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e-SMART
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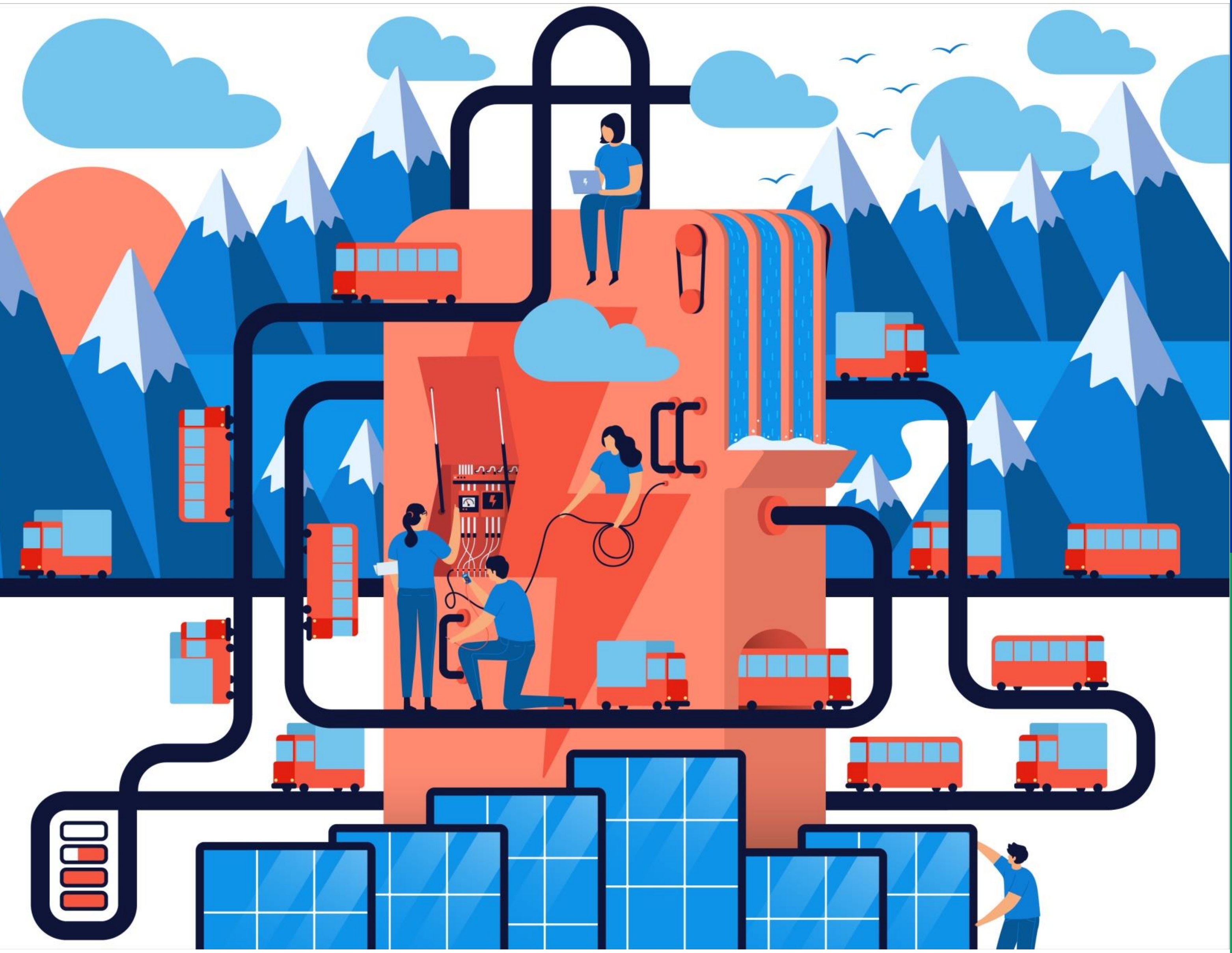

e-SMART TRAINING MATERIAL

Procedure model for electrification of LPT

This project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme.

The e-SMART project

While electrification of private transportation has continued to expand constantly, ambitions should move forward towards electric vehicles solutions in Last-Mile-Logistics (LML) and the Local Public Transport (LPT), with electricity generated from renewable energy sources.

The decarbonisation of the transport sector and particularly the mass deployment of electric vehicles need truly interoperable roll-outs of electric vehicle charging infrastructures powered by renewable energy as well as an intelligent charging management to prevent peak loads. This is especially important in the Alpine Space, where mobility and transport have always played a significant role.

The e-SMART project addresses this challenge: Bringing developments in e-mobility in LML and LPT together and improving the electric vehicle ecosystem building up on the concept of smart-territorial relationships.

Find out more about the e-SMART project:
www.alpine-space.eu/projects/e-smart

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Objective

This procedure model for the electrification of local public transport using the practical example of the conversion of the bus fleet in Klagenfurt shall be shared as a transferable best-practice-example for other cities in the Alpine-Space-region with this training material.

This training material aims at demonstrating a systematic approach to finding a technically, economically suitable input to develop a decarbonisation strategy of the existing fleet of diesel buses, to be implemented between 2023 and 2030.

The City of Klagenfurt and its public transport operator KMG Klagenfurt Mobil GmbH (KMG), together with the electricity grid operator Energie Klagenfurt GmbH (EKG), are currently conducting a market consultation of all system components required for the full decarbonisation of the bus fleet. The e-bus technologies in question are battery electric buses (depot charging and opportunity charging at terminal stops), also battery trolleybuses (dynamic charging via current collectors on overhead lines) and fuel cell hybrid buses.

To gain knowledge regarding the feasibility of an e-bus system specifically designed for the City of Klagenfurt, a feasibility study is currently being conducted. This study will deliver an operational, technical, ecological, risk and city layout assessment as well as a conversion concept.

The outcome of the study will be used as a reference for setting up the functional, open technology tender.

1. Introduction

As part of its “Smart City Strategy”, the City of Klagenfurt am Wörthersee targets a reduction of greenhouse gas emissions by at least 70 % and 90 % by 2030 and 2040, respectively, compared to 2011. To reach these figures, a more sustainable transportation system is required. The current traffic situation in Klagenfurt, with its well-developed road network and favorable parking conditions, favors the use of conventional passenger vehicles.

Currently, more than half of all journeys in Klagenfurt are done using conventional diesel or petrol passenger vehicles. The modal share for public transport was estimated at ca. 9 % in 2018. On top of this, the COVID-19 pandemic led to a strong drop in customers since April 2020. Today’s situation stands in stark contrast to the short- and long-term City’s climate targets. Making public transportation more attractive by increasing its availability, reliability, and simultaneously enhancing overall energy efficiency are the main challenges to be addressed to improve today’s transportation system.

In light of the challenges described above, the city developed a “sustainable mobility concept”, which encompasses measures focused on maximizing synergies between sustainable, less polluting, and emission-free transportation modes such as public transport, cycling, sharing e-mobility services with e-bikes and e-vehicles, and walking.

These measures reflect the goal of a substantial modal shift, especially towards a higher share in public transport supported by doubling the driving frequency (10-min) on five main corridors by 2026, which would constitute doubling and tripling of passenger figures by 2030 and 2035, respectively.

To develop the implementation of these measures several Key-Players work on a technically and economically detailed, contract-ready, financially viable investment programme, starting with planning, concept and strategy development on three key topics: 1) e-buses and accompanying infrastructure including the realization of a new depot, 2) bus rapid transit measures, including the required intelligent transportation management system, and 3) mobility hubs for the dissipation of shared transportation and other mobility services.

This training material lays focus on the electrification of the public transport of the City of Klagenfurt. It presents the steps being taken to develop a thorough understanding of the challenges surrounding the electrification of a relatively large fleet of buses.

2. Boundary Conditions

KMG Klagenfurt Mobil GmbH (hereinafter: KMG) operates the local public transport in Klagenfurt am Wörthersee with currently 70 diesel buses (3 midi, 38 solo and 29 articulated buses) and a battery midibus (from 2013)[1].

KMG is planning the gradual conversion of the bus fleet to (a) climate-neutral, decarbonised and sustainable drivetrain technology(ies) by 2030. A first test phase with electric buses is set to start as early as 2024.

KMG also plans to successively introduce a new line concept by the end of 2025, (Figure 1, [1]), with 13 lines made up of five main corridors and eight secondary corridors with a 10-minute and a 20-minute frequency, respectively. The vehicle requirement including reserves after the implementation of the new line concept is estimated at around 90 buses ("diesel bus equivalents", excluding solo and articulated buses). A total of around 5.8 million kilometers should be covered each year. The requirements of the new line concept serve as the basis for creating a concept for the changeover to alternative drive technologies. The estimated driving range for an assumed diesel bus fleet is depicted in Figure 2. The average and median range are approx. 265 and approx. 270 km, respectively.

To develop the implementation of these measures, the City of Klagenfurt was awarded € 2,31 Mio. for the € 2,57 Mio. project KEBIP (Klagenfurt Electric Bus Investment Project) by the European Investment Bank (EIB) in 2020 through the European Local Energy Assistance (ELENA).

[1] This 8-year-old e-bus was the first fully electrified public transport bus in Austria.

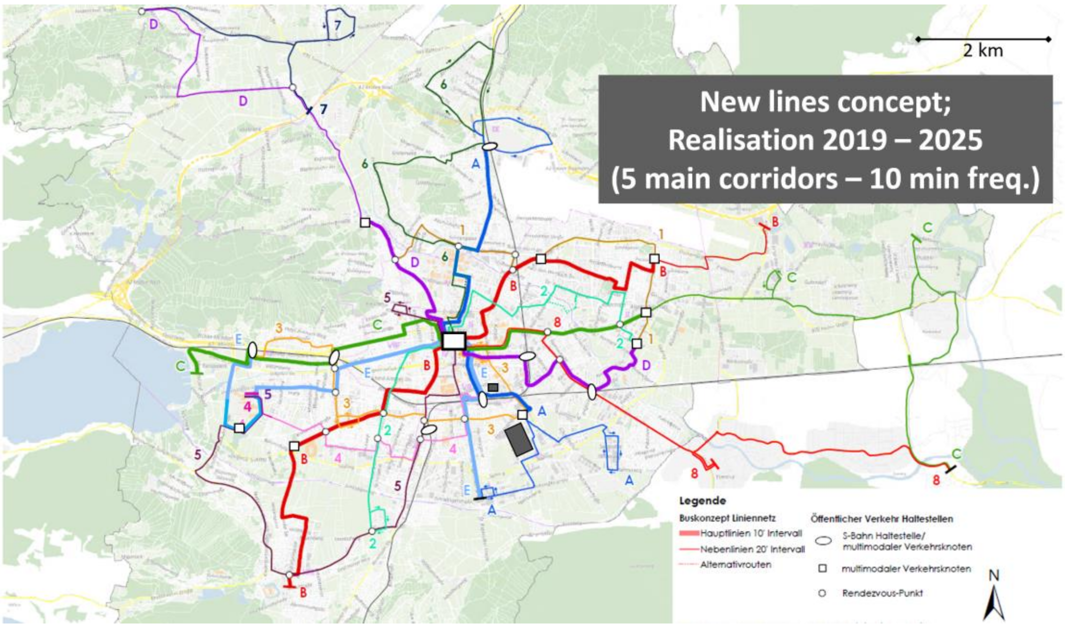


Figure 1. The new lines concept with 13 lines (5 main corridors –A, B, C, D, E– and 8 secondary corridors –1, 2, 3, 4, 5, 6, 7, 8– with frequencies of 10-min and 20-min, respectively).

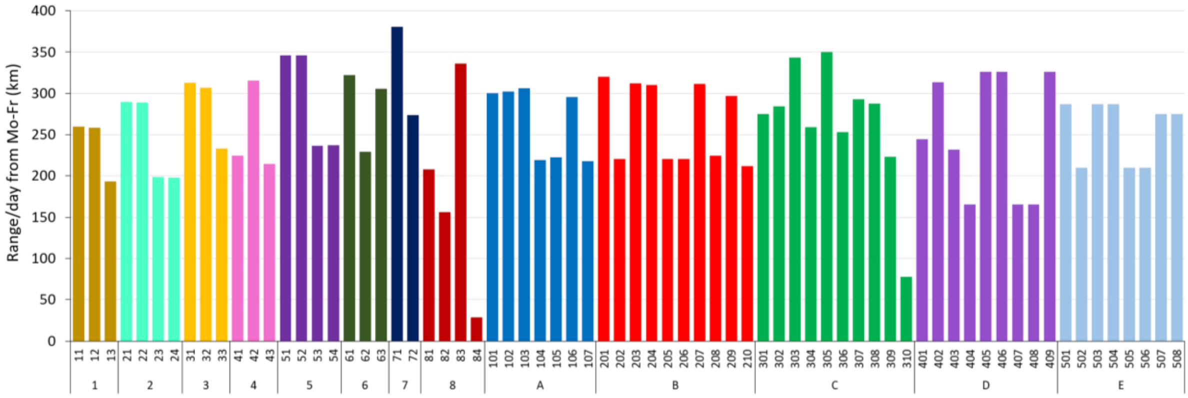


Figure 2. Estimated range of a diesel bus fleet for the new lines concept. The average and median range are 265 and 270 km, respectively.

3. Integral view

Electricity and power-grid infrastructure are provided by Energie Klagenfurt GmbH. The entire electricity provided by EKG stems from renewable sources.

KMG Klagenfurt Mobil GmbH and Energie Klagenfurt GmbH are subsidiaries of Stadtwerke Klagenfurt AG, the municipal utilities company.

The municipality and its companies aim to find a cost-benefit optimized solution for the electrification of LPT and therefore examine an integral view over all the connected resorts from the busses to road- and electricity-infrastructure. There is a clear objective to analyze necessary investments to discover potentials to avoid expenses that can be reduced by other cheaper or more efficient investments in other areas.

The possible technology options of the busses, more precisely their charging-infrastructure have a wide variety regarding its power-demand.

This is especially challenging concerning the impact on the power-grid. The technology-open-analysis on the potential bus-systems makes it necessary to evaluate different scenarios with varying requirements concerning load an simultaneity regionally distributed over the whole city-area., While the demand for a depot-charging system at one defined location can be relatively easy calculated and matched with existing capacities - or capacities to be built, scenarios for opportunity charging with high-power at bus-terminals are complex to examine.

In order to determine the necessary extent of the expansion of the power grid, with the exception of the transformer stations and the overhead line system the effects have to be calculated with a simulation-tool that has to be set-up with the corresponding parameters for each szenario. This investigation on the grid and the load flow calculation on medium-voltage network level are necessary to provide a decision-basis regarding technical boundaries of the existing infrastructure.

Simultaneity is a key-word in this context and means to map bus-lines with its timetables, just-in-the-moment-power-demand of the busses with their individual state- and need of charge with the power-grid. There are different possibilities where and how to charge the busses on the track, so this simulation can also support the intelligent selection of bus-stops to be equipped with chargers. If this local distribution is not possible or has no effect, at least the demand for extensions on the power-grid and the resulting cost for the implementation of the variant for charging the e-buses can be derived

Not only taking the direct cost for busses - including different batterie capacities and charger-hardware - into account, but also this environmental parameters and the macroeconomic view with its consideration of the overall costs will have important impact on decisions of investments in the bus system

4. Technology Options

The e-bus technologies in question are (Figure 3):

1. Electric buses with stationary charging of batteries (depot charging as well as depot charging combined with opportunity charging at terminal stops)
2. Electric buses with dynamic charging of batteries via current collectors on overhead lines (dynamic charging) - battery trolleybuses
3. Electric buses with hydrogen refueling - fuel cell hybrid buses, also battery buses with fuel cell range extenders.

Figure 3. All e-bus technology options of KMG.

As depicted in Figure 2, most of the planned routes would require a range greater than 200 km, which cannot be guaranteed all year long by any existing electric bus that is only charged in the depot. This means, one e-bus with depot charging cannot substitute one diesel bus. Because of weight i. e. battery size limitations and the resulting range limitations, depot-charging of buses leads to a higher demand for e-vehicles than theoretically needed. To suppress the higher demand, e-buses could also be charged outside of the depot at strategically located places at relatively high power, such as terminal stops.

A second option for reducing the number of e-buses needed to replace diesel ones is the use of overhead catenary. In this area, battery trolleybuses (which are trolleybuses equipped with high power batteries that can be charged while driving under the overhead catenary) offer several advantages, such as drives without catenary lines in areas where these are not desired (such as the city centre) or technically possible (underpasses; power-grid constraints).

The third option is the adoption of battery fuel cell buses, that either use a small battery and a large fuel cell (so-called fuel cell hybrid buses) or a large battery and a small fuel cell (so-called battery buses with fuel cell range extender). Klagenfurt has neither overhead wires nor a hydrogen generation unit, storage facility and fueling station.

5. Market consultation of all technology options

The first step after analyzing the status quo of the bus fleet was carrying out a Europe-wide market consultation of

- all e-bus drivetrain technology options,
- all required infrastructure (for charging and fuelling), and
- all required peripheral components such as depot, load and energy management software systems

One of the main objectives of such a market consultation was to have an exchange with potential bidders on conditions and design of the planned tendering (size, lots, contract duration, level of freedom, risk allocation, financing support etc.) in order to raise interest in tender participation.

The exchange with bidders is being carried out within the framework of so-called hearings with market participants. The development of an electrification concept of at least two bus lines by market participants (especially those delivering e-buses) was set as one of the prerequisites for being invited to these hearings. Like this, a discussion on a technical level is guaranteed.

The findings of the market consultation flow into the feasibility analysis and the design of the functional tendering.

6. Feasibility analysis and cost assessment of all technology options

In order to gain knowledge regarding the feasibility of an e-bus system specifically designed for the City of Klagenfurt, a feasibility study is currently being conducted. This study will deliver an operational, technical, ecological, risk and city layout assessment as well as a conversion concept. Additionally, the outcome of the study will be used as a reference for setting up the functional, open technology tender.

Data for the feasibility analysis was obtained from the market consultation, which is being carried in parallel.

Electric buses with stationary charging of batteries (depot charging)

The concept of depot charging and its resulting higher vehicle demand compared to the diesel solution is analyzed in dependence of different battery sizes. In our feasibility study, three battery sizes were considered for each bus size (12 m and 18 m). The optimum battery sizes are then elicited by means of a parametric study considering total costs of ownership (life cycle costs) over 20 years.

Electric buses with stationary charging of batteries (depot charging combined with opportunity charging at terminal stops)

To evaluate the concept of charging at termini, a technical analysis was made, which delivered frequented termini with the potential to serve as charging spots.

The evaluation of termini was done in collaboration between several stakeholders, such as:

- the City's Facility Management Department
- the City's Climate and Environmental Protection Department
- the City's Department for Road Construction and Traffic
- the City's Department for Urban Planning
- the City's electricity grid operator EKG
- the City's PTO KMG

Feedback was required on different relevant aspects to assess the suitability of different termini, such as traffic obstruction, real estate or land ownership, available area/space at the termini for simultaneous charging of at least two buses, assessment of available substations near the termini, assessment of the impact on the cityscape, among others.

This coordinated approach delivered a relatively high number of potential charging spots in the City.

Electric buses with dynamic charging of batteries via current collectors on overhead lines (dynamic charging) - battery trolleybuses

Potential dynamic charging routes were identified by analyzing the frequency of drives along the different routes. The suitability of the routes in question was assessed by the City's Department for Urban Planning, which is responsible for evaluating the impact of infrastructure on the cityscape.

Electric buses with hydrogen refueling - fuel cell hybrid buses, also battery buses with fuel cell range extenders

The operation of a fuel cell hybrid bus fleet is, at least in theory, less complex than that of electric buses with stationary charging, as the refuelling characteristics are comparable to those from conventional diesel buses in regards to time requirements.

Instead, the complexity arises from the need for a hydrogen supply infrastructure including the corresponding required hydrogen storage amount. A new study will be carried out which will lay focus on the suitability of two different areas in the City to refuel fuel cell vehicles and store hydrogen considering existing regulatory constraints, such as the Seveso III directive.

7. Tendering

The supply of the clean bus system shall be decided based on the outcomes of the market consultation and feasibility analysis incl. an assessment of the total cost of ownership including potential necessary investments in the power-grid-infrastructure as an macroeconomic approach.

The functional tendering is challenging with regard to the description of the requirements and performance specifications and awarding criteria. The basic approach for awarding the contract shall be to compare life cycle system costs with discount factors based on criteria like operational flexibility, primary energy consumption, emissions (greenhouse gases, noise, etc.) up to considerations of effects on upstream energy-infrastructure.

8. References & Further Readings

For more information on KEBIP, please refer to:

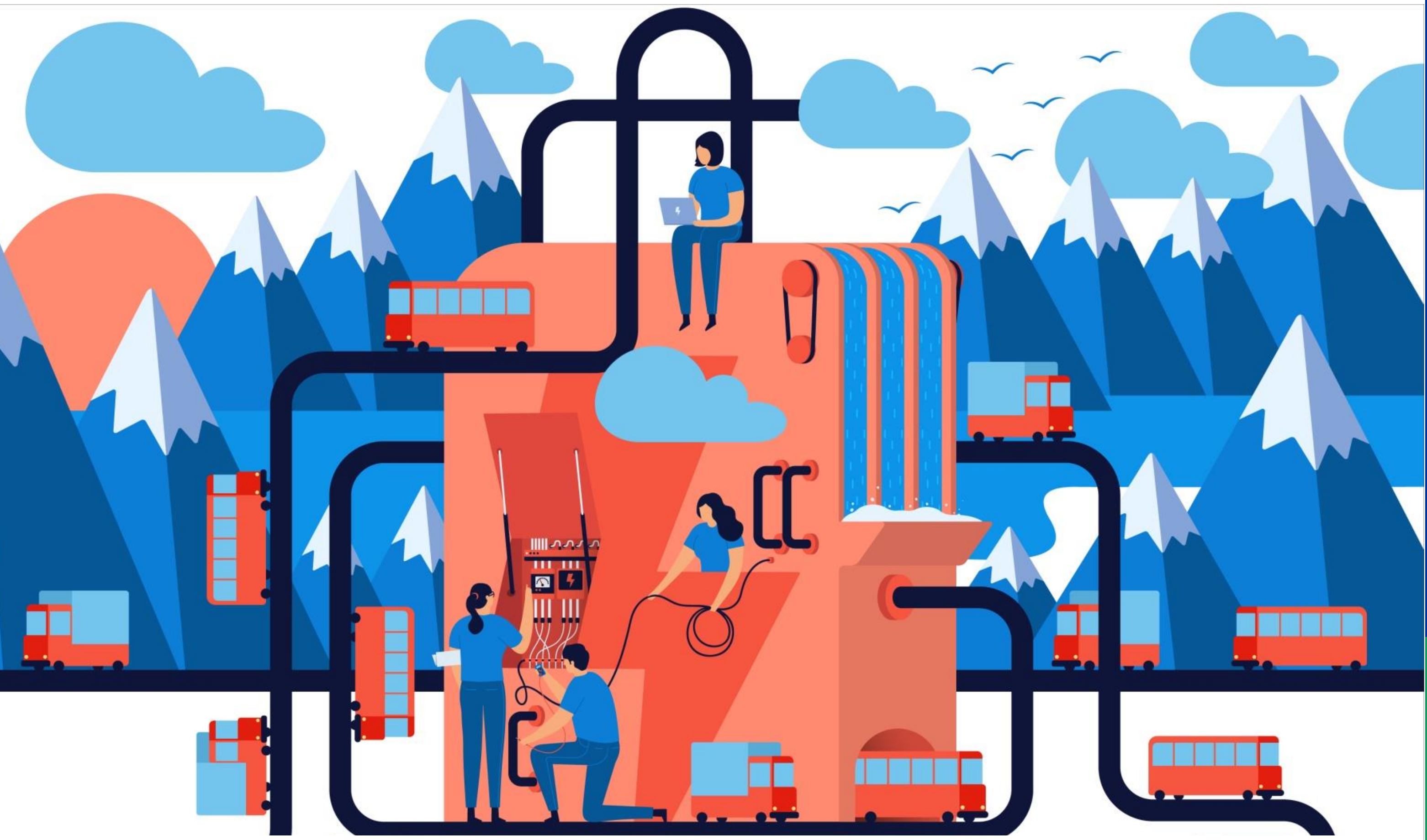
Ms. Sandra Habib (project coordinator), City of Klagenfurt

Mr. Alejandro Santis (project manager), KMG Klagenfurt Mobil GmbH

Mr. Wolfgang Hafner (project responsible, senior expert), City of Klagenfurt

The information concerning KEBIP for this training material was provided by Mr. Alejandro Santis and recorded by Mr. Martin Florian.

Author: Martin Florian (Stadtwerke Klagenfurt AG – STW)



Imprint

Ricerca sul Sistema Energetico - RSE S.p.A. (Lead Partner)

via R. Rubattino 54, 20134 Milano
Tel. +39 023992.1
PEC rse@legalmail.it

Editors: Stadtwerke Klagenfurt

Partner

www.alpine-space.eu/e-SMART