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EfficienCE

TRANSNATIONAL HANDBOOK FOR ENERGY-EFFICIENT PUBLIC TRANSPORT INFRASTRUCTURE TECHNOLOGIES DEPLOYMENT

(5) Transnational Guide on Recommendations for Policies, Legal and Institutional Frameworks

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About the EfficienCE 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.

Photo by Rupprecht Consult

Contents

Executive Summary

Photo by City of Leipzig

The EfficienCE project has developed action plans and pilot demonstrations that aim at increasing energy-efficiency in public transport to 1. increase the share of RES integration, 2. enable multipurpose usage of PT infrastructure, and 3. share and use data to plan for energy-efficient PT infrastructure. The present document describes the project’s activities and results in developing these action plans and implementing pilots, and compiles the partners’ recommendations based on their approaches to PT infrastructure planning, testing and evaluating under each topic and in general. Further recommendations for policies, legal and institutional frameworks based on the project partners’ lessons learned about barriers and drivers for implementing the managerial approaches and investments complement the document. An outlook on the partners’ further implementation activities and suggestion for future transnational cooperation is given.

1. Planning for energy-efficient public transport infrastructure

Planning of electric mobility infrastructure will, in the coming years, be increasingly integrated with the design and development of decentralized renewable energy production, grid services, smart recharging, digital transformation and spatial planning. In this context, public transport (PT) electrification represents an opportunity to rethink the city's urban infrastructures, as it enables to 1. increase the share of renewable energy sources (RES) use in the local PT infrastructure, 2. support multipurpose use of existing or new charging infrastructure for different modes of transport, and to 3. improve infrastructure performance based on insights through data-sharing between stakeholders.

The EfficienCE project partners developed action plans and demonstrated pilots – revolving around the three topics - that are integrated in their local strategies[1]. They used the sustainable urban mobility planning (SUMP) framework[2] to structure their planning process, and to prepare and evaluate their pilots. The SUMP process is illustrated as an idealized cycle in Figure 1.

Figure 1: The SUMP planning cycle. © Rupprecht Consult 2019

Following the SUMP cycle helped the partners to work at the interface between mobility and energy ecosystems in an integrated way (illustrated in Figure 2).

1 Leipzig mobility strategy 2030, Vienna climate strategy, SUMPs: Gdynia, Maribor, Pilsen, Bergamo, BKK.
2 Rupprecht Consult (editor), Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan, Second Edition, 2019.

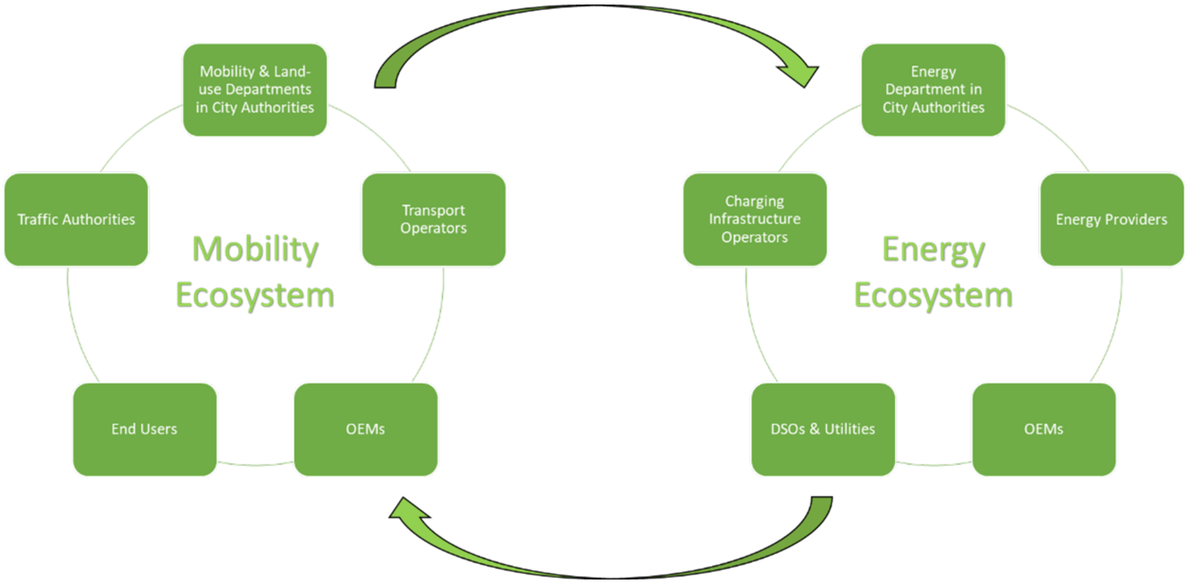

Figure 2 Integration of mobility and energy ecosystem, Source: SUMP Topic Guide Electrification (adapted)

Based on the project partners' experiences from planning, implementing, and evaluating their project activities[3], the present document summarizes their recommendations how to make PT infrastructure more energy efficient. In the next chapter, the three main EfficienCE topics are explained, followed by a description of the project's activities and results under each topic, and by EfficienCE recommendations.

3 Described in detail in: D.T1.1.1 Managerial approach data-based planning and financing for energy-efficient PT infrastructure, D.T1.1.2 Managerial approach on the integration of RES into PT infrastructure, D.T1.1.3 Managerial approach on multipurpose PT infrastructure use.

2. Increase the share of RES in the public transport infrastructure

Renewable energy sources (RES) present a clean, inexhaustible, and highly competitive source of energy. During its conversion no greenhouse gas emissions (GHG) or other polluting emissions are generated, and their sources[4] cannot be used up or depleted. To reach the European Commission's Climate Action goal to become climate-neutral by 2050, RES presents a viable option to meet energy needs. However, 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[5]. The trend for PT electrification presents a great opportunity to increase the share of RES in the PT infrastructure, as greening the power needed for electrified PT is possible through decentralized green energy integration.

2.1 What the EfficienCE partners did

The partners developed an action plan and demonstrated two pilots under this topic.

The **City of Bergamo** developed its action plan as a strategic instrument for electrification and integration of RES in local PT infrastructures[6]. Starting from an analysis of the reference context, the plan examines the European, national and local regulatory framework for energy and mobility, existing local plans and studies for mobility & energy including SUMP, and their interrelation. Based on a participatory design, strategic scenarios were developed, as well as use cases and measures that can be implemented in the coming years.

Developed measures aim at increasing the share of RES and energy-efficiency through instalment of photovoltaic (PV) systems, and stationary energy storage at ATB depot and the mobility hub Porta Sud in the context of a large urban renovation project. Charging infrastructure is linked with new BRT and tram lines, and with redeveloping a railway connecting 5 cities. Additional measures refer to renewal of ATB fleet with e-buses and smart charging infrastructure, and possible investments for energy storage technologies (e.g. 2nd life)[7].

Figure 3: Bergamo's Master Plan for the mobility hub 'Porta Sud' - crucial for sustainable PT electrification. Source: City of Bergamo.

4 Renewable energy sources to generate green energy are sun, wind, biomass, or the recollected braking energy from, e.g., buses or trains.
5 Greenhouse gas emissions from transport in Europe (europa.eu)
6 Leveraging more than 10 million Euros future investments in innovative energy-efficient infrastructure by 2027, and more than 40 million Euros by 2033.
7 D.T1.2.3 Action Plan Bergamo & O.T1.2 Output Factsheet Bergamo, D.T1.1.2 Managerial approach on the integration of RES into PT infrastructure.

Table 1. Measures developed by the City of Bergamo with PT operator ATB

Category	Specific measures	Time	Funding	Estimated costs (€)
PT fleet renewal	Purchase of 60 electric vehicles	2033	National Recovery and Resilience Plan (NRRP)	21 million
	Implementation of charging infrastructure at depot		Ministerial funding, own resources	4 million
Efficient depot	Study for storage and PV connections	2026-2030		5 million
	Implementation smart charging solutions			
	Implementation storage solutions			
	Implementation PV panels on depot roof			
	Implementation Bus2Grid technology			
Smart node (Porta Sud urban renewal project)	Detailed study RES integration, storage, multipurpose infrastructure use	2026-2030		5 million
	Installation PV panels on bus stop roofs and shelters			
	Implementation energy storage slutions (flywheel)			
	Multifunctional use of mobility hub			
Linear infrastructure (tram, E-BRT)	Test supercapacitor systems	2030		N.a.
	Energy storage solutions – flywheel and second life batteries			

PT company Wiener Linien (WL, AT) tested a PV-system on the roof of a metro station (Ottakring) in Vienna. For the first time, PV foils were bonded to the roof of a subway station, which otherwise – for static reasons – would not be able to carry a normal and heavier PV plant. The PV-produced energy supply was integrated into the station's energy system to supply auxiliary power units. As main result, the yearly energy output of the PV plant is higher than expected with 62.000 kWh of solar power, covering 50 % of the station's energy needs on a sunny summer day, thus reducing CO2 emissions by 50 %. In the next years, Vienna plans to install 20 PV plants on metro stations, of which 2 are PV foils. In summary, the PV foils are a very good option for older buildings with static challenges, but if it is possible for static reasons, standard modules should be used for economic reasons. The partner also developed and tested a tool to monitor the energy-consumption in its metro stations with the result that 20 % of the station energy can be saved through ventilation efficiency measures. The tool and results will be applied for the energy-management of other metro stations, too[8].

8 Transnational Handbook on EfficienCE pilots & best practices for energy-efficient PT infrastructure, O.T3.1 Pilot factsheet PV system, O.I1 investment factsheet PV system, O.T3.5 Pilot factsheet energy audit tool, D.T3.4.3 pilot evaluation report

Figure 4: Aerial picture of Photovoltaic system (05-2020), © Wien Energie GmbH

Trolleybus company Przedsiebior stwo Komunikacji Trolejbusow PKT Gdynia (PL) tested an energy inverter to feed the otherwise wasted energy into the building's energy system or to the charger. A specifically designed DC/AC inverter was placed in the depot to connect the DC traction grid and the charging station or building's AC grid. To increase reliability of the power supply (e.g., in the event of excessive drops of converter input voltage) and the flexibility of accumulation of regenerative braking energy, the station was equipped with a second-life traction trolleybus battery. Advantage of the device: this type of charger is not fixed to the ground, and can be moved. The connection of the station does not require additional installation costs and no building permits shorten the investment period.

After implementation, the model of linking individual transport and public transport was tested by charging electric cars. The power conversion process is split into two stages. First, the system uses the DC/DC converter, which provides galvanic separation from the traction network voltage and regulates the battery charging current. Next, the DC/AC converter delivers the power to the charging station via an additional transformer used for insulation purposes. The output power is 50 kW. The charging station is supplied by 3 × 400 V AC, which is a commercial standard. Hence, a typical fast charger for electric cars was used[9].

In the future, PKT wants to link a PV plant to the inverter and storage device to either store or directly feed the generated energy into the trolleybus grid.

Figure 5: Battery-based electric energy storage; usage of a second-life traction battery from a trolleybus. Source: PKT.

9 Transnational Handbook on EfficienCE pilots & best practices for energy-efficient PT infrastructure, O.T3.2 Pilot factsheet inverter, O.I2 investment factsheet inverter, D.T3.2.3 Pilot evaluation report

Photo by City of Leipzig

2.2 EfficienCE recommendations

Create political and institutional commitment

- Make increasing the share of RES in the PT system a strategic objective within municipal and regional decarbonisation strategies, and facilitate horizontal and vertical integration & cooperation between departments and external stakeholders to reach these objectives.
- National strategies with clear targets for the energy mix, facilitating access to funding, are still missing in come central European countries, e.g., Hungary or Poland.

Search for the right local partners

- In Vienna, WL and the energy provider Wien Energie successfully cooperated in procuring, implementing, and testing their pilot. Some cities have their own energy providers who can contribute, others need to find external partners.

Figure 6: PV foil installation in Vienna. Source: WL.

Plan for storage and charging

- Renewable energy is produced in a volatile way: There are peaks of low and high energy generation not congruent with the energy needed. When more energy is produced than consumed, surplus energy produced during peak production hours needs to be stored to provide the energy during low production hours.
- Through combining recuperation of braking energy with inverter and storage systems, a higher energy-efficiency and reduction of energy costs can be achieved, as, e.g., auxiliary units of metro/tram stations can be powered using the recuperated energy.

Integrate 2nd life concepts for batteries into storage systems

- E-vehicle batteries wear out, due to an increase in charge and discharge cycles, and see efficiency drop below the utilization threshold, which is conventionally set at 80 %, before the vehicle has covered the mileage guaranteed for its life cycle. Second life bus batteries can then be used to store, e.g., recuperated braking energy from trolleybuses (see pilot by PKT), or potentially also in buffer storage stations (see pilot by PMDP).
- To mitigate supply risks of raw materials there is a need for clear and harmonized supra-local standards and battery provisions that enable reuse of materials.

Figure 7 Charging e-cars from recollected braking energy. Source: PKT

Think in infrastructure and vehicle systems

- Electric vehicles, thanks to their batteries, can provide, via charging infrastructure, flexibility services to the grid. Bus2grid (B2G) or Vehicle2grid (V2G)[10] technology allows e-buses to recharge during night-time hours, at times when energy demand is low and tariffs cheapest, feeding energy back into the grid when demand is high, resulting in an overall balancing of the grid and increased system efficiency. Ongoing tests for B2G will provide important results to better understand usage conditions.
- Vehicles that are not part of the PT fleet can also be integrated into the system approach, as demonstrated by PKT Gdynia by charging e-cars from recuperated trolleybus braking energy.

Use tools for smart charging optimisation strategies

- Simultaneous charging of vehicles at depots leads to potential power absorption peaks. To avoid oversized recharging infrastructure, recharging must be managed through smart charging systems, modulating recharging according to the power available at the depot, as well as the charging time available to each vehicle based on the service schedule. Therefore, intelligent ad hoc dynamic modulation strategies – also for the functional urban area (FUA) - are needed based on the specific characteristics of fleet vehicles, overcoming the standard "blind" charging approach. To create transparency about available tools to develop smart charging optimisation strategies, EffienCE provides an overview in its online toolkit[11].

10 Vehicle to grid (V2G) is a technology that enables power transactions between electric vehicle batteries and the grid as part of an intelligent energy system, where the energy stored in the battery can also be used to power other electric devices than vehicles.

11 EfficienCE toolkit

Create social acceptance through participation, communication, and marketing

- To increase acceptance for RES generation, a transparent and participatory approach from planning to operation of new facilities is recommended. Strategies and action plans should be developed in a participatory way. Also, marketing and communication measures, as carried out by PKT Gdynia and WL, can facilitate a greater understanding of the economic and social benefits of RES integration. PKT distributed gadgets with relevant information about their pilot in buses (see image below), and WL produced a video about the pilot[12].

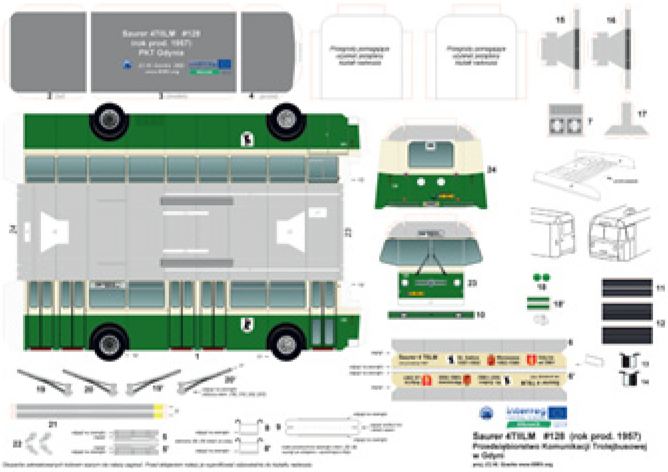

Figure 8: Gadget for passengers to inform about its pilot, the energy inverter, on the backside. Source: PKT.

Charge your own fleet first

- Due to current regulatory barriers in most European countries, it is very difficult for PT operators to resell energy to 3rd parties. Therefore, it is recommended to start charging one's own fleet such as service cars or buses, as this does not involve any complicated metering and billing processes.

12 https://youtu.be/K6Q0x2-y-Vs

Photo by Rupprecht Consult

Legal and regulatory actions needed

- If PT companies “open” their traction power supply systems to third parties, e.g., if they change from being pure power consumers to being active participants in the energy system, they are often confronted with requirements for complex delimitations and measurements. PT tax privileges and subsidies are granted only for the core transport business, not for selling energy. A practical solution could be to require installation of meters to measure the energy sold to third parties, which, in turn, could be deducted from the energy amount that is privileged[13].
- Support for mass production of inverters is needed to make them affordable for public transport. Inverters, as demonstrated by PKT to recuperate and store braking energy, are needed to change the current from DC to AC and vice versa. Still a niche product and uncommon, it makes charging stations powered from the traction network more expensive than standard charging stations.
- Regulatory measures should aim at proper remuneration of services provided with V2G technology that compensate for vehicle battery consumption and enable new businesses.

Green and innovation procurement: facilitate by internalising external costs

- In calls for tender for the supply of electricity for local PT, the requirement of RES is critical due to possibly higher costs caused by the environmental policies undertaken by the entities. Efficient electrification needs fair competition between energy carriers, which requires a thorough review of energy taxation measures. Key actions should reduce or eliminate subsidies to fossil fuels, including through well-designed tariffs and considering environmental externalities.
- A review of the market structure is needed to encourage greater RES penetration in PT, recognizing RES technologies as key strategic value chains promoting corporate power purchase agreements from RES to encourage demand-side participation.

Figure 9: Energy-management at LVB, source: Mobilissimus.

13 As already processed in the Eliptic project by EfficienCE partners LVB, Maribor and Gdynia, this recommendation remains in place: Eliptic policy recommendations, p. 27.

3. Enable multipurpose use of public transport infrastructure

Multipurpose use of PT infrastructure means to use existing or new PT infrastructure (e.g., tram, metro or trolleybus) to charge different e-vehicle types. From a circularity perspective, it reduces energy and resource consumption and extends the lifetime of existing infrastructure. It also brings clear economic advantages due to lower investment costs, as not every vehicle type needs its own charging infrastructure. It helps using space more efficiently through shared charging hubs with consolidated energy demand. Multi-purpose use of PT infrastructure leads to new operational and business models requiring systems re-thinking and coordinating with stakeholders that PT operators might not have considered before.

3.1 What the EfficienCE partners did

Three action plans and two pilots serving to increase the multipurpose use of PT infrastructure were developed and implemented by the PT company Plzeňské městské dopravní podniky (PMDP, CZ), City of Maribor (SL), and the PT authority Budapesti Közlekedési KözpontBKK (BKK, HU).

In Pilsen, it is a declared SUMP goal to further electrify PT by extending the tram and trolleybus network, with the outlook to also cover the functional urban area (FUA), thereby replacing Diesel buses by battery trolleybuses. This leads to an increase in overhead power consumption, and partial limits of power supply. The result is a reduction in voltage on overhead lines when the load is higher, leading to failures. To limit voltage drops on bus line #11 through introducing a battery trolley bus, PMDP tested a battery buffer storage station (BS). The BS was used directly in the problematic overhead line section, is based on high-performance batteries and intelligent computer control, and requires neither an external power supply nor extensive construction work.

Overall, the station helped equalizing the electric power demand by providing power in peak moments, while storing electric energy in off-peak minutes. It made the PMDP trolleybus power network smart and more stable, providing extra power supply for battery trolleybuses through mitigating the fluctuances in a trolleybus power network, when battery powered vehicle need to recharge itself. The pilot supported replacing 2 Diesel buses on the bus line, which would lead to an annual reduction of Diesel consumption by 112.000 l or 295 t of CO_2, and to less noise and air pollution.

The project learned that a BS can be an alternative to constructing classic traction rectifier substations, and a place for using second-life batteries, as well as PV panels. The solution is transferable to any trolleybus or tram operator in need to strengthen their power supply network by preventing voltage drops at high loads[14].

Figure 10 PMDP tested a buffer storage station with an IMC Trolleybus to replace Diesel buses. Source: PMDP.

14 Transnational Handbook on EfficienCE pilots & best practices for energy-efficient PT infrastructure, O.T3.4 Pilot factsheet BS, O.I4 investment factsheet BS, D.T3.4.3 Pilot evaluation report BS

PMDP involved higher planning levels from Pilsen who used the evaluation results to update their SUMP. Thereby, the project results amplify energy-efficiency in Pilsen's PT by giving evidence to grid stabilization measures that support further fleet electrification through battery-technology in trolleybuses, extension of further trolleybus lines, and overall increase of travel comfort in trolleybuses[15].

The **Municipality of Maribor** invested in the modernization of an existing cable car station and integrated a fast-charging station for e-buses[16]. This allows using the electricity from the cable car station both for operating the cable car and for charging an e-bus. The investment will serve as a showcase for a multi-purpose PT infrastructure not only in Maribor but throughout Central Europe. By supporting the electrification of one bus line with e-busses, the pilot contributes to (annually) 190 t less C02 emissions, 40 % less noise, 80 % less energy costs, reduced maintenance, short charging time (5 minutes to charge with 12 kWh), and a return of investments within 8 years.

Figure 11: Demonstration of the operation of the pantograph in Maribor

Due to high replication potential in Maribor for cost-effective substation upgrades, the pilot contributes to expanding the PT multi-purpose infrastructure in the city. Thus, for its action plan, the city developed a line electrification hierarchy with technical & economic feasibility analysis for solutions. The action plan supports strategic objective to fully electrify its PT by 2030, as laid out in Maribor's SUMP, SULP[17], and the municipal energy concept. It contains measure groups such as mobility and logistic hubs, integration with rail, energy storage and PV solutions, to be integrated with SUMP measures (e.g., bus priority, open boarding)[18]. Implementation of detailed measures and investments will lead to 20 % less GHG emissions and noise, and 25 % less energy-costs by 2027.

BKK[19], PT authority in Budapest, developed an electrification strategy with scenarios to reach its goal to fully electrify local PT by 2050. The partner investigated its future PT infrastructure and energy needs in parallel to developing the Budapest vehicle strategy (e.g., for trams, metros, e-buses incl. fuel-cell, trolley) against its assumed socioeconomic and spatial development. In a consultation process with local stakeholders, BKK identified trends, vehicle groups, costs, and plans additional studies to specifically plan for depots, charging points, and procurement.

Figure 12 BKK developed an action plan to decarbonize its PT system. Source: BKK.

15 D.T1.2.3 Action Plan PMDP, O.T1.2.1 Output factsheet PMDP action plan, D.T1.1.3 Managerial approach on multipurpose PT infrastructure use

16 Transnational Handbook on EfficienCE pilots & best practices for energy-efficient PT infrastructure, O.T3.3 Pilot factsheet fast charger, O.I3 investment factsheet fast charger, D.T3.3.3 Pilot evaluation report

17 Sustainable Urban Logistics Plan

18 D.T1.1.3 Managerial approach multipurpose infrastructure, D.T1.2.3 Action Plan Maribor, O.T1.2.1 Output factsheet Maribor action plan

19 D.T1.2.3 Action Plan BKK, O.T1.2.1 Output factsheet BKK action plan, D.T1.1.3 Managerial approach on multipurpose PT infrastructure use

3.2 EfficienCE recommendations

Think in systems to plan efficiently and cost-effectively

- Find out whether the existing PT grid should be used – and extended - for multipurpose use, or whether the entire PT network should be newly planned for e-bus deployment or trolleybus, factoring multipurpose solutions. Planning should consider three different objectives: 1. achieving net zero transport, 2. increasing energy efficiency and 3. accommodating the growth of electric mobility at an affordable cost of infrastructure and energy, by keeping new investments at a minimum.
- In case of different owners of PT infrastructure, search for support within your national regulations, joining energy distributors to minimize energy costs (e.g. bigger operators and railways has normally lower energy costs, due to big consumption). If possible, seek for energy distributors which provide green energy.
- Identify problems such as energy loss (braking energy) or the need for additional power/ reinforcements of the grid to power e-buses (massive problem to deploy e-buses in scale). Identify opportunities such as surplus energy in the trolley grid or cable car substation's capability of taking additional load in the form of a charging hub created with high power charging stations.
- Build scenarios, including pessimistic ones like grid companies not able to accommodate additional consumers including EVs, and optimistic ones like technology development to cost-effectively harness braking energy with innovative business models (key for decision-making).
- Rethink the functionalities and land-use that enable combining different mobility functions (such as logistics operations, heavy duty vehicles, PT-centered mobility hubs) in joint strategic locations to consolidate the energy demand as well as increase the potential for shared use of infrastructure.

PT: Develop new business models

- As the use of charging facilities can be optimized through multipurpose use, adequate business and management models must be elaborated to guarantee efficient use of the network and power supply. Identify revenue streams for financial sustainability and develop new business models for PT operators.
- Bring in the end users to leverage/market the benefits of cleaner air, to attract investments for expansion of the charging network.

Legal and regulatory actions needed

- Integrated tenders for design, supply and installation of the system - vehicles and charging infrastructure - would allow participants in public tenders to carry out an optimization of the entire system based on the performance required by the PT operator, transferring the design risk of the system to the suppliers.
- To better integrate electric vehicles and infrastructure within PT fleets, it seems necessary to review current methods of accessing funds by extending them to operating leases for integrated offerings of vehicles, infrastructure and energy, as well as allowing operators to also access funds through the adoption of Public Private Partnerships for bus line electrification projects.

Industry: Support standardization to enable interoperability

- For innovative in-motion charging concepts, systems available for rail and e-buses miss standards & regulation that allow interoperability between them.

4. Share data to plan for energy-efficient public transport infrastructure

Data create value as their analysis helps understanding and predicting, e.g., driver behavior, wear and tear of infrastructure, and current and future user needs. Generation, storage, and sharing of data between stakeholders, processed through statistical or machine-learning analysis, can, thus, lead to insights and predictions that help reduce waste, improve energy performance, infrastructure maintenance, and lead to a better understanding of future investment needs.

4.1 What the EfficienCE partners did

The City of Leipzig (DE) together with its PT company Leipziger Verkehrsbetriebe (LVB, DE) developed an explorative use case for energy-efficient PT infrastructure planning to test and further develop their urban data platform (UDP). It’s an instrument to facilitate systematic use of data between city departments and utilities with a systematic, networked and standardized approach to data-sharing and a set of rules. While its more general objectives are to improve services and to increase the quality of life by connecting data silos, the goal for the EfficienCE use case was to understand how the UDP can be applied to its increase PT infrastructure’s energy-efficiency.

For the use case, large data amounts from on-board computers and Raspberry PI sensors in trams were linked with other data sources. Several possibilities were explored how findings derived from the data sets can be used for infrastructure planning, and sustainably implemented in the monitoring and process control architecture.

Figure 13: Data sources for the EfficienCE UDP use case

Specifically, statements were made on energy consumption of rail sections within supplying electrical substations, journey time performance, rail infrastructure and their impact on tram performance. Explorative data science analysis methods were applied to derive causalities. This also provided scientific validation of the data used, thus, quality assurance of the data processing. Resulting recommendations for action are to develop a predictive tram infrastructure maintenance application, and further methods for digital transport planning[20]. Leipzig exploits the results in a follow-up project as the UDP progresses into a digital twin[21].

20 D.T1.2.3 UDP use case Leipzig & LVB and O.T1.2.1 Output factsheet Leipzig & LVB UDP use case, D.T1.1.1 Managerial approach data-based planning and financing for energy-efficient PT infrastructure

21 CUT project

4.2 EfficienCE recommendations

The benefits of data-sharing can only be realised if major obstacles in organisations are overcome. For example, urban data resources remain in "silos" in many organisations, and data exchange takes place on case-by-case basis. To connect the silos, the human factor plays an important role (missing data literacy, concerns about privacy and risks in handling sensitive and personal data). Another problem is reluctance by market participants to share data (e.g., e-bus providers do not readily share sensor data with cities and PT providers even if useful for understanding infrastructure and maintenance needs). Also, municipal data are still subject to many different regulations and cultures to collect, process, store, disclose, publish data.

The following recommendations can support managing these obstacles.

Build capacities

- Create awareness and improve talent by fostering data literacy and training about hardware, software, artificial intelligence, digital twins, to support acceptance towards data-driven monitoring and decision-taking.
- Buy-in of experts can only support to initiate the process. Change needs to come from within organisations, based the "coalition of the willing".

Get political support and define objectives

- A political decision is the starting point for developing a UDP. E.g., the City of Leipzig defined the concept and development of its UDP as one of its strategic priority projects in 2019.
- Define visions and clear objectives the UDP is applied for. Thus, Leipzig UDP is used to implement its mobility strategy 2030, and to support the city – selected as model city by the European Commission in 2022 – in becoming climate-neutral by 2030.

Define how value is created

- Leipzig decided that the value of the UDP is to support integrated urban development through facilitating information, planning, control, and simulation to improve system performance and quality of life.

Dedicate resources to develop a data strategy

- A data strategy defines how data will be shared, with standards for documentation, quality, infrastructure, security and protection, internal and external access regulation, and operational objectives. It also defines how to manage risks. This requires resources. Leipzig uses a follow-up project to further develop its data strategy, also building on other cities' expertise[22].
- Before having a strategy in place, install a core interdisciplinary and interdepartmental working group to define guiding principles of the UDP, and involve top-management and policymakers. This group can define a common understanding on added values, central terms, guiding principles for the use of data, and a basic governance model.
- Translate their findings and framework conditions into a target and implementation concept with a clear understanding of roles and tasks of each actor.

22 CUT project

Define how data will be managed and shared

- Enable public-private data-sharing through an open urban data platform.
- Foresee structured data collection based on interoperable standards and interfaces and ensure the continuous updating of data. The use of standardized platforms facilitates the process.
- One approach to build powerful and demand-driven open data platforms, regardless of future developments, is to digitize all information in a way that the heterogeneous data can be restructured and used as repeatedly as needed.
- The type of hardware or end devices must not play a role.

Implement use cases to make your UDP visible

- Set up a test lab for your UDP. Elaborate use cases that illustrate its added value, which should demonstrate special challenges to real-time capability (e.g., energy-efficient PT infrastructure planning between municipal departments and utilities).

Ensure data accessibility through the vertical and horizontal structure of the organisation

- Provide an operating model that meets the growing challenges of flexibility and dynamism, such as those posed by IoT devices. Establish a dynamic data flow within the municipal family so that the data flows and analysis results as processed in the use case are permanently integrated into operational processes.
- Ensure that all stakeholders of the local authority family organise data access via the UDP as a data hub. The focus should be on a (fully) automated process with dynamic processing of a wide variety of information from different data sources as well as their provision, aggregation and comparative analyses (benchmarking).
- In parallel, the raw data model and, if necessary, the analysis results should be automatically fed back into the UDP, to provide the data and insights gained to the municipal structures.

Legal and regulatory actions needed

- It would help PT authorities and providers to better plan for energy-efficient PT infrastructure if they could use sensor data from the industry, e.g., from e-bus suppliers. As some suppliers withhold data, a legal obligation to share sensor data with PT operators and authorities would be a great support.
- Another possibility is to create the tender specifications for e-bus procurement in a way that data-sharing will be of advantage for the bus provider (as currently planned by ATB Bergamo for procurement of 64 new electric buses).

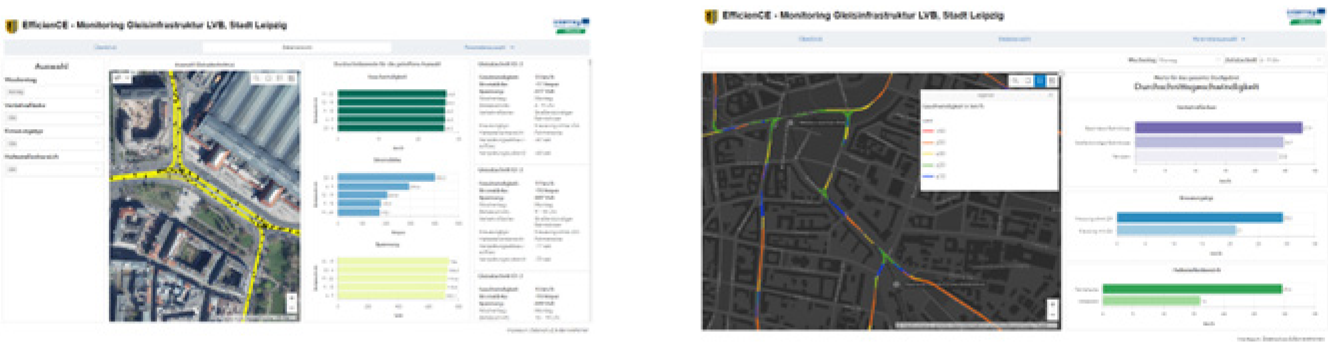

Figure 14: 40.5 Mio data points with 60 attributes processed into data model are used for the use case dashboard visualization. Source: Leipzig.

5. General recommendations

Other, more general, recommendations for all three topics are:

Create support on the local level

- Start big, don't give up, and reserve time and resources to get local support.
- Participate in European projects and learn about good practices. City leaders are more likely to say "yes" to a new idea if the funding is already (partly) there.
- Work together with neighboring regions to share costs.

Figure 15 Installation of fast charger in Maribor. Source: City of Maribor.

Procurement

- Before the actual tender, communicate extensively with the industry and cities that have already implemented the innovative technology to gather information for the tender specification.

Build up talent

- Resources and capacity-building through training are crucial to build up competences in the transport ecosystem (route re-planning, demand forecasting, etc.) and in the energy ecosystem (identification where surplus power is available, efficient use of PT grid/substations which are currently used for powering only trams, e-buses, etc.)[23]. LVB and WL have trained energy-managers and energy-management departments. To support others build up similar capacities, EfficienCE with LVB produced a Competence Profile and Curriculum for Energy Audit Management[24].

Provide for evaluation

- Develop key performance indicators (KPI) to measure progress[25].

Enable interoperability, standardization and new business models

- Interoperability and standardization at all levels of the charging process including physical connection of charging devices to vehicles, communication protocols (ISO 15118-20 future-oriented covering enablers for V2G communication as well) between vehicle & charger, and payment modules drive the concepts of RES integration, charging hubs and multipurpose use of infrastructure forward.
- As an outlook, the aggregate of e-buses can become a "virtual power station" providing local services to the distributor. Such technology can help companies to earn money or free energy in exchange for the balancing service provided. Incentives could encourage the deployment of such technologies.

23 EfficienCE handbooks for energy-efficient PT infrastructure technologies deployment (storage, multipurpose use, depots, pilots)
24 D.T2.1.3 Competence Profile and Curriculum for Energy Audit Management
25 D.T2.4.2 Final evaluation report

6. Outlook: Towards climate-neutral public transport systems

Making PT energy-efficient is essential for achieving the European Climate, Green Deal, and EU Mission "Climate-neutral and Smart cities" objectives. In this light, the implementation of EfficienCE action plans, and upscaling and replication of pilots, will contribute achieving these goals in the partner regions.

Participating in EfficienCE helped the partners gaining local visibility and support to plan and implement actions for higher energy-efficiency in their PT infrastructures. This shows the high value of transnational cooperation and capacity-building programmes like Interreg CE. But even more value was created as Leipzig, Bergamo and Budapest were selected by the European Commission as three of the hundred "Mission" cities to receive special support in becoming climate-neutral by 2030. Of course, these partners will exploit their EfficienCE results in achieving this goal.

The project also involved other regions, e.g., public authorities and PT operators from within and outside central Europe, to give input to, learn from and discuss with the project. Communication and capacity-building activities have reached – and still reach through online resources - a considerable number of participants[26].

Future transnational cooperation could take up the project recommendations to overcome managerial, regulatory and legal obstacles for achieving energy-efficient PT as presented in this document, and thereby facilitate the rapid decarbonisation of PT in central Europe.

26 More than 4.000 persons reached at targeted events (e.g., Green Week, EU week of regions). Ca. 350 persons participated at transnational trainings and EfficienCE e-course.

References

Polis, and Rupprecht Consult (2019): SUMP Topic Guide Electrification. Planning for electric road transport in the SUMP context. Weblink
Günter, H., Backhaus, W. (2018): Eliptic policy recommendations. Weblink

EfficienCE resources (on the EfficienCE website).
D.T1.1.2 Managerial approach on the integration of RES into PT infrastructure
O.T1.2 Output Factsheet Bergamo
D.T1.2.3 Action Plan Bergamo
O.T3.1 Pilot factsheet PV system
O.I1 Investment factsheet PV system
D.T3.5 Pilot factsheet energy audit tool
D.T3.4.3 Pilot evaluation report energy audit tool
O.I2 Investment factsheet inverter
O.T3.2 Pilot factsheet inverter
D.T3.2.3 Pilot evaluation report inverter
D.T1.1.3 Managerial approach on multipurpose PT infrastructure use
O.T1.2.1 Output factsheet Maribor action plan
D.T1.2.3 Action Plan Maribor
O.I3 Investment factsheet fast charger
O.T3.3 Pilot factsheet fast charger
D.T3.3.3 Pilot evaluation report fast charger
O.T1.2.1 Output factsheet PMDP action plan
D.T1.2.3 Action Plan PMDP
O.I4 investment factsheet BS
O.T3.4 Pilot factsheet BS
D.T3.4.3 Pilot evaluation report BS
O.T1.2.1 Output factsheet BKK action plan
D.T1.2.3 Action Plan BKK
D.T1.1.1 Managerial approach data-based planning and financing for energy-efficient PT infrastructure
O.T1.2.1 Output factsheet Leipzig & LVB UDP use case
D.T1.2.3 UDP use case Leipzig & LVB
D.T2.1.3 Competence Profile and Curriculum for Energy Audit Management
D.T2.4.2 Final evaluation report on the EfficienCE website

Transnational EfficienCE Handbooks for energy-efficient PT infrastructure technologies deployment storage, multipurpose use, depots, pilots and best practices – available in all CE languages)
EfficienCE toolkit
EfficienCE e-course

Other online resources:
SUMP Online Guidelines | Eltis
https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-transport
https://youtu.be/K6Q0x2-y-Vs
Connected Urban Twins - Stadt Leipzig

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