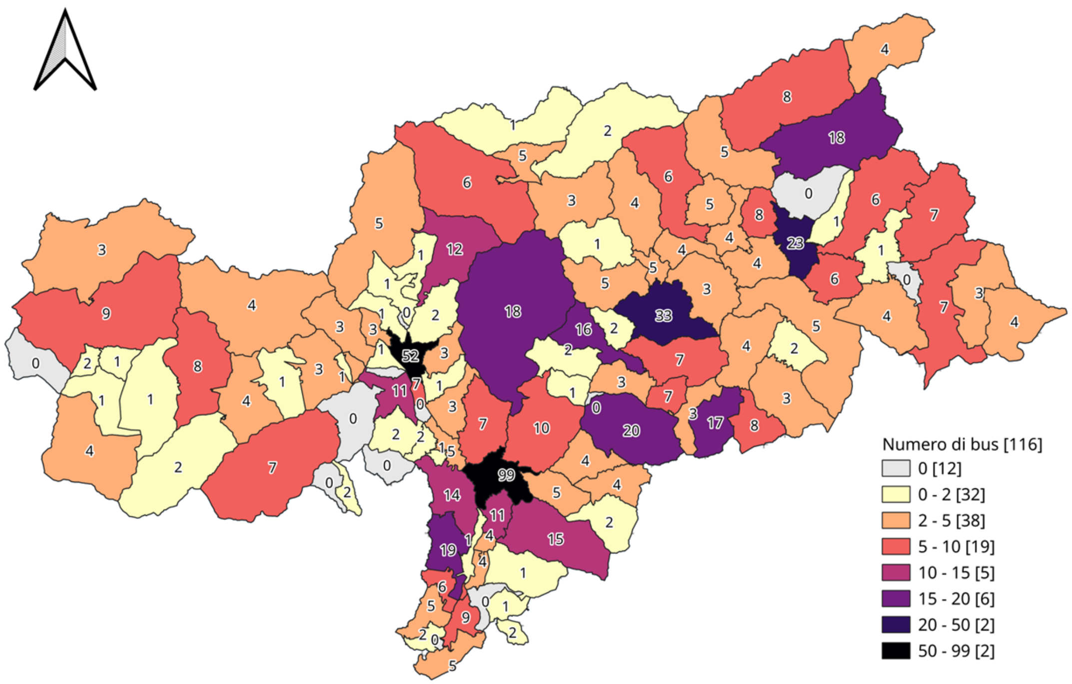
The number of needed buses raises by 6%, if no interchange of buses between the single bus lines is considered!

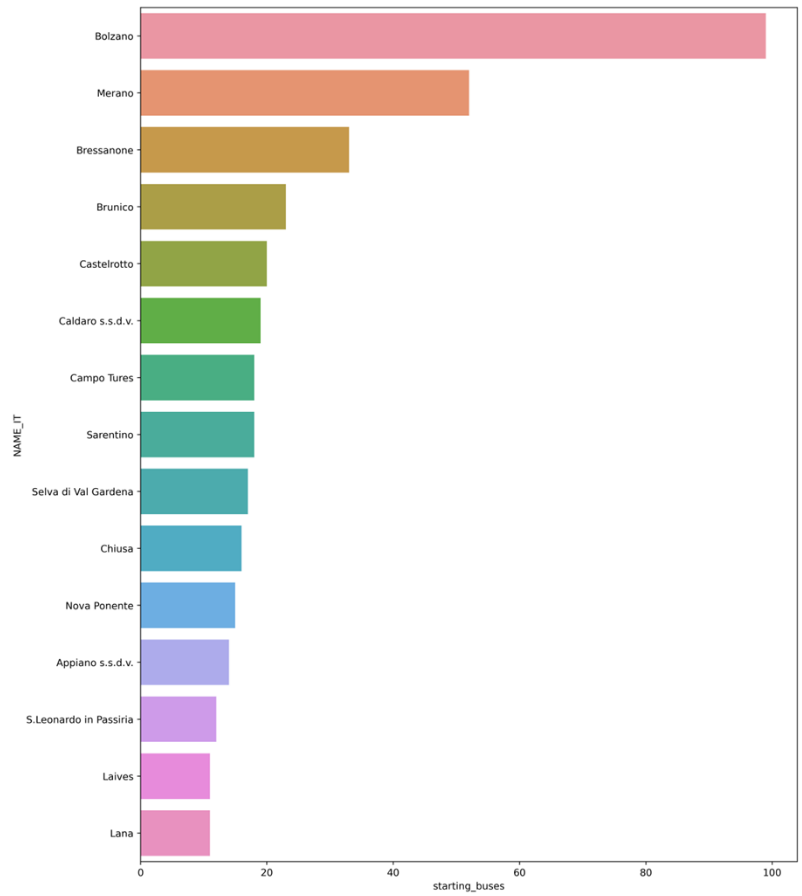


4) Analysis of the recharge points and gas stations

Photo: SounderBruce, Flickr

Number of buses that start the service





Number of buses starting the service split by municipality

Results chapter 4) Charging stations and H_2 fueling stations

Assuming **150 kW charging points** the full conversion to battery electric buses results in around **200 different charging locations**

In the case of the application of **hydrogen electric buses** the number of refueling stations results in **21 stations if a cluster of 15km is applied** (so all stations “created” by the program within 15 km are combined to 1 station).

This are the straightforward simulation results without further optimization or analysis.

Conclusions (1)

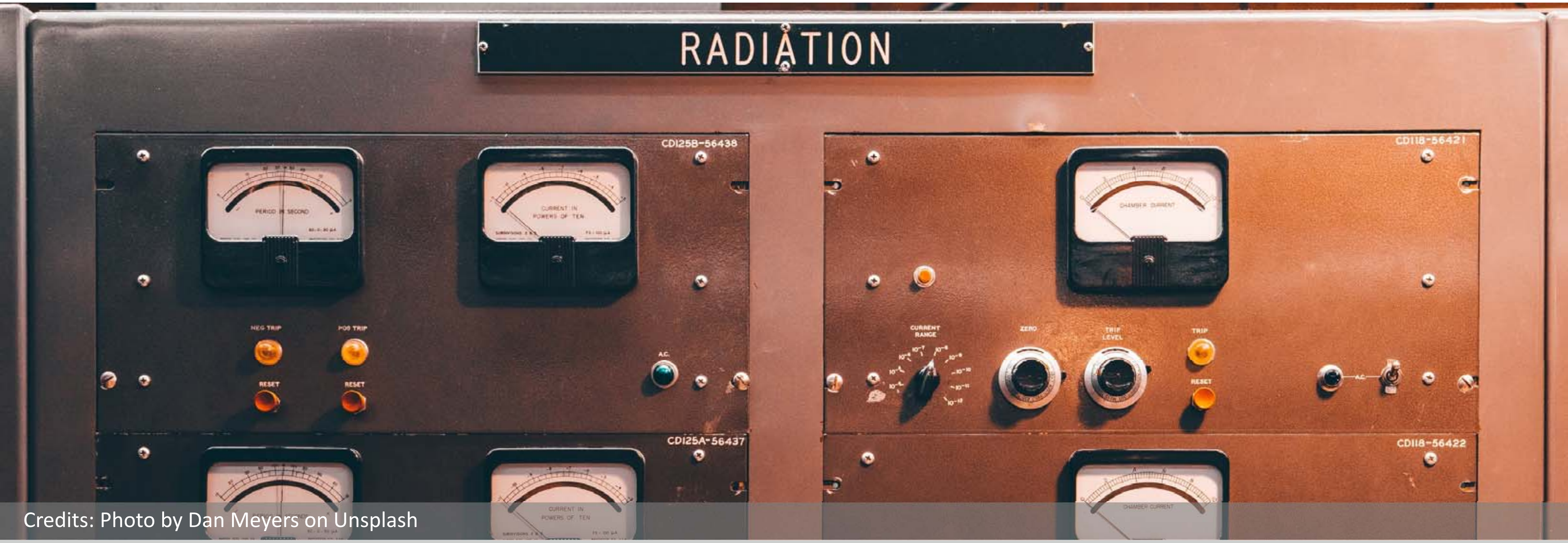
A **digital model** and the transformation of routes **in energy / H_2 consumption** allows effectively to give a pre-information **if and how a transition to zero emission of the fleet is possible**.

The data **suggests that both technologies** (H_2- and e-buses) **can be used in daily applications in direct replace of diesel buses**.

Monitoring data are needed in order to calibrate the model based on real local experiences.

Part B) Research question – monitoring and data collection

What is the **average consumption of E-buses and H_2 buses in daily use in South Tyrol**?
What is the **impact of outside temperature** to the electricity / H_2 consumption?
What is the **energy efficiency** and what are **the costs per driven km** for both technologies?



Credits: Photo by Dan Meyers on Unsplash

Information’s will be made available after publication.

Probably in the first month of 2023

Conclusions & outlook

Credits: Eurac Research, progetto Mobster, www.progettomobster.eu/viaggia-elettrico-con-mobster/, photo by Luca Meneghel

Conclusions (2)

Monitoring data are an effective tool to see the performance and show that **both technologies can be applied in daily use**.

The **advantage of H_2** buses is the **limited temperature sensibility** and the **possibility to manage the fleet "as always done"** regarding the refuelling process.

The **advantage of e-buses** is the relevantly **higher fuel efficiency**, leading to a lower energy need and a **lower cost / driven km**.

In **both cases**, **for the transition** not only the vehicles, but the **combination vehicles + charging / refuelling infrastructure + fleet management** has to be considered.

Outlook …

Considering the **actual energy and climate crisis** and the set European / National / regional CO_2 emission targets the **focus of thoughts and action** should the implementation of a **fast transition** of **full fleets, in all sectors, to zero emission mobility**!

Thank you
for your attention

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