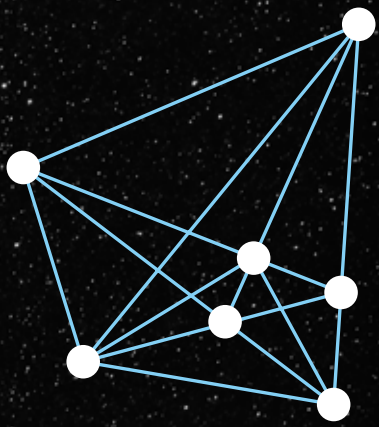


STARDUST

BEST PRACTICES BOOK

Table of Contents

List of Acronyms

API
App Programming Interfaces

BaU
Business-as-Usual

BEMS
Building Energy Management System

CO2
Carbon Dioxide

DH
District heating

DHS
District Heating Substations

EIT
European Institute of Innovation & Technology

EPBD
Energy Performance of Buildings Directive

EPC
Energy Performance Contracting

ESCO
Energy Service Company

EU
European Union

EV
Electric Vehicle

GDP
Gross Domestic Product

GDPR
General Data Protection Regulation

GPS
Global Positioning System

HIT
Hub Innovazione Trentino

HVAC
Heating, Ventilation and Air Conditioning

IAQ
Indoor Air Quality

ICT
Information and Communication Technologies

IoT
Internet of Things

IT
Information Technology

KPIs
Key Performance Indicators

LED
Light Emitting Diodes (LED lighting)

LPG
Liquefied Petroleum Gas

LTZ
Limited Traffic Zone

NGOs
Non-governmental Organizations

NPV
Net Present Value

PPPs
Public-Private Partnerships

PV
Photovoltaic

REST
REpresentational State Transfer

ROI
Return on investment

SEAP
Initial Sustainable Energy Action Plan

SMEs
Small and Medium Enterprises

SPP
Simple and Discounted Payback Periods

VCF
Value Capture Financing

Introduction

Against a backdrop of climate change, many cities are aiming to become climate neutral in the coming decades, in line with the European Union's climate policies such as the European Green Deal.

Cities are also seeking to improve residents' quality of life and to involve people in the energy transition.

In this respect, the Smart City project STARDUST has worked across key areas of innovation – **energy, mobility, ICT and citizen engagement** – to develop holistic solutions that can be replicated in other towns and cities in Europe.

We've developed these solutions in "lighthouse cities"* – Pamplona (Spain), Tampere (Finland) and Trento (Italy); and then adapted them to the "follower cities"** – Cluj-Napoca (Romania), Derry (UK) and Kozani (Greece)**, to test their potential for replication.

For example, many **nearly zero and low-carbon buildings** have been built and renovated. We've designed, built and validated innovative **district heating and cooling solutions**. **Our e-mobility pilots** have been particularly successful, with pioneering solutions for integrating clean energy into public transport.

Furthermore, **IoT city platforms** have been introduced along with various **city apps** for residents. In the "follower" cities Derry, Kozani and Cluj-Napoca, local project teams have set out thorough **replication plans** drawing on the work of the "lighthouse cities". And STARDUST has provided cities with useful knowledge for their own decarbonisation plans. Three out of the six cities in the project – **Tampere, Kozani and Cluj-Napoca – now feature among the EU's "100 Climate-Neutral Cities by 2030" mission**.

During the six years of STARDUST, many challenges had to be negotiated: mayors and municipal teams changed, as did their priorities; the worst global pandemic in modern times broke out; and the war in Ukraine, apart from the obvious humanitarian disaster, led to higher **energy costs and shortages of key technological components**.

Legislation too changes over time and can thus pose a challenge. And whatever the context, **the optimal integration of systems, technologies and business models is never easy**.

All these challenges have been instructive, and they have given us perspectives that we would not have had otherwise.

This handbook draws on our experience as a whole and it sets out some of the **best practices, pitfalls and lessons learnt**. It is intended for use by other European cities, policy makers, technology providers and businesses.

Florencio Manteca,
STARDUST coordinator
CENER

*In the project, a "lighthouse city" is where solutions are developed and validated, setting an example for other cities to follow.

**A "follower city" adapts and replicates the solutions developed in the lighthouse cities.

CHAPTER 1

Stardust at glance

About Stardust

Cities are highly complex systems. As ever more cities seek to become more sustainable, more liveable, and climate-neutral, they must deal head-on with challenges such as atmospheric pollution, traffic congestion, fuel poverty, high energy consumption, digital gaps, and issues relating to economic growth and job creation.

Energy, mobility, and information and communication technologies (ICT) are important areas for tackling these urban challenges, but they need a **holistic approach** – one that delivers cross-cutting solutions, one that embraces both technical and non-technical measures.

In STARDUST, intelligent solutions for energy, mobility, and ICT have been integrated in cities, together with innovative business models, which can serve as blueprints for replication in other towns and cities. **The project team has connected and engaged with residents, turning the STARDUST cities into living labs where this community engagement has helped drive improvements in people's way of life and in their local economies.**

The main goal of STARDUST has been to introduce low-carbon, highly efficient, intelligent, and citizen-oriented cities. It has thus developed green technical solutions and innovative business models to address the urban challenges identified by the cities involved.

These challenges have to do with the **environment, society, mobility, energy, economy, and the cities' visibility.** This may concern, for example, urban poverty, poor waste management, incremental air pollution and traffic congestion, lack of jobs, high energy costs and poor international recognition.

According to the challenges pointed out, focus areas were selected by STARDUST, which include:

- **"Innovation islands", or urban incubators** that demonstrate scalable, cost-effective, and bankable urban-scale solutions;
- **Smart ecosystems** that make use of the new economic paradigm in European cities that is based heavily on eco-innovation, market competitiveness, low carbon usage, and promotion of a circular economy;
- **Open city information platforms**, an ICT platform that allows both lighthouse and follower cities to engage actively with one another and to address effectively their issues with the technical partners;
- **Lighthouse Cities' solutions**, which have been adapted to the follower cities.

Lighthouse Cities

Pamplona

Pamplona, the capital of the Navarre Region in northern Spain, is a city with 205,000 inhabitants in a metropolitan area of over 300,000 (around half of the entire region of Navarra, 650,000).

It is characterized by a high rate of industrial activity (automotive and renewable energies), the presence of 3 universities, the headquarters of the National Centre for Renewable Energies (CENER), and a high density of innovation-driven companies. Pamplona has been a pioneer in fostering renewable energies during the last 20 years. Today 9.5% of the final energy consumption in the city comes from renewable sources.

Pamplona signed the Covenant of Mayors in 2009 and the CO2 emissions were reduced by 15.6% between 2005 and 2018. In 2021 the City Council approved the local Energy Transition and Climate Change Strategy, with the following objectives for 2030:

- 64% emissions reduction compared to 2005;
- 39% improvement in energy efficiency with regard to future predictions (BAU);
- 37% of final consumption of energy from renewable sources;
- 0 energy poverty in 2030;
- Reduce the impact of higher temperatures on people's health;
- Reduce the impact of intense rain on the built environment;
- Reduce the impact of increased drought episodes.

To achieve these challenging objectives, the City Council is working with different public and private organizations, as well as with NGOs and non-profits, as part of the Urban Agenda, which established a Government model facilitating their participation and communication.

Tampere

Tampere is 3rd largest city in Finland with 253 000 inhabitants. Formerly known as a traditional industrial town, Tampere is now Finland's most active start-up city. Heavy industries are increasingly joined by smart technology. Leading industries are manufacturing, intelligent machines, automation, AI and analytics, health technology, circular economy and cleantech.

Tampere signed the Covenant of Mayors in 2009. The aim was to exceed the European Union's target of reducing climate emissions by 20% by 2020. The city met this target as early as 2014, according to a calculation in the CO2 report.

Tampere's target is to be carbon-neutral by 2030. The aim is to reduce direct carbon emissions by 80 per cent compared to 1990 levels and to compensate for the remaining emissions.

Emissions in Tampere have already gone down: total emissions fell by 29% from the year 1990, and emissions per capita fell by 48% (confirmed data from 2017).

In 2020 the City Council approved the Climate Neutral Tampere 2030 Roadmap that compiles city's climate actions. Most effective planned actions include the construction of a new biogas plant, energy renovations of city properties and developing public transportation with the tramway. Ensuring biodiversity is also an important part of climate work. The LUMO programme promotes biodiversity in Tampere.
The city cannot achieve its goals without the participation of its residents, businesses and communities. To achieve carbon-neutrality, the City Council is working with the different public and private organisations, as well as with NGOs and non-profit organisations.

Trento

Trento, the capital of the Autonomous Province of Trento (Trentino) in Northern Italy, boasts a diverse population of nearly 120,000 residents living from the valley floor at 200m to the high mountain peaks at 2000m. Its rich history dates back to Roman times when it was known as "Tridentum" and later served as an Ecclesiastical Principality for eight centuries, hosting the renowned Council of Trento from 1545 to 1563.

Today, Trento is recognised as a vibrant Alpine city, consistently ranked among Italy's top cities for quality of life. It was acknowledged as the “Alpine City of the Year” in 2004, and as the European Volunteering Capital in 2024.

Trento is dedicated to sustainability. It joined the EU Covenant of Mayors in 2014 and signed its first Sustainable Energy Action Plan the next year. In 2019 the city reduced its CO2 emissions by 22%, compared to 2006, thus surpassing the 20% threshold set at the EU level. In recent years, the city has committed to even more ambitious targets, by signing a new Sustainable Energy and Climate Action Plan to achieve at least a 40% CO2 reduction by 2030 and climate neutrality by 2050. Trento emphasises sustainable mobility strategies and policies, exemplified by the adoption of the Sustainable Mobility Urban Plan in 2023, including a specific “Bike Plan”.

Anchored in a strong research and innovation ecosystem, the city is a key driver for the development of the area, fostering collaborations between policymakers, research centres, universities, and businesses.

The University of Trento is the leading academic entity in the area, accompanied by Fondazione Bruno Kessler, a multidisciplinary research institution that may count on 450+ researchers specialised in technology, innovation, and human/social sciences. In 2012 Trento was selected as the headquarters of the EIT Digital Italian Node to work on topics like smart cities, cybersecurity, and big data. This research excellence is complemented by Trentino Sviluppo Agency and Hub Innovazione Trentino (HIT) with activities in the field of business incubation/acceleration, technology transfer, open innovation, and territorial marketing.

Follower Cities

Cluj Napoca

The Cluj Metropolitan Area covers 1,603 square kilometers, occupying 24% of the territory of Cluj County. The population of the 20 localities totals 418,153 people, of which 324,576 live in Cluj-Napoca, according to the 2011 census.

The Metropolitan Area had a total population growth by 11.2% (2011-2021) while, nationally the population dropped by 1.74% (2011-2021). In the last 10 years, Cluj-Napoca has become the second most developed urban centre in Romania. Between 2014 and 2017, the nominal GDP of Cluj County grew by 44%, compared to a 28% increase at national level and 31% in the Bucharest-Ilfov region.

Cluj-Napoca is transitioning to a knowledge-based economy. It has more than 80.000 students/ year, the largest student population in the country. Also it inhabits more than 1800 IT companies and more than 350 IT start-ups/ year and approximately 20.000 employees in IT field.

Cluj-Napoca was the European Capital of Youth 2015 and shortlisted for the European Capital of Innovation 2020.

As a part of the 100 Climate Neutral Cities Mission, Cluj-Napoca City together with the Net Zero Coalition (21 actors joined) built the 2030 Climate Neutrality Action Plan.

The main objectives include: to reduce CO2 emissions by 81.37%.

Among the listed actions are:

- Efficient district heating and cooling in Cluj-Napoca;
- Local (off-site) renewable energy generation and integrating RES into private and public buildings;
- Major green public transport infrastructure and reduction of congestion in the city;
- Promotion of large-scale use of Electric Vehicles;
- Extension of Walkable City Programme;
- Extension of Cluj Bike Programme;
- Green-blue corridors

Net Zero Coalition will use the momentum of intensive collaboration for “Climate neutrality” to engage the private sector in completely neutralizing GHG emissions, with a contribution of up to 15% of the emissions that are not accounted for the Action Plan.

Derry

The Derry City & Strabane District Council area serves a population of 150,100. It includes mountain ranges, rivers, agricultural land, and coast offering vital habitats for species, destinations for tourism and recreation, a rich cultural heritage as well as settlements for local communities.

Urban areas include the regional city of Derry connected to several vibrant towns and villages including Strabane. In addition, the Council area shares a 140km border with Donegal County Council. Derry and Strabane’s direct carbon footprint fell by 20% between 2000 and 2022 while total emissions were 1.7 kt CO2e, in 2022 compared to 2.2 kt in 2000.

Currently, 65% of all emissions from the region come from land-use and industry, with homes accounting for 15%, transport 12%, public and commercial buildings contributing 4%, and the waste sector emitting 3% of emission. The first Northern Ireland Climate Change Bill and subsequent Act was passed in 2022, establishing a Net Zero emissions target by 2050 and 46% methane reduction target by 2050.

Sustainability and environmental protection are strategically embedded within the City and District’s Strategic Growth Plan and City Deal proposition with an emphasis on environmental wellbeing, circular economy and sustainability and inclusivity. The 'Inclusive Strategic Growth Plan' vision is to achieve: A thriving, prosperous and sustainable City and District with equality of opportunity for all. Derry & Strabane is the first local authority in North of Ireland to develop a Climate Adaptation Plan, passed by Council in July 2020. Derry declared a climate emergency in July 2019 followed by the Climate Emergency Pledge to achieve a net zero climate resilient City & District by 2045, which is supported by the "NorthWest Regional Energy Strategy".

Derry & Strabane 'Green Infrastructure Plan' brings together cross sectoral stakeholders to deliver the vision that ‘By 2032 the environmental, economic and social benefits of Green Infrastructure will be valued and maximized by all.’ Council have committed to the following national and international declarations:

- Global Covenant of Mayors for Climate & Energy
- Glasgow Food & Climate Change Declaration
- United Nations Race to Zero & Race to Resilience
- Council currently reports to the Global Covenant of Mayors, CDP and ICLEI EU climate change platforms and NI National Adaptation Programme in an annual basis.

Derry's innovation ecosystem has been strengthened by the recent formation of the "Derry and Strabane Climate Commission", which bring together energy stakeholders from the private and public sector, the education and community sector, and from the emerging energy cooperatives and communities sector. Developing new sources of renewable energy and positive energy districts are a key priority for the Commission.

Kozani

Kozani, Greece's 35th-largest municipality, is home to a population of 71,388 and covers over 100,000 hectares. With a continental climate, Kozani is the main energy-producing area in Greece, supporting thermo-electric plants with a capacity of approximately 2,845MW and employing over 4,000 people in coal mines and power stations.

The city is the capital of the Region of Western Macedonia, a coal region in transition. The industrialisation has limited other productive activities, and the challenge is to find new features and exploit advantages, something that local forces are seeking to do.

In recent years, energy efficiency, mobility and climate considerations have gained substantial importance in the municipality, exemplified by the Mayor signing the Covenant of Mayors in 2011. With the support of the Engineering Department of Western Macedonia University, energy requirements and the main sources of CO2 emissions in the municipality have been recorded using 2010 as a reference year, and the key results are summarised as follows:

- The Initial Sustainable Energy Action Plan (SEAP) targeted a reduction of CO2 emissions by at least 21.4% in 2020 within the municipality's limits.
- Energy-efficient retrofitting of private and public buildings offers the highest CO2 reduction potential at approximately 63%.
- Local energy generation contributes to around 20% of CO2 reduction.
- The tertiary sector accounts for approximately 12% of CO2 reduction potential.

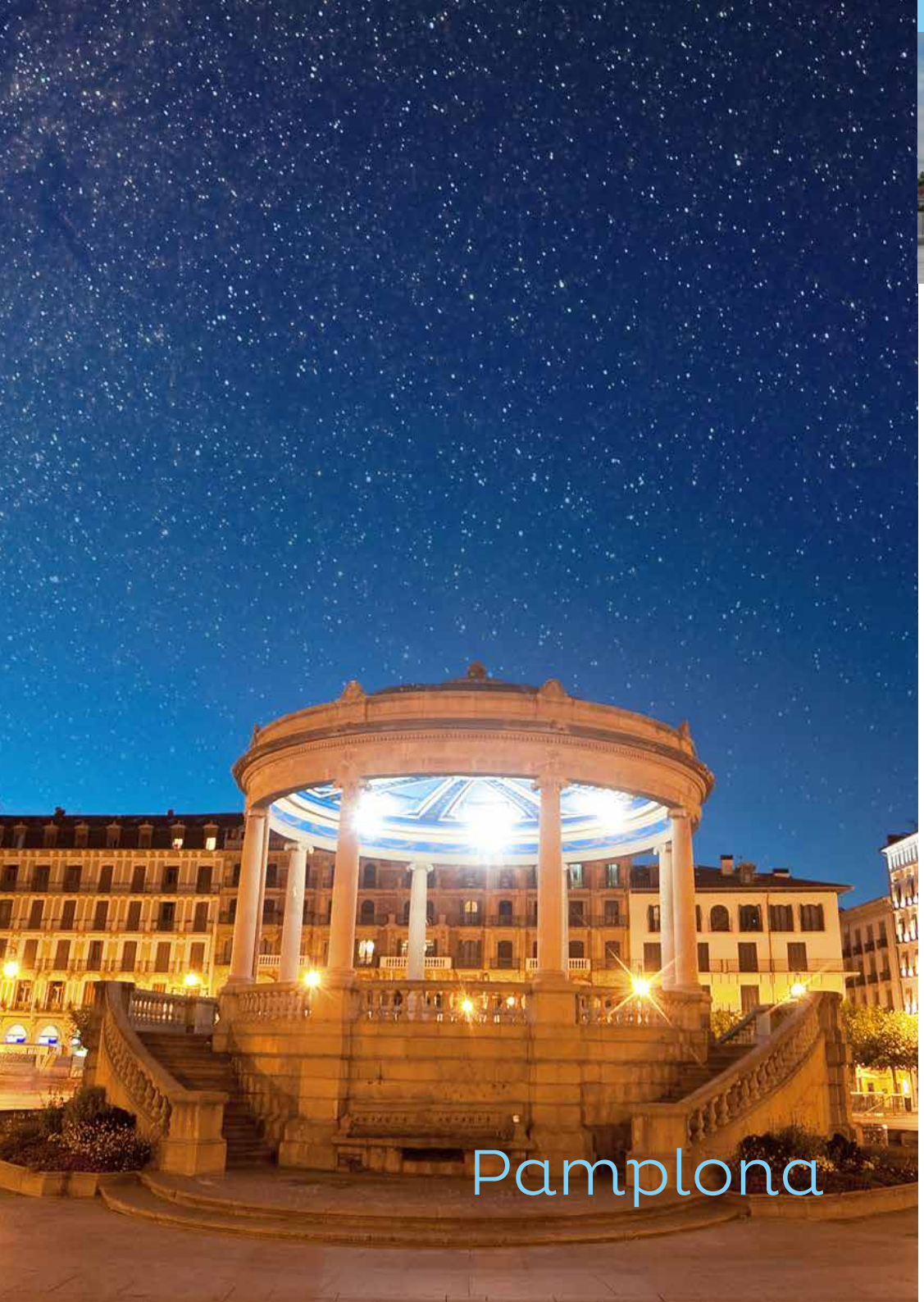
The 2020 objective was reached, with certain levels of CO2 reduction surpassing the target. The Kozani CO2 emissions census and energy road map have been incorporated into the current Sustainable Energy Action Plan. The municipality has developed a new Sustainable Energy and Climate Action Plan aimed at a 100% reduction in CO2 emissions by 2030. To achieve these ambitious objectives, Kozani has decided to strive for climate neutrality by the year 2030.

Recently, Kozani was selected to be a member of the EC's 100 climate-neutral city initiative by 2030.

CHAPTER 2

Lessons learned

on technnological, regulatory and social levels



Pamplona

District Heating + NEMS

Nasuvinsa has developed a district heating network for private residences and public buildings in the Txantrea neighbourhood of Pamplona. This system is set to provide heating and domestic hot water to over 4,500 dwellings and 8 public buildings in an area constructed between the 1950s and 1970s. Approximately 90% of the heat will be generated using forest biomass, specifically wood chips. As such, sustainable forest management is verified through certification, and extraction must not exceed 150 km by road from the power plant.

Real case

The physical implementation of this project has been planned in two phases to ensure that both the building and the general facilities of this district heating (DH) system can accommodate future demand.

- 1st Phase: To cater to the heat requirements of consumers near the installation.
- 2nd Phase: To extend the DH network to cover the entire Txantrea neighbourhood.

Our advice

It should be borne in mind that private consumers prioritize a competitive price over the renewable origin of the energy they consume.
Public consumers/managers have bureaucratic challenges when transitioning to a different model for the procurement of heat energy.
Therefore this aspect must be taken into account when establishing timelines. Public tenders should evaluate bids in a way that gives more weight to the renewable origin of the energy.

Solar Taxi Fast Charging Station

Pamplona City Council installed a 50 kW fast-charging station for taxis, fed by PV panels and second life batteries for energy storage (provided by Bee Planet), and for grid peak power reduction in the bus station. The photovoltaic installation is controlled through the energy management system INGECON SUN EMS, which allows the user to easily implement different strategies. Furthermore, at the bus station, users can view the overall status of the installation through an display screen.

Real case

A careful study of possible sites was necessary, with the capacity to host a photovoltaic installation, which would firstly allow easy access for taxis and subsequently allow access for private vehicles.

Our advice

The visual impact that photovoltaic installations can have in protected environments should be assessed.
Losses in the charging and discharging batteries should be taken into account as this can significantly reduce the expected economic profit.

Electric smart mobility

STARDUST guided public-private investments in the promotion of e-mobility in Pamplona. The following actions were carried out by the City Council:

• Bikes:
+ Sheltered bike-parks: 4 bike parks with CCTV for residents with 500 racks and 6 public bike park with 300 racks. They have e-chargers for e-bikes.
+ E-bike system with 400 bikes; it is being extended with 240 e-bikes, financed with NGEU funds.

• EV-charging infrastructure: EV-charging points in the streets, public buildings, underground car parks and at a park&ride with a PV roof (66 charging points).

Real case

For public E-bike system and E-charging infrastructure, Pamplona City Council put out to tender a contract for the “Administrative concession of the public domain of the city of Pamplona for the installation, management and operation of the system”. In addition, the municipality is setting up its own network of recharging points, managed by the municipality itself.

Our advice

A municipality may wish to maintain its own management of these services to ensure they are deployed as essential in the city.
E-bike system is very successful: the ratio is very high, and it has been focused on daily mobility.

New e-Bus Line Integrated with Smart Grid

Charging stations can cause voltage drops, disrupting the electricity distribution network. Therefore, a smart charging station with backup battery and photovoltaics has been installed at the Public University of Navarre. The battery provides the peak power to the buses and charges at constant power from the distribution network for the rest of the time. Three main elements were analysed: power electronics conversion system, battery energy storage system and the energy management system.

Real case

The system finally installed is a second-life battery with a storage capacity of 84 kWh and a PV system with a power of 136 kWp. The monitoring and control system was installed in a programmable logic controller in a university building, permanently connected to the microgrid via the campus' internal ethernet in order to allow the energy management strategies to be properly integrated and executed.

Our advice

To avoid disruptive high electricity peaks during e-bus recharging, smart charging stations should include a backup storage system and not be too large. Due to the high number of cycles, a smart energy management is key to optimising batteries lifespan.

HEMs and BEMs

Nasuvinsa has developed a software platform to monitor and control its social rental buildings, both newly constructed and recently retrofitted for energy efficiency.
The system consists of two distinct parts: the local management system located in each building and the centralised system that manages information from these buildings.
The tool has been developed under open-source software licenses, enabling integration with any type of building and adaptation to user needs.

Real case

In Nasuvinsa's residential portfolio, the management of energy use was integrated, with all residences monitored in terms of consumption levels and energy sources. Inappropriate use of energy can be detected and personalised guidance given. Residences and utility rooms benefit from preventive and predictive maintenance.

Our advice

It should be borne in mind that the introduction of HEMs/BEMs in high-performance new buildings, comes with an additional cost that may not always be easily absorbed by the developer.
The development of an open-source software that can communicate and integrate controllers/BEMs from different brands, enabling remote management of all buildings, regardless of proprietary systems.

Entrepreneurial Discovery Process

As a result of the Entrepreneurial Discovery Process, Pamplona City Council organised the "Smart Iruña Lab" where local startups proposed smart ideas to be implemented in the urban context. The City Council offered the scenario for the low-scale demonstrative pilots, while the startups covered the implementation cost.
The results were shown at a workshop reported to STARDUST. This task aimed at taking three of these validated ideas to a next level in the city.

Real case

The three ideas are:

- IAQ (Indoor Air Quality) has a significant impact on health and quality of life for people. Pamplona implemented the system in various kindergartens, to improve air quality.
- Safety solution for pedestrians in the city centre, including a prototype of a horizontal traffic light.
- IoT solution to inform drivers via APP about the parking spaces available in the city centre.

Our advice

Local authorities can support local entrepreneurship by facilitating testing their innovative solutions in public spaces and buildings. Indeed, the implementation of the pilot on horizontal traffic lights supported the creation of the STOPLED company, and the pilot on reserved parking spaces led to the deployment of the system with 372 sensors.

Hydrothermal heat pump integrated with PV

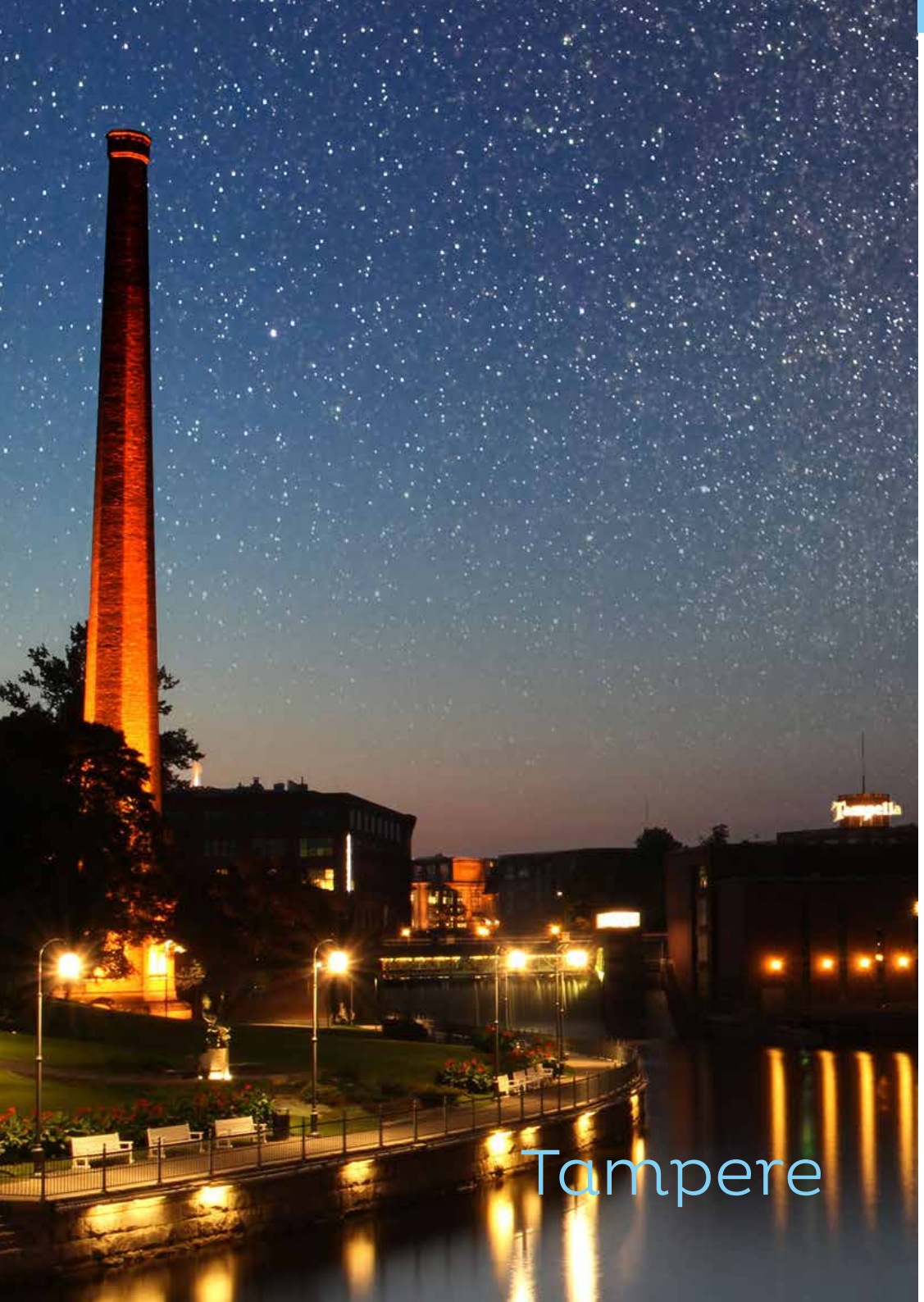
Mancomunidad de la Comarca de Pamplona (MCP), in collaboration with CENER, has analysed the potential use of water and wastewater networks to recover waste heat. The aim is to take advantage of the thermal stability of the network to air-condition some of the most energy-intensive public buildings using heat pumps. A PV system has also been integrated on the roof to compensate for the extra electricity consumed by the HVAC.

Real case

MCP is carrying out a demonstration project at the Eguillor water treatment plant. The office/laboratory building has been renovated, improving the thermal envelope, and replacing the old oil boiler with a heat pump connected to the water network.

Our advice

The final scope of the building refurbishment must be clearly defined before the final HVAC system is sized. In this pilot case, the ambition of the refurbishment ended up greater than envisaged, resulting in an oversizing of the heat pump selected.
The new heat pump effectively meets the heating and cooling needs of the building, but the efficiency of the system is lower than expected. One of the possible reasons for this is that the system operates at very low part load.



City application for residents, tourists and businesses

City applications offer an easy, accessible, fun and interesting way to provide information about services for citizens, tourists and businesses. They contribute to a better, safer and more engaging city environment for the individual, thus improving the city experience. Contents can be built natively from original sources, for example via City app programming interfaces (API), partners' APIs and open APIs.

Real case

Tampere.Finland City Service Application is a result of an innovation partnership procurement in collaboration with STARDUST. In its first four years of use since 2019, it has had about 190,000 unique downloads and 30,000 active daily users. The app uses open data and APIs. It is available free of charge for Android and iOs, in Finnish and English. Content is customisable by user profiles.

Our advice

It's good to have a single product owner, but otherwise it makes sense to have people from different parts of the organisation involved in content production. New development ideas can be collected from app users, and the city and partner organisations. To attract users, it's good to include benefits and offers from different companies if possible. Marketing is needed to make users aware of the app.

Mobility carbon footprint calculator

Cities need information about where and how people move. The aim of the carbon footprint calculator is to provide users with information on the climate impact of their own mobility in relation to the city's climate target and to encourage them to change their mobility habits to be more sustainable. A second aim is to collect mobility data at the same time.

Real case

In Tampere, the Mobility CO2 calculator was added to the city app in 2021. It features open-source implemented backend and automatic transport mode detection that uses GPS, gyroscope and accelerometer data sent by the mobile phone, and public transport interface data. There's also a separate analytics tool with data visualisation.

Our advice

The first version of the calculator included low-carbon mobility offers but these were later removed due to cost and lack of interest. GDPR issues need to be managed as raw location data is considered personal data. The calculator's data isn't always accurate enough for traffic planning. Trips might not be saved due to power-saving setting on mobile phones. The calculator doesn't work well on some phone models.

Smart City IoT platform

Through the IoT platform, data is generated and maintained efficiently, allowing data to guide and plan future actions reliably. Outdoor lighting is controlled though the platform to save energy and CO2 emissions. A more accurate view of maintenance needs keeps the costs under control, even though the city is growing rapidly. Future development projects can also use the platform data or the platform itself to collect and generate their own data.

Real case

City of Tampere developed an IoT platform to help towards its sustainability goals. The platform collects data and builds a situational picture of the city's operations. It can be used to combine different data sources, visualise them and use them to automate operations. At SCEWC 2023, the platform won an award for its replicability, usability, and ability to generate social added value.

Our advice

Enough time should be planned for market dialogue and defining requirements in the procurement phase. With a smaller pilot area, problems can be spotted before scaling up solutions. Transparency is needed in the procurement and deployment phases. The service should have a monitoring group with representatives from the city and service provider.

Electric buses in harsh winter conditions

Fossil emissions from transport can be reduced by switching from diesel to electric propulsion. But will electric buses work in cold conditions?

Real case

Tampere had no previous experience with electric buses. The main aim was therefore to learn how they may operate in low temperatures with slush, freezing snow and icy streets. The Municipality monitored four buses charged at the last stop of the bus line that goes through the city centre. WRM-247 devices collected data for more than two years.

Our advice

Electric buses also work in northern conditions. What matters in terms of energy consumption is how the cabin is heated, not just the mileage: heating with heat pumps is better than heating with LPG. Battery technology has developed rapidly, and longer distances can be covered on a single charge.

Remotely produced solar power helps towards the net-zero concept

The idea is for a dense urban area to have its own power generated in a rural area where there is more free space. This is in line with EPBD for energy efficiency and energy certificate calculation of new buildings. In northern Europe, the sun doesn't shine all year and production exceeds consumption for just 25% of the year – the rest of time, electricity is generated from batteries or purchased energy.

Real case

In Tampere's new Ilokkaanpuisto residential area, residents own part of a solar power plant located 25 km away in the countryside. The buildings can achieve net zero annually by producing electricity in their own solar power plant. Electricity generated during the light period (summertime) is not directly transmitted to buildings but sold to the local energy company. Its electricity network then acts as a virtual battery for housing companies and residents.

Our advice

It can be time-consuming to adapt a new energy concept for a block of flats to the legislation related to buildings, electricity markets and tax. Upscaling this kind of net-zero concept much depends on the power grid's ability to serve as a virtual battery. Geothermal heating in buildings reduces energy consumption more than district heating does.

Smart district cooling with lake water

The use of waste heat and lake cooling reduces emissions. For the operation and energy consumption of the district cooling network, it is important that the water is sufficiently heating during circulation.

Real case

In a Tampere district, the district cooling network started in 2016. It gets cooling energy from a lake – Näsi. The system underperformed. Data analysis identified the cause and the solution. The return temperature water was too low and prevented the use of free cooling during the warmest summer period. For the district cooling network to work properly, customer equipment had to be improved.

Our advice

To reach correct operation, customers' equipment must work well to ensure the efficiency of the entire district cooling system. The district cooling supplier should, at least, guide customers how to dimension and use the equipment correctly and offer solutions to problems.

Use of waste heat as an energy source in district heating

Cities must actively look for ways to increase the share of renewable and emission-free energy sources in district heating. The use of renewable energy sources in district heating makes it low-emission. One option for reducing fossil emissions from district heating is to use waste heat. Data centres are constantly consuming more and more energy for cooling. The result of cooling is heat that could be used by heating systems.

Real case

A data centre needs plenty of cooling energy, which generates waste heat. Industrial heat pumps are installed on the premises to sufficiently raise the waste heat temperature. The waste heat is directed to Tampere's district heating network through a new pipeline.

Our advice

The waste heat purchased from customers is typically low-heat and requires several heat pumps connected in series to be accepted into the district heating network. Despite several pumps, the temperature can rarely be raised enough.
As district heat production moves away from combustible energy sources, the dimensioning temperature of district heating will go down to about 65-70 degrees and will enable the profitable use of waste heat from more sources.

Towards last mile solutions step by step

Trams are the backbone of public transport in several cities. Buses feed passengers to interchange stops. However, conventional bus routes do not cover the city completely, and last mile walking or cycling is not an option for all passengers.

Real case

In Tampere, robot buses for last-mile cover have been studied during different tests. Now, the city has regular scheduled services with the next text in 2025 with remote operation. Drivers for robot buses have been trained by the city's educational institutions.

Our advice

A robot bus moving at a walking or running pace can cause danger and irritation, but it is a good way for disabled persons to reach local services. Technology is not a barrier, legislation is. If remote operation can be made to work, it will also be commercially viable.

Trento

Building retrofit and low temperature district heating in Madonna Bianca

The regeneration of the Madonna Bianca social housing district aimed to combine innovative retrofit solutions on 3 out of 14 high-rise residential buildings ("the Towers") with the development of a low temperature district heating (DH) prototype and an innovative approach on the building envelope (active and passive systems). The retrofit of the 3 Towers was based on the concept of a modular Plug & Play façade system with BIPV to be installed on the southern, eastern, and western façades and on the so-called "technological hat" placed on the rooftop, to extend the BIPV surface. The DH was designed to replace centralised gas boilers, providing thermal energy by means of ground source heat pumps and borehole heat exchangers to allow a high share of local BIPV utilization for heating.

Real case

Onsite activities focused exclusively on preliminary analysis and design. STARDUST retrofit actions and low temperature DH did not take place due to unforeseen changes in the regulatory framework, leading to different technical and financial solutions (application on 2 out of 3 buildings of the national financial scheme "Superbonus 110%"). Nonetheless, the following actions were carried out on the 3 Towers:

1. Preliminary energy performance analysis
2. Design competition to identify the most appropriate retrofit approach, considering the building architectural features and the peculiarities of the district
3. Retrofit design process (i.e., BIPV optimisation, Plug & Play façade module)
4. Pre-monitoring in 23 dwellings and design of the post-refurbishment monitoring system

Our advice

The Madonna Bianca case study demonstrates that:

- Architectural integration of the Plug & Play concept is feasible
- Technology solutions are there, but legislative and economic framework conditions can be a barrier
- Social understanding, decision making, and trust are key elements to success
- Unforeseen conditions may occur, so flexibility and responsivennes are necessary

Neighbourhood Energy Management System

The activity aimed to map and quantify the available waste heat in the Madonna Bianca district and consequently to perform a technical and economic feasibility study of the exploitation of recovered heat for thermal energy supply in the low-temperature district heating (DH) prototype.

Real case

About 40 industry/tertiary activities nearby Madonna Bianca Towers were mapped. The potential waste thermal energy to be recovered within 1.5 km radius around the Towers amounts to almost 10 GWh per year. More than half of this value could be derived from a food sector company. A technical feasibility study and a preliminary economic analysis have been performed for two scenarios defined according to the distance between the waste energy source and the Towers.

Our advice

- Waste heat can be a relevant driver in local urban energy transition strategies, even to establish Positive Energy Districts
- Waste heat sources should be collaboratively shared: building owners should be interested to purchase heat from the network and the municipality needs to facilitate administrative procedures
- The governance and management of such an innovative infrastructure is not straightforward, being more challenging than technical feasibility

Last mile logistics for clean and sustainable deliveries

Trento Limited Traffic Zone (LTZ) allows vehicle access to the city centre only during some specific time slots. The idea was to create a sustainable last mile delivery service to have LTZ full access and to reduce CO2 emissions by using an e-van fleet.

Real case

The so-called TRENto YOU delivery service ran as a test between 2021-2023 and was based on 2 e-vans. The service design targeted several commercial activities located in LTZ, including a survey to investigate their delivery needs and trends. The service had competitive fares but was closed after 2 years due to few numbers of deliveries and some economic sustainability constraints. An analysis to modify Trento LTZ regulation is ongoing.

Our advice

- Negotiating the procurement of a public-based logistic service is challenging: opting for a private delivery company may attract opposition from other market players
- The success of such a public service is realistic if private express couriers are consistently restricted from entering the LTZ
- The logistic sector is transitioning to clean e-vehicles as companies gain confidence in the technology and integrate a "green" approach as a distinctive characteristic against competitors
- Managing logistics requires upfront investment and specialised skills not readily available only from public resources

Enhancing sustainable mobility through e-vehicles

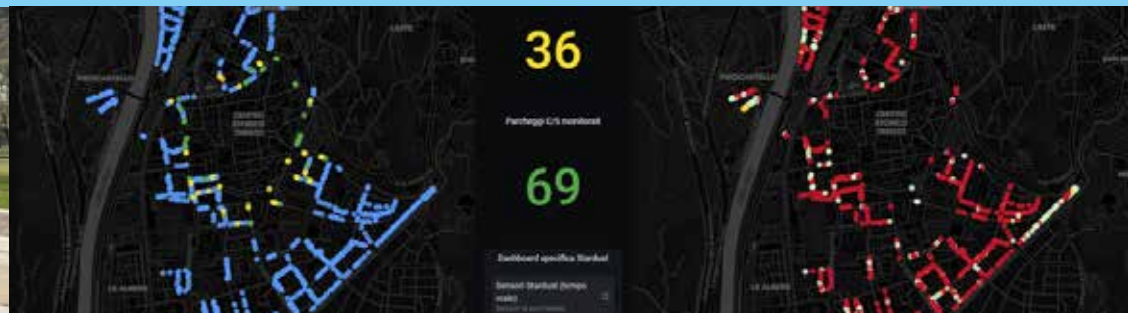
This action aimed to replace some polluting cars from the municipal car fleet with 10 brand new e-cars to be used by the city staff for working fares. Additionally, a public e-scooter service has been put in place to enhance the urban sustainable mobility of multiple users.

Real case

The 10 e-car fleet started operating gradually in 2021. In parallel, the Municipality tendered an e-scooter sharing system based on 500 e-scooters fully available to local users.
A digital monitoring system was deployed at the city level to collect, analyse and evaluate data from both vehicle typology (i.e., n° of e-scooters booked, distance travelled, e-car consumptions). E-scooter data has allowed for some improvements: dedicated parking lots were created to minimise interference with other users. E-car data can be sued to monitor their actual use and to compare consumptions against fuel-based vehicles: for instance, 5,317 CO^2 kg were saved between October 2021 and July 2023.

Our advice

- E-scooters are appealing yet challenging to organise. Through data gathering and analysis, it is possible to help improve service standards and social acceptance
- Training courses and guidance offered to city officers are crucial to increase social acceptance and encourage an appropriate and effective use of e-cars



Smart sensors deployment in Trento

A smart lighting system and a parking occupation monitoring system were deployed in Trento as new innovative urban services. To make them full operational, a common technical approach was followed:

- **Infrastructural works in target areas of the city for data acquisition**
- **Creation of a LoRaWAN network for data transmission**
- **Data collection and management**
- **Creation of specific dashboards tailored for citizens and stakeholders**
- **Availability of the developed services via websites, apps, smart points throughout the city**

Real case

Smart lighting sensors were installed on a total of 156 light posts located in a public garden and across 2 cycling paths. When the sensors don't detect the presence of people, the illumination decreases by 75%, thus saving up to 50% energy. 105 parking sensors were installed on both load/unload parking bays and for disabled people nearby Trento LTZ. Given their high reliability, additional 1,200 sensors have been purchased and installed by the city in some paid parking areas.

Our advice

- Need for cross-departmental coordination and cooperation: a data driven city will break silos among departments to foster advanced data analysis, and to allow better technical solutions
- In the planning stages and design phases, regulatory challenges, such as light pollution regulations near highways, should be addressed to prevent delays and ensure legal compliance
- Smart lighting needs further investigation related to daytime energy savings monitored

Evolution of the citizens app “La mia Trento”

This action aimed to add new features to Trento official mobile app, thus unlocking its innovation potential. There were two purposes. The first was to be able to have the app extended by any third-party developer including individuals, companies, and the municipality itself. The second was to improve user experience and customisation of the information and services displayed in the app.

Real case

The app has been modified to enable the seamless integration of external modules, ensuring flexibility, scalability, and effectiveness.
An authentication functionality has been added: the app modules can now take advantage of a common authentication mechanism to identify the user and provide him/her with customised services, including some of them otherwise unavailable, such as public room bookings, electoral and registry office certificates, payments, and more.

Our advice

- Data quality is crucial. It is better to analyse a subset initially and check its quality, then expand the assessment to more data to have a full understanding (in terms of quantity, distribution over time, etc.)
- It is good to prioritise API integration for streamlined data ingestion to mitigate manual errors and enhance automation
- The inclusion of API/REST access policies in public contracts should be emphasised in order to facilitate automatic data retrieval
- Focus groups are key to select the topics/services to include in the app

Sustainable Behaviour Change Gaming Tool

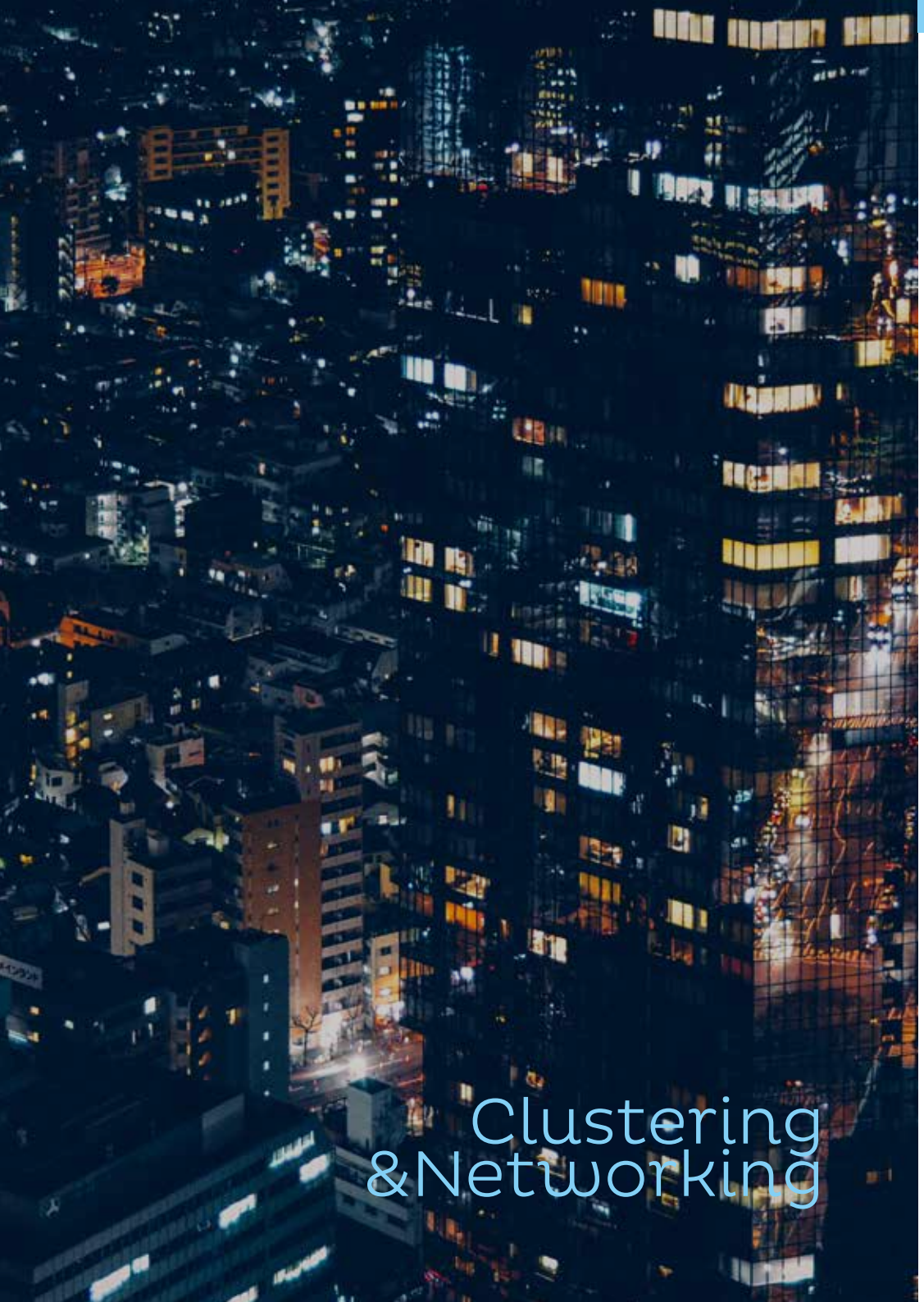
The activity was designed and implemented as part of Trento citizen engagement and awareness raising actions around STARDUST thematic tracks, particularly regarding energy consumption in buildings.

Real case

Taking place in autumn 2023, the activity consisted of a gamified tool for sustainable energy behaviour, to inform young people about energy consumption topics and to promote sustainable energy behaviour change. The initiative targeted a total of 200 students aged 14-16 from a secondary school in Trento. They were involved in a gamified energy measuring challenge at school, supported by a web-tool where students can put their estimated values and learn more about consumption factors and optimisation.

Our advice

- The potential for adapting gamification and webtools to other energy education programmes should be explored: i.e. focusing on energy consumption fluctuations across different seasons
- The functionality of the web tool should be extended to incorporate scientific insights regarding thermal comfort and energy usage for heating/cooling, tailored to diverse climates across Europe
- Similar gamified challenges in residential buildings could be applied, thus expanding the scope of such measures.



Clustering And Networking Activities

Clustering activities and networking cooperation between different actors is crucial for integrating different perspectives and expertise, which is essential for tackling the complexity of smart city projects. Collaborative networks allow researchers to share knowledge and resources, exchange ideas and develop new methodologies, leading to more comprehensive and innovative solutions.
In addition, such networks can act as platforms for capacity building, empowering local communities and professionals through education and engagement in sustainability projects, thereby facilitating the uptake and replication of measures implemented in cities.

Real case

The Finnish Smart Cities have established a stable cooperation network to share information and exchange experiences. The network includes the cities of Tampere, Helsinki, Kerava, Oulu, Vaasa, Turku, Vantaa and Espoo.

As a result of this cooperation, the projects have jointly organized:

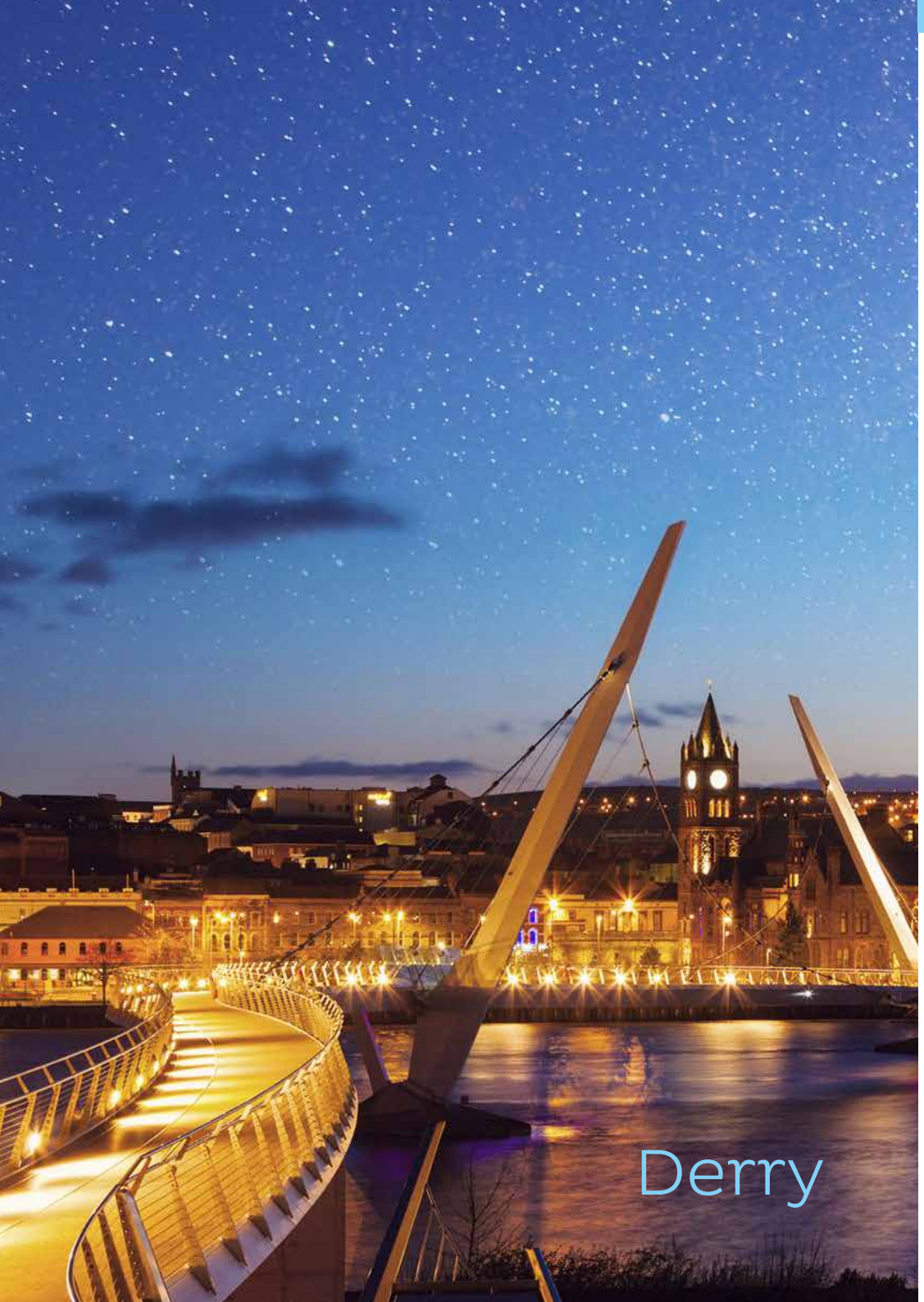
- A replication event in Tampere in January 2020
- The Finnish Local Government Association's climate conference in 2021
- An event on mobility hubs and the future of mobility in April 2022.

Our advice

Facilitate and stimulate the creation of local innovation ecosystems, organised in technology clusters and thematic working groups, to bring together people working in the same fields in different cities, to find out how they are tackling common challenges elsewhere and to learn from each other's experiences. Always involve citizens and as many stakeholders as possible to ensure that no perspective is missing.

CHAPTER 3

Replicability



District Heating – getting an initial network started

Derry has been carrying out a feasibility study into the potential for district heating for the City of Derry, inspired by Pamplona's new biomass district heating system. Heat networks currently only provide around 2-3% of total UK heat demand, and it has been stated that the biggest challenge in developing district heating in a city is getting an initial network started. Both the UK and Republic of Ireland governments now recognise the potential of district heating in terms of decarbonising heating at scale.

Real case

Waste/surplus heat options within the City of Derry were explored, with one potential source identified at the city's biomass power plant located near the Port of Derry. It generates significant surplus heat, which is currently not being exploited. However, the temperature of the surplus heat has proven too low to make the project commercially viable, due to the distance from the energy centre to the proposed anchor customer. New locations for the Energy Centre are now being considered, including in closer proximity to the anchor customer, with all energy sources being explored including geothermal, given N Ireland's untapped geothermal potential and favourable geology.

Our advice

- Time should be taken to identify all potential 'surplus' heat sources, at the outset – to ensure valuable sources aren't overlooked
- All potential business models should be considered in detail, to identify the most viable options available to any local authority/organisation – with consideration of the funding options available, to ascertain how much commercial investment is essential.

Business models for developing EV infrastructure

There are many business models open to local authorities to develop their EV infrastructure, with many private chargepoint operators in the UK keen to invest 100% in such infrastructure. This is due to the potentially attractive long-term commercial return.

Real case

Derry has been approached by a number of private companies interested in investing in EV infrastructure. However, the model used in Pamplona, which was adopted for the PV solar-covered car park, is of interest to Derry. Currently Derry does not sell any electricity to the community from ownership of its solar panels, however the council is now considering this model – which would involve significant investment in solar at the outset from the council, but with long term financial returns. EV chargepoints could be funded by public sector EV infrastructure funds.

Our advice

Consider all business models – ranging from fully private models to fully public, with consideration of the potential risks to the council/ organisation.

Implementation of Smart Metering systems – lessons

Smart metering and energy management systems are highly recommended to manage energy more effectively and improve decision-making, however it is not always cost-effective to invest in them for every building.

Real case

Smart building energy management systems and smart meters have been installed in some of Derry's key buildings, but we have learned that it is better to prioritise the 'high energy consumption' buildings when investing in smart metering – to maximise the use of limited building decarbonisation funds. These systems can be costly, so we have learned that it is a better use of funds to prioritise the buildings that consume large amounts of energy – when weighing up where smart metering is needed most. The money saved on smart metering for the lower consumption buildings is better used on energy decarbonisation and retrofitting.

Our advice

It is better to prioritise the high energy consumption buildings when investing in smart metering/ Energy Management Systems.

Smart LED Lighting

LED lighting is the recommended solution when upgrading lighting but challenges can crop up with the software that's required to manage it.

Real case

Derry has installed a number of smart LED lighting schemes. However, the software needed to manage and monitor the lighting can be complex for an untrained council employee. Derry has learned that comprehensive training needs to be delivered to relevant staff on the lighting solution that has been implemented.

Our advice

Both the financial and human resources required for 'software training' needs to be factored in when planning and installing an LED lighting scheme.

Public Procurement & Contracting - EV infrastructure

Harnessing the private sector and exploring joint ventures is a must to meet net zero targets. However, finalising procurement and contract documents is a real challenge in developing EV and energy decarbonisation projects.

Real case

Derry is currently finalising a tender and concession contract for EV infrastructure, and agreeing the evaluation questions particularly for 'price' has been difficult – given that the long-term sustainability of the company's business model is what is most critical, and not the price of the EV chargepoints, particularly when the contract may last 20 years or longer. Derry wants to maximise the number of chargepoints with the investment that's available, but also important is the electricity charging 'tariff' that the tenderers will be proposing, as this cost will affect the consumer.

Our advice

- Tenderers should be asked to propose a 'margin cap' or ceiling price for the electricity/ EV charging, and to build in periodic reviews so that there is joint agreement on tariffs
- If the companies go above the margin cap, the overcharge is due back to the council
- A percentage 'Revenue' Share should be sought as opposed to a Profit Share – once EV chargepoint utilisation reaches a sufficient threshold
- A set annual fee, in combination with the % Revenue Share should be sought

High efficiency eco school buildings

The 11th Nursery School is located in the city of Kozani and belongs to the municipality. The 179.5 m² two-story building is solely used as a school. It was built in 1983 according to standards in force at the time. This means it is insulated according to the 1979 Law on the Insulation of Buildings.

Real case

A thermal system on the external wall is deemed best for results and profits. Double-glazing (24mm) will replace old wooden window frames. In addition, the heating and cooling system will be upgraded as will the lighting. The energy category is expected to rise from G to B following the works.

Our advice

Installation of external thermal insulation on the walls and roof is crucial improving energy efficiency and thermal comfort.
Enhancing the heating and cooling system with upgrades such as thermostatic valves and energy-efficient components can further improve energy efficiency and comfort levels.
A monitoring and evaluation framework should be set up to assess the impact of the energy upgrade works on energy consumption, indoor comfort, and cost savings.

High efficiency eco-swimming pool building

The swimming pool building is made of polyurethane panels. It has aluminium windows and panel doors. Thermal insulation is good. The pool has one floor and a roof area of 967m². It has a small basement used as a boiler room. The heating system is an oil boiler with a 350 kW power, no cooling system, and 11.34 kW installed power from the public grid. The pool is open year-round, except for maintenance periods, with an estimated 200 swimmers daily.

Real case

To save energy and improve thermal comfort, 200m2 of collectors for hot water and pool heating are planned. A flexible building management system will be set up which can be controlled via a web browser, a allowing for over 20% energy savings and increased usability. LED lights will replace existing luminaires, resulting in a 42.5% reduction in installed capacity. After the works, the energy category is expected to reach C.

Our advice

Monitoring energy consumption and system performance is crucial for identifying areas of improvement and ensuring optimal operation.
A building management system should be used to track energy usage, analyse data, and identify opportunities for further energy efficiency enhancements.
Regular maintenance checks should be carried out on energy systems to ensure they perform well.

Mathematical simulation model of Kozani's district heating

A mathematical model for the operation of Kozani's district heating substations (DHS) has been developed and trialled, leading to the development of a smart pilot application (pay per go) for the apartments/ houses and the consumers. Kozani's district heating company – DEYAK – will apply the results of the study as a 3rd party of the Municipality.

Real case

The project seeks to optimise the district heating network by developing a remote control and monitoring system based on a mathematical programming model. This will allow for smart control strategies such as peak shaving and load shifting techniques. The remote control and monitoring system will help predict thermal request profiles at a building level and optimise substation operation.

Our advice

It is necessary to work closely with stakeholders, including DEYAK, the Municipality, and potential end-users, throughout the project lifecycle.
Real-time monitoring and feedback mechanisms should be incorporated to enable timely adjustments and decision-making.
Predictive and optimisation algorithms can be used to anticipate heating demand fluctuations and adjust system parameters in real-time.

Renewable district heating system in the municipality of Amyntaio

The project envisages the construction of two thermal power plants with biomass of a total installed capacity of 30 MWth (2x15MW). Existing buildings of villages of Amyntaio, Levaia, Filotas. 1,850 connected buildings and 2,500 dwellings.

Real case

The core of the investment programme for the DH system of Amyntaio was the installation of a new biomass combustion plant to serve Amyntaio's existing district heating system as well as its future extensions. The thermal energy production unit, the implementation of which has been launched, uses biomass with a small amount of lignite. It has a total capacity of 30 MW (2x15MW).

Our advice

Suitable sites for the construction of the biomass power plants should be based on factors such as proximity to biomass sources, existing infrastructure, environmental considerations, and community acceptance. Local communities and stakeholders should be involved in order to foster transparency, trust, and support for the biomass power plant projects.
Comprehensive operation and maintenance plans should be drawn up to ensure the reliable and efficient operation of the biomass power plants over their lifecycle.

Autonomous Vehicle Charging Stations using photovoltaics

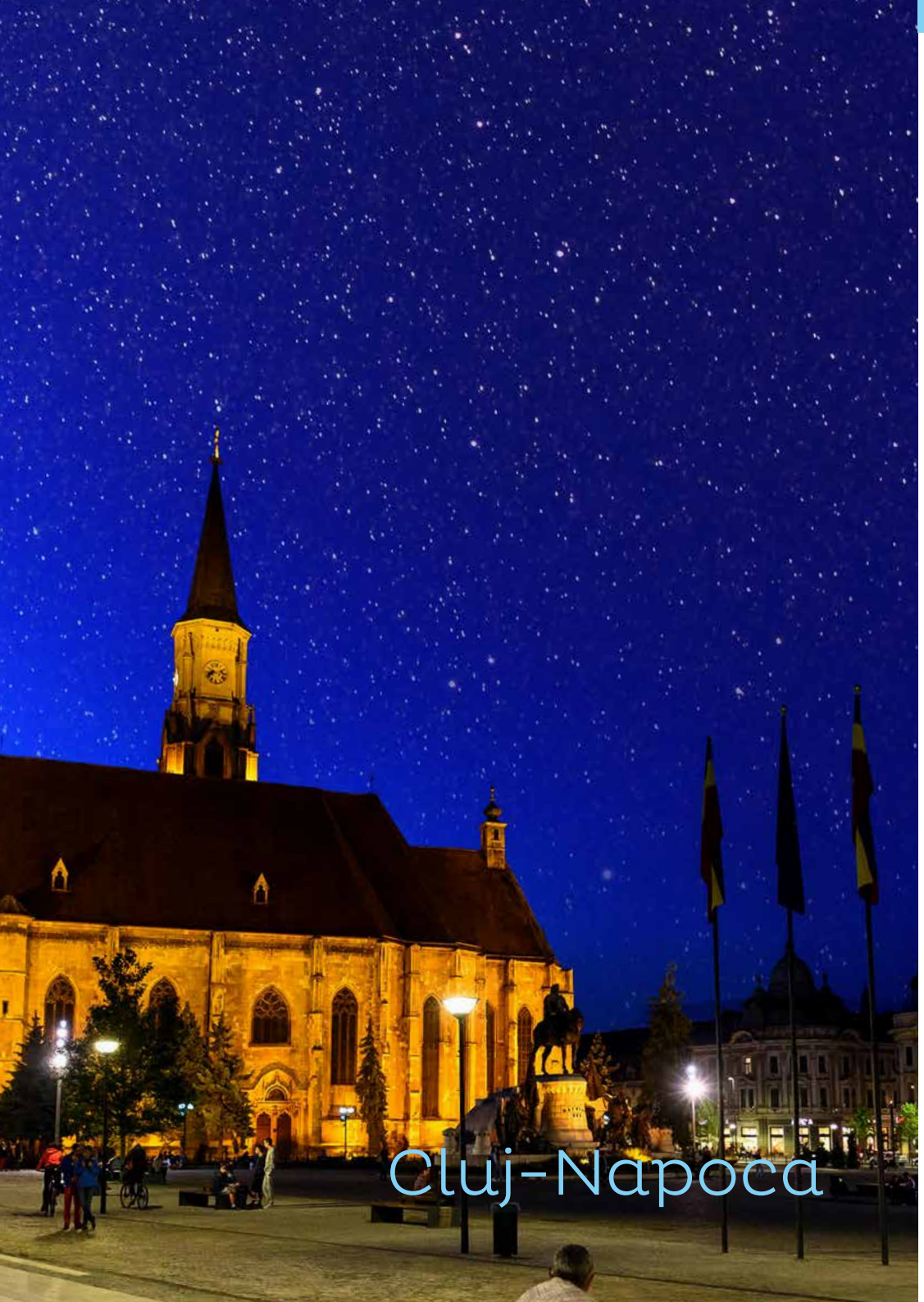
The Kozani e-mobility project has been extended to include 2 new autonomous charging stations using photovoltaics.

Real case

For municipal electric vehicles, three conventional charging stations (coupled with PV system – 8 kW) and one autonomous charging station (7 kW) have been set up. Two charging stations have been introduced for citizens' use (22 kW) and there are plans for 52 more charging stations.

Our advice

Any new autonomous charging stations should be accessible, convenient and visible for users of e-vehicles.
User experience and accessibility should be a priority when designing and operating charging stations as this will encourage widespread adoption of e-vehicles.
To raise awareness about the benefits of e-mobility and charging infrastructure, the local community and stakeholders should be involved in the whole process.



Rollout of EV Infrastructure in Cluj-Napoca

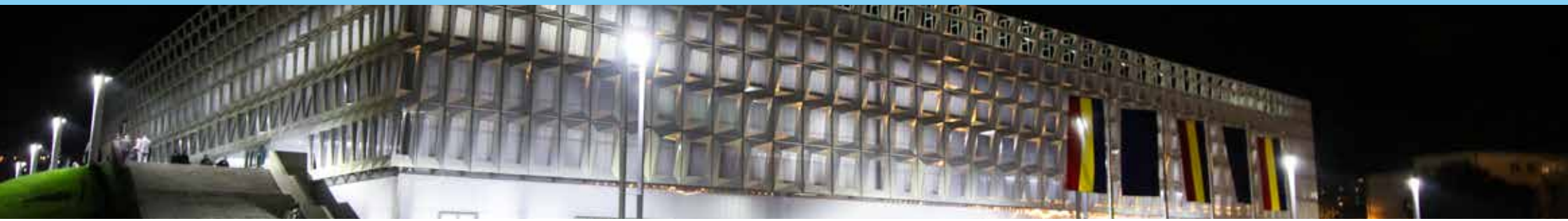
In Romania, dependence on automobiles is still high with an average of 400 cars per 1000 inhabitants. To reach carbon neutrality, the country has taken sets of measures and passed laws to shift from the use fossil fuels for transport to cleaner ones. One of these measures is the rollout of charging stations for the electric vehicles.

Real case

In the Cluj-Napoca area there are now about 41 EV charging stations However, the network needs to be expanded, especially in collective housing districts, at the exits of the city, etc. For the City Council, the challenge is linked to the capacity of the electricity grid to cope with demand and to finding the best places to install the charging stations.

Our advice

Investment synergies should be created for the strategic expansive of parking areas in for collective housing.
Relevant actors of urban amenities such as commercial areas, public institutions, office buildings should be involved, and negotiations established with them.
Existing parking areas should be leveraged to build charging stations short- to medium-term use.



Energy efficiency of public buildings

Cluj-Napoca has enacted national laws locally with restrictions and green incentives. Challenges have been encountered: the availability and capacity of private contractors to deliver in time and at the agreed quality level, high inflation, poor availability of labour; extended deadlines to deliver the new technologies that are in high demand.

Real case

A case study involved a new high-school building with 33 classrooms, 9 laboratories, a modernised gym equipped with an automatic consumption management system (BEMS). Solar panels, air conditioning and LED lighting have been installed. It is the first school in Romania to be certified by BREEAM.

Our advice

For new technical solutions, enough time should be planned for their purchase and implementation.
A person should be trained on BEMS and on the new technologies so that they can provide datasets and receive end-user feedback.

Implementation of non-polluting public transportation

**Studies say that private cars are big emitters of greenhouse gases in the transport sector – and car dependence is high in Romania.
Therefore, cities in Romania seek to encourage greater use of public transport and to limit private car use.**

Real case

Since 2017, the City of Cluj-Napoca has been changing its fleet of buses to a non-polluting one. So far, 52% of transport within the city is electric (tram, trolleybus or electric bus). The aim is to reach 100% by 2026. Challenges remain: public transport is still under-used and traffic jams continue at rush hour.

Our advice

Before purchasing a non-polluting means of public transport, a city council should conduct a feasibility study to ensure it meets local needs and specificities. In addition, digital monitoring should be set up (as was the case in the lighthouse city of Tampere) to adapt the transport system over time.

Bike/scooter sharing system

Cities are today promoting bike and scooter sharing systems to relieve public transport in rush hours and to foster greener ways of getting about. They set up cycle paths for this, which must connect all districts with the city centre, and also with points of interest with the city.

Real case

Cluj-Napoca launched a bike/scooter scheme in 2015 and an app exists for it. The council is always seeking to extend cycle paths with the necessary connections across the city. A private sharing scheme has also been set up (Bold, Lime, GoGreen) with the council establishing the rules for its operation and use.

Our advice

Trendy mobility solutions may be fine if they are adapted to local needs. A permanent dialogue with users should be organised so that the schemes can be improved over time.

Car sharing systems

Cities can achieve their carbon neutrality and sustainability goals better, in terms of mobility and emissions, if they focus on well-developed car-sharing services (through their own resources or through private partnerships). The transition to EVs for private vehicles takes longer and is not a reliable or efficient policy in itself.

Real case

A formal private car sharing system (Pony) existed in Cluj-Napoca but due to lack of economic efficiency the service has been closed. According to our questionnaire, citizens do not like this kind of service, which is too similar to car rental and involves too much bureaucracy and responsibility. For car sharing they prefer a system similar to the electric scooter sharing system (by using an app you take the car, use it and park it in a parking place).

Our advice

Any new service must be adapted to local needs and reality; it should be affordable, straightforward, and safe. It should also be promoted as climate-friendly. New ways of encouraging citizens to be environmentally friendly have to be found. The climate neutrality goal depends on this.

CHAPTER 4

Innovative Smart Business Models

Lesson learned

on public procurement process;
private owners //private-public collaboration

This chapter contains some lessons from the design and implementation of business models, and alternative financial and investment solutions in the STARDUST project in the three Lighthouse Cities Pamplona, Tampere, and Trento.

Some business models and financial solutions are innovative; others are not, but in all cases, experience teaches us how these could be replicated and adapted in other socio-economic environments.

During the project, we conducted financial and economic analysis. We also devised and applied business models, investment models, and risk-sharing models. This was to demonstrate how leading municipalities and other stakeholders can effectively find financial solutions to implement the business.

Financial solutions and alternative business models have been refined and customized to local conditions, in some cases providing advice and policy recommendations on financial schemes to be implemented in the next future scenario.

The business models and financial solutions have been developed and applied to RES installation and EE measures like PVs, e-vehicles mobility, buildings, and huge infrastructures.

For each energy asset intervention, concrete financial outputs and results are shown and commented, and they are synthesised by the application of KPIs such as the Simple and Discounted Payback Periods (SPP), Return on investment (ROI), Net Present Value (NPV). These results are available and give guidance on how to optimize similar and replicable business scenarios.

The end of this chapter contains a list of the 10 most important financial schemes for innovation support in cities.

Empowering Smart Citizens and Stakeholders

To empower and support local authorities, residents, SMEs, and industry, it is crucial to set up a smart innovation ecosystem. This will increase a city's competitiveness, promote the use of sustainable resources, and change people's behaviors and attitudes. This initiative involves living labs as a way to analyze and predict how smart city technologies may achieve these aims against a backdrop of urban dynamics.

Real case

The creation of the Smart Innovation Ecosystem is grounded in the Quadruple Helix approach, which connects government, industry, academia, and civil society representatives. Through the establishment of three Living Labs, one in each Lighthouse City the goal was to cultivate stakeholder engagement and citizen empowerment through activities such as gamification, initiatives, and hackathons.

Our advice

Existing ecosystems should be used by leveraging the capacities of the cities and actors involved.
Stakeholders from various sectors – government, industry, academia, and citizens – should be involved and work together.

Exploitation strategies and business plans for the project results

This practice is about making the project outcomes go further. It involves identifying opportunities, assessing the market, and evaluating intellectual property rights to draft robust exploitation plans.

Real case

Project partners recognise that innovative business models, IT and smart city technology aren't fully understood or appreciated. Currently, the market is dominated by large industrial players. However, SMEs hold significant potential for driving the adoption of innovative solutions and smart technologies.

Our advice

Exploitable results should be prioritized according to their feasibility, the market assessment, and potential impact. To protect innovations and optimize commercialisation strategies, a project should evaluate intellectual property rights.
It is a good idea to work with small and medium enterprises (SMEs) as they can provide expertise and agility in implementing and scaling up solutions in the market

Analysis and Validation of Business Models and KPIs for Lighthouse Cities Interventions

This practice develops, analyses and validates innovative business models and financial schemes while monitoring key performance indicators for interventions in lighthouse cities.

Real case

The project developed financing schemes and explored alternative scenarios for interventions to identify the most applicable and profitable solutions. This entailed navigating challenges in collecting economic and financial data, particularly when private partners were involved. The aim was to consider long-term prospects and changes in the regulatory framework within the cost opportunity analysis. Additionally, the project encouraged the public and private sectors to interact, and in doing so it incorporated social and environmental indicators alongside economic factors.

Our advice

It's crucial to consider long-term perspectives and adapt to changes in regulatory frameworks within the cost opportunity analysis. Furthermore, promoting collaboration between the public and private sectors should prioritize incorporating social and environmental indicators alongside economic factors to ensure holistic and sustainable interventions.

Top 10 Financial Schemes

applicable in the smart city context

• Public-Private Partnerships (PPPs)

Collaborative agreements between government entities and private sector organizations to finance, develop, and operate urban infrastructure projects.

• Green Bonds

Fixed-income financial instruments used to raise capital for projects with environmental benefits, such as renewable energy installations or sustainable transportation systems.

• Energy Performance Contracting (EPC)

Contracts where an energy service company (ESCO) finances, implements, and guarantees energy efficiency improvements in buildings or infrastructure, with payment based on the energy savings achieved.

• Tax incentives and subsidies

Government-provided financial benefits, such as tax breaks or grants, offered to incentivize investment in sustainable urban projects or technologies.

• Crowdfunding platforms

Online platforms that allow individuals or organizations to raise funds from a large number of investors or donors for specific urban initiatives, ranging from community gardens to renewable energy projects.

• Revolving loan funds

Financing mechanisms where funds are initially provided for urban sustainability projects and then repaid over time, with the repaid funds being reinvested in new projects.

• Municipal bonds

Debt securities issued by local governments to finance infrastructure development projects, such as public transportation systems or water management facilities.

• Carbon pricing mechanisms

Policies that impose a price on carbon emissions, such as carbon taxes or cap-and-trade systems, to incentivize emission reductions and fund low-carbon initiatives in cities.

• Impact investing funds

Investment funds that target projects or businesses with the intention of generating positive social and environmental impacts alongside financial returns, including those focused on urban sustainability.

• Value Capture Financing (VCF)

Mechanisms that capture a portion of the increase in property values resulting from public investments in infrastructure or amenities, such as transit-oriented development or urban regeneration projects, to fund further urban development.

Conclusions

After 6 years of the STARDUST project, our cities have been able to implement innovative and technological solutions with the support of partners with multidisciplinary profiles. The overall objective was to improve environmental, economic, technical, and social aspects, creating the necessary evidence for replication in other cities.

However, the road traveled has not been linear, nor has it been a “bed of roses”. But the journey has offered many lessons for the field of Smart Cities and there have been successes along the way.
The solutions deployed in the Lighthouse cities have generated impacts that have been measured and evaluated, demonstrating their effectiveness in addressing the challenges related to the carbon neutrality of Europe.

Finally, at the end of this long journey, it is important to thank those who have accompanied the consortium of partners up to here. Without the trust of others and strong teamwork, nothing would have been possible.

Annexes

REPORTS

STARDUST partners have released a set of confidential and public documents accounting for the activities carried out and the results produced during the project. Below is the list of public deliverables updated to March 2024.

D1.1: Report on Smart cities' key performance indicators (KPI) for the STARDUST cities, with common metrics and terminology
Authors: Terttu Vainio (VTT); Aapo Huovila (VTT); Jose Costero (City of Pamplona); Maarit Vehviläin (City of Tampere); Giacomo Fioroni (Trento); Sergio Diaz Garayo Baltasegui (CENER); Pertti Peussa (VTT); Daniele Vettorato (Eurac Research); Marco Pistore and Gabriele Zacco (Fondazione Bruno Kessler); Michael Heidenreich (Greenovate! Europe).

D1.2: Smart City level in lighthouse and follower cities
Authors: Terttu Vainio (VTT); Kaj Mäntylä (VTT); Sergio Diaz de Garayo(CENER); Gabriele Zacco (Fondazione Bruno Kessler); Alyona Zubaryeva and Adriano Bisello (Eurac Research).

D1.3 Report on availability of local RES and potential use in lighthouse and follower cities
Authors: Jennifer Adami, Silvia Croce and Marco Lovati (Eurac Research)

D1.4: Portafolio of Smart City Solutions
Authors: Sergio Díaz de Garayo (CENER), Marta Sampedro (CENER), Pertti Pausa (VTT), Lumihaco Aki (VTT), Gabriele Zacco (Fondazione Bruno Kessler)

D1.5: Smart City Indicators, for a Technology Assessment Matrix (TAM) development
Authors: Pablo E. Branchi, Ambrosio Liceaga , and Ignacio R. Matías (Public University of Navarra)

D1.6: Technical specifications for BEMS and HEMS
Authors: Annalisa Andaloro, Daniele Antonucci; Ilaria Vigna, and Roberto Lollini (Eurac Research) - with the contribution of CENER; Fondazione Bruno Kessler; VTT.

D1.7: Report on requirements and architecture for the open city platform (revision 1)
Authors: Enrique Gómez (SIC); Carita Isomäki,and Maarit Vehviläinen (City of Trento); Raman Kazamiakhin and Gabriele Zacco (Fondazione Bruno Kessler); Luis Tarrafeta (City of Pamplona); Alex Tomasi (City of Trento)

D2.1: Pamplona Pilot detailed plan
Authors: Jose Costero, Leire Iriarte and Monika Carcar (City of Pamplona), Florencio Manteca, Sergio Díaz de Garayo and Faisal Bouchotrouch (CENER), Laura Larraya, Enrique Gómez (SIC) and Javier Martínez (NASUVINSA).

D3.1: Tampere Pilot detailed plan
Authors: Terttu Vainio (VTT); Maarit Vehviläinen and Anna Vilhula (City of Tampere)

D4.1; Trento Pilot detailed plan
Authors: Alex Tomasi and Giacomo Fioroni (City of Trento); Alyona Zubaryeva and Sonia Gantioler (Eurac Research); Gabriele Zacco (Fondazione Bruno Kessler); Michele Fioretta (ITEA); Francesco Linder (Dolomiti Energia Holding); Marco Cattani and Micol Mattedi (Habitech); Angelo Giordano (Officinae Verdi)

D5.1; Establishment of the Deployment Desk
Authors: Michael Heidenreich, Guillaume Corradino, and Bénédicte Julliard (Greenovate! Europe)

D.5.2: Report on stakeholder and citizen engagement activities (stakeholder mapping)
Authors: Nikolaos Ntavos; Yannis Fallas; Aikaterini Tsepoura; Guillaume Corradino; Bénédicte Julliard (Greenovate! Europe).

D5.3: Report on capacity building and knowledge exchange activities
Authors: Guillaume Corradino and Michael Heidenreich (Greenovate! Europe).

D6.1: Definition of impact assessment indicators and assessment methodology
Authors: Paula Ala-Kotila and Terttu Vainio(VTT); Gabriele Zacco (Fondazione Bruno Kessler); Victoria Lara (CENER).

D6.2: Specification for STARDUST monitoring protocol and Data Management Plan
Authors: Luis Tarrafeta (City of Pamplona), Alex Tomasi (City of Pamplona), Maarit Vehviläinen (City of Trento), Terttu Vainio (VTT), Gabriele Zacco (Fondazione Bruno Kessler).

D6.3: Implementation of the STARDUST monitoring protocol and Data Management Plan
Authors: Gabriele Zacco and Diego Viesi (Fondazione Bruno Kessler), Paula Ala-Kotila, Kalevi Piira and Terttu Vainio (VTT), Daniele Antonucci, Aaron Estrada, Daniele Vettorato, Pietro Zambelli, Martino Gubert and Alyona Zubaryeva (Eurac Research), Victoria Lara and Sergio Diaz de Garayo (CENER), Enrique Gomez Gonzalez (SIC), Janne Laurila and Maarit Vehviläinen (City of Tampere), Alex Tomasi (City of Trento).

D6.4: Collaboration plans and protocols for data exchange with the SCIS
Authors: Terttu Vainio (VTT), Sergio Diaz and Victoria Lara (CENER), Alyona Zubaryeva (Eurac Research), Michael Heidenreich (Greenovate! Europe), Valentina Luzzatto (Officinae Verdi).

D6.5: Baseline on Impact assessment of Lighthouse cities
Authors: Victoria Lara and Sergio Díaz de Garayo (CENER); Paula Ala-Kotila and Terttu Vainio(VTT); Gabriele Zacco (Fondazione Bruno Kessler); Alyona Zubaryeva (Eurac Research); Luis Tarrafeta and Mónica Carcar (City of Pamplona).

D7.2- Smart City Innovation Ecosystem and Business Modelling
Authors: Sonja Gantioler and Silvia Tomasi (Eurac Research), Leyre Iriarte Oyaga (City of Pamplona), Maarit Vehviläinen (City of Tampere), Alex Tomasi (City of Trento), Michael Heidenreich (Greenovate! Europe)

D7.3 Business models and KPIs analysis and validation for Lighthouse Cities interventions
Authors: OV, City of Pamplona, City of Tampere, City of Trento and EURAC with the contribution of VTT, NASUVINSA, ITEA, and Trento Mobilità.

D7.5: Exploitation strategies and business plans for the project results
Authors: Juan Cristóbal García and Natxo de Marco (Zabala Innovation)

D8.1: STARDUST Communication and Dissemination Plan
Authors: Marcello Bardellini; Angelique Lusuan; Raffaella Moreschi (ICONS)

D8.2: STARDUST Website online
Authors: Marcello Bardellini; Angelique Lusuan; Raffaella Moreschi; Mario Martinoli (ICONS)

D8.3: Project flyer
Authors: Giulio Mazzolo; Angelique Lusuan (ICONS)

D8.4: Short project video
Authors: Marcello Bardellini; Angelique Lusuan; Raffaella Moreschi; Mario Martinoli (ICONS)

D8.5: seven web videos for each pilot
Authors: Giulio Mazzolo, Angelique Lusuan (ICONS)

D8.10 Report on collaboration with other project activities
Authors: Sergio Diaz de Garayo (CENER), Giulio Mazzolo (ICONS), Anna Vilhula (City of Tampere), Adriano Bisello (Eurac Research), Jose Costero (City of Pamplona), Alex Tomasi (City of Trento), Vaino Terttu (VTT), Michael Heidenreich (Greenovate! Europe), Jaroslv Klúsak (City of Litomerice).

D9.2 Project Management Handbook
Authors: Inés Díaz Regodón (CENER); Florencio Manteca (CENER); Juan Cristóbal García and Natxo de Marco (Zabala Innovation)

INFO-SHEETS

In the final months of the project, STARDUST partners have produced a series of info sheets to support the replication and exploitation of project's results. Below is the full list:

Smart City Matrix to assess the impact of innovative technologies
Authors: Gustavo Vargas-Silva and Pablo Branchi (Public University of Navarre – UPNA)

Innovate and replicate – Lessons learned by follower cities in the STARDUST Smart Cities project
Authors: Anne Artt (Derry) Athanasios Labropoulos (Kozani) Melania Blidar (Cluj-Napoca) Michael Heidenreich and Laura Nieto (Greenovate!Europe).

Sustainable Behaviour Change Gaming Tool in Trento School
Author: Nicolas Caballero (Eurac Research)

Derry and the Northwest Regional Energy Strategy
Authors: Anthony Donoghue, Donegal County Council Eddie Hessell, Ciaran McGrath, Derry City and Strabane District Council
Summary Info Sheet by Anne Artt, Derry City & Strabane District Council

STARDUST enlightens Cluj-Napoca on its way to climate neutrality for 2030
Authors: Melania Blidar (Cluj-Napoca), Michael Heidenreich (Greenovate! Europe)

Feasibility Study for a Neighbourhood Energy Management System in Trento
Author: Rosanna Paradiso (Eurac Research)

Municipality of Kozani 2030 Roadmap: A giant leap to carbon neutrality
Authors: Ioannis Fallas, Nikolaos Ntavos, Katerina Tsepoura, Ellie Mavroudi, Thodoris Gkiourkas, Thanasis Lampropoulos (CluBE)

STARDUST lays the foundations for energy transition in Pamplona
Authors: Florencio Manteca (CENER); Sergio Diaz de Garayo (CENER); Javier Martínez (NASUVINSA)

The benefits of technologies introduced by lighthouse cities are monitored and also assessed
Author: Terttu Vainio (VTT)

Carbon Neutral Tampere 2030 Roadmap Combines Many Actors for Action
Authors: Maarit Vehviläinen and Anna Vilhula (City of Tampere)

SCIENTIFIC PAPERS

STARDUST partners have capitalized on the project results to develop several scientific publications that have been published in international peer-reviewed journals. The papers produced cover several topics that are fundamental to fostering technological innovations applied to the cities. These topics and the related publications are listed below.

Riccardo Nanni & Maurizio Napolitano (2024), "**Dataspaces, public administration, and collective rationality: opportunities and limits for data-driven policy-making**", Public Money & Management, DOI: 10.1080/09540962.2023.2298260

M Vehviläinen and T Vainio 2022, "**New Kind of IoT Platform for Smart City by innovative procurement procedure**" IOP Conf. Ser.: Earth Environ. Sci. 1122 012010

Diego Viesi, Antonio Galgaro, Giorgia Dalla Santa, Eloisa Di Sipio, Tomas Garbari, Paola Visintainer, Alberto Zanetti, Raffaele Sassi, Luigi Crema, "**Combining geological surveys, sizing tools and 3D multiphysics in designing a low-temperature district heating with integrated ground source heat pumps**", Geothermics, Volume 101, 2022, 102381, ISSN 0375-6505

Della Valle N, Gantioler S and Tomasi S (2021), "**Can Behaviorally Informed Urban Living Labs Foster the Energy Transition in Cities**?" Front. Sustain. Cities 3:573174

Matti Pihlajamaa & Maria Merisalo (2021), "**Organizing innovation contests for public procurement of innovation – a case study of smart city hackathons in Tampere**", Finland, European Planning Studies

J. J. Astrain, F. Falcone, A. Lopez, P. Sanchis, J. Villadangos and I. R. Matias, "**Monitoring of Electric Buses within an Urban Smart City Environment**", 2020 IEEE SENSORS, Rotterdam, Netherlands, 2020, pp. 1-4.

Elisa Braco, Idoia San Martín, Alberto Berrueta, Pablo Sanchis, Alfredo Ursúa, "**Experimental assessment of cycling aging of lithium-ion second-life batteries from electric vehicles**", Journal of Energy Storage, Volume 32, 2020, 101695, ISSN 2352-152X.

Diego Viesi, Luigi Crema, Md Shahriar Mahbub, Sara Verones, Roberto Brunelli, Paolo Baggio, Maurizio Fauri, Alessandro Prada, Andrea Bello, Benedetta Nodari, Silvia Silvestri, Luca Tomasi, "**Integrated and dynamic energy modeling of a regional system: A cost-optimized approach in the deep decarbonisation of the Province of Trento (Italy)**", Energy, Volume 209, 2020, 118378, ISSN 0360-5442

Hicham Klaina 1, Imanol Picallo Guembe José Javier Astrain 2, Peio Lopez-Iturri 2,3, 4, Leyre Azpilicueta 5,(Senior Member, Ieee), Otman Aghzout 6, Ana Vazquez Alejos And Francisco Falcone 1, (Member, Ieee), 2,3, (Senior Member, Ieee), "**Implementation of an Interactive Environment With Multilevel Wireless Links for Distributed Botanical Garden in University Campus**"

J. D. Trigo et al.,"**Patient Tracking in a Multi-Building, Tunnel-Connected Hospital Complex**" in IEEE Sensors Journal, vol. 20, no. 23, pp. 14453-14464, 1 Dec.1, 2020

A. Berrueta, A. Soto, J. Marcos, Í. de la Parra, P. Sanchis and A. Ursúa, "**Identification of Critical Parameters for the Design of Energy Management Algorithms for Li-Ion Batteries Operating in PV Power Plants**," in IEEE Transactions on Industry Applications, vol. 56, no. 5, pp. 4670-4678, Sept.-Oct. 2020

I. Ojer, A. Berrueta, J. Pascual, P. Sanchis and A. Ursúa, "**Development of energy management strategies for the sizing of a fast charging station for electric buses**," 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Madrid, Spain, 2020, pp. 1-6

Ala-Kotila, Paula, Terttu Vainio, and Janne Heinonen. 2020. "**Demand Response in District Heating Market—Results of the Field Tests in Student Apartment Buildings**" Smart Cities 3, no. 2: 157-171.

Kankaala, K., Vehiläinen, M., Matilainen, P., & Välimäki, P. (2018), "**Smart city actions to support sustainable city development**". TECHNE - Journal of Technology for Architecture and Environment, (1), 108–114.

Videos

STARDUST partners have produced several videos over the course of the project. Among them, there are also the webinars hosted by the partners on the technological, economic, and social innovations in the Lighthouse and Follower Cities. Below is the full list of the webinars.

STARDUST Smart Cities presentation video

STARDUST wins the EU. Awards 2018

Discovering the Stardust Cities
Join Stardust: The City of Pamplona
Join Stardust: The City of Tampere
Join Stardust: The City of Trento
Join Stardust: The City of Cluj-Naoca
Join Stardust: The City of Derry
Join Stardust: The City of Kozani
Join Stardust: The City of Litoměřice

Smart Pamplona Lab interviews series
Smart Pamplona Lab presents AGROPESTALERT
Smart Pamplona Lab presents INBIOT
Smart Pamplona Lab presents Smart AQUA
Smart Pamplona Lab presents STOPLED
Smart Pamplona Lab presents uRAD

Tampere Smart Week 2020: Stardust Project Interview Series

Interview with Juha-Pekka Häyrynen
Part 1 - Part 2 - Part 3

Interview with Mauritz Knuts and Johanna Kusisto
Part 1 - Part 2 - Part 3

Interview with Maria Viitanen

Interview with Diego Brancatelli
Part 1 - Part 2 - Part 3 - Part 4

Interview with Leo Strawbridge
Part 1 - Part 2

Interview with Adrian Răulea

Interview with Maarit Vehviläinen
Part 1 - Part 2 - Part 3

Voices from Stardust Lighthouse and Follower Cities

Status quo of Derry's Replication Plan

Business models and funding sources in the case of the Follower City Derry

What has been done so far? Derry's objectives regarding the North West Regional Energy Strategy

How to access data for energy monitoring? Experience of the Lighthouse City Limerick

How to access data for energy monitoring? Experience of the Lighthouse City Tampere

2nd Stardust Capacity Building Workshop in Derry - Introduction to Stardust and WP5

Towards sustainable mobility in the Czech Republic: Experience of the Follower City Litomerice

Beginning of e-mobility in Greece: Objectives of the follower city Kozani

The success story of the Follower City Cluj-Napoca: road to fully electric mobility by 2028

Towards sustainable mobility in Spain: Experience of the Lighthouse City Pamplona

Becoming a finnish leader in sustainable mobility: The Experience of the Lighthouse City Tampere

Towards decarbonization and energy-efficient building stock in Greece Link

Towards decarbonization and energy-efficient building stock in Romania

Implementation of energy-efficient district heating systems in the Txantrea District

Tampere: Energy cooperation between housing associations and the City

Waste heat analysis and valorization in the Madonna Bianca case

Smart Pamplona Lab 2020: 5 projects

Stardust IoT Tampere platform awarded

Replication strategies compared: Challenges and lessons learnt from projects Stardust and Pocityf

Public buildings and climate neutrality: real cases and real lessons learned

Smart City Academy Webinar Series

Why should cities be interested in digital twins?

Policies about third-party data within Public Administration. Lessons learned from the scooter STARDUST use case

Urban city apps: experiences from Pamplona, Tampere, and Trento

The role of shallow geothermal energy in the future renewable district heating and cooling networks

The electrification of bus fleets: lesson learned by Cluj, Pamplona and Tampere

Electric mobility in Trento: Technology infrastructure approach and action plan

Insights into assessing urban waste-heat sources for use in district heating

Innovative business models: barriers and lessons learnt

Sustainable Smart City Matrix: how to assess impact of innovative technologies in STARDUST cities

Disclaimer

Authors of this document:

Ilaria Orfino (ICONS)
Mark Thompson (ICONS)

The description and data on the included practices are provided by the following partners, who are the sole responsible for the accuracy and completeness of the information included in this best practices book:

For the Lighthouse Cities:

CENER (as a coordinator)
Pamplona City
Tampere City
Trento City

For the Follower Cities:

Derry city and Strabane district council
Kozani City
Cluj_Napoca Metropolitan Area
CluBE

For the scientific and technological aspects:

VTT
Eurac Research
Fondazione Bruno Kessler
Greenovate! Europe
Officinae Verdi SpA
NASUVINSA
Habitech – Distretto tecnologico trentino S.c.a.r.l

Photo credits:

Visit Tampere
Municipality of Tampere
Ayuantemento de Pamplona
NASUVINSA
Municipality of Kozani (with the contribution of CluBE)
Municipality of Cluj-Napoca

STARDUST

www.stardustproject.eu @stardustH2020

coordinator@stardustproject.eu

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement N° 774094.