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EfficienCE

LESSONS-LEARNT BROCHURE

CE1537

IMPRINT

About the project

EfficienCE was a cooperation project funded by the Interreg CENTRAL EUROPE programme that aimed at reducing the carbon footprint in the region. Most central European cities have extensive public transport systems, which can form the basis of low-carbon mobility services. More than 63% of commuters in the region are using public transport. Measures to increase the energy efficiency and share of renewables in public transport infrastructure can thus have a particularly high impact on reducing CO2.This was achieved by supporting local authorities, public transport authorities and operators by developing planning strategies and action plans, implementing pilot actions, developing tools and trainings to plan and operate low-carbon infrastructure, and by transferring knowledge and best practices on energy-efficient measures across Central European regions.Twelve partners, including seven public transport authorities/companies from seven countries were working together for three years to exploit the untapped potentials in this sector and to contribute to the EU's 'White Paper' goals to cut transport emissions by 60 percent by 2050 and to halve the use of 'conventionally fuelled' cars in urban transport by 2030.

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WHO ARE WE?

AUSTRIA

Wiener linien

CZECH REPUBLIC

Pilsen Transport Company (PMDP)

HUNGARY

Centre for Budapest Transport (BKK

Mobilissimus

POLAND

Gdynia trolleybus operator (PKT)

Univeristy of Gdansk

SLOVENIA

Municipality of Maribor

University of Maribor

GERMANY

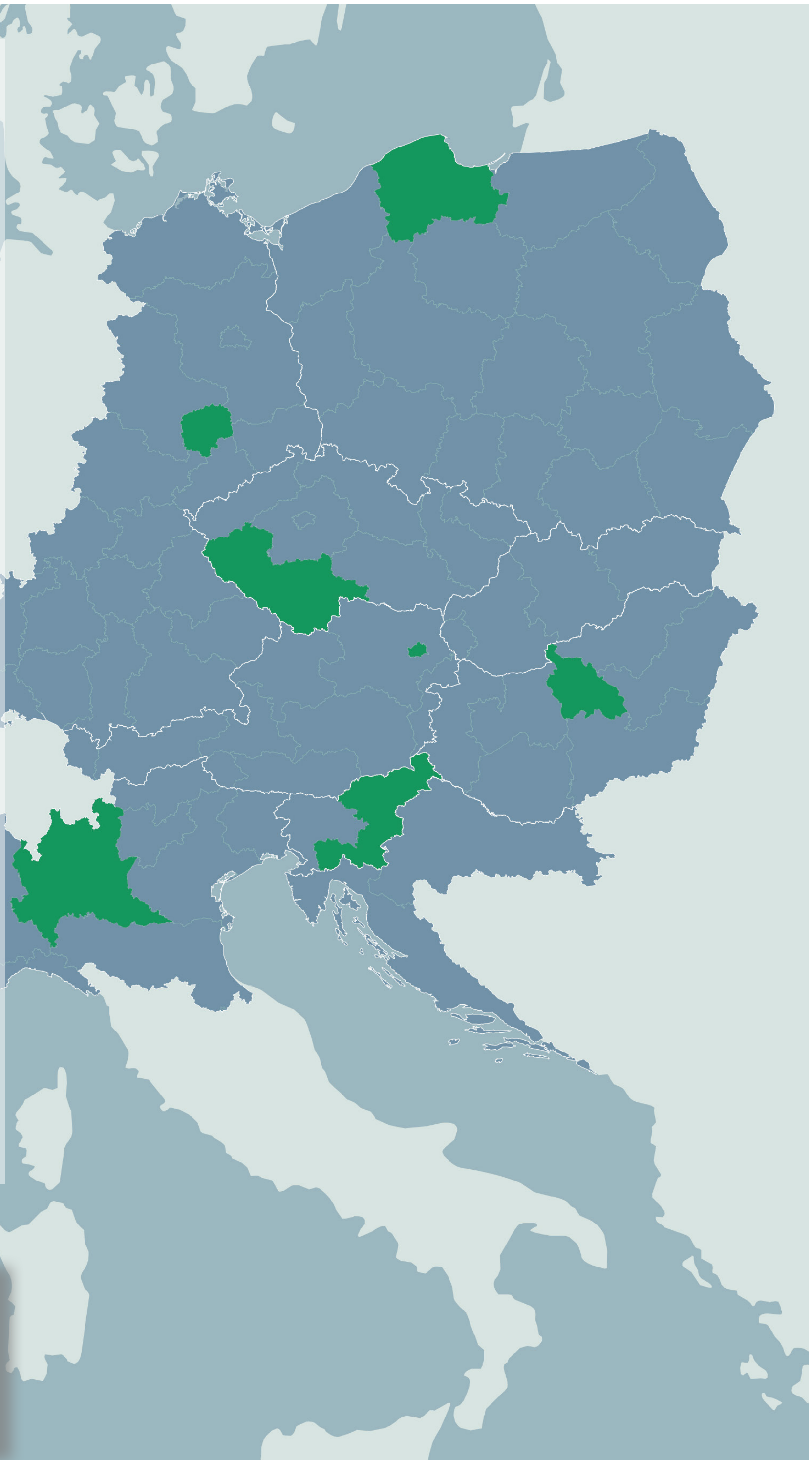
City of Leipzig

Leipzig Transport Company (LVB)

ITALY

Municipality of Bergamo

Redmint



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IMPLEMENTED PILOTS

Implementing a metro-station integrated PV-system to power building auxiliaries with RES

Wiener Linien (Austria)

Territorial description

Wiener Linien GmbH & Co KG (WL) is Vienna's public transport (PT) operator and is responsible for underground, tram and bus lines incl. its infrastructure as an integrated service provider. Vienna is the capital city of Austria and has approximately 1.9 million inhabitants. In 2021 Wiener Linien covered 30 % of the modal split in Vienna, 26 % were covered by cars, 35 % by foot and 9 % by bike. With about 600 million passengers in 2021, WL make a major contribution to mobility in Vienna. Before Covid-19, 960 million passengers used the public transport possibilities of Wiener Linien.

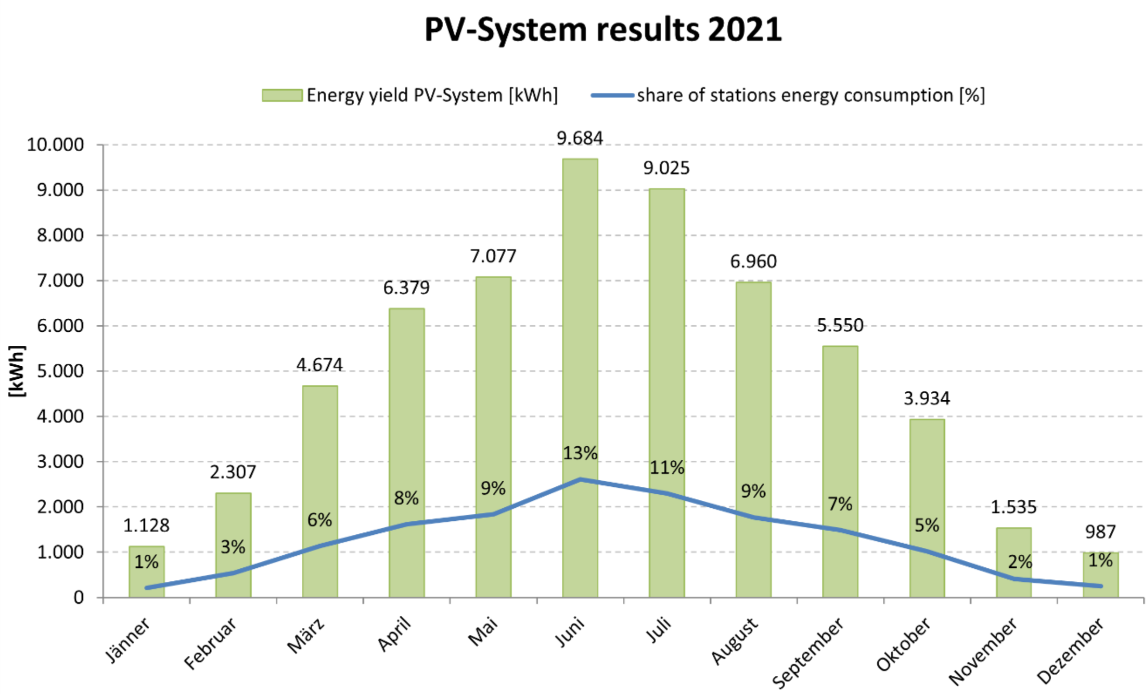
1. Figure: Light photovoltaic foils on the roof of a metro station in Vienna (source: Wiener Linien)

Why is the selected topic important for the city?

In EfficienCE WL's main aim was to reduce the energy consumption in the Wiener Linien metro network, i.e. metro stations. Therefore, **WL tested a novel PV installation technology on the roof of the metro Station Ottakring**. Before EfficienCE project not a single PV-System was in operation at WL metro network. There were reservations in the company about the construction of PV-Systems on metro stations because of electrotechnical concerns, the statics of the buildings and the compatibility with Austrian railway law. **The aim of the pilot was to implement a metro station integrated PV-System, to power building auxiliaries like lighting devices, ventilation systems, elevators or escalators with renewable energy sources.** Further goals were to increase the share of renewable energy sources in the metro network and to gain experiences for potential future projects in Vienna and in the CE-region of Europe. The installation of the PV-system was done by WL's sister company Wien Energie, which is Austria's largest operator of PV-systems with about 320 PV-plants around Austria. Due to static reasons very light PV-foils were used.

Main outcomes

EfficienCE showed a very high potential to increase renewable energy sources to the public transport network. Over the monitoring period of two years, the data obtained from the PV foils were recorded and analysed in detail. The photovoltaic plant has a size of 360 square metres and a maximum power of 60.3 kilowatt peak. It produces around 60 000 kilowatt hours of solar energy per year. This saves more than 8 tons of CO_2 every year, based on the current electricity mix in Austria. The PV-System can cover up to 50 % of the metro station's power demand. A look at the energy quantities shows, the PV-System supplies up to 13% of the monthly energy demand of the metro station, including the enclosed metro depot building, and approximately 7% of the yearly energy demand. The figure below shows the monthly energy yield of the PV-System and the share of the station's energy consumption which is covered by renewable energy gained by the PV-System.



2. Figure: The monthly energy yield of the PV-System and the share of the station's energy consumption (source: Wiener Linien)

What are the main learnings?

The learnings are, that there are no problems regarding Austrian railway law - the realisation of a PV system on a railway building is possible. In terms of electrotechnical concerns there are no negative effects from the PV-System to the traction power supply and no negative effects in the other direction. In conclusion, the PV-foils are a very good possibility for older buildings with static challenges but when it is possible concerning the statics of the building, standard modules should be used because of economic reasons. To sum up, **EfficienCE showed a high potential to increase RES in the metro network and Wiener Linien started a cooperation with its sister company Wien Energie to build more PV-Systems on metro stations in Vienna**. As a first step, 20 sites are identified to build a PV-System in the next 4 years.

Buffer storage in public transport infrastructure

PMDP, Plzeňské městské dopravní podniky, a.s. (Pilsen)

Territorial description

3. Figure: Buffer storage station in Pilsen (source: PMDP)

Pilsen is the 4th largest city in the Czech Republic. It is in western Bohemia. Pilsen is an important industrial, commercial, cultural, and administrative centre. The City of Pilsen covers 125 square kilometres, and its population is 169,000 inhabitants. Modal split according to the distance travelled: 47% of residents use public transport for transport within the city, 38% individual car transport (33% driver, 5% passenger), 7% on foot, 3% bicycle, 2% train and 2% regional buses.

Pilsen City Transport Company (PMDP) ensures most of the public transport in the Pilsen area. The system consists of three means of transport: trams, trolleybuses, and buses. Three tram lines form the backbone of city transportation; they connect the biggest suburbs with the city centre, the Railway Station and the Central Bus Station. A similar function is performed by trolleybuses that serve, except for the Northern suburb, the rest of the big suburbs. The bus lines supplement the tram and trolleybus net and operate transport to smaller urban neighbourhoods.

Why is the selected topic important for the city?

Public transport in Pilsen is environmentally friendly and popular mode of urban transport. 65 % of its annual performance is clean and zero-emission thanks to existing tram and trolleybus system. This is a starting point for the development of e-mobility and an opportunity for synergies in the use of infrastructure. The significant increase in the share of electric traction and reduction of diesel buses is effectively achievable by expanding the trolleybus system, using battery technologies. Deployment of a larger number of in-motion charging trolleybuses means higher electricity consumption in the sections where these vehicles move and charge. **One of the possibilities of the technical solution are innovative technologies such as the buffer storage station, which has been tested and evaluated within the EfficienCE project.**

Main outcomes

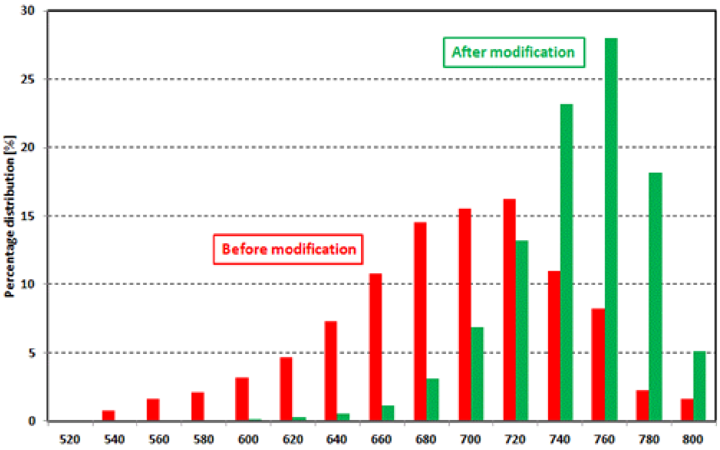
As part of the EfficienCE project, a battery storage station was tested in Pilsen. The battery storage station was purchased in the form of a lease agreement. The buffer storage station made it possible to

1. equalize the electric power demands during the whole day, by providing power in peak moments, while storing electric energy in off-peak minutes;
2. make the trolleybus power network more stable;

3. provide extra power supply for battery trolleybuses, mitigating the fluctuances in trolleybus power network, when battery powered vehicle needs to recharge itself from power network.

During the design works, the algorithm for controlling the battery charging of the buffer station was modified. The purpose of the modification was to improve the interception of energy recovery by the buffer station. After changing, the battery is charged mainly with energy from regenerative braking. The diagram shows the voltage at which the buffer station is charged.

After modifying the control algorithm, charging occurs at higher voltages, which means that the regenerative braking energy is used.



4. Figure: The voltage at which the buffer station is charged (source: PMDP)

What are the main learnings?

The buffer station effectively reduces occurrences of excessive voltage drops, which leads to the improvement of the quality of power supply to the trolleybus network. The buffer station can be used as an alternative to constructing new traction substations. It is predestined to strengthen the supply of long power sections with relatively little traffic, where problems with providing power occur but the construction of a new substation is not economically justified. The construction of the buffer station allows for the use of various types of electrochemical cells.

5. Figure: Trolleybus line 16 in Pilsen (source: PMDP)

At the beginning, lead-acid cells were tested. However, the use of lithium-ion technology (e.g., LFP or LTO) allow to reduce the dimensions and weight of the BS, which may be important in the case of a lack of space upon which to build a station. Used batteries ("second-life") from electric vehicles, which after several years of operation have a reduced capacity and are not suitable for use in a vehicle but can still be used in stationary applications like the buffer station. The buffer station can also be used as an emergency power source in the event of a power failure of the traction substation supply from the MV/HV energy grid. From this point of view, it is inadvisable to reduce the battery capacity. The battery station was also able to operate successfully as an opportunity charging station for static charging of trolleybuses (without moving), i.e., in the same mode as for the electric bus. The functionality of the buffer station can be developed by adding other elements of intelligent Smart Grid networks, e.g. a photovoltaic system or power supply for electric car charging stations.

Integration of braking energy and RES to power trolley depot

PKT, Przedsiebiorstwo Komunikacji Trolejbusowej Sp. z o.o (Poland)

Territorial description

Gdynia is a coastal port city with 250,000 inhabitants located in the north of Poland. The contribution of the Tri-City agglomeration is included. There has been an extensive trolleybus system in Gdynia since 1943, currently there are about 100 trolleybuses in operation. The trolleybus system is expanded using an auxiliary battery drive (In Motion Charging).

Why is the selected topic important for the city?

Przedsiebiorstwo Komunikacji Trolejbusowej Sp. z o.o (PKT) attempts to limit existing energy losses within the trolleybus network by making use of recuperated braking energy. The recovered and unused braking energy can be used to power the building of the trolleybus depot or will be directed to e-cars charger. This is realised by deploying an innovative energy inverter allowing to feed the otherwise wasted energy directly into the building's energy system or to the charger. For this it was necessary to have a specifically designed DC/AC inverter placed in the depot for connecting the DC traction grid and the charging station or building's AC grid. To increase the reliability of the power supply (e.g., in the event of excessive drops of converter input voltage) and to increase the flexibility of accumulation of trolleybuses regenerative braking energy, the station was equipped with a battery-based electric energy storage. For this purpose, a second-life traction battery from a trolleybus was used.

6. Figure: Energy inverter in Gdynia, Poland to use or recuperated braking energy (source: PKT)

Main outcomes

The advantage of the device is that this kind of charger is not permanently connected to the ground and can be moved wherever there is a traction network (trolleybus or tram). Thus, this investment has a huge advantage over the traditional solutions of the EV mobile charging stations. Connecting the station does not require additional installation costs, construction permits and shortens the investment time. The prepared pilot inverter solution can be supplied by easy way from trolleybus or trams traction network, without high complicated procedure of connection to public energy system.

What are the main learnings?

The advantage of the traction network is its extensive spatial range in many cities and thus its wide accessibility. This enables it to be deployed to power vehicle charging stations where there is a problem of connecting to the AC power line, e.g. due to the need for construction works. Therefore, inverter station UPNEiMT can be used by any city with a tram or trolleybus network to supply additional buildings and facilities. This will allow better use of the existing infrastructure - infrastructure sharing.

Generally, development solutions:

- allows for the expansion of the electric car charging network
- enables easy use of the existing trolleybus infrastructure

The main problems identified were:

- charging stations powered from the traction network are much more expensive than standard charging stations, this is due to the unitary nature of their production;
- there are no business models that would make power supply to external recipients attractive to the bus/tram infrastructure operator.

7. Figure: The energy inverter connected to an electric charginc station (source: PKT)

The main factor affecting the further development of realised pilot low demand for charging stations. Now electric cars are still not very popular, so there is noy hight demand for charging services. Although there is an increase in their number, the demand for charging stations is relatively small and the currently available standard solutions are perfectly sufficient.

Modernization of an existing cable car station and integration of fast-charging station for e-buses

Maribor (Slovenia)

Territorial description

Maribor is Slovenia´s second largest city with about 110.000 inhabitants and an urban area of 147 km2. Maribor lies on the river Drava, at the point where the Pohorje Mountain, the Drava valley, the Drava plain, and the Kozjak and Slovenske Gorice Hill ranges meet. The city's development is determined by its geographical position on the juncture of roads connecting Central Europe with Southern Europe and Western Europe with the Pannonian plain. Due to its distance of just 18 km from the Austrian border, Maribor represents the gateway into the country as well as to the Balkans. This favourable position makes the city a cultural and economic centre of the north-eastern Slovenia. Out of it comes also the environmental pollution caused by traffic.

Maribor has 110.000 inhabitants, and the model split was the following in 2016: car 56%, public transport 6%, pedestrian 29%, bicycle 8%, other 1%. Most citizens use individual cars for traveling to work and for other activities over the day. Many trips include the city centre. Car transport has no real competitors. The inhabitants, who do not drive or do not own a car, do not have the same mobility conditions. Many of the implemented activities in the past years have a positive impact on the state of the mobility (e.g., the expanding of the pedestrian zone in the city centre, network of cycling routes), however, some key obstacles remain (e.g., inefficient public transport system).

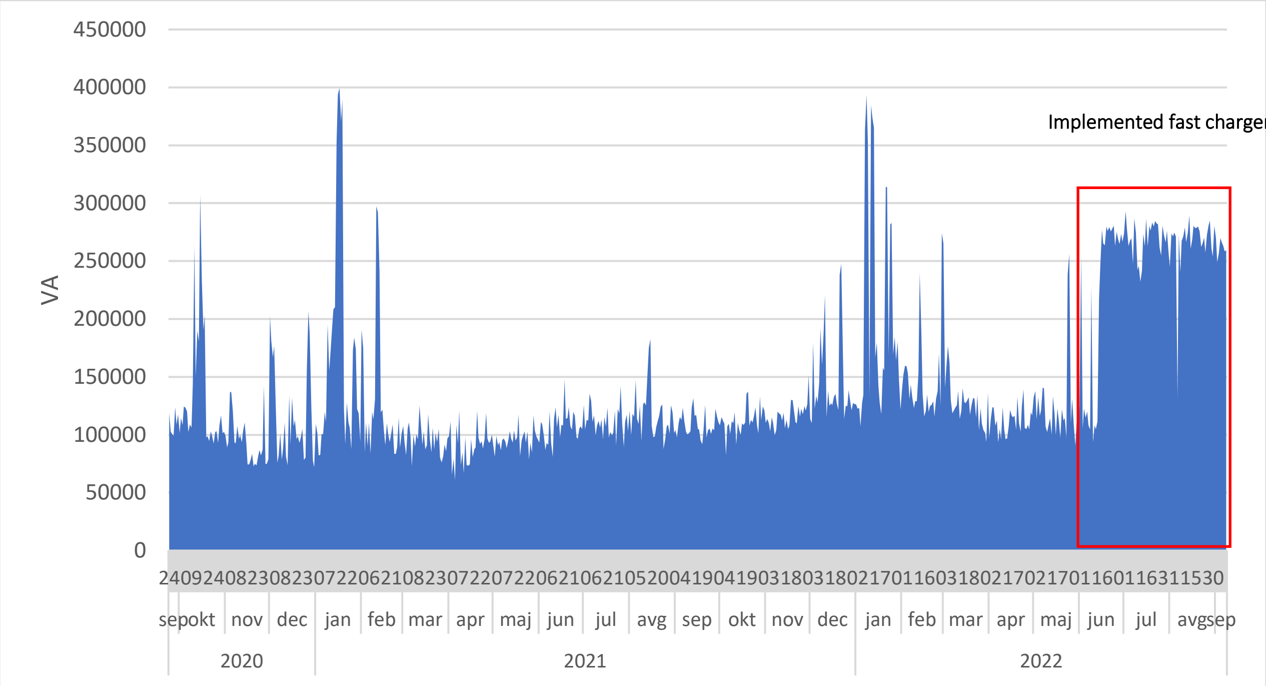
Why is the selected topic important for the city?

The Municipality of Maribor implemented the pilot project - installation of fast-charging station for e-buses in EfficienCE project. Two multifunctional charging stations were installed for e-buses. One charging station was installed at the cable car station Vzpenjača. The other one was installed at the Main bus station. Both charging stations started operating for bus line 6 in May 2022, when the newly purchased e-buses for fast charging were delivered.

The pilot is important for the city to ensure environmentally friendly, energy efficient, and competitive PT. Future needs are considered in local energy, electric mobility, sustainable mobility, logistics plans, and national PT infrastructure plans.

Main outcomes

The pilot demonstrated that with the integration of e-bus fast charger with 150 kW (117 kVA), the power supply from existing substation ensures grid stability also in peak conditions. The charging station was connected to the transformer station and the measuring device of the University of Maribor was set up to make an evaluation of the charging station after the official commissioning.



8. Figure: Data from the measuring device, namely the peak values of apparent power in the period from the beginning of the measurement (source: University of Maribor)

In between, the peak values occurred mainly in winter, during the operation of the snow cannons. From June 2022, when the fast charger was implemented, an increased can be seen. The fast charger charges the e-bus within 5 minutes with 12 kWh.

What are the main learnings?

The process of implementation took longer than expected, due to different administrative hurdles and decisions on choosing the best option for charging (Slow charging overnight or fast charging at start and end of the line). Simulations and analysis for the best options were obtained, considering real life data on driving cycle, turnover time and timetable. A Feasibility study assessed different alternatives, based on TCO (Total Cost of Ownership). In June 2022 the line went in full operation with two 12 m e-buses. Some technical failures were reported in the start-up phase, but in general the concept is transferable to other lines within the city and cities with similar PT network.

The experience and lessons learned from EfficienCE will enable Municipality of Maribor to expand the PT multi-purpose infrastructure in the city. The charging infrastructure is owned by the Municipality of Maribor, which manages the infrastructure and leases it to the public company Marprom.

ACTION PLANS

Action plan for data-based PT infrastructure planning & financing

Leipzig (Germany)

Territorial description

With currently around 610,000 inhabitants, Leipzig is the most populous city in Saxony, Germany. The city's consistently positive population and economic growth in recent years has also led to an increase in traffic. Against this background, a Mobility Strategy 2030 with several scenarios has been developed in Leipzig in the past years. The vision of the strategy is to ensure safe, clean, reliable and affordable mobility for citizens in Leipzig. The sustainability scenario of the Mobility Strategy 2030, which was adopted by the city council in 2018, follows the priority of sustainable mobility and the strengthened promotion of the environmental association (sustainable modes of mobility).

The goal is to achieve a modal split in 2030 with a share of 23 % public transport, 24 % walking, 23 % cycling and max. 30 % motorised private transport. This is intended to achieve the lowest possible emission (zero-emission), low-noise and climate-neutral urban mobility. The 2018 underlying modal split was 17.5 % public transport, 27.3 % walking, 18.7 % cycling and 36.5 % motorised private transport.

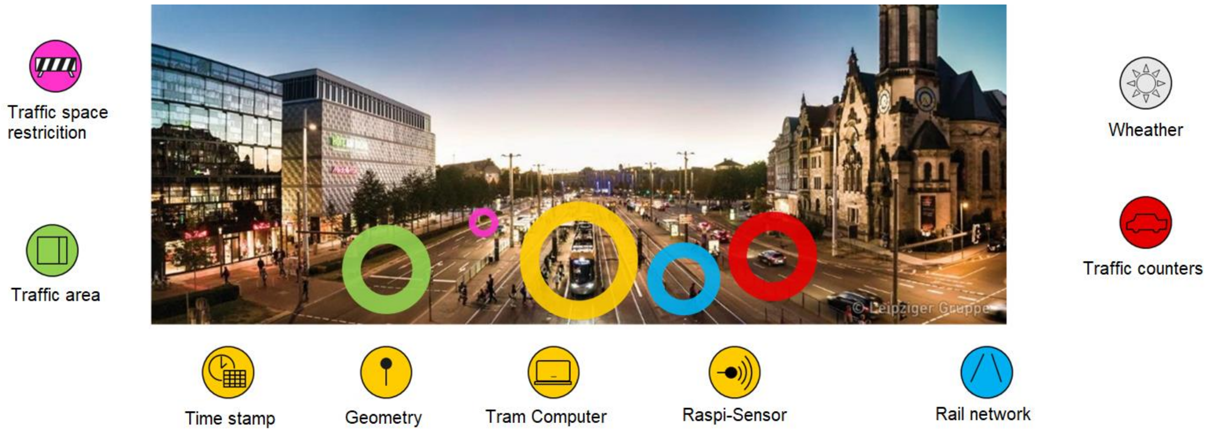
9. Figure: Mobility strategy Leipzig 2030

(source: https://www.leipzig.de/umwelt-und-verkehr/verkehrsplanung/mobilitaetsstrategie-2030)

Why is the selected topic important for the city?

Against the background of growing cities and the pressure of climate change, sustainable urban mobility is increasingly becoming the focus of urban action. Public road space is used by many road users with different requirements, resulting in competition for space that is subject to rapid change. New requirements due to the change in traffic and mobility require rapid adaptation of urban and traffic planning. Digitalisation can help to optimise planning processes and make them more efficient. The data basis necessary for this must be expanded and made more effectively usable.

Therefore, **an urban data platform (UDP) is to be developed in Leipzig as a central hub and mobility data is to be consolidated, processed, and harmonised**. The use case "Data-driven public transport infrastructure monitoring" developed and tested in the EfficienCE project should provide initial findings on the joint exchange and processing of data between the city of Leipzig and the Leipzig transport companies. This forms the basis for further implementation within the framework of the UDP.



10. Figure: Data sources of use case prepared by Municipality of Leipzig (source: Leipziger Gruppe)

Main outcomes

As part of the EfficienCE project, the Digital City department, the Office for Geoinformation and Land Use Planning the Leipziger Verkehrsbetriebe (LVB) are developing use cases for more energy-efficient public transport planning for the city of Leipzig. For this purpose, **data from sensors in trams are combined with other data sources to improve data-based public transport planning**.

In detail, these are data from the on-board computers of the trams, energy data from the Raspi sensors (currently 6 trams), municipal data on traffic area design as well as stop areas, crossing areas and external information from the German Weather Service (temperature, precipitation, wind, ...). By combining the different data sources, it is possible for the first time to collect continuous information on the interaction between trams and urban space. For visual processing, the raw data is transferred into a data model, which forms the basis for an interactive dashboard.

The data compiled and analysed by the project creates added value and can be used, for example, for predictive maintenance, energy optimisation of the driving style, detection of interactions with individual traffic or optimised traffic space design.

What are the main learnings?

The data compiled and analysed by the project creates added value and can be used, for example, for predictive maintenance, energy optimisation of the driving style, detection of interactions with individual traffic or optimised traffic space design. To harness this added value it is necessary that a dynamic data flow between the city and the LVB is realised.

In addition to the creation of concrete technical structures, the holistic integration of data-driven processes also includes soft factors in the sense of cultural change. In this context, the administration and municipal companies must become aware of the value of their own data stocks, consolidate them and benefit from them - in other words, work with them in a way that is profitable and beneficial to the common good. The permanent establishment of data-driven monitoring processes and the decision-making that builds on them includes the obligatory guarantee of mutual data access across the horizontal and vertical structure of the organisation. This data-processing practice must be embedded administratively (as well as legally) through the definition of a data governance strategy and include, for example, the use of standardised data formats and services. This transparent set of rules enables clearly structured and fast access, support by external contractors as well as accelerated data provision and data enrichment.

The Urban Data Platform as central platform will be established within the Smart City Model project Connected Urban Twin. Within the framework of the project, which will run until December 2025, the IT architecture of the urban data platform is to be developed and tested based on three use cases. One of the planned use cases is digital transport planning. In addition, further funding should be used to generate new mobility data and integrate it into the data platform.

11. Figure: City of Leipzig (source: City of Leipzig)

Action Plan for energy-efficient PT infrastructure deployment in Budapest

Budapest (Hungary)

Territorial description

Budapest, the capital of Hungary, has 1 723 836 inhabitants (3 million in FUA). The model split within the city in 2021 was distributed in the following way: 48% private / 42% PT / 1% cycling / 9% walking. Car dependency is still very high – the COVID-19 pandemic promoted car usage that significantly increased the rate of car users within the city. In addition, the number of commuters is increasing as a result of the suburbanization process that resulted in congestions, lack of parking spots, increased journey times.

Why is the selected topic important for the city?

The current share of diesel buses in Budapest's public transport vehicles is 56%, while the electric (fully electric or trolley) buses represent only 12%. In line with the aims of European Union, the vehicle fleet should be carbon-neutral until 2050, which indicates the substitution of all emitting buses. The action plan complements the Vehicle Strategy of the Centre for Budapest Transport (BKK), as it specifies the decarbonisation process of Budapest's public transport sector for the 2022-2050 timeframe. **The action plan evaluated the timing of procurement activities, to reach the zero-emission goal for 2050.**

Main outcomes

The action plan identified the main attributes and limits of future developments and defined the most likely scenario of external factors. Analysis of these key indicators resulted the inputs for establishing the decarbonisation timeline of Budapest's public transport vehicle fleet. Main milestones were identified according to the possibility of available funds, vehicle and infrastructure amortisation, involvement of external service providers, and regulation development.

12. Figure: New trolleybus introduced in Budapest (source: BKK)

What are the main learnings?

The action plan itself will serve as a base in future developments and vehicle procurements aiming the decarbonisation initiatives of the European Union and BKK. The round-table discussion initiated between relevant stakeholders (research institute/university, public transport service providers, transport management authority) made a common cause to achieve the future goals identified in the action plan. Understanding the differences of operational needs between carbon-based and electrified solutions will help the design process of future transportation infrastructure in Budapest.

Action Plan for energy-efficient PT infrastructure deployment

Bergamo (Italy)

Territorial description

Bergamo has 120 393 inhabitants. The trips within the Municipality of Bergamo take place in 53% of cases by car (as driver or passenger), 32% on foot or by bicycle, and 14% by public transport (rail/tram/road).

Bergamo has recently approved the Sustainable Urban Mobility Plan (SUMP) which is an instrument that outlines the infrastructural and strategic scenario of Bergamo's mobility over the next ten years. The document shows that the local mobility network in Bergamo is composed by the regional railway system, the inter-urban tramway system (tram line T1 + forecast of the new tram line T2), wide network covered by the local public transport. In the municipal area of Bergamo, the demand for mobility on a daily basis is estimated to be 205.000 trips/day.

Why is the selected topic important for the city?

The City of Bergamo, in collaboration with the company ATB and with the support of the Redmint Impresa Sociale S.c.r.l., has developed the Local Action Plan, strategic instrument aimed at deepening the issues related to the electrification and integration of renewable resources in local public transport infrastructures with the ultimate aim of facilitating future investments in innovative energy infrastructure efficient.

The electrification of urban public transport plays a fundamental role in achieving two strategical objectives: nowadays to raise the quality of life in cities, it's important to change the world of transport and to make traffic more sustainable reducing noise, local and global emissions. Furthermore, the raise of electromobility is expected to revolutionise passenger (and freight) mobility systems, according to criteria as greater energy efficiency, environmental and urban sustainability, security, accessibility, connectivity, and multi-modality. The electrification of local public transport then offers the opportunity to rethink the urban infrastructure of our cities, from the location of bus depots to the design of the streets, bringing significant benefits to citizens. In this sense, Bergamo is approving the 'Plan for the development of electric mobility in the Municipality of Bergamo' called E-Plan whom the Local Action Plan is part.

Main outcomes

Thanks to the discussions held during the path that led to the drafting of the Local Action Plan, Bergamo municipality has achieved the following objectives:

- analysing the monitoring data of the existing Electric Bus Line 'C' in order to prefigure possible transpositions of this experience to other city lines;
- to outline energy efficiency measures to support infrastructural and urban transformations of the territory;
- to carry out a feasibility check of new infrastructures planned by the PUMS and analysed in detail by the sector studies;

- to plan new development projects and scenarios correctly and consciously, deepening their decision-making, programming and financing aspects.

What are the main learnings?

Within the three years of the project, Bergamo has developed the local municipal plan for electric mobility, which has given significant inspiration for the drafting of the Action Plan. In the same period the local public transport company, ATB has revealed a strategic player give that they launched significant urban mobility projects related to energy efficiency issues which contributed to the drafting of the E-plan.

Currently, ATB is planning the renewal of the bus fleet and it consists in specific measures such as the introduction of new electric vehicles, some of them for e-BRT line and the implementation of charging infrastructure at ATB depot in Bergamo.

The tools developed within EfficienCE project will in future allow the Municipality of Bergamo and the in-house company ATB to access a wide pool of knowledge and experience developed by the partnership to facilitate the implementation of the measures contained in the Local Action Plan.

13. Figure: Bergamo's Master Plan for the mobility hub 'Porta Sud' - crucial for sustainable PT electrification (source: City of Bergamo)

The action plan for the multi-purpose use of public transport infrastructure

Maribor (Slovenia)

Territorial description

Maribor is Slovenia´s second largest city with about 110.000 inhabitants and an urban area of 147 km2. Maribor lies on the river Drava, at the point where the Pohorje Mountain, the Drava valley, the Drava plain, and the Kozjak and Slovenske Gorice Hill ranges meet. The city's development is determined by its geographical position on the juncture of roads connecting Central Europe with Southern Europe and Western Europe with the Pannonian plain. Due to its distance of just 18 km from the Austrian border, Maribor represents the gateway into the country as well as to the Balkans. This favourable position makes the city a cultural and economic centre of the north-eastern Slovenia. Out of it comes also the environmental pollution caused by traffic.

Why is the selected topic important for the city?

Municipality of Maribor developed a long-term solution for energy-efficient public transport and fast charging of e-buses in the form of an Action Plan for Multipurpose Use of Public Transport Infrastructure (PT). It includes ways to invest in providing charging infrastructure for PT in Maribor in parallel with charging of other e-modes and integration of different novel functionalities of multipurpose hubs. Identified challenges represent the broad area of impact of electrification framework and the obstacles in the implementation process. Vision and long-term goals set the ways to introduce decarbonized Public Transport and renewable energy solutions in the public transport in Maribor and represent the basics for the developed measures in action plan. A priority list of PT routes for electrification represents the future PT lines to be electric. For each line the concept of charging is also proposed.

Main outcomes

Main measures are based on the electrification of the urban PT service in conjunction with other modes of mobility and logistics. The action plan includes technical measures on infrastructure and vehicles investments, RES and management measures to improve the energy efficiency of PT in Maribor. Since rerouting the PT network affects the location and performance of the charging infrastructure, the selection of charging concepts must be based on the selected future PT network that is planned to be implemented.

Multipurpose use of PT Infrastructure in Maribor refers to the multimodal and multifunctional use of infrastructure PT, which combines various solutions for the integration of PT networks (railroad, cable car, regional bus, city bus), mobility and logistics hubs with different modes of transport and RES.

What are the main learnings?

In developing the action plan, partners learned many important things from examples of good practices in Europe, as well as from the EfficienCE project consortium, which are important for planning the further development of public transport electrification in Maribor. By talking to the other experts of the consortium, partners had the opportunity to review other strategies that the cities are preparing. The EfficienCE project has helped the Municipality of Maribor to network with other like-minded cities that want to implement action plans for public transport electrification in a similar way.

In regard to real life implementation, the strategy on the Multipurpose use of PT infrastructure is not so interesting for the broader audience/media as other SUMP measures (e.g., increasing the parking fee), also due to its quite technical background. On the other side the implementation of real-life measures must be studied from different perspectives and end users. In general, it integrates spatial, energy and transport aspects to fulfil e-mobility and e-logistics needs of the cities transport, where the public transport represent the backbone.

14. Figure: E-bus fast charger in Maribor (source: Municipality of Maribor)

The Sustainable Mobility Strategy of the Pilsen Metropolitan Area ITI

Pilsen (Czech Republic)

Territorial description

The Sustainable Mobility Strategy of the Pilsen Agglomeration is dedicated to the area of the city of Pilsen and its surroundings, where more than 300 thousand inhabitants live in 108 municipalities. The share of car traffic on the commute is between 30-50%, public transport varies between 30-70% depending on the location of the establishment, the share of walking and cycling does not exceed 10%. Public transport serves the largest proportion of trips in the ITI area. The share of public transport is 43% of the total number of trips in the ITI area, followed by car transport with a share of 41%. A large share of the transport performance of Pilsen's public transport is realized by electrified modes of public transport with very little negative impact on the environment and human health in the city.

15. Figure: Trolleybuses in Pilsen (source: PMDP)

Why is the selected topic important for the city?

The Sustainable Mobility Strategy of the Pilsen Metropolitan Area ITI (hereafter SUMP ITI or the Strategy) is to set up strategic transport planning in the defined area of the ITI. The Strategy should allow the City of Pilsen and the surrounding cities and municipalities in the entire Pilsen Metropolitan Area ITI to achieve a long-term increase in the quality of life while not burdening traffic unnecessarily environment or public resources. The strategy is not limited to the administrative boundaries of the Pilsen metropolitan area ITI (the area being addressed) but describes real transport relations that actually go beyond these boundaries and cover the territory of the entire Pilsen region. The strategy deals with these threats: Absence of integrated planning between different actors; Pilsen without high-speed railway; Disfunctional cooperation with developers; Low population density; Tight public budgets; Change in traffic behavior after the pandemic; Endangerment of pedestrians by other users; Trends in city logistics; Suspension of freight traffic on the streets of Pilsen.

Main outcomes

The Vision of mobility is: *"The synergy and interconnectedness of different modes of transport will be chosen in such a way that the most suitable type of transport is always used for the given transport requirements. It does so in the form of an active organization of the transport system, so that the choice of means of transport is deliberately influenced and the division of transport work is thus influenced. The goal is to support social requirements for increasing the quality of life in cities and towns."*

The strategy of sustainable mobility of the Pilsen agglomeration (SUMP PA) brings in its design part a total of 93 measures for the development of an integrated transport system, pedestrian, and bicycle transport as well as the road network.

In the topic of PT electrification and energy-efficient PT infrastructure deployment, the strategy of SUMP ITI declares these measures:

- Examination of the possibilities of electrification of bus public transport and regional bus transportation
- Development of electromobility – battery-powered technology in trolleybuses: Increasing the share of electric public transport on overall performances. Extension trolleybus lines and transfers selected bus to trolleybus traction with use alternative battery drive.
- Trolleybus line in the Northern Suburbs - Connecting the city centre and Severní suburbs via an alternative electrified public transport route. Creation of new attractive direct connections

What are the main learnings?

Strategic goals develop a vision of mobility according to the specific needs of the residents and visitors of the Pilsen agglomeration. They were compiled in cooperation with experts familiar with local conditions. The top body for preparing the Strategy was the Steering Group. The Working group was the executive body of the Strategy. It worked as a multidisciplinary team of experts familiar with the area being addressed and the area of interest. Public participation was ensured using a Traffic opinion map and panel discussion. The Strategy was discussed with the professional public at specified milestones. A group of 90 people were nominated, whose work or interests are related to at least some segment of mobility in the area under consideration. In the SUMP ITI, there was set a list of measures in all means of transportation.

The Sustainable Mobility Strategy of the Pilsen Metropolitan Area ITI is now being assessed in the SEA process. The resulting evaluation will be known by the end of 2022. From 2023, the plan will be implemented. Every two years, the development of the implementation of the measures will be reviewed according to the individual areas of the SUMP ITI and their guarantors. Stakeholders will be included in this process in the same way as those nominated to the steering group of the SUMP ITI project.

More information: https://sump-iti.plzen.eu/

WHAT EFFICIENCE ACHIEVED ON PROJECT LEVEL

Transnational guide on recommendations for policies, legal and institutional frameworks

Taken from the experiences of the EfficienCE partners in developing action plans and demonstrating pilots, the transnational guide summarizes recommendations for planning of electric mobility infrastructure for planners, politicians, industry, legal and regulatory decision-makers and their integration in the design and development of decentralized renewable energy production, grid services, smart recharging, digital transformation and spatial planning. In this context, public transport electrification represents an opportunity to rethink the city's urban infrastructures, as it offers opportunities to 1. increase the share of renewable energy sources use in the local public transport infrastructure, to 2. enable multipurpose use of existing or new charging infrastructure for different modes of transport, and to 3. improve infrastructure performance based on insights through using and sharing data between stakeholders.

16. Figure: Transnational guide made within the EfficienCE project

Description of the three managerial approaches

<u>Data</u>: Generation, storage, and sharing of data by different stakeholders, processed through statistical or machine-learning analysis, can lead to insights that help improve or create new services to increase the energy-efficiency, give insights into current and future user and infrastructure needs and to reduce waste of resources in the public transport infrastructure maintenance. Through measures like the application of predictive maintenance methods, benefits like an improved energy performance and an extension of the existing infrastructure's lifetime can be achieved.

<u>Multipurpose usage</u>: To lower investment costs and to reduce space consumption by using the existing space more efficiently, multipurpose use of charging infrastructure, like the implementation of shared charging hubs, brings clear economic and environmental advantages. At the same time, it involves new operational and business models requiring systems re-thinking and coordinating between public transport operators and other stakeholders.

<u>RES</u>: With currently less than 5%, transport is the sector with the lowest share of RES while at the same time producing almost 1/3 of the European GHG emissions. During the EfficienCE project, planning practices and pilots to increase the share of RES in the local PT infrastructure were demonstrated. The trend for PT

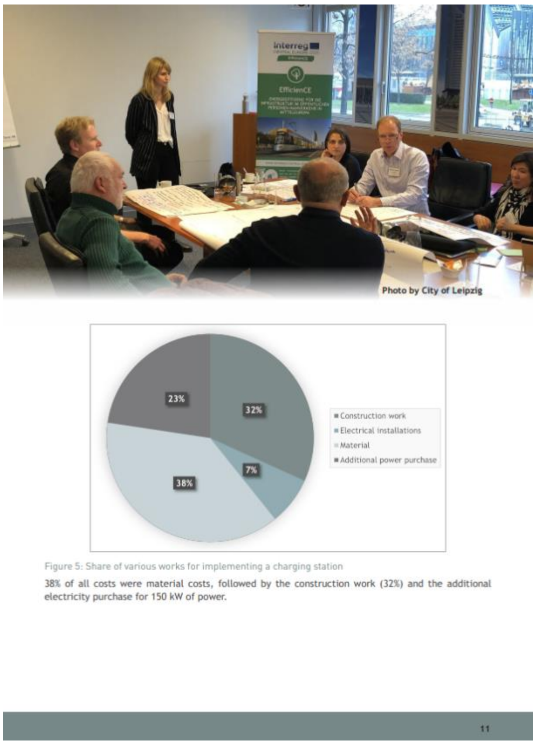
electrification presents a great opportunity, as greening the power needed for electrified PT is possible through, e.g., installing decentralized energy plants, commissioning green energy, and recovering braking energy.

Transnational handbooks for energy-efficient PT infrastructure technologies deployment

Handbook on pilots

The project implemented and tested solutions to improve the energy efficiency of PT's infrastructure and integrate RES into PT's systems to reduce PT's dependency on fossil fuels and ensure that PT remains affordable and efficient in CE countries.

Four pilot investments in the EfficienCE project address the above topics. Wiener Linien implemented a metro-station integrated PV-system to power building auxiliaries with RES. Gdynia Trolleybus Transport Company (PKT) researched all three topics of the EfficienCE project in the recent years. However, the EfficienCE project presents the results of the investments in the use of recuperated braking energy and RES for the power supply of the trolleybus depot. Municipality of Maribor upgraded an existing cable car substation and integrating an e-bus fast charger. Lastly, PMDP municipal transport company from Pilsen demonstrated the integration of a buffer storage system into the trolley network. The research work focused on increasing energy efficiency. The handbook describes these implementations in detail.



17. Figure: Extract from the Handbook on pilots

Handbook on multipurpose PT

Transportation systems are facing challenges due to increasing urbanization. Aging transportation infrastructure is struggling to meet today's demands, while personal choices about urban transportation have evolved in ways that the car-oriented transportation policies of the past are no longer adequate.

This handbook presents a primer on the multipurpose use of public transportation infrastructure for cities where public transportation infrastructure is not a planning priority and for cities with an advanced public transportation infrastructure planning culture.

Multipurpose use of public transport infrastructure integrates energy, mobility, and logistics aspects to minimize CO_2 emissions and make transport operations more energy efficient through various technologies. Energy-efficient multi-purpose infrastructure technologies for public transport are generally structured into solutions for multi-modal use, multi-functional use, and innovative approaches to IMC charging technologies under development. Each of the technologies have several advantages and benefits. These may be technical, financial, or safety related.

However, each of the technologies presented also have technical and regulatory barriers, e.g., lack of technical standards, compatibility between different manufacturers, safety limitations, low energy efficiency, additional costs, standardization of infrastructure and systems.

An overview of current practices related to different solutions for multimodal use of infrastructure PT and a case study from the EfficienCE pilot project present new technologies in operation with their benefits, experiences, and transfer possibilities.

Handbook on depots

Although the non-traction energy is a minor expense, environmental and geopolitical pressure for energy transformation delivers arguments to search improvements in depots. The depot consumes electric energy but also gas, oil, and district heating. The structure depends on the particular case and the usage depends on such factors like technical condition of buildings, availability of renewable energy sources, equipment (painting facilities,lightning) as well as procedures implemented to save energy consumption.

Literature review brought only partial answer for the topic of the energy efficiency for depots. Majority of papers focused on the use of the renewable energy sources. The issue of the energy and thermal efficiency of the technical facilities of public transport operators is scarcely mentioned in the literature.

Using selected six case studies of different public transport operators from Central Europe, a thorough analysis was conducted. It showed that there are a variety of different activities focused on the increasing energy efficiency of depots. Their scale is dependent not only on the size of the operator, but also on local circumstances and national legal framework.

2. Use case

2.1 DPMB Brno

The only owner of the DPMB is the city of Brno. Annual ridership in 2020 exceeded 272 mio. of trips, and decreased by 25% in comparison to 2019[14]. In total, electric traction provided 52% of public transport supply in Brno in 2020. DPMB is planning to develop the trolleybus subsystem, making more use of the advantages of in-motion charging[15].

Figure 1: Skoda Solaris trolleybus in the two-storey trolleybus depot in Brno (Photo by Marcin Wolek)

2.2 DPO Ostrava

Dopravni Podnik Ostravy a.s. is the operator of public transport in Ostrava owned by the city of Ostrava. The supply of DPO amounted to 30.7 mio. of vehicle-kms. In total, electric traction provided 46% of public transport supply in Ostrava in 2020[16] but it will be increased due to expected introduction of the electric battery buses since 2022. Moreover, there is a plan in Ostrava to build hydrogen filling station in the Hranecnik depot.

Figure 2: The trolleybus system in Ostrava services part of the city and has a share of 10% in total public transport supply (Photo by Marcin Wolek)

14 Výroční Zpráva Dopravní Podnik Města Brna, A. S. 2020. Brno 2021
15 https://ceetransport.com/40-sor-trolleybus-kits-to-be-assembled-by-brno-carrier-637/
16 Dopravni Podnik Ostrava, Výroční Zpráva 2020. Ostrava 2021

8 CE1537 EfficienCE: Energy storage in public transport infrastructure

18. Figure: Use cases in the handbook on depots, extract

These actions were clustered into five main groups including buildings, heating, renewable energy sources, lighting, and paint shops as they represent very specific area of daily exploitation. Optimising energy use at the depot is an integral part of improving public transport companies' energy and economic efficiency. This is particularly important when fossil fuel and electricity prices are soaring and are unpredictable as never before.

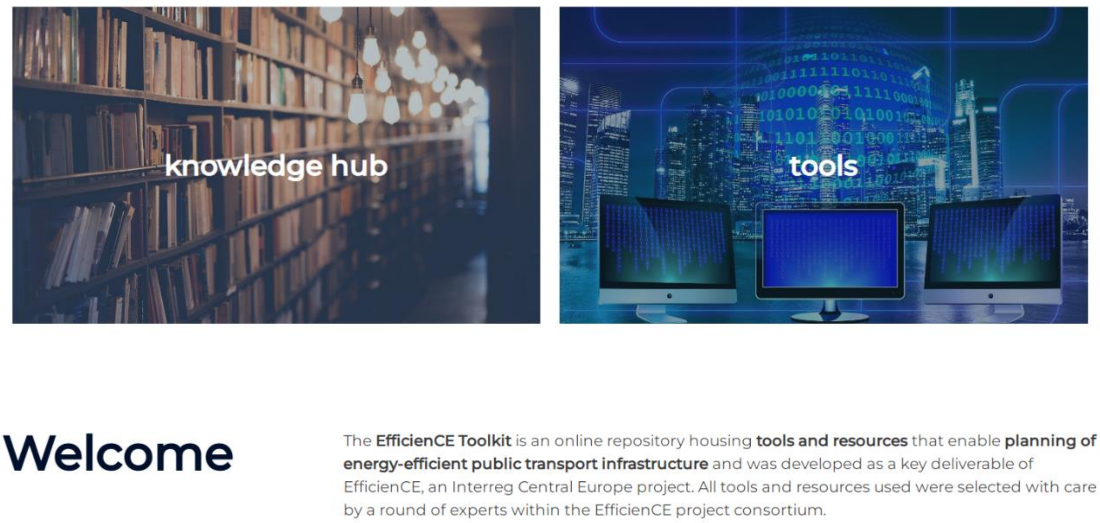
Handbook on storage

The EfficienCE handbook on energy storage in public transport infrastructure identifies the main enabled functionalities and technologies for energy storage that can be applied to public transport infrastructure, and investigates their application in both project pilot actions and international good practices. The results are summarized three use cases (energy efficient depot, smart node, linear infrastructure) describing the typical endowment to be developed in order to enhance the energy efficiency performance of PT infrastructure and covering the main exemplary applications enabling a higher energy efficiency, a higher integration of renewable sources and a more effective contribution to the grid by public transport infrastructure.

The use cases intend to highlight the main key elements, expected benefits, challenges and barriers to be considered when planning for integrating storage technologies in PT infrastructure, providing direct references to the pilots and good practices analyzed within the project for further guidance and benchmarking.

EfficienCE Toolkit

The EfficienCE Toolkit is an online repository housing tools and resources that enables planning of energy-efficient public transport infrastructure. It shows a collection of guidance documents, methodical approaches, policy briefs, use cases and many more in different application areas like analysis of scenarios, data gathering, evaluation and monitoring, financing, and procurement. The Knowledge Hub, as the centrepiece of the EfficienCE Toolkit, contains a broad variety of resources that inform, educate, and help make decisions on energy-efficient public transport. Its goal is to build solid knowledge bases founded on the experiences of previous projects dealing with efficiency in public transport. It can be accessed via: www.tools4efficience.eu.

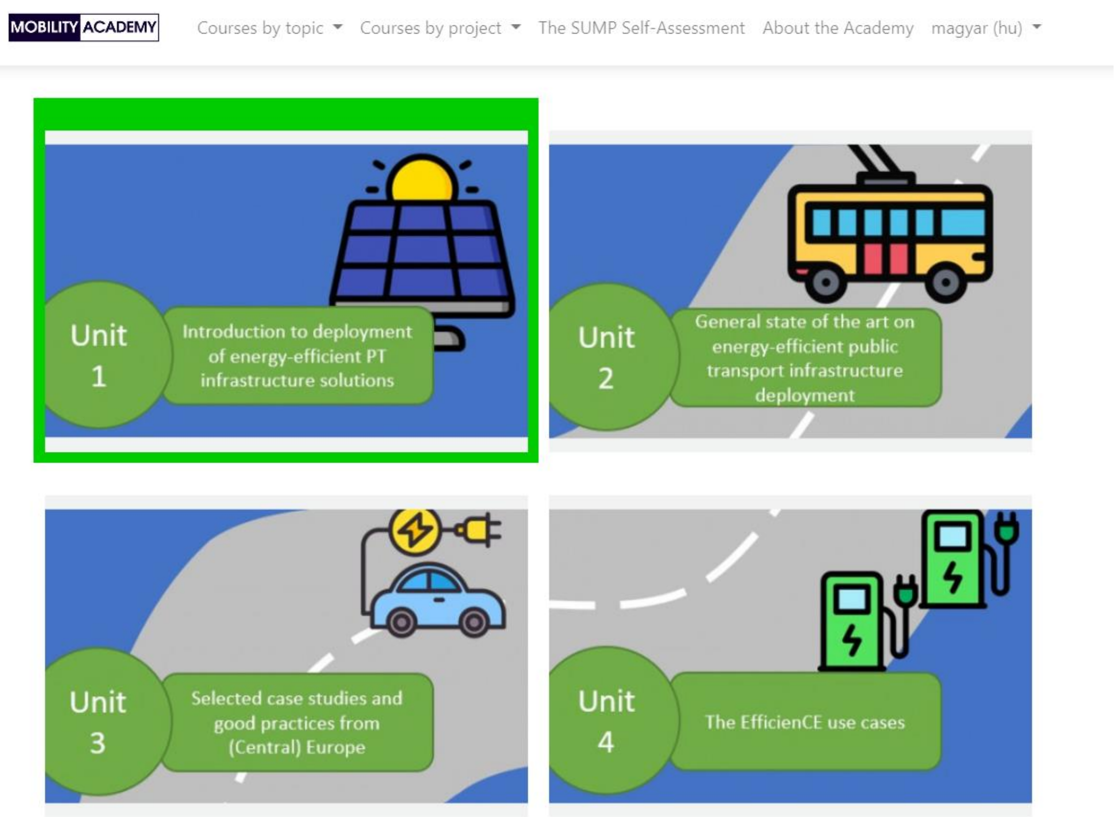


19. Figure: EfficienCE Toolkit (source: www.tools4efficience.eu)

E-course on energy-efficiency PT infrastructure technologies deployment

Running from end of March until End of June in 2022, the e-course on energy-efficient public transport infrastructure technologies deployment, aimed to provide a solid knowledge basis for planning of energy-efficient public transport infrastructure to public transport operators/companies, as well as practitioners at public administrations. Participants were introduced to the overall topic, given examples of technologies and solutions available and tested in (Central) Europe, and specific use cases based on the evaluation of pilot actions deployed during the project. The course is still openly available to the interested public but no longer moderated via https://www.mobility-academy.eu/course/view.php?id=131

By completing the e-course, 60 participants received a solid knowledge base for planning of energy-efficient public transport infrastructure. They got an understanding of the EfficienCE project, its main thematic topics and activities in the partner cities. As hands on experiences, the participants got insights into various use cases as well as an analysis of challenges and barriers that may occur during planning and implementation. They gained inspiration from the EfficienCE pilots on possible actions in their cities and the open discussion forum in the e-course encouraged participants to develop a network of colleagues to discuss developments, ideas and challenges in their own organizations.



20. Figure: EfficienCE e-course on Mobility Academy (source: https://www.mobility-academy.eu/course/view.php?id=131)

CONCLUDING REMARKS

21. Figure: Project partners at the Final Conference in Leipzig (source: City of Leipzig)

"The transport sector contributes with about one third of the total final energy consumption in the European Union. In Germany, this share was around 27 % in 2020. To achieve our ambitious climate targets and the reduction of greenhouse gas emissions, we must therefore also increase energy efficiency and the use of renewable energies in public transport sector. To achieve our goals, we have worked together during the past 3.5 years with 12 project partners from Germany, Austria, the Czech Republic, Hungary, Italy, Poland as well as Slovenia in the EfficienCE project. We learned from each other through the implementation of pilot projects and exchanged ideas. These pilot projects included the installation of a photovoltaic system on the roof of a public transport station in Vienna, the installation of an inverter to use the braking energy of trolleybuses in Gdynia, the test of a fast charger in the context of multimodal charging in Maribor or the integration of a buffer storage in the trolleybus network of Pilsen.

As part of the EfficienCE project, we worked on the topic of digital traffic planning in Leipzig. Here, for the first time, traffic data from the Leipzig Public Transport Company (LVB) was combined with other traffic data, including on the design of traffic space, and visualised in a dashboard. The data collected and analysed in the project create great added value for us and can be used e.g., for predictive maintenance, energy optimisation of the driving style, detection of interactions with individual traffic or optimised traffic space design. Therefore, we benefit from the experience gained from the EfficienCE project and are also working on the implementation of the digital traffic planning use case and the Urban Data Platform in follow-up projects."

Dr. Beate Ginzel, managing director Digital City Unit Leipzig

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EfficienCE

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