THE SMART CITY MARKET IN GERMANY

2021–2026

Partners of the Study

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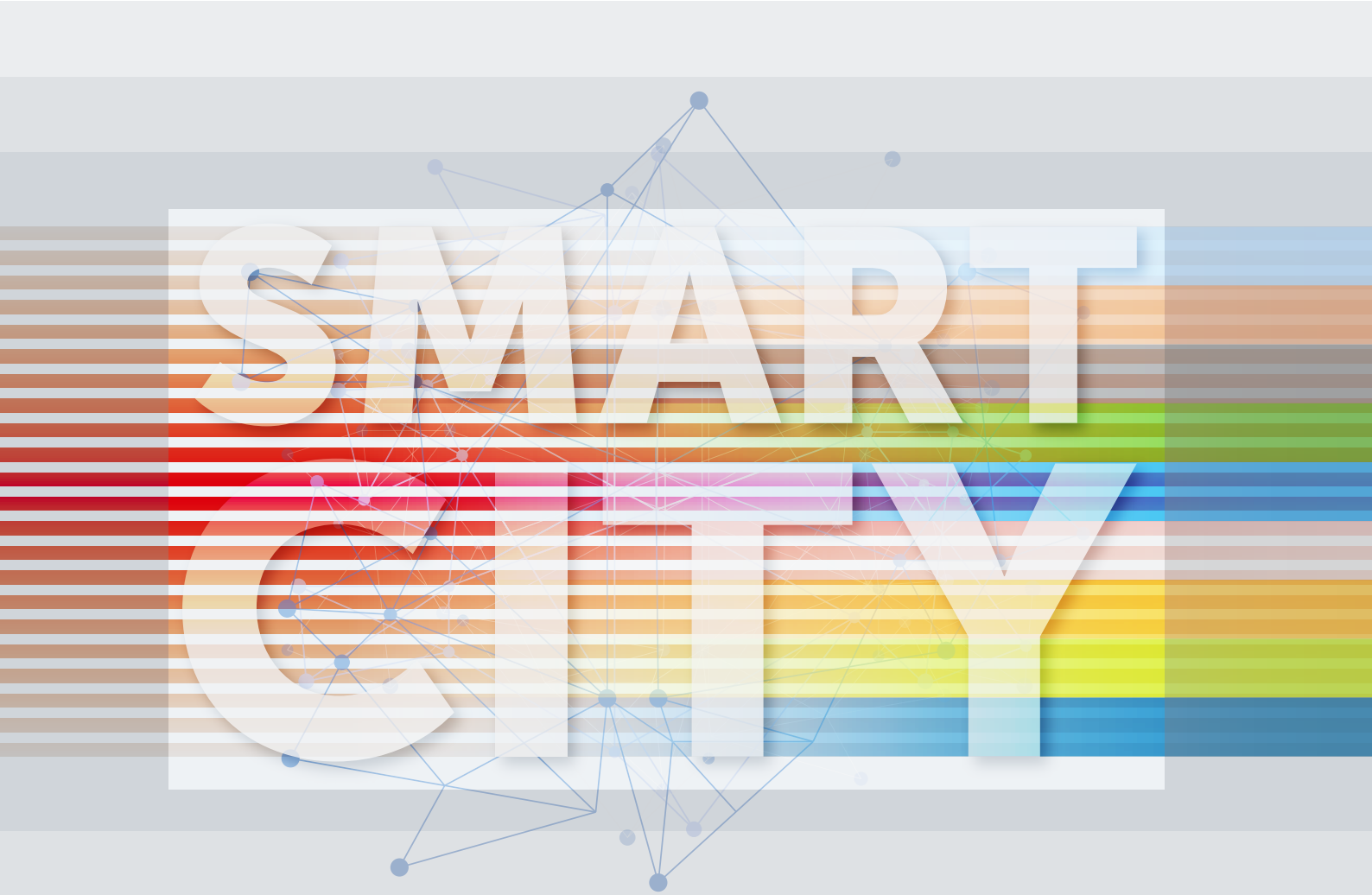

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Oliver J. Süme, Chair of the Board
Board Member for Policy, Law & Regulations
eco – Association of the Internet Industry

Prof. Dr. Norbert Pohlmann
Board Member for IT Security
eco – Association of the Internet Industry

The Smart City Market in Germany 2021-2026

Dear Readers,

More and more people are living in cities and conurbations. In Germany, the figure is currently around 76 per cent and rising. This poses a number of challenges for cities and municipalities: for example, in the areas of transport and logistics, administration, energy supply and the circular economy; but also moving beyond the classic supply role in the context of cultural and leisure offerings, high-quality space for living, as well as health, education and sustainability. Here, the linchpin of future-oriented and holistic urban and municipal management comes down to the question: How can we make cities more efficient, technologically more advanced, greener and more socially inclusive?

Digitalisation offers countless answers and solutions. The vision of the Smart City combines these technological innovations in a coordinated and interlocking overall concept for urban space.

German cities and municipalities are currently working intensively on the implementation of the Online Access Act of the Federal Ministry of the Interior (BMI) in order to offer administrative services electronically via administrative portals by the end of 2022. The Smart City is a further logical step to providing additional IT services to citizens and businesses. This is why municipalities are currently on their way to becoming Smart Cities, building urban platforms and fine-tuning a cloud infrastructure. Which needs and demands are particularly in focus here? What are success factors for a functioning Smart City ecosystem? And what does this mean for providers and business models?

With this study, we would like to contribute to answering these questions.

We are convinced that sustainability and an efficient digital infrastructure are the foundations of a functioning and flourishing Smart City.

Digitalisation and sustainability are two sides of the same coin. The positive effects of digitalisation are becoming increasingly clear, especially in times of crisis: the increased share of teleworking resulting from working from home has led to considerable CO_2 savings. With the help of digital solutions, we can also gain efficiency in the areas of production, logistics and mobility.

Data centres play a key role in this development, a fact which is still often overlooked. These data centres form the backbone of digitalisation. By storing and processing enormous amounts of data, they are growth engines and innovation drivers for other industries. In recent months in particular, data centres have kept both our economic and social lives up and running. Data centres in Germany are among the most energy-efficient in the world. Their energy consumption has fallen by 90 per cent per computing unit over the past ten years. The CO_2 emissions of European data centres have already been declining for the past five years. Political promotion of the recovery of waste heat generated in data centres and its smart integration into urban planning and municipal heat supply concepts could further improve the energy balance of data centres and cities.

With additional support for the roll-out of digital infrastructures, further investment in research into innovative technologies, and an energy mix oriented towards sustainability, it would be possible to achieve a 100 per cent reduction in CO_2 emissions from data centres by 2030. The industry thus forms a central building block for the sustainable and climate-friendly Smart City.

At the same time, the roll-out of the 5G network will also lead to even more sustainable IT in the medium term, as both the antennas and the data transmission itself are much more energy-efficient than previous mobile standards.

An efficient digital infrastructure means not only high-speed Internet, but also a sovereign and secure data infrastructure. The European cloud and data infrastructure Gaia-X is therefore likely to soon become an important basis for successful Smart City platforms for cities and municipalities.

The present study shows: The Smart City market is booming and, with an average annual growth of more than 17 per cent, forms one of the most exciting digitalisation markets of this decade.

With this study, we intend to contribute to the following: familiarising those responsible for urban development, as well as decision-makers in the digital and Internet industry, with this dynamic market; offering decision-making aids; and providing inspiration and ideas for future Smart City projects and business models.

We would like to thank our member companies NetCologne, Cloudflare, Uber and the Vodafone Institute for Society and Communication for supporting this study and wish you an interesting read!

Oliver J. Süme **Prof. Dr. Norbert Pohlmann**

Foreword

Peter Altmaier
German Federal Minister for Economic Affairs and Energy

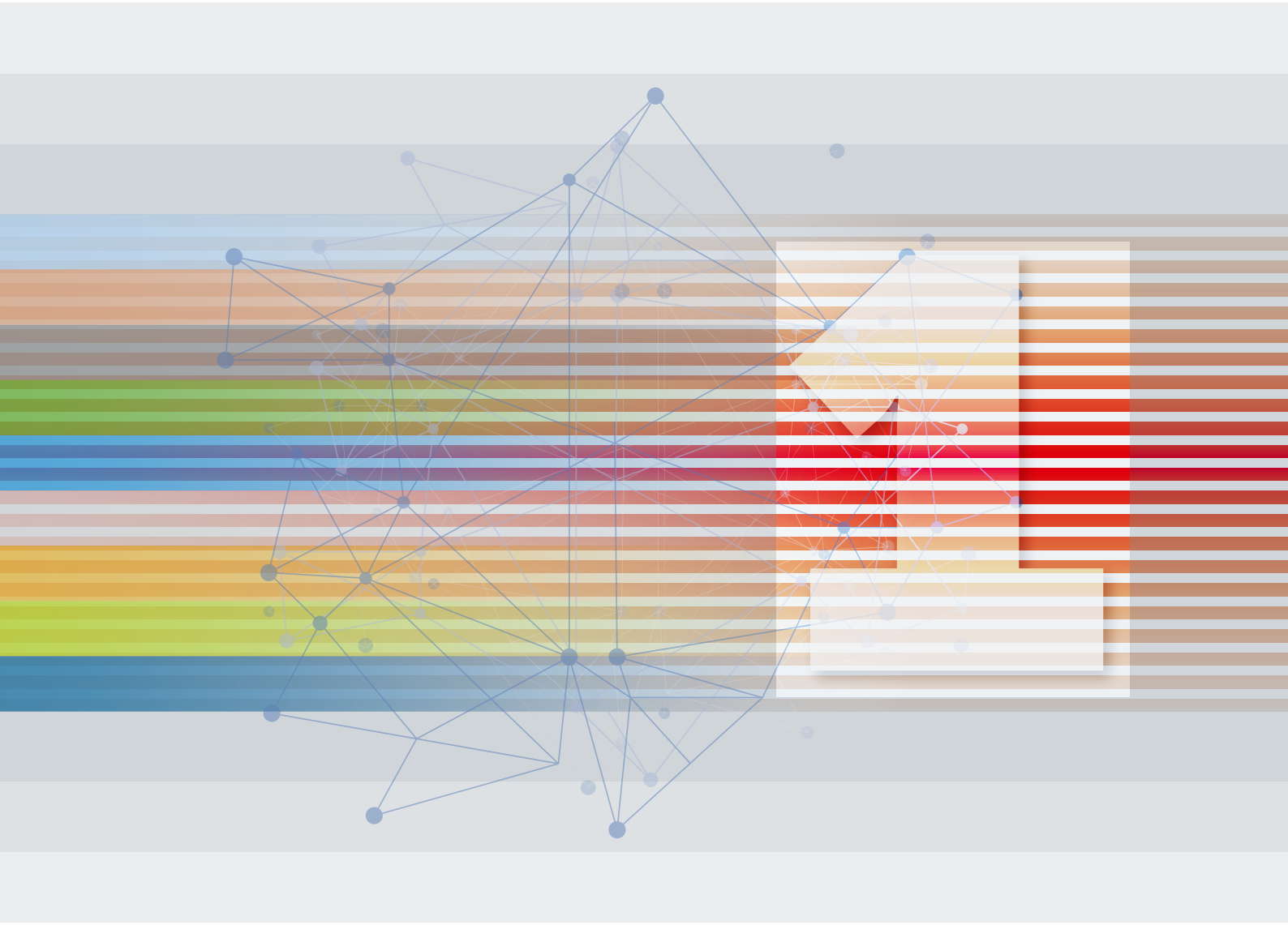
Dear Readers,

The eco study "The Smart City Market in Germany 2021-2026" is an important indicator of the trends and challenges in the Smart City market in our country. It is very encouraging that the growth trend for Smart Cities in Germany, which was already evident in 2017, will continue unabated until 2026. With the chapter on sustainability, the study takes a look at an area of application in which digitalisation can have a particularly high benefit – here I am thinking in particular of climate protection.

The Covid-19 pandemic has shown us how important digital solutions and offerings are. They help us to maintain distance and hygiene rules while continuing to stay in contact with each other. With the "Stadt.Land.Digital" (City.Country.Digital) initiative, the Federal Ministry for Economic Affairs and Energy supports municipalities in their digital transformation – and not just since Covid-19. Our support starts with holistic digitalisation approaches. The initiative informs, accompanies and connects municipalities that are on their way to becoming "Smart Cities and Regions". With the Smart City Navigator, we offer an overview, with examples from German municipalities that show how Smart City projects contribute to the fulfilment of the UN Sustainable Development Goals.

Digitalisation in cities and municipalities means transformation, and thus the opportunity to renew existing structures and make cities and municipalities more competitive, innovative and sustainable. Let us seize this opportunity and together place our country in the best possible position for the future.

Peter Altmaier



1. Introduction

Lars Riegel
Partner, Arthur D. Little

Dr. Nejc Jakopin
Principal, Arthur D. Little

The Covid-19 pandemic, climate protection goals, increasing urbanisation and international competition for technological trends and locational advantages for industry are stimulating the digitalisation of large parts of society. This development poses major challenges for cities and municipalities in terms of the prioritisation and financing of projects related to the Internet of Things (IoT) and the Smart City. In recent years, the concept of the Smart City has become a driver for the automation of central pillars of societal and economic coexistence. In the study "The Smart City Market in Germany 2021-2026", eco – Association of the Internet Industry and Arthur D. Little have conducted analyses and expert interviews to investigate the following: how the market and its segments will develop over the next five years, what effect the Smart City will have on climate targets, and what implications this will have for cities and companies.

Those responsible for urban development will learn from our study about trends, best practices and recommendations for action to make cities more interesting and sustainable for citizens and businesses. For the Internet industry and its companies, the study's results show that the Smart City is an attractive growth market for the future.

The revenue volume of the German Smart City market will grow from 38.5 billion Euro in 2021 to 84.7 billion Euro in 2026. According to the study, this corresponds to an average annual growth of 17.1 per cent. The continuous and strong growth is attracting many established technology giants, but also numerous start-ups. In every segment of the Smart City, a multitude of innovative business models can be found that use future-oriented technologies to turn the status quo on its head. The concentration of start-ups is highest in the areas of "Healthcare", "Financial Services" and "Transport & Logistics (Mobility)", and lowest in the areas of "Digital Education" and "Public Administration". Arising from this, when compared with the 2017 study, current figures reveal that new stakeholders and technologies have now become established. This development stands to intensify competition in the German Smart City market in the future and increase growth further.

But how can German Smart Cities cope with the flood of innovative technologies, organisational challenges and financial barriers? How can companies and investors serve as a solid source of much-needed funding? And how can German cities and municipalities achieve their sustainability goals with Smart City building blocks? In this study, Arthur D. Little and the Association of the Internet Industry aim to provide answers to these questions.

Data ecosystems as the basis for successful Smart City platforms

Expert interviews and case studies make it clear that the success and scaling of Smart City initiatives strongly depend on the underlying infrastructure. In addition to extensive high-speed Internet coverage, the data infrastructure in particular plays a central role. A cross-segment architecture of data ecosystems and a corresponding "data governance" allow the countless data points to be aggregated, new business models to be developed, and synergies between the segments and the building blocks to be harnessed. German cities and municipalities should continuously scrutinise their existing database landscape and validate it with technological trends and their requirements. In this respect, the study offers an exciting insight into current developments and the future of the Smart City market.

As the study emphasises, individual use cases and pilot projects not only require individual consideration but must also be brought into relation with existing and future projects, as well as other segments. A silo mentality limits opportunities for holistic development and leads to further challenges. Smart Neighbourhoods are good playgrounds for such holistic considerations, as examples in leading German Smart Cities – Berlin, Cologne and Munich – show.

Much more than just funding: new financing options for Smart Cities

Many German cities continue to rely on the numerous funding opportunities and subsidies from the EU and the German federal government. But experience shows that the bureaucratic effort is too extreme and the financial resources are not sufficient to devise cross-segment Smart City platforms. Mostly it remains at the level of individual pilots – especially in medium-sized cities. A key lesson to be learned from some other countries and companies is that revenues and savings allow private financing constellations, while simultaneously offering the promise of cooperation with experienced Smart City providers.

Based on the analysis of international case studies on Smart City projects, eco and Arthur D. Little have identified three essential steps for the development of individual financing models for German decision-makers:

1. **How should the value proposition and the resulting business model be designed?**
2. **Which financing mechanisms and instruments are suitable for the business model and the project?**
3. **Which form of cooperation is optimal for the project to be carried out?**

Arthur D. Little wishes you an interesting read of the study.

Lars Riegel **Dr. Nejc Jakopin**

1.1 Reality Check of the Statements from the Previous Study

In the current study, the prognoses on market sizes and growth trends from our 2017 study can generally be confirmed. In order to take the latest developments and challenges into account in the forecasts, new areas of the Smart City were identified and quantified. These explain the slight difference between the revenue figures and other factors. The market volume was slightly underestimated for 2017 (16.9 million Euro) and 2020 (26.7 million Euro) in the previous study. In fact, it was approximately 20 per cent higher than these expected levels, as detailed in this study (20.5 million Euro in 2017 and 31.1 million Euro in 2020). However, the average market growth was predicted very well and, at 16.5 per cent, was only 1.6 per centage points higher than that highlighted in the present study (14.9 per cent).

A detailed look at the individual segments illustrates the most important developments from 2017 to 2021 in the Smart City market:

- In 2017, the segments of "Transport & Logistics (Mobility)", "Physical Security" and "Building Automation" represented the strongest segments of the German Smart City market, with a cumulative market share of 59 per cent. Four years later, in 2021, the aforementioned segments still dominate the market, albeit in a slightly lower concentration (43 per cent), as other segments have gained momentum. Segments such as "Healthcare", driven by legal requirements and the Covid-19 pandemic, will play an even stronger role than expected in 2021 (15 per cent market share).

- In the current study, the "Digital Education" segment also shows the largest annual growth in the German Smart City market (23 per cent). This confirms the forecasts with regard to the "digitalisation of education" from the last study. According to the OECD, Germany – despite this strong development over recent years – still has a lot of catching up to do in European comparison.

- Measured purely in terms of volume-based size and growth, the segments of "Public Administration" and "Financial Services" are comparatively small in the current study. However, these areas play an important role as a foundation and enabler for all areas.

- In 2017, three trends in particular dominated the Smart City market: Medical wearables, Smart Homes and Smart Meters. But have these trends been able to prevail? The Covid-19 pandemic has led to higher adoption of smart and digital products across segments. Due to multiple restrictions in public life, the use of medical wearables, among other things, has gained in growth. Smart Home products have also increased in importance, as expected, but are still far from reaching maturity in the mass market. Smart Meters have missed the expected target of almost complete household penetration. This trend is mainly due to the postponed roll-out of Smart Metering systems. At the beginning of 2020, the starting gun sounded for the legally mandated roll-out, which nurtures the hope of a nationwide installation of Smart Meters by 2030 at the latest – even though not all legal issues have yet been conclusively clarified.

1.2 The Smart City Ecosystem and its Market Segments

The foundations of the Smart City ecosystem are communication networks, data centres and security infrastructures. Viewed as Layers 1 and 2 of the Internet industry (see the study "The Internet Industry in Germany" by eco and Arthur D. Little from 2020), these layers include all players that enable stationary and mobile access to the Internet and provide the diverse infrastructure services that build on it.

The foundation of the Smart City ecosystem

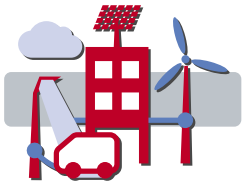
Layer 1 and 2 infrastructures ensure data traffic is trustworthy, fast, stable and both cost and energy-efficient. In the eco and Arthur D. Little layer model, "Network, Infrastructure & Operations" are categorised together in Layer 1. This infrastructure forms the basis for all kinds of Internet services and is used by private users and companies as well as by providers at other layers of the Internet industry, thus also by the Smart City. In Layer 2, "Services & Applications", cloud services, cybersecurity and edge/fog computing are particularly relevant for Smart Cities. The two layers of the Internet industry are explained in more detail in Chapter 2.2, "Turnover and Market Growth". Among other things, they pave the way for all nine Smart City segments.

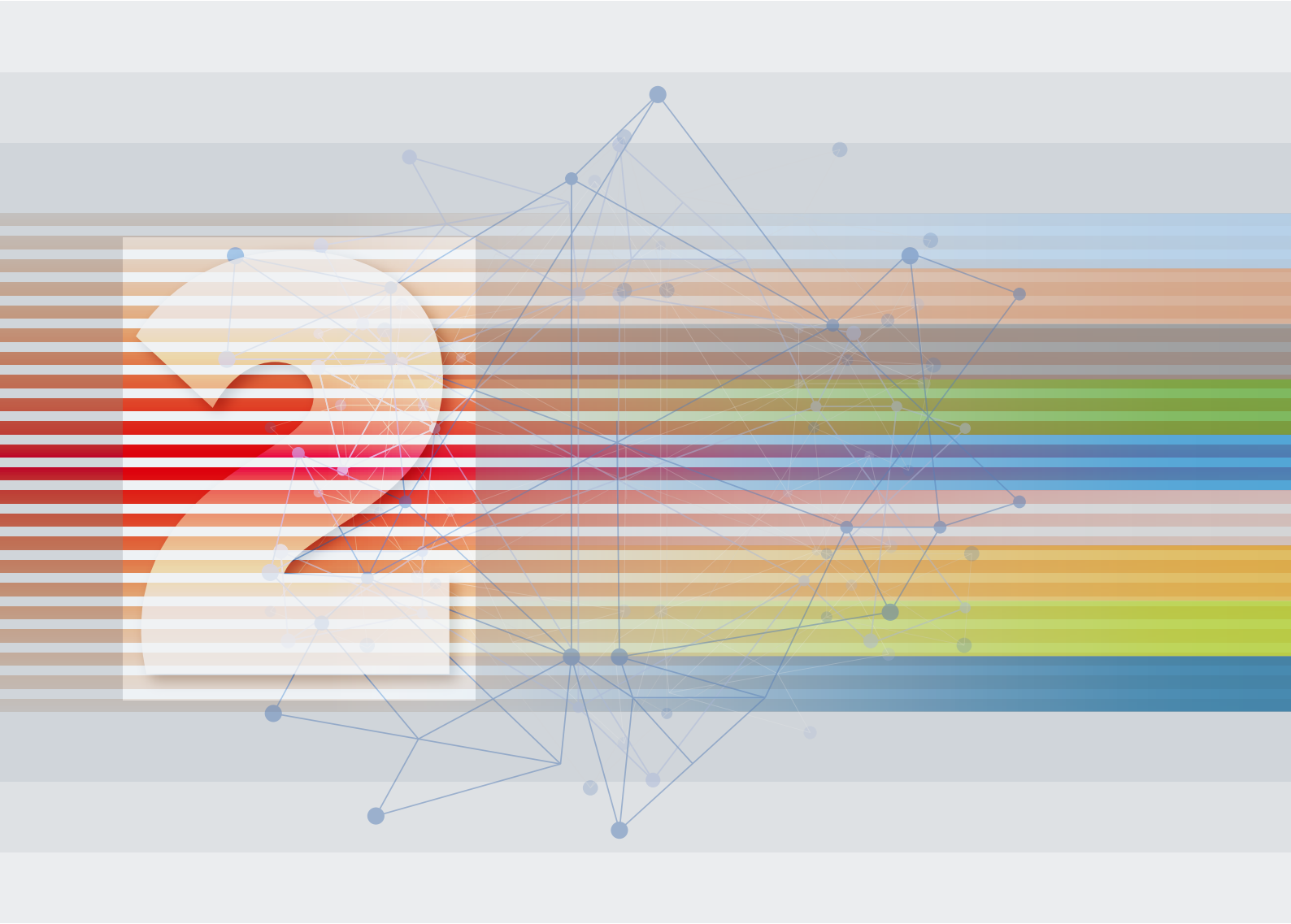
Market segments in the Smart City ecosystem

In the following section, the market segments of the Smart City ecosystem are presented, including their individual characteristics as well as examples related to the service offering and stakeholders.

FIG. 1 Market Segments in the Smart City Ecosystem

Segments	Characteristics	Service examples	Key players
Public Administration 	Digitalisation in the public sector enables more efficient processes through better control of administration and the provision of digital government services. In addition, digital participation in political life promotes the involvement of citizens.	→ Digital administration (internal) → E-services for citizens and businesses (e.g. online applications, intelligent forms, digital administrative procedures in accordance with the Online Access Act) → Digital participation of citizens (e.g. elections) → Making data available to citizens and businesses (Open Data)	→ Public Administration entities
Digital Education 	Smart Education primarily includes the digitalisation of educational institutions and the establishment and roll-out of virtual learning platforms. Fundamental steps are the equipping of schools with digital end-devices and the establishment of reliable ICT and cloud services. In addition to digital learning materials, the promotion of digital skills for teachers and students is of particular importance.	→ Digitalisation of educational institutions and offers (learning platforms, communication channels, digital skills, curriculum content, other ICT services – esp. Wi-Fi)	→ Schools → Universities and colleges → Adult education institutions → Further education institutions
Health 	Even before the Covid-19 pandemic, the digitalisation of processes in the health sector and (digital) communication between institutions such as hospitals, pharmacies and patients were becoming increasingly important. Innovations such as telemedicine and mobile health are urgently needed to enable new treatment methods, especially – in times of the Covid-19 pandemic – to avoid contact, but also with a focus on demographic change in the field of elderly care.	→ Digital patient records and information → Digital prescriptions → Personal health management (e.g. telemedicine & Internet medicine) → Medical wearables and evaluation of the data → Digital health apps	→ Hospitals → Retirement and nursing homes → Pharmacies → Manufacturers of medical devices → MedTech/Digital Health start-ups
Retail & Hospitality 	The Retail & Hospitality segment includes the digitalisation of retail advertising and the use of Smart Vending Machines. For example, innovative advertising spaces using location-based services via mobile devices are gaining in importance.	→ Digital advertising space → Smart Vending Machines → Location-based services → Online delivery services → AI shopping applications for local shops and shopping centres → AR/VR in stationary retail	→ Airports, railway stations → IT companies → Retail, shopping centres → Vending machine manufacturers → Hospitality → Delivery services

Segments	Characteristics	Service examples	Key players
Transport & Logistics (Mobility) 	Not least due to increasing urbanisation and the expansion of online retail, the burden on urban transport is rising. Only with intelligent, intermodal and connected transport platforms can inner cities and conurbations sustainably optimise road traffic.	→ Autonomous means of transport → Traffic management → Parking management, ticket systems & passenger information → Construction site management systems → Intermodal transport platforms → Control of vehicle fleets → Car, bike and ride sharing → Smart Urban Logistics	→ Transport operators (rail/bus company, underground network, city bikes) → Logistics companies → Sharing platforms
Physical Security 	The increasing population density in cities makes intelligent security systems indispensable. Improved physical security in public, e.g. through Smart Camera Surveillance or intelligent warning systems, increases the quality of life of citizens.	→ Video surveillance of public places → Access controls → Identification management → Warning and information systems (e.g. KATWARN / NINA)	→ Police → Public institutions → Electronics manufacturers → Transport operators
Building Automation 	Public institutions, companies and private households can improve energy efficiency, security and comfort in their buildings. Smart Home solutions optimise (internal) processes, especially the monitoring, control and regulation of buildings and equipment.	→ Automatic security systems → Intelligent energy systems & lighting concepts → Automated devices → Predictive maintenance → Indoor navigation	→ Construction industry → Household appliance manufacturers → Electronics manufacturers → IoT companies
Energy 	An efficient energy supply ("Smart Grid") includes the digitalisation of the power grid (from power generation to transport to the consumer) and the strengthening of decentralised supply systems. Smart Street Lighting and electric charging stations are promising and innovation-driven markets.	→ Smart electricity, gas and water networks → Decentralised energy supply → Smart Waste Management → Intelligent street lighting → Electric charging stations	→ Energy companies → Network operators → Automotive manufacturers → Start-ups
Financial Services 	The digitalisation of financial services includes both the revenue share of Internet payment methods (e.g. PayPal) and improved security systems (e.g. remote monitoring around the clock) for cash withdrawals in banks. In addition, completely new, digital forms of currency (crypto currencies) are emerging that could revolutionise the financial sector in cities.	→ Cashless (online) payment methods → ATM security → Embedded finance → Peer-2-Peer payments (P2P)	→ Banks → Retail → FinTechs



2. The German Smart City Market in Facts and Figures

2.1 Trends and Challenges in the Smart City Market in Germany

The significant increase in the use of video conferencing and streaming services has driven demand for high-speed Internet – not least due to the ongoing Covid-19 pandemic, which is fundamentally changing lives. Nationwide 5G and fibre availability will meet these needs and ensure more energy-efficient communications in the long term. Commercial IoT use cases in the Smart City (for example, Smart Mobility, Smart Grid, Smart Home) also require these infrastructures and call for significant efforts from telecommunication network operators and, in some places, greater government support.

The topic of "cybersecurity" remains critical to the system: The reliability, security and trustworthiness of all Smart City building blocks stands and falls with the ability to protect the systems from hackers. To this end, cybersecurity clusters are increasingly being formed. One example is the "Alliance for Cybersecurity", which – initiated by the German Federal Office for Information Security (BSI) – unites academia, industry and the authorities to improve cybersecurity at all levels.

The trends and challenges currently emerging for the nine segments of the German Smart City market are outlined below:

Public Administration

A recent report by the German Federal Ministry for Economic Affairs and Energy (BMWi) confirms what became obvious as a result of the pandemic: Public administration in Germany is lagging behind in some areas and needs to catch up in order not to lose touch in terms of digitalisation. Cost-intensive solutions, such as the digital identity card, were rolled out throughout Germany, but were hardly used due to a lack of user orientation. A wide variety of legal measures, such as the Register Modernisation Act or a uniform data strategy, are intended to increase the data competence of public administration in the coming years and connect it to the digital world. One measure of this strategy is the Online Access Act passed in 2017, according to which all administrative services must be digitalised by 2022 and citizens must be provided with uniform access (via a citizen portal or service portal). In the throes of the Covid-19 pandemic, the calls of citizens and businesses for uncomplicated, time-independent access to administrative services have grown louder. In addition to increased transparency and competitiveness, digital administration (e-government) brings with it fundamental prerequisites for innovative Smart City services and business models. A uniform, user-centred access portal that enables all administrative services to be provided digitally (e.g. digital identity, authentication, e-signature, tax returns) is needed to make Germany an attractive, modern business location and to catch up with other EU countries. Investments in countless initiatives which are together worth billions, such as Tech4Germany by the German federal government and the Online Access Act, give hope for speedy implementation.

However, due to advancing digitalisation and the shift of public administration activities to the cloud, the question of how to deal with the data generated is coming into focus. eco and Arthur D. Little see a clear trend here towards "data governance" concepts and urban data platforms. At the European level, representatives from politics, academia and business are working with Gaia-X on the next stage of roll-out of the European data structure and are seeking a balance between digital sovereignty and strong support for innovation. The goal is a value-based transparent digital ecosystem for data and services. An extensive example of data intensity will soon be found in Saudi Arabia: The future city NEOM promises to collect 90 per cent of all data centrally and, based on this, to increase the quality of life of the inhabitants.

Digital Education

As the core foundation for international competitiveness, the topic of "Digital Education" also plays a major role for Germany in the Smart City context. It remains the case that Germany lags behind in international comparison with regard to the digitalisation of education. Major challenges include not only the equipment availability, but also the targeted and sustainable use of the future-oriented technologies. This starts with the connection to fibre-optic networks and equipping of schools with sufficient Wi-Fi, mobile devices, IT experts and, above all, interactive digital platforms for uploading learning content and information. Even after the Covid-19 pandemic has been surmounted, there will be an increasing number of hybrid and digital teaching options and thus the need for digital technologies in this area will continue to grow. In this regard, start-ups are driving the development of "Digital Education" and online learning platforms.

In the long term, "Digital Education" will be revolutionised by artificial intelligence (AI) and augmented reality (AR). These disruptive technologies enable, for example, realistic simulations and training in virtual environments – so-called "immersive learning". However, the basic prerequisite for teaching these future competences with the above-mentioned technologies is having teachers who undergo training and further education in this area and who can thus become mediators of digital competences.

Healthcare

The Covid-19 pandemic has shown that digitalisation can be a central factor for the stability of a resilient healthcare system. In the future, health authorities must be securely connected, processes must be digitalised and health data must be collected and analysed securely and in accordance with data protection regulations. Only in this way will cities and municipalities and their health authorities be better prepared for future crisis situations.

Holistic (secure and trustworthy) health platforms must be developed that cover digital patient records, vaccination cards, digital prescriptions, digital health insurance cards and other services seamlessly and without media breaks. The German legislator has already taken the first steps here: A digital Covid-19 vaccination card was planned and the electronic patient record arrived in July 2021. From 2022, vaccination cards and other digital supporting documents will also be transferred to an SSI (Self-Sovereign Identity) app. However, simple services such as online bookings and telemedicine offers are still comparatively rare at present. Nevertheless, more and more start-ups (Kry, TeleClinic, Doctolib) offer digital solutions and remote treatment. The high level of competition driven by the pandemic in the market for digital medical care – some of which is also international – is of great relevance.

The high degree of maturity of AI and robotics is also enabling more and more use cases in the "Healthcare" sector. These include, for example, AI-based diagnostic systems (e.g. preparation and evaluation of X-ray or CT images), personalised treatments and the dispensing of medication. eco and Arthur D. Little expect increased disruption in some aspects of hospitals, doctors' practices and retirement and nursing homes in the coming years, which will accompany the spread of machine learning (especially neural networks). Analogous to "FinTechs" in "Financial Services", "HealthTechs" will transform medical processes and create new business models.

Smart Cities can contribute to these trends by driving and promoting the digitalisation of local health authorities and doctors' practices. For example, a regional booking platform for doctors' appointments or the automated ordering of prescription drugs can be implemented with perspective. But telemedicine and digital counselling services can also be deployed in Smart Districts or Cities.

Retail & Hospitality

In the "Retail & Hospitality" segment, experts see enormous potential for disruption through the use of Augmented Reality (AR) and Virtual Reality (VR). For example, travel agencies can give their customers an exclusive foretaste of the next trip. In local retail, on the other hand, the use of AR/VR makes it possible to virtually expand limited stationary sales areas with information and consultation possibilities. Above all, the sharing of emotions enables a change in the customer experience. In online retail, the application of innovative technology solutions can create a completely new product experience, previously only known from stationary retail. However, the technologies are still in their infancy and they continue to be shaped primarily by US corporations. The primary goal for Smart Cities is to create the technical basis for this technology and at the same time to strengthen the digital competence of stationary retail. Regional apps and intelligent vending machines are just two of many examples.

In the retail food industry, existing business practices and established companies have come under increasing pressure in the recent past. Thanks to the efficiency in the field of "Smart Urban Logistics" and the resulting decrease in delivery costs, food delivery services can replace the trip to the supermarket. German delivery service start-ups in the food industry, such as Gorillas and Flink, promise citizens delivery in less than ten minutes. With every new customer, these apps gain insight into buying patterns and consumption habits that traditional supermarket chains struggle to access. Nevertheless, the existing business model of these delivery services has not been profitable so far and is running at a loss per delivery.

One technology with enormous potential in the business sector is blockchain. For retail, the use of blockchain primarily offers transparency in the form of transactions which are safe from manipulation, as well as validated suppliers, thereby harnessing a high potential for streamlining. The Dutch chocolate manufacturer Tony's Chocolonely has demonstrated how blockchain can be used to develop a transparent supply chain. At the same time, new blockchain-based loyalty and reward programmes are emerging in the "Retail" sector.

Transport & Logistics (Mobility)

The closure of shops, restaurants and hospitality businesses during the Covid-19 pandemic has further accelerated the growth of online retail. It can be assumed that, despite the desire for physical experiences, this change in consumer behaviour will continue in the future. Together with the continuous population growth in cities, eco and Arthur D. Little therefore expect the demand for "Smart Mobility" and "Smart Urban Logistics" (package stations, same-day delivery, grocery delivery services) to continue increasing, even after the pandemic. Logistics companies, "gig economies" and new sharing platforms are becoming active in Smart Cities, optimising interfaces and revolutionising traditional transport and traffic systems. For cities, "sharing concepts" in particular offer a lever to relieve traffic congestion. By-products of this development are an increased complexity in urban transport and the resulting trade-off between city-owned solutions, commercial platforms and cross-regional interfaces. Irrespective of these aspects, the mobility platforms of the future will develop into centralised service and data platforms that are decisively shaped by artificial intelligence. On the basis of this, in addition to service and transport, pedestrians should also be optimally steered and guided through active intervention.

The development of autonomous means of transport remains to be monitored. Autonomous buses and trams hold great potential to make local public transport more reliable, efficient and attractive – as examples in Barcelona and Copenhagen show – and to establish new business models in the area of "Mobility". While only a few cities support concrete projects, research continues to be conducted and funded commercially. This is still in the testing and development phase. According to forecasts by Arthur D. Little, fully autonomous means of transport are not likely to become established in everyday life before 2030.

On the commute between city and country, intelligent traffic management can have an enormous positive impact, just as it does in the city centre. In particular, coordinated intermodal systems reduce waiting and transfer times. At the same time, automation of suburban and underground trains increases the reliability and punctuality of public transport. If more people use public transport due to more attractive offers, commuting by train, bus or car will be more sustainable and stress-free in the future.

Physical Security

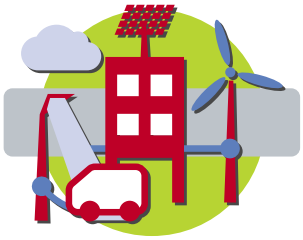
While the topic of "cybersecurity" is experiencing a strong tailwind, the area of "Physical Security" remains largely in the background. The reason for this is on the one hand the low commercial interest and potential, especially in the Covid-19 times, and on the other hand the high value placed on data protection, privacy and anonymity in Germany. Nevertheless, in a representative survey conducted in 2017, more than two thirds of German citizens saw advantages in surveillance cameras (Statista, 2017). Meanwhile, advances in artificial intelligence allow for other new use cases such as automated recognition of number plates, highly controversial facial recognition software, and the automated evaluation of surveillance camera footage.

However, the protection of sensors for IoT use cases is becoming increasingly important: Until now, it has been difficult to control who gains access to sensors in public spaces and when and where this happens. Manipulation of measuring stations and systems can be outlined as risks. The integrity of such stations and sensors requires new approaches to the physical protection of IoT systems.

Building Automation

Central use cases in the "Building Automation" segment are heating (Smart Heating) and lighting (Smart Lighting), which save energy and costs through intelligent and demand-driven control of lighting and temperature. Thanks to a dynamic development in the private Smart Home market, cities can also benefit from "off-the-shelf" products, such as those from the German provider tado°. This means that public buildings can be optimised in terms of energy, and the heating and lighting of private living spaces can be intelligently adapted for citizens. At the same time, more complex projects are also possible. The maturity of artificial intelligence enables various more sophisticated application scenarios in the field of "Building Automation", such as predictive maintenance in building management. Trends are, above all, the controversial facial recognition systems in building surveillance and predictive maintenance in building management. The greatest convenience for citizens is offered by so-called indoor navigation systems. In large public buildings such as airports or railway stations, people or objects can be precisely guided from A to B and supported with the help of additional information.

A Smart City platform that interconnects sensors and systems while aggregating and evaluating data supports energy and cost efficiency in the area of "Building Automation". With the help of appropriate IoT solutions and evaluation software, companies in the Internet industry offer numerous opportunities for public buildings.



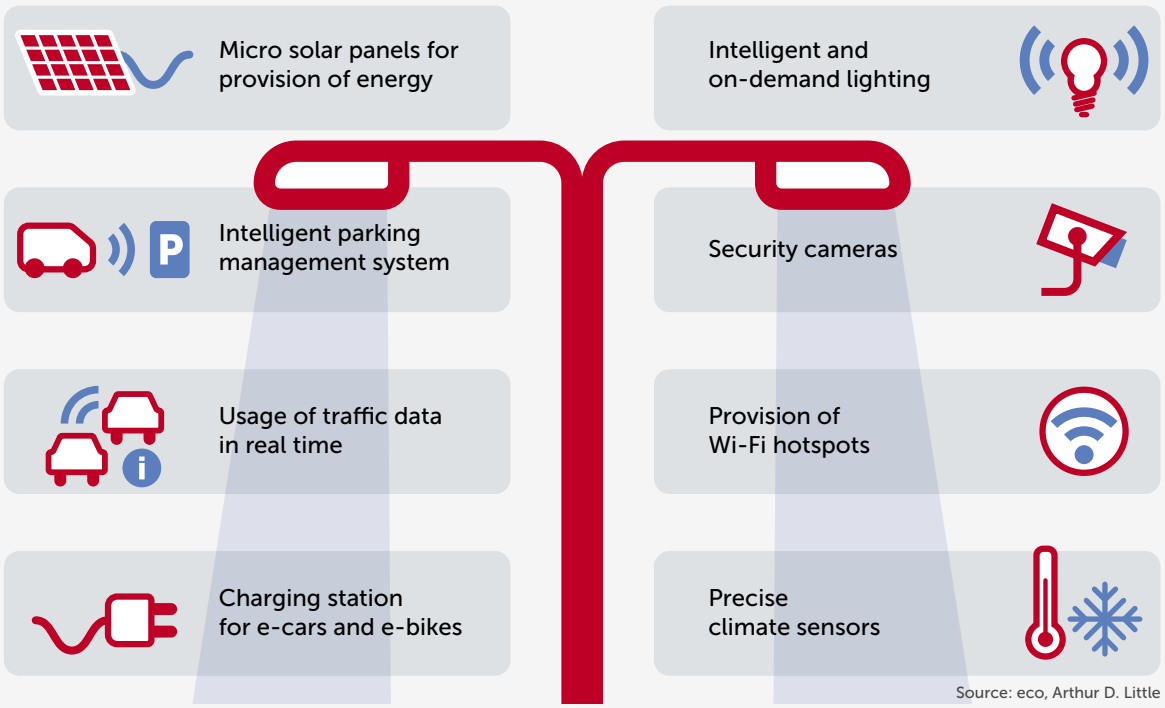
Energy

The strongest trend and at the same time the greatest challenge is the expansion of electric charging stations as a central basis for sustainable mobility. Car manufacturers like Tesla no longer act solely as original equipment manufacturers (OEMs), i.e. pure vehicle manufacturers, but also as infrastructure providers and energy suppliers. Industry experts see the competition on the market as correspondingly high: Energy suppliers, municipal utilities, heavyweights from the automotive industry, new start-ups and foreign competitors are contending for the charging station business model. According to Statista, the share of purely electric vehicles in the passenger car sector is still only around 0.58 per cent. But with the ever-increasing share of new registrations of electric vehicles, this picture will change in the long term.

Financial Services

The financial sector is currently in a state of upheaval. Numerous "FinTechs" are revolutionising the financial sector – enabled by diverse technologies such as predictive analytics, blockchain and digital identities. Through these, entirely new ecosystems are forming, consisting of traditional banks, insurance companies and "FinTechs". The result is that more and more online payment methods and apps are available to customers. The first digital-only banks are even completely dispensing with physical customer contact. During the pandemic, they were able to gain many new customers. Other start-ups are developing new, digital forms of currency – crypto currencies. Although cities should not participate in the "mining" of digital currencies – not least for reasons of sustainability – they will be challenged in the coming years to enable the framework conditions for the use of innovative financial services in the everyday lives of citizens. With the market penetration and product maturity of blockchain, the "Financial Services" segment will change completely and ultimately also pave the way for "embedded finance". Payments, loans and insurance can be processed automatically in the background of digital services through Smart Contracts and their equivalent. "Embedded finance" includes, for example, the complete automation of payment processes in e-commerce, the integrated granting of instalment loans, or the provision of digital wallets. Smart Cities can standardise and simplify payment methods in public transport and public administration.

FIG. 2 **Possible Applications for Smart Street Lights**



Source: eco, Arthur D. Little

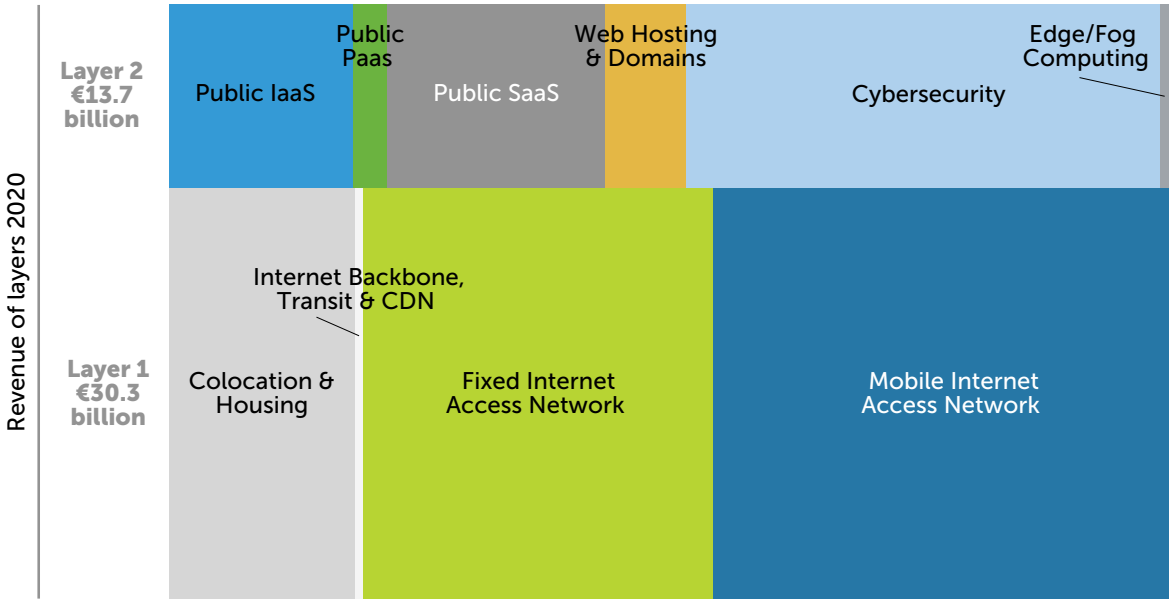
Focus: Smart Lighting

The Smart Lighting service example clearly illustrates how individual elements of the Smart City can be interconnected. In the context of the Smart City, Smart Lighting is strictly understood as the intelligent control of lighting in streets and public buildings. Light and motion sensors can be used to adjust the lighting to the current lighting conditions and requirements. This saves energy on the one hand and costs on the other. In addition, necessary maintenance measures can be predicted and optimised on the basis of the collected data. In a broader sense, however, Smart Streetlights primarily offer a platform for services from various other segments, as Figure 2 illustrates.

Among other things, the lights can house:

- Climatic sensors to provide information about temperature, weather conditions or air quality. This provides, for example, clearing services in winter with real-time indicators for their operations.
- Wi-Fi hotspots. In this way, citizens gain access to energy-efficient network services.
- Sensors for traffic and Smart Parking. This allows a large amount of data to be collected for intelligent traffic control.
- Solar systems, to cover the light's own energy needs and to enable and support the operation of charging stations for e-cars and e-bikes.

FIG. 3 **Revenue of the Internet Industry in Germany 2020 (in % of the revenue volume of the respective layer)**



Layers 1 and 2 of the Internet Industry in Germany (particularly relevant segments for Smart City highlighted)

Source: eco, Arthur D. Little

2.2 Revenue and Market Growth 2021-2026

Layers 1 and 2 of the Internet Industry as enablers of the Smart City

In **Layer 1, "Network, Infrastructure & Operations"**, more than 80 per cent of the revenue volume of 30.3 billion Euro in 2020 was generated by the marketing of Internet access in the mobile and fixed network sectors. A large part of the remaining 20 per cent was generated by renting out data processing capacities in the form of Colocation & Housing. Layer 1 is, as a whole, well advanced in terms of market penetration and thus already in a development phase with lower growth rates. Nevertheless, the comprehensive implementation of innovations such as new broadband technologies in the fixed network (fibre optics) and mobile communications (5G), as well as more efficient, sustainable data centres, are needed here for the success of digitalisation and for the realisation of the Smart City.

Due to the continuing trend towards outsourcing and the increasing need for additional data storage and computing power capacities, revenues in the "Colocation & Housing" segment will continue to grow. The continuous increase in data traffic creates a strong demand for additional data centre capacity. Drivers of this increase are video streaming and a variety of entertainment services, as well as new digital business and application fields of the Smart City (e.g. connected cars, Smart Buildings, industrial IoT and 5G).

Another trend within the segment is the regionalisation of data centres and the roll-out of infrastructures for edge/fog computing. Access points are increasingly being brought closer to the immediate consumer (or closer to the producer in the area of Industry 4.0) in order to minimise any latencies, relieve the burden on networks and more easily ensure data security. Capacity utilisation in the data centres in Germany is good and will continue to increase over the course of the next few years, so that further new construction and expansion of data centres can be expected.

In **Layer 2, "Services & Applications (including IT & cybersecurity)"**, the total revenues of 13.7 billion Euro in 2020 were distributed relatively evenly between public cloud services and cybersecurity solutions as important enablers of digitalisation. Within the public cloud computing market, infrastructure and software services dominated in 2020. Layer 2 is, as a whole, in the central growth phase in terms of market maturity and thus continues to record high growth rates.

The growth trend of public cloud will continue in the coming years due to the attractiveness of the segment for a very broad customer base. Due to the high flexibility and scalability of solutions and the low capital commitment, cloud services are in demand from start-ups, medium-sized and large companies alike. A key growth driver of the demand for public cloud services is the integration of smart devices within the framework of IoT. The currently growing fields of IoT application include

some Smart City fields of application and related fields of innovation. Another growth driver is the multiplication of storage capacity, which is constantly expanding the service spectrum of cloud solutions.

Due to changes in the regulatory framework in Europe, as well as growing awareness of online threats and the upswing in digital business models, the demand for cybersecurity solutions in Germany is growing significantly. At the end of May 2018, the provisions of the General Data Protection Regulation (GDPR) came into force in the European Union. The increased awareness of data protection throughout the German economy has helped the segment to achieve additional growth. The increasing demand for cloud services is another growth driver for cybersecurity.

Edge/fog computing enables the relocation of data processing from a data centre to the periphery of the IT network (edge) or into the network (fog). Data generated by machines and sensors on site are collected, stored and immediately processed by a server at the network input node (edge server). Such decentralised data architecture has two major advantages: First, edge/fog computing can accelerate data streams. Due to the local server structure, devices and intelligent applications can process data in close-to-real time (i.e. without significant latency) and react to it even during the generation process. High data transfer rates over the network to a remote data centre and the associated delays are eliminated. Second, edge/fog computing allows large amounts of unstructured data to be pre-sorted, interpreted and prioritised at the point of origin. As a result, only derived knowledge is forwarded to servers or the cloud and the network load is reduced.

The demand for edge/fog computing is increasing in line with the requirements for quantity, speed, security, scalability and flexibility of the data to be processed. Due to the current relatively low market penetration of sophisticated IoT applications, the German market for this segment remains very small. However, the volume of data to be processed and the relevance of real-time data will increase exponentially in the coming years, among other reasons due to the increasing availability and use of IoT solutions and the recently announced EU-wide goal of establishing 10,000 carbon-neutral edge nodes by 2030.

Case Study Cloudflare

from Thomas Seifert, Chief Financial Officer at Cloudflare

In order to realise the economic, civic and sustainable goals of Smart Cities, secure and, above all, reliable communication is needed. The Internet, with all its services and applications, provides the infrastructure needed to connect the smart building blocks of tomorrow's connected cities. Already today – and the Covid-19 pandemic has clearly accelerated this – digitalisation is advancing with great strides. Therefore, now is the ideal time to adapt processes and move them into the digital sphere.

For many industries and companies, at first glance this step appears to be too complicated, costly and time-consuming– but the opposite is actually the case! How does Cloudflare specifically help here? As a point of contact for cloud solutions, Cloudflare has made it its mission to support companies and organisations from all sectors in these steps – digitalising work processes and migrating data to the cloud. We make everything connected to the Internet safer, more private, faster and more reliable – exactly what Smart Cities need!

But what characterises Smart Cities in the first place and how does Cloudflare fit in? Smart Cities have a comprehensive ecosystem of communication networks, data centres and security infrastructures as their foundation. Cloudflare offers products such as DDoS protection and web application firewall (WAF) that protect these structures. In eco and Arthur D. Little's layer model of the Internet industry, Cloudflare is particularly relevant in Layer 2, as a provider

FIG. 4 **Cloudflare Data Centres Worldwide**

of "Services & Applications" for Smart Cities, when it comes to cybersecurity and the associated protection of data and its secure transfer. Cloudflare is also the first cloud solution provider to be certified according to the new ISO data protection standard (ISO/IEC 27701).

Looking at the individual market segments of Smart Cities and at the individual smart contributions to these, it becomes clear that cybersecurity is an elementary factor in maintaining connectivity and, above all, protecting it from possible harm. Attacks on security systems in building automation or in digital patient records in the health sector, or interference in the digital participation of citizens in the course of elections: these are all scenarios that are prevented by Layer 2 players. From the public sector to private companies and individuals, all organisations and citizens in a Smart City must be protected from such attacks.

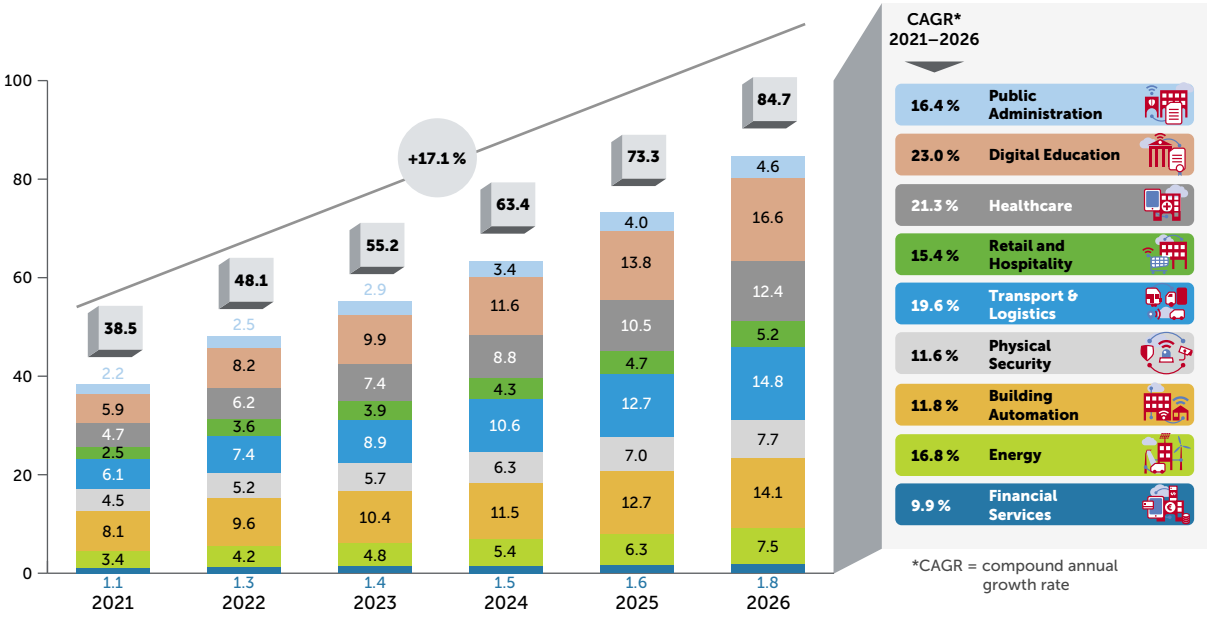
With its global network, Cloudflare helps to create a secure digital infrastructure for a sustainable future in Smart Cities worldwide. With every single location, websites, apps, APIs and IoT are even better protected and can even be accelerated. The future of life should not be characterised by fear of attacks on one's own data. The future of life should always do justice to all demands for security, speed, reliability and performance. And because Cloudflare cares about the future of life, we are happy to help shape it.

As a provider of web performance and security services, Cloudflare stands for:

- state-of-the-art and secure cloud solutions,
- cybersecurity that provides complete protection, even against sophisticated attacks,
- transparent services for data processing (e.g. regional services),
- secure and fast access to corporate resources thanks to Zero Trust and Cloudflare One,
- a simple network infrastructure with uniform architecture through SASE,
- the latest certified data protection with full control for the customer.

CLOUDFLARE®

FIG. 5 **Revenue and Growth of the Smart City Market in Germany, 2021-2026 (in billion Euro)**



Source: eco, Arthur D. Little

Note: The impacts of the Covid-19 pandemic on the Smart City market were taken into account in the modelling of the market.

Nine Smart City segments

By 2026, eco and Arthur D. Little expect significant revenue growth of 17.1 per cent per year on average in the Smart City sector in Germany. The growth potential extends across all nine market segments. However, a closer look at the individual areas reveals clear differences in size and growth dynamics. Figure 5 illustrates in which of the services or nine segments of the Smart City market companies, citizens and the public sector will invest the most in the years 2021 to 2026.

The revenue volume of the Smart City market in Germany, which is driven by public as well as private investments, will amount to around 38.5 billion Euro in 2021. In addition to numerous established Smart City providers and tech giants, new players – both large players and numerous start-ups – are increasingly entering the market.

Despite the already high volume in 2021 and the growth of the last few years, the overall market shows further dynamism from 2021 to 2026. In the period under consideration, eco and Arthur D. Little forecast an average annual growth in revenues of 17.1 per cent. As a consequence, revenues will develop to a level of 84.7 billion Euro by 2026. The market thus offers a promising business field for companies from a wide range of industries. The increasing convergence of various technological trends is driving the development of holistic Smart City platforms, applications and services, such as intermodal mobility and cloud platforms for end customers. Hardware and connectivity also remain fundamental market building blocks but, relative to applications, are losing in weight.

The key drivers of the German Smart City market are, in particular, the expansion of holistic and intermodal mobility platforms, spending on cybersecurity, further urbanisation, and an advancing wave of digitalisation in the health sector and education. In combination with increased environmental awareness among citizens, the demand is growing for ecologically sustainable initiatives and even more environmentally-conscious technological developments.

The five main market drivers are:

- In addition to public transport, commercial platforms such as Uber are driving the acceptance and use of car, bike and ride sharing business models. In combination with the development of autonomous means of transport, the mobility offer in cities is therefore facing a major transformation – moving towards "Mobility as a Service". This transformation towards a stronger focus on the customer and the benefits is accordingly reflected in the considerable investments by market players. Cities need to create an ecosystem for such sharing offers and corresponding cooperative initiatives.

Christoph Weigler, General Manager Germany, Austria and Switzerland at Uber

"Mobility brokerage services like Uber offer alternatives to owning a car. The transport transition needs an intelligently connected mobility mix of strong public transport and efficient shareable services. Only with this connection, and together, can traffic in cities be reduced and the environment relieved."

Uber

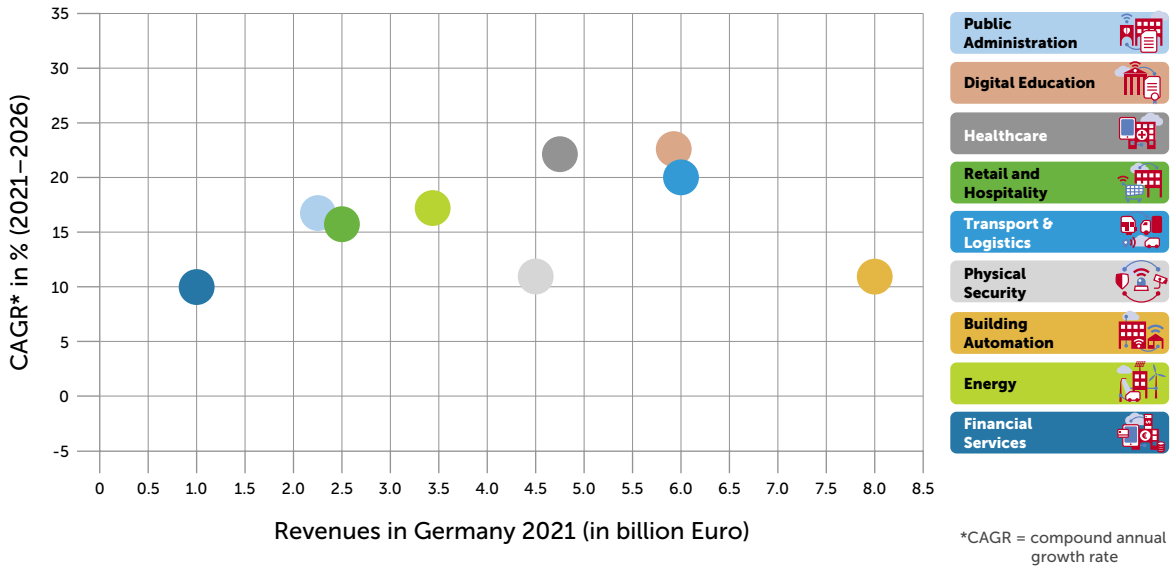
- Despite extensive investments in modern mobility strategies, there is still a strong demand for intelligent transport systems. Optimised multimodality or intermodality, i.e. the linking of public transport with other mobility services, can relieve inner cities in a sustainable way. Examples include the interoperability of rail travel and electromobility with CleverShuttle from Deutsche Bahn (The German Rail) or the integration of bicycles and e-scooters in the app of the Munich public transport company. In this context, cities need to manage complex traffic management solutions and the orchestration of mobility service providers.

- Due to the challenges posed by the Covid-19 pandemic, the digitalisation of public and private education has been and will be strongly promoted. This will require higher spending on hardware, software and services such as cloud platforms, as well as digital learning content in the future. A stronger focus on the area of "Digital Education" will improve the locational advantage and the quality of life of German Smart Cities in the long term.

- With the increasing implementation of Smart City building blocks, the amount of data generated is growing by the hour. Therefore, experts see a high demand for holistic data management platforms. Cloud solutions are the absolute driver here and represent an optimal solution for Smart Cities to establish reliable data integration and data evaluation across segments.

- Comprehensive networking in all market segments makes investments in IT security and communication infrastructure (e.g. fibre optics, 5G) indispensable. Many cities have yet to build the foundation of their Smart City, while others are already using their solid ICT infrastructure to exploit the numerous use cases.

FIG. 6 **Revenue and Growth Comparison of the Smart City Segments in Germany**



*CAGR = compound annual growth rate

Source: eco, Arthur D. Little

Note: The impacts of the Covid-19 pandemic on the Smart City market were taken into account in the modelling of the market.

The detailed comparison of all nine segments by revenue size in 2021 and annual growth 2021-2026 is shown in Figure 6. This illustrates the market potential in the area of Smart Cities.

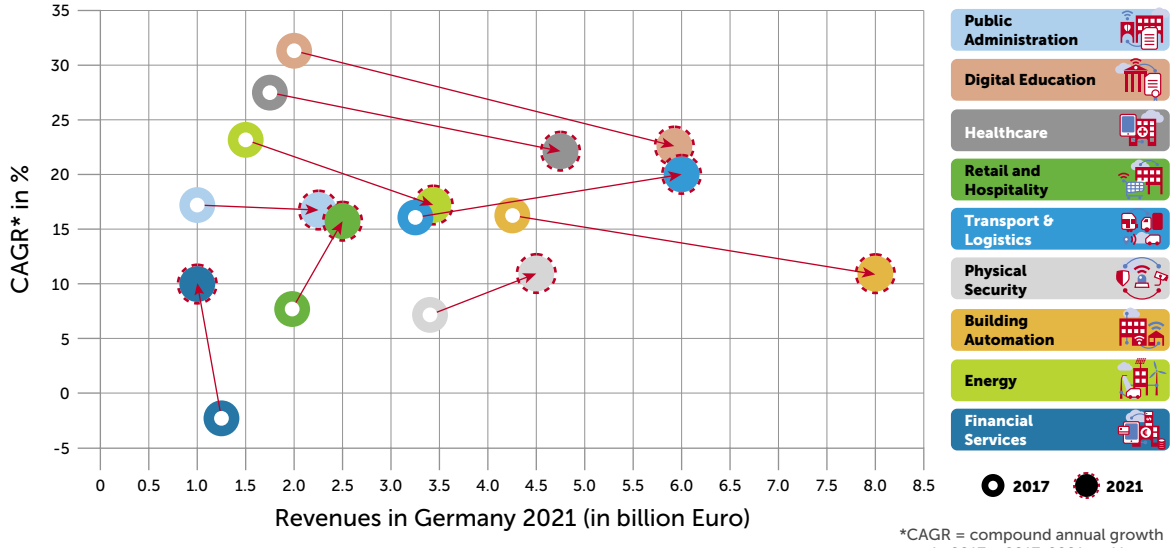
Figure 7 shows different growth dynamics of the market segments between 2017 and 2021 – both in terms of distribution and forecast growth in revenues:

- In 2021, the four market segments "Building Automation", "Transport & Logistics (Mobility)", "Digital Education" and "Healthcare" will account for over 64 per cent of the total Smart City market. The dominance of these segments will not have changed by 2026.

- With annual growth of around 23 per cent, the market segment "Digital Education" is growing the fastest and can thus catch up somewhat in comparison to leading countries. In the view of eco and Arthur D. Little, the international pioneer is Sweden, where holistic digitalisation concepts have been pursued for a long time.

- The segments "Financial Services" and "Retail & Hospitality", on the other hand, will record comparatively moderate growth of around ten and 15 per cent respectively by 2026 and are among the smaller segments of the Smart City market, with revenues of just under two billion Euro each in 2021. Relatively low growth over the course of recent years is due to, among other aspects, the moderate increase in digital advertising space, whose revenues (2017) accounted for just under 40 per cent of the segment. Nevertheless, a closer look shows that sub-segments and growth areas such as location-based services and cashless online payment methods (e.g. PayPal) will gain in importance and show annual growth rates of up to 30 per cent.

FIG. 7 **Development of the Smart City Segment Comparing 2017 and 2021**



*CAGR = compound annual growth rate in 2017 = 2017-2021 and in 2021 = 2021-2026

Source: eco, Arthur D. Little

Note: The impacts of the Covid-19 pandemic on the Smart City market were taken into account in the modelling of the market.

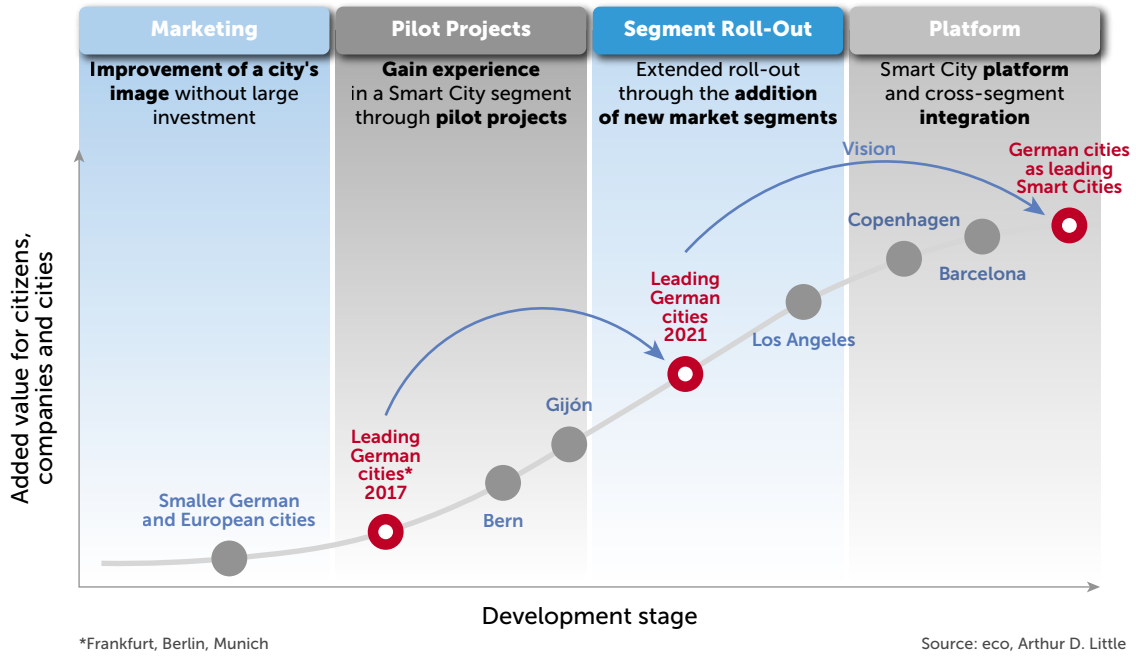
2.3 Need for Action by German Cities

A look at global Smart City indices shows that three German cities - Hamburg, Munich and Berlin - are those typically cited in international comparison. While pioneers like Barcelona are setting up extensive Smart City platforms and can boast over 200 projects each, German cities are only slowly moving from isolated pilot projects to the holistic expansion of segments and platforms (Figure 8). Exciting examples of this are Cologne, Berlin, Hamburg and Munich. These cities illustrate that high population density, financial clout and an extensive fibre network are key factors for the implementation of Smart City platforms. However, if we look at medium-sized European cities instead of global metropolises, we see that German cities are increasingly represented in the rankings: increasingly, but still far too seldom. According to experts, in the medium-term so-called Level 2 cities – or medium-sized cities, i.e. cities with about 100,000 inhabitants – must be equipped with financial resources and the basic technical infrastructure. The goal of these cities and municipalities should be to create the right framework conditions to generate entrepreneurship and innovation.

Subsidies are particularly suitable for medium-sized cities and municipalities to get started in the "Marketing" and "Pilot" stages. In a new round, the "German Reconstruction Loan Corporation" (Kreditanstalt für Wiederaufbau – KfW) and the German Federal Ministry of the Interior (BMI) are funding 32 "Smart City Model Projects" to the tune of over 350 million Euro. These include cities such as Mannheim, Paderborn, Rostock and Gelsenkirchen, as well as 12 inter-municipal collaborations and districts. In addition to this specific Smart City support, there are a large number of other initiatives in Germany:

- The climate protection initiative "Municipal Climate Protection Model Projects" (Kommunale Klimaschutz-Modellprojekte) is offering support for financially weak municipalities with up to 10 million Euro in grants for sustainable Smart City projects until the end of the year.
- The "Energy-Efficient Construction and Renovation" (Energieeffizient Bauen und Sanieren) initiative supports municipalities in the construction of new non-residential buildings with loans of up to 25 million Euro.
- With the information platform of the "Stadt.Land.Digital" initiative, the German Federal Ministry for Economic Affairs and Energy (BMWi) supports municipalities in their target group-oriented search for funding to develop a Smart Municipality or Region.

FIG. 8 **Smart City Development Stages: German Cities in International Comparison**



*Frankfurt, Berlin, Munich

Source: eco, Arthur D. Little

Cities such as Cologne, Munich and Hamburg rely on so-called "neighbourhood development" to implement their Smart Cities. In the process, neighbourhoods and districts undergo transformation in the spirit of the Smart City. Initially, such Smart Neighbourhoods serve as pilots, on the basis of which the concepts developed can subsequently be scaled up. The so-called "digital twin" has proven to be a particularly helpful tool. In Industry 4.0, this enables the constant optimisation of processes and production procedures, as well as the prediction of maintenance requirements. In the context of the Smart City, urban planners and technicians can transform their city into a virtual model and ultimately simulate and test energy grids, traffic flows and the equivalent.

According to experts and decision-makers, however, co-ordination efforts and legacy interfaces between the contracting entity, providers and adjacent stakeholders – such as property or building owners – are hindering the rapid implementation of the Smart City. Complicated permission and approval processes cost time and resources on the part of IT providers and cities. Another organisational challenge is data management. The countless data sources, such as sensors, apps and systems, must be brought together and orchestrated within the framework of data protection. This process is extremely complex and expensive, so that smaller cities in particular reach their financial limits. Examples such as that of the City of Cologne illustrate how successful cooperation between different players can succeed.

Case Study Cologne

The City of Cologne laid the foundations for its Smart City early on. With one of the largest shares of fibre-optic in Germany, optimal conditions exist for the digitalisation of schools, public administration and hospitals. In addition to setting up high-performance networks, the City of Cologne and the Cologne utilities provider are also addressing the challenge of data management in order to be able to build knowledge on the basis of the data generated. By creating a sustainable infrastructure, a central basis for efficient scalability and replicability of Smart City use cases is to be established. In this way, decentralised data can be integrated and made usable across segments.

In Cologne, the close cooperation between the administration and municipal companies (including NetCologne, RheinEnergie, AWB Abfallwirtschaftsbetriebe Köln, KVB and HGK) is a central success factor in this regard. This can not only be target-oriented with regard to efficient approval processes for a further roll-out of fibre-optic cables, but also in the identification of suitable antenna and sensor locations in building management. The following projects are exemplary:

- **Smart Education:** The infrastructure roll-out in the field of education has been exceptionally high. Cologne has a school and operational model that has been established for years:
  - → All schools are connected to the NetCologne fibre-optic network with symmetrical 1 Gbps access.
  - → 5,300 access points provide 250 schools with Wi-Fi coverage.
  - → The IT landscape has been modernised with central management of user data for the use of different cloud services (central identity management system).
  - → A total of 60,000 Apple and Windows devices are in use at schools – the number of iPads in particular has risen sharply during the pandemic.
  - → There is a support and operating model for the IT infrastructure at Cologne schools.
  - → The City of Cologne has extended the provision of Microsoft 365 to secondary schools and special needs schools

- **Smart Climate:** Due to the impacts of climate change, current weather data and long-term climate data have become essential factors for urban decision-making and work processes. Services of general interest also include precautions against extreme weather events and the long-term negative developments of climate change. Cities need accurate, up-to-date and, in particular, local data in order to be able to act quickly and sustainably. The "Smart Climate" project is developing a comprehensive and continually updated data platform – a digital climate twin of the city – via a tight grid of environmental sensors.

- **Smart Parking:** In the Cologne district of Nippes, RheinEnergie and the City of Cologne have implemented the "Smart Parking" use case in close cooperation with the Munich-based company Cleverciti Systems and with financial support from the German Federal Ministry of Transport and Digital Infrastructure (BMVI). One of the aims of the "ParkPilot" project is to relieve traffic and ease the parking situation in the area. The project will equip around 800 parking spaces with 80 sensors to show drivers where a free parking space is available and to detect parking infringements. Furthermore, 27 displays have been mounted on lampposts to show the next available parking space in real time. In a further step, RheinEnergie is supplementing these measures with a simple smartphone app. The system has been in operation since June 2020. The initial results indicate that the system is accepted by the road users and that it works. Compared to January 2020, parking occupancy has increased from 88.3 per cent to 96 per cent. Sixty six per cent of the originally available and scarce parking spaces can be found specifically with the help of the system, thus reducing the amount of traffic searching for parking spaces. Internal evaluations of the system have also shown that it reduced the average time spent looking for a parking space by 45 per cent and the distance travelled by 41 per cent.

- **Smart Neighbourhood:** In the Stegerwaldsiedlung district in Cologne, there is a so-called "Smart Neighbourhood". The EU Horizon 2020 project "GrowSmarter" enables holistic smart and ecological living. With the project spread over 689 residential units on a total area of 39,000 m^2, RheinEnergie is demonstrating that decentralised energy supply can work. Within the scope of the energy modernisation, the cellar ceilings, attics and roofs of the buildings have been insulated. Furthermore, windows have been replaced with triple glazing. In some cases, the attics of buildings have been extended. This has increased the total number of apartments by 95 and the living space in the buildings by

5,000 m². The stairwell lighting has been replaced with efficient LED lighting and energy-efficient lifts have been installed. The former gas-powered central heating systems have been replaced with modern central heating systems. Heat is supplied, among other things, by 41 electrically operated air-to-water heat pumps from RheinEnergie, which are powered by a combination of photovoltaic systems and storage batteries. All energy systems are connected via the "Neighbourhood Management" energy management software and are thus controlled and optimised in an integrated manner. The above-mentioned measures have reduced CO_2 emissions by 72 per cent and the primary energy factor by about 78 per cent.

Statement from Timo von Lepel, Managing Director NetCologne:

Especially in the past months of the Covid-19 pandemic, it has become clear that resilient infrastructures and cities are vital for the survival of our future society and economy. This applies to Cologne, but also to all other cities and municipalities.

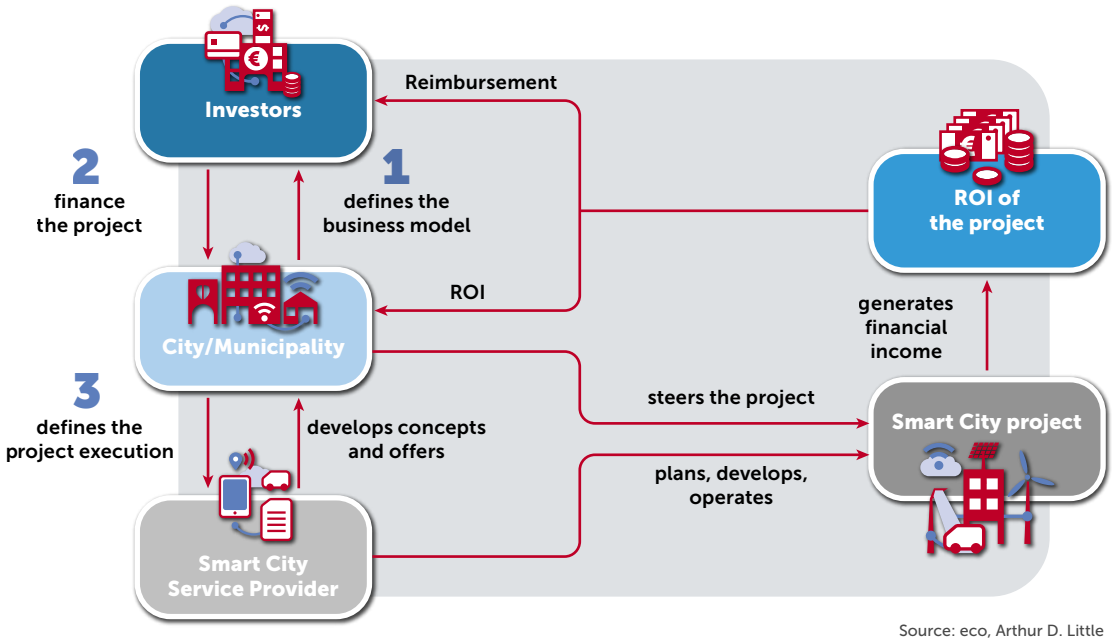
Digital infrastructures are a central basis for this resilience. This involves the construction and operation of high-performance communication networks such as fibre optics, Wi-Fi or LoRaWan – but in Cologne we understand the term digital infrastructure to mean even more. In addition to providing high-performance networks for the urban society, it is also about creating a more extensive infrastructure to make data usable in the first place – to generate information and thus knowledge from data. To achieve this, new data sources must be developed using suitable sensors, and IT standards and IT infrastructures must be established to enable the integration and analysis of this data. In such an Internet of Things environment, we can leverage efficiencies through digitalisation in almost all areas of life and work. This conserves resources and makes the city more liveable. In this way, digital infrastructures and digital technologies make their contribution to sustainability and the achievement of climate goals.

We will only be able to build our social and economic future with a Smart City if we can act and decide in a self-determined manner on the basis of digital sovereignty. To achieve this, we are working with the various stakeholders in the city on three focal points:

1. **Building and operation of efficient and secure digital infrastructure**
2. **Building and mastering key competences and technologies**
3. **Building a functional digital ecosystem**

NetCologne

FIG. 9 **Investment Infrastructure for Smart City Projects**



Source: eco, Arthur D. Little

3. Modern Financing Options as Levers for Smart Cities

For both large and small cities, as well as entire regions, there are numerous new points of departure for expanding segments and taking the step towards holistic Smart City platforms. The high speed at which the private sector is moving forwards and the increasing convergence of innovative technologies are compelling cities to follow suit. This is being done in order to provide state-of-the-art infrastructure – in national and international comparison – for citizens and industry.

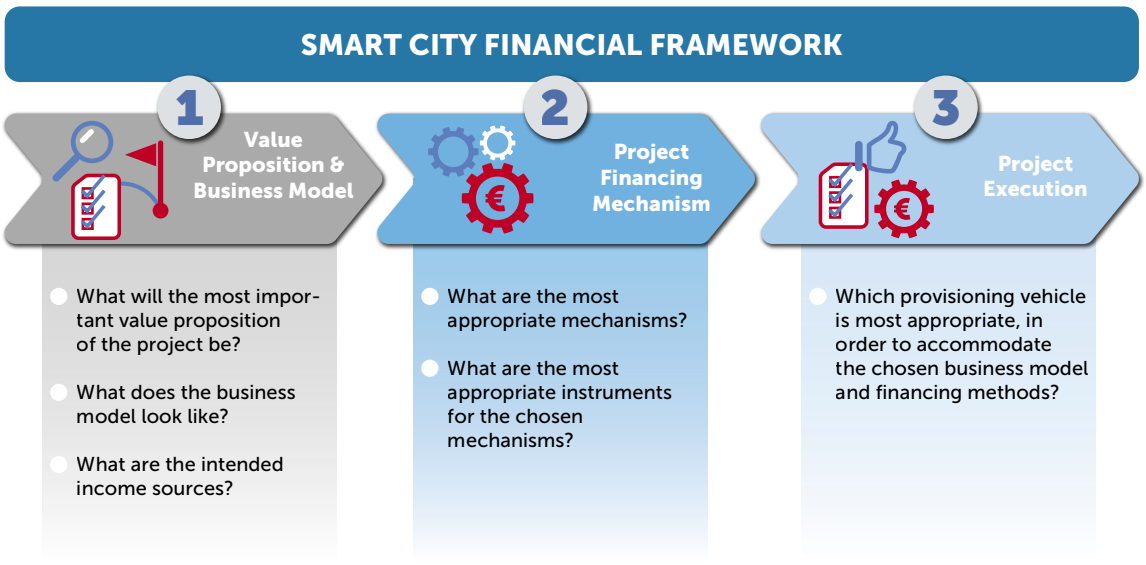
Which drivers are important from the perspective of mayors and decision-makers? The return on investment for cities from Smart City projects is multifaceted. This motivates them to take on additional Smart City projects: to protect the environment, promote sustainability, increase civic security, promote innovation and reduce costs.

The basic challenges are the high initial costs and the increasingly limited public budgets, with the latter exacerbated as a result of the Covid-19 pandemic. Many municipalities have to tightly economise due to debts – they can barely move beyond their obligatory expenditure and therefore have to prioritise projects. Apart from financial support through model projects of the EU and the German federal government, cities and municipalities have to raise most of the funding from their own resources. As such, German cities are prone to lagging behind when it comes to the latest developments and opportunities. But in this regard, digital services and business models in particular offer numerous opportunities to obtain important funding, as examples in New York City, Eindhoven and Manchester illustrate. This is why new financing concepts, to which German cities should also pay more attention, are increasingly gaining ground in the context of Smart Cities.

3.1 Financing Options for Smart City Projects

By adding private investors, reliable and urgently needed funding can be acquired for Smart City projects. Potential private investors include investment companies and banks, as well as large, financially strong IT companies. In particular, the latter financing-enablers can contribute additional valuable resources and the type of know-how that is usually not available to public institutions. The experience of eco and Arthur D. Little also shows that infrastructure funds are increasingly willing to invest in Smart City projects. A combination of public budgets, subsidies, private investors and IT companies is also possible.

FIG. 10 **Three-Step Smart City Masterplan**



Source: eco, Arthur D. Little

Figure 9 shows an exemplary complex of co-financing by private and public investors.

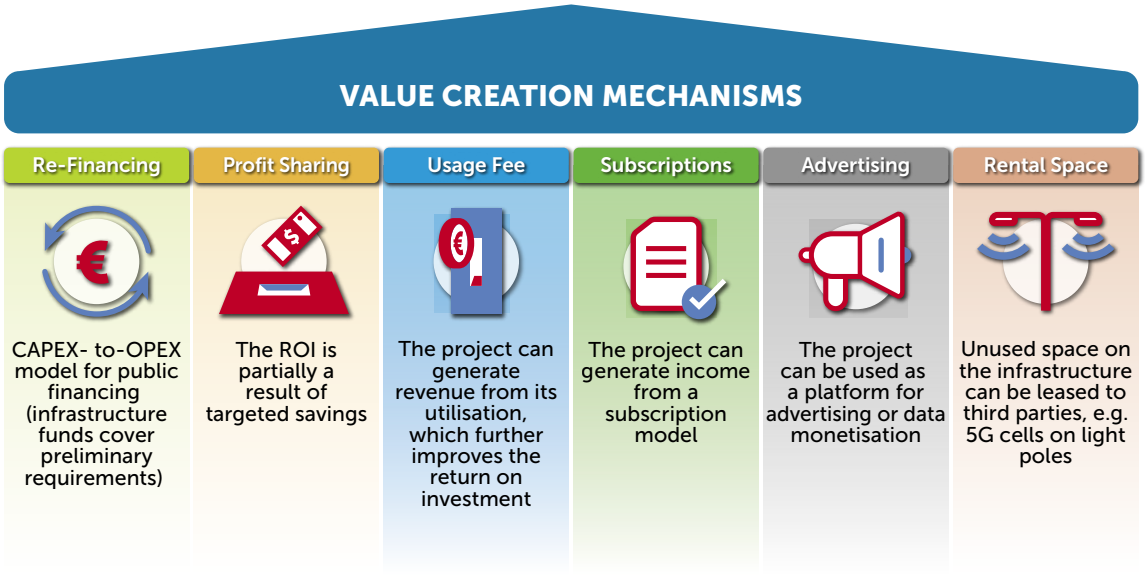
Cities should take an integrated approach to financing Smart City projects across the key project phases. eco and Arthur D. Little see three stages as essential for overall financial planning. Figure 10 shows the process of financial framework planning. What lies behind each of the stages is explained below.

1. Development of the value proposition and the business model

Decision-makers often only relate the costs of the Smart City project to the cost savings which can be realised. However, many Smart City service modules also bring many other – also monetary – advantages. The continual connection and digitalisation of services generate significant cost advantages as well as new digital business models (for example mobility offers), usage concepts and versatile sources of income, such as data, user fees or advertising media. This is where the basis for new financing models emerges. Figure 11 provides a clear overview of the central refinancing sources. In addition to cost reduction, the following revenue sources in particular are interesting for for German cities striving to become Smart Cities.

- Municipal infrastructures such as 5G networks, fibre-optic connections or Wi-Fi hotspots can be made available to third parties for a usage fee.
- Unused infrastructure such as Smart Streetlights can be leased to private companies as cells for 5G networks or for sensors.
- The data generated from the Smart City building blocks can be commercially marketed and simultaneously used to improve public services, taking into account the GDPR and other legal frameworks.
- Renting out additional advertising space – for example on Smart Bins or digital information surfaces – generates additional revenues.

FIG. 11 **Value Creation Mechanisms in Smart City Ecosystems**



Source: eco, Arthur D. Little

2. Selection of the funding mechanism

Based on the business models and sources of revenue and refinancing identified, decisions can be made about the form of financing and the design of the financing mechanisms. In principle, the following mechanisms are available to Smart Cities:

Funding Mechanism	Description
Traditional project financing	Traditional financial valuation of the project focusing on future cash flows.
Loans and leasing contracts	The project is paid for over time, with payments coming from the public sector or consumers – usually through a third party.
Supplier financing	The financing comes from a provider, e.g. an equipment vendor or a building contractor, who can better assess the risks involved.
Consumption-based financing	Financing is provided via the supplier level and is paid by the project owner according to consumption. The capacity can be adjusted according to need.
"As-a-Service" financing	The technology is purchased as a service and not directly.
Preferential financing	A concession is granted, giving the project additional revenue and a lean cost base.
Financing with revenue sharing	The project receives funding through the offer of a share in future revenues.
Equity financing	Funding comes from a third party that acts as a strategic partner and, for example, scales the model to other cities.

When making the selection, what must be taken into account above all are the individual requirements with regard to time, growth dynamics and other criteria. Rights, roles and rules within the funding constellation must be defined. Industry experts recommend developing transparent key performance indicators (KPIs), identifying risks, and assessing the value of investments based on these and other aspects. The usual instrument deployed here is the payback calculation to compare different constellations and financing mechanisms for each use case.

3. Determine suitable options for project execution

In a further step, the involvement of investors and providers must ultimately be determined. Traditionally, public authorities have sought a low level of private stakeholder participation in the form of direct delivery of products and services or conventional purchasing processes based on specific requirements. With the new refinancing sources mentioned above and the complex requirements of Smart City projects, a stronger participation of private stakeholders proves to be an interesting project delivery option. Examples of this are joint ventures or licensing agreements. These offer decision-makers a clear definition of tasks and responsibilities, but still entail a high level of risk with little flexibility. An even stronger bond can be implemented through partnerships or franchising. These variants allow for better knowledge transfer between a city and provider, as well as a flexible setup. However, such constellations require special framework conditions (trust, processes, etc.). The example of Gijón illustrates such privatisation in the form of supplier financing.

Smart Lighting in Los Angeles

The example of Smart Lighting (see Figure 2) in Los Angeles showcases the diverse business models and their advantages. The city identified four key refinancing sources to replace the inefficient street lights with new LED lights:

- Energy saving potential (63 per cent)
- Savings through optimised maintenance and servicing (USD 2-3 million)
- User fees for EV charging stations
- Leasing fees of cells for 4G technologies

Based on these cash flows, the city decided to integrate the Bank of America into the project as a private investor and lender. In the form of classic loan financing, the financial resources were provided by the bank and repaid over 10 years with the help of the energy savings and the cost savings for maintenance. Furthermore, additional income could be generated. Analyses by eco and Arthur D. Little estimate that, in such a case, a return of even about 10 per cent can be achieved. Such projects prove how a Smart City can be advanced, even without state subsidies.

Energy Management System in Gijón

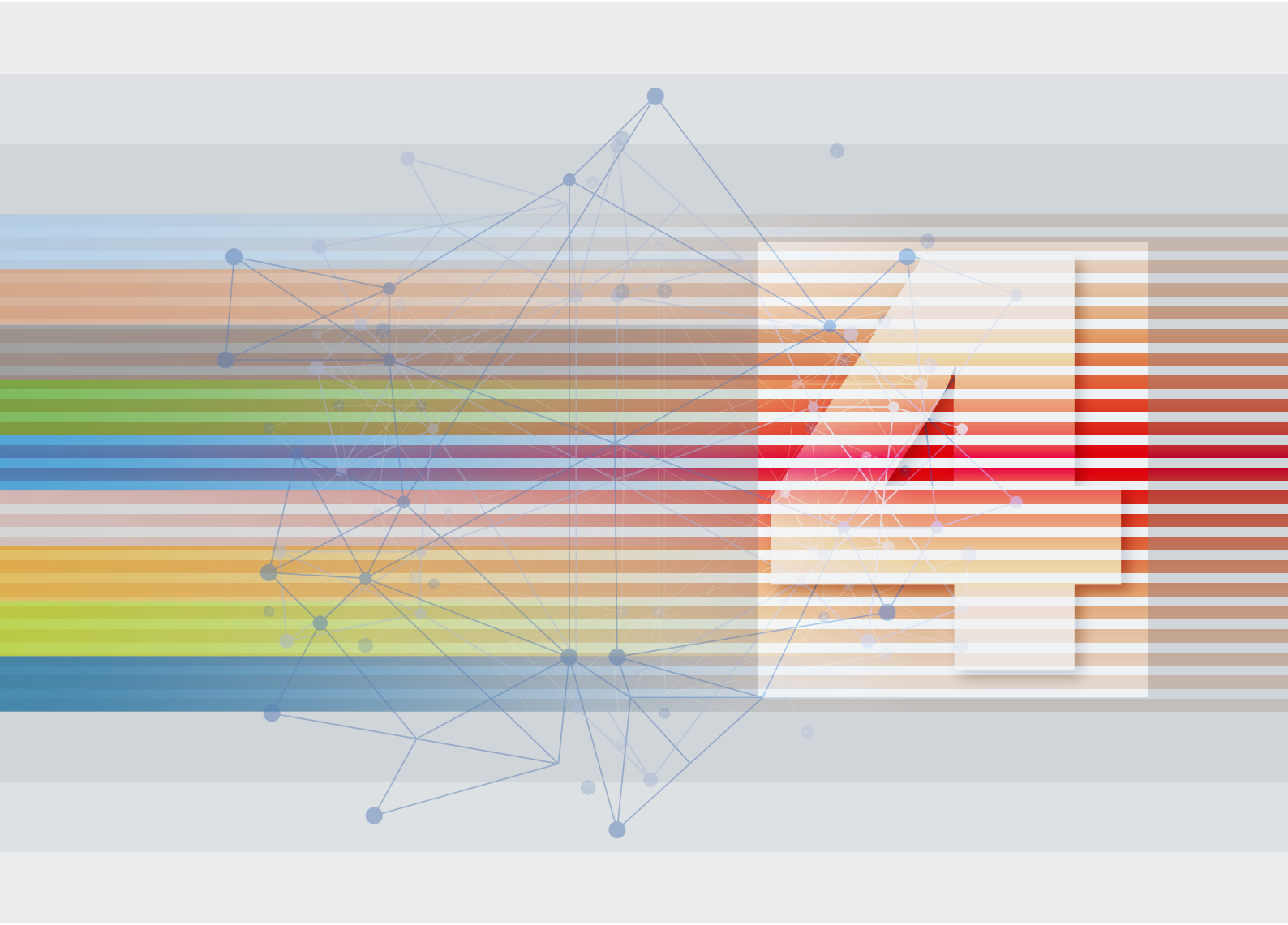
The city of Gijón on Spain's north coast is one of many Smart Cities in Spain that is driving innovation with great dynamism. In order to achieve its goals – for example, saving energy, creating ecosystems of innovation, modernising public administration and promoting technical and organisational know-how – the administration has taken new, bold paths in awarding and financing Smart City projects. A striking example is Gijón's Smart Energy Management System. Here, the municipality set up an elaborate tender procedure, defined basic requirements for the system, and left the issue of financing and implementation to the bidders. Such "vendor financing" means that the business partner – usually a large IT service provider – is responsible for financing the project, selecting other business partners and coordinating them. In the case of Gijón, for example, subsidies were also to be applied for by the supplier. Based on a technical scoring and the consideration of the project price, the best provider was selected.

Advantages for the city:

The "vendor financing" offers the advantage that Gijón can rely on the expertise of the business partner in finding reliable funding, partners and ultimately IT service providers. Furthermore, the city has been able to save resources and communication efforts in this way, as only one exchange between the city and the business partner was required.

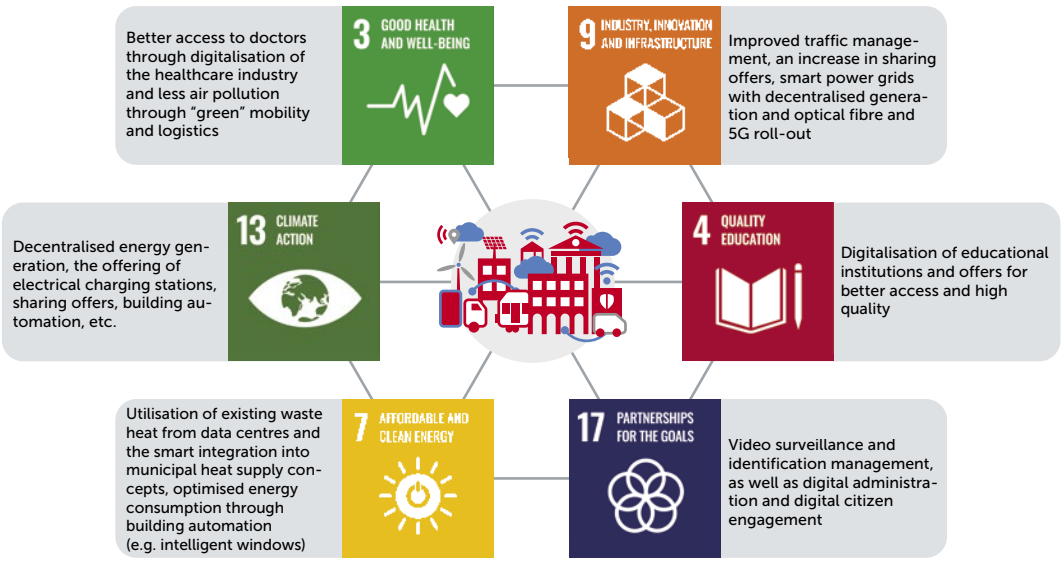
Advantages for the supplier:

The Gijón financing model has been well suited for IT providers, but also for investors, to enter the market and subsequently scale the technologies and business models. At the same time, they benefit from the close exchange with central decision-makers in Gijón. This gives them access to information, public processes and further tenders, and thus enables them to better manage strategic decisions and investments.



Vodafone Institute
for Society
and Communications

FIG. 12 **The Smart City and the UN Sustainable Development Goals**



Source: United Nations, eco, Arthur D. Little

4. Smart Cities and Sustainability

4.1 Consideration of Sustainability in the Smart City

Smart City initiatives offer immense potential to achieve the sustainability goals that have been formulated by the UN and the EU, and to which the German federal government has also committed. The targeted use of innovative technologies and digital applications in the context of the Smart City enables the saving of resources and increases in efficiency, and thus contributes significantly to climate protection. In times of increasing awareness of the climate crisis, this is a crucial factor. While, nationwide, CO_2 emissions have been steadily reduced in Germany in recent years, the climate targets in 2020 would have been severely jeopardised without digital technologies and applications, which were increasingly used during the Covid-19 lockdowns. This is because the eco-balance of digital technologies and applications is clearly positive when used properly. This can be implemented and monetised – if necessary, also in combination with new business models – in an exemplary manner in the context of the Smart City.

In 2019, the German federal government passed the Climate Protection Act. However, based on new EU requirements and the resulting inadequacy of the measures adopted, the climate targets for Germany were sharpened in May 2021 and binding emission targets were adopted. In principle, the German climate targets are ambitious: By 2030, greenhouse gas emissions are to be reduced by 65 per cent (in the EU, the requirement is a minimum of 40 per cent) compared to 1990 levels. Ultimately, Germany is to be completely carbon-neutral by 2045, while the EU only assumes a reduction in emissions of 80 to 95 per cent. In line with these objectives, German cities and Smart Cities in particular are pursuing an ambitious climate policy. Munich, Heidelberg, Berlin and other large cities want to be carbon-neutral by 2050. Compared to international leaders, however, the goals do not seem to be overly ambitious. Copenhagen, for example, plans to be carbon-neutral by 2025. Smart City concepts play a decisive role in this context.

Carbon-Neutral in 2025 – Copenhagen's Smart City Approach

Despite an expected population increase of around 20 per cent in the next ten years, Copenhagen has already set itself the goal of carbon neutrality for the year 2025. With this, the Danish capital wants to be the first carbon-neutral metropolis in the world and prove that sustainable living can be in harmony with economic growth and technological progress. A three-stage plan based on the four central pillars of energy consumption, energy generation, city management and mobility will lead Copenhagen to this unique goal.

Pillars	Targets for 2025
Energy consumption	→ 20% reduction in heat consumption → 20% reduction in electricity consumption in companies → 10% reduction in electricity consumption in households
Energy generation	→ Carbon-neutral district heating supply → Wind power and energy generation through sustainable biomass
City management	→ 40% reduction in energy consumption of public buildings → Carbon-neutral municipal vehicle fleets → 60,000m² of solar panels on public buildings
Mobility	→ 75% of all mobility is carried out on foot, by bicycle or by public transport → Public transport is carbon neutral → 20-30% of all light vehicles run on new environmentally-friendly fuels → 30-40% of all heavy vehicles run on new environmentally-friendly fuels

Copenhagen's Smart City strategy thus has a strong focus on smart and decentralised energy supply systems, Smart Buildings and Smart Homes, promoting and enabling alternative fuels, and strengthening public transport. Between 2005 and 2014, annual emissions had already been reduced by 31 per cent. Even though the city missed its 2016 target by 300,000 million tonnes of CO_2 emissions, the city's effort and transparency on climate issues is impressive and a model for many European cities.

eco and Arthur D. Little have found that all Smart City segments positively influence the sustainability of cities, i.e. also the quality of life and infrastructure in cities in general. A variety of service examples have been proven to lead to reduced resource consumption (for example, reduced energy consumption or paper consumption). In combination with the increase in the share of renewable energies, fossil-fuel resources can thus be spared and CO_2 emissions reduced. In many areas, Smart Cities reduce not only emissions, but at the same time also cut down on noise pollution and air pollution.

A qualitative comparison of the individual service modules of the Smart City with the UN's Sustainable Development Goals leads to the following findings:

- All segments – at least in the form of individual services – contribute to climate protection when used correctly. In most cases, intelligent control of systems save resources and thus directly or indirectly reduce greenhouse gas emissions.
- Especially in the areas of "Transport & Logistics (Mobility)", "Energy" and "Building Automation", the increased use of renewable energy and the increase in energy efficiency – achieved through the use of digital technologies and applications integrated into an urban planning context – can contribute significantly to the climate goals. Here, cities have a large influence, but at the same time face great challenges and high financial hurdles: large project scopes, numerous important stakeholders, countless interfaces and consequently an enormous coordination effort.

4.2 Sustainability Effects of the Smart City Segments

A large proportion of the positive environmental effects of Smart Cities can be attributed to "virtual mobility". Virtual meetings reduce travel and journeys: Telemedicine eliminates trips to the doctor, e-banking eliminates trips to the nearest bank, online shopping eliminates trips to the city centre. The possible use cases extend across all segments and they have become increasingly established due to the Covid-19 pandemic. For example, in a study, Greenpeace was able to demonstrate the environmental benefits of working from home, while the University of Freiburg was able to prove the positive climate balance of virtual and hybrid conferences.

Layers 1 and 2 of the Internet Industry

Not only the streaming of video calls, films or series, but also the operation of IoT solutions require energy-efficient communication systems and data centres. Studies have shown that fibre optics and 5G have enormous advantages over their predecessors DSL and 3G, due to the more efficient transmission of data. According to Vodafone, the transmission of mobile data using 5G infrastructures is 98 per cent more efficient than its transmission with 3G. The energy produced by the transmission process can in turn be used efficiently: Waste heat from data centres can be utilised, for example, to operate "vertical farming" (systematic and scaled indoor farming) or even to supply residential areas with heat. According to a study by the Borderstep Institute, all private households and office buildings in Frankfurt could be supplied with waste heat from data centres by 2030. In addition, many large network operators, such as Vodafone, promise to make their infrastructure and processes carbon-neutral in the coming years with the help of renewable energy, the circular economy and green IoT solutions.

eco and Arthur D. Little have examined selected segments for the most important sustainability aspects:

Transport & Logistics (Mobility)

In the area of "Transport & Logistics (Mobility)", holistic, intermodal and connected transport platforms and increasing offers of sharing concepts provide high potentials for climate protection. This is due to a reduction in individual transport and through the associated reduction in emissions. Indirect effects from optimising traffic include less congestion and waiting times, shortened search times for parking spaces, more efficient ways of driving and, finally, climate-friendly modes of transport. Overall, the "Transport and Logistics" sector makes a significant contribution to reducing CO_2 emissions through direct and indirect sustainability effects. For city dwellers, the changes imply greater comfort, more flexibility and enormous reductions in time and stress.

Building Automation

Smart Lighting and the Smart Home can demonstrably increase energy efficiency and reduce CO_2 emissions. Already in 2017, the Fraunhofer Institute for Systems and Innovation Research ISI assumed a savings potential of around 20 per cent. With new trends such as the intelligent window handle from Vodafone, energy consumption can be optimised in addition to the air circulation in buildings. Public buildings and institutions can serve as role models for private Smart Home systems. In addition, predictive maintenance approaches can be used to constantly optimise CO_2 emissions.

Energy

Renewable energies are the fuel of the sustainable Smart City. This is because if the urban e-vehicle fleet or the private e-car is powered by coal-fired electricity, the footprint per kilometre is almost 25 per cent higher than with conventional combustion engines. To operate electric urban vehicle fleets and private car transport, the roll-out of electric charging stations powered by green energy is a central basis for sustainable mobility. In this

way, there would no longer be any consumption-based CO_2 emissions for e-cars.

The development of decentralised generation plants in German cities can further increase the share of renewable energies. For example, local solar and wind power plants are connected to decentralised grids and used directly as an energy source. This requires digitally supported Smart Grids that balance the volatility of energy generation with the required stability of the grids. The higher share of renewable energies can reduce CO_2 emissions for municipal buildings and properties, as is the case in Münster, by up to 30 per cent.

Healthcare

There is massive potential in this segment: Its share of global CO_2 emissions is 4.4 per cent. Investments in the digitalisation of hospitals and health authorities thus not only have a direct impact on the well-being of citizens, but also on the environment.

In addition to reduced CO_2 emissions through digital health apps, the consumption of textiles can also be reduced through circular business models and digital technologies in hospitals. Digital prescriptions and package inserts reduce paper consumption and thus CO_2 emissions.

Retail & Hospitality

Online shopping and in-city delivery services can make shopping more efficient from a logistics perspective by aggregating delivery routes. At the same time, online shopping increases the burden on urban logistics. In combination with intelligent delivery services and transport systems, overall savings potentials can nevertheless be achieved. In addition, Smart Vending Machines could reduce building space and, put in perspective, the use of AR/VR glasses by private and commercial customers could replace every trip to the shopping centre or business meeting. Digital marketing and digital advertising spaces initially contribute to increased consumption and thus to potentially higher CO_2 emissions through high induction effects. The potential of modern blockchain technologies to provide more transparency in the supply chain and to guarantee fair and ecological products in the food industry is worth highlighting.

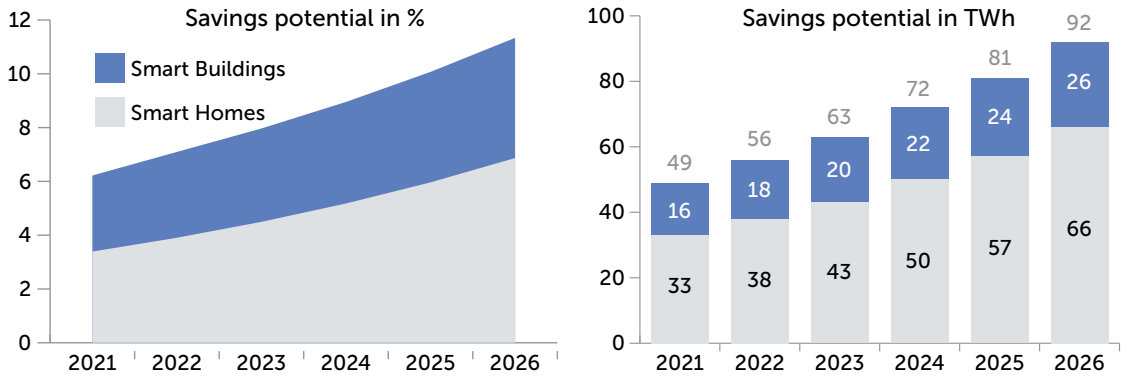
The examples and the analysis of the individual segments demonstrate that a cross-segment view is necessary: The sustainability of digital services depends on the energy efficiency of their communication systems and data centres. The footprint of electric vehicle fleets is significantly shaped by the share of green energy. Smart Cities must therefore think in connected terms. Comprehensive Smart City platforms exploit the holistic sustainability potential thanks to the synergies between the segments. It becomes clear that the segments not only have directly detectable and measurable effects for the cities, but they also serve as an ecosystem and driver for additional sustainable progress. For example, charging stations for public transport can be an enabler for electric garbage collection vehicles and can promote private e-mobility in the long term.

4.3 Quantitative Sustainability Effects

While the very general UN goals serve as a basic orientation for German cities, the prioritisation of concrete Smart City building blocks requires a more detailed consideration. To achieve carbon neutrality, investment decisions must be weighed against quantitative sustainability effects. This can be represented in elaborate models that presuppose a large number of assumptions. However, the effort is worthwhile and the examination of direct and indirect effects as well as rebound and induction effects will sensitise decision-makers to critical investment decisions.

Applying a simplified model to popular and common Smart City building blocks shows that, with the forecast market development and penetration of the segments, remarkable savings potentials can be realised. One of the biggest levers, for example, is offered by the field of "Smart Buildings" and the related field of the "Smart Home". With these technologies, up to 20 per cent of energy consumption can be avoided in each case (Fraunhofer, 2017). As shown in Figure 13, eco and Arthur D. Little expect a saving of up to 12 per cent, or 92 terawatt

FIG. 13 Sustainability Effects of Smart Buildings and Smart Homes



Public and commercial buildings (319 TWh) and private households (644 TWh) comprise an enormous energy consumption and are therefore responsible for 30% of CO_2 emissions in Germany.

The objective – the carbon neutrality of buildings and households – requires strong market penetration, further increases in efficiency and renewable energies.

Source: Deutsche Energie-Agentur, eco, Arthur D. Little

hours, in 2026 with regard to the entire building sector. Converted into CO_2 equivalents, this amounts to 275 million tonnes of CO_2 over the period from 2021 to 2026 (assuming an expected phase-out of coal-fired power in Germany by 2038). However, the local electricity mix, i.e. the share of renewable energies, plays a central role.

Another very promising use case is the combination of Smart Lighting and Smart Parking. Many cities and municipalities are replacing their street lighting with modern LED technologies that consume up to 70 per cent less electricity (OÖ Energiesparverband, 2020). However, the major sustainability effect only becomes apparent when the streetlights are intelligently connected and equipped with sensors, and the resulting infrastructure is also used for Smart Parking systems. In this case, the time during which the lights are consuming power is reduced by a further 50 per cent. On the other hand, the optimised search for parking spaces saves about 1.3 million tonnes of CO_2 annually (Figure 14). This combination offers not only ecological advantages: Cities can save a total of 184 million Euro in energy costs and generate 480 million Euro in revenue through Smart Parking by 2026, while citizens will save up to 34 billion Euro in costs associated with searching for a parking space.

In the area of "Mobility", car-sharing services will enable direct sustainability effects of around 0.52 million tonnes of CO_2 by 2026. Even if the number seems relatively small in comparison, station-based solutions offer an attractive investment that has a variety of effects in a city (for example, vehicle reduction in cities).

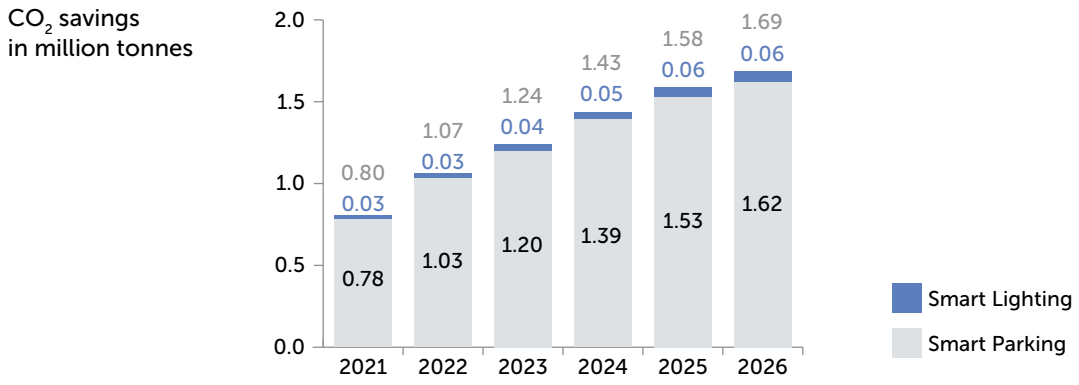
As the examples mentioned above themselves do not have a negligible energy consumption, the switch from copper connections to fibre-optic lines is also important from this perspective. Through the introduction of fibre optic, eco and Arthur D. Little expect a saving of 270,000 tonnes of CO_2 emissions for data transport by 2026.

Based on the analyses, key recommendations for action can be formulated for established and new Smart Cities with regard to achieving climate targets:

- German cities must create the conditions for sustainable digital services. Among other things, energy-efficient data centres (especially through increased heat recovery) and low-resource communication services must be implemented and renewable energies must be used. For this, among other things, framework conditions must be created for the attractive utilisation of heat pumps to process waste heat for municipal local and district heating networks. At the same time, professional protection of the ecosystem through investment in cybersecurity is recommended.

- A closer look at Smart City solutions reveals: the boundaries between vertical segments are becoming blurred. For urban planners and politicians, the motto is: think cross-segmentally and identify dependencies in order to leverage synergies. This is because a

FIG. 14 **Sustainability Effects of Smart Lighting and Smart Parking**



Approx. 30% of city car traffic results from the search for a parking space. This results in an annual CO_2 footprint of around 8.9 million T CO_2 and search costs of around €40 billion.

Smart Lighting projects should simultaneously be used as the foundation for further sustainable Smart City components with strong effects, such as Smart Parking.

Source: ADAC, INRIX, eco, Arthur D. Little

holistic application of Smart City concepts is the key to sustainable digitalisation.

- After prerequisites and dependencies have been taken into account, the services must be continuously optimised and improved. With regard to the sustainability of the Smart City and its components, it is also important to check the building blocks for circularity. In this way, the potentially negative, direct sustainability effects can be reduced in the medium term.

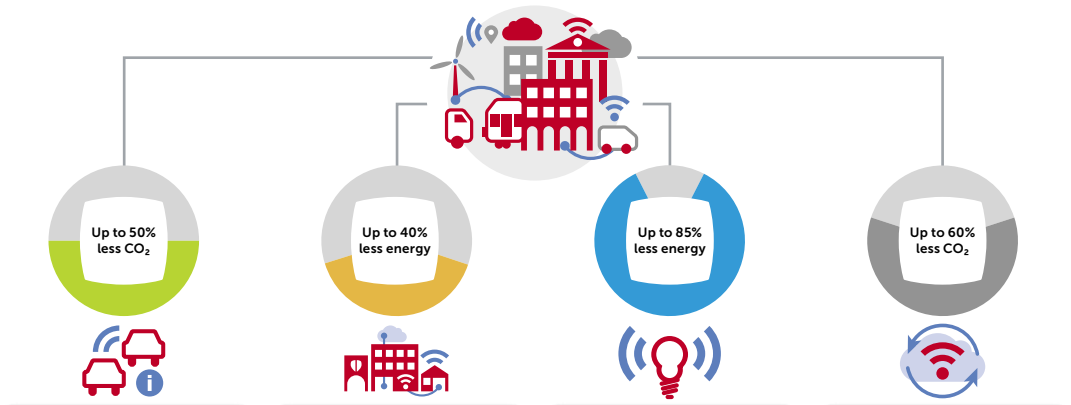
- Although the quantification of effects proves to be complicated and time-consuming, it offers the only possibility to evaluate the Smart City building blocks and to align the Smart City strategy with the climate goals. In addition to the calculation, the tracking of the effects should also not be neglected. With the help of sensor data and AI, emissions can be tracked and further optimisation measures can be initiated.

- Carbon neutrality will not be achievable with technology alone. Adjustments in consumption, movement, travel and eating habits are also required. Smart City concepts are by no means greenwashing measures. But if Smart City building blocks such as digital marketing increase consumption through induction effects – or the consumption of energy or resources in general – the ambitious goals become out of reach and the integrity of the cities suffers. Thus, a balance of consumption-oriented and sustainability-promoting solutions is important and should always be considered in the context of Smart City offerings.

A continuation of the market development and a continuous increase in efficiency gains through Smart Systems lead to the expectation that, with investments in digitalisation in the central areas of transport, communication services, buildings and energy, Smart Cities can gradually approach the German climate target of 55 per cent CO_2 reduction in the selected areas.

Sharing concepts and optimisation of traffic flows, for example through Smart Parking, are estimated to be capable of reducing CO_2 emissions in urban car traffic by up to 50 per cent by 2030. If one assumes that the efficiency gains of Smart Buildings and Smart Homes double during the current decade, up to 40 per cent of electricity consumption can be saved in the public building sector. The greatest potential for energy savings is expected in the area of public lighting. Smart Lighting concepts require up to 85 per cent less energy. In combination with an ever-growing share of renewable energies, the corresponding effects on CO_2 emissions are much higher.

FIG. 15 **More Climate-Friendly Smart Cities in 2030**

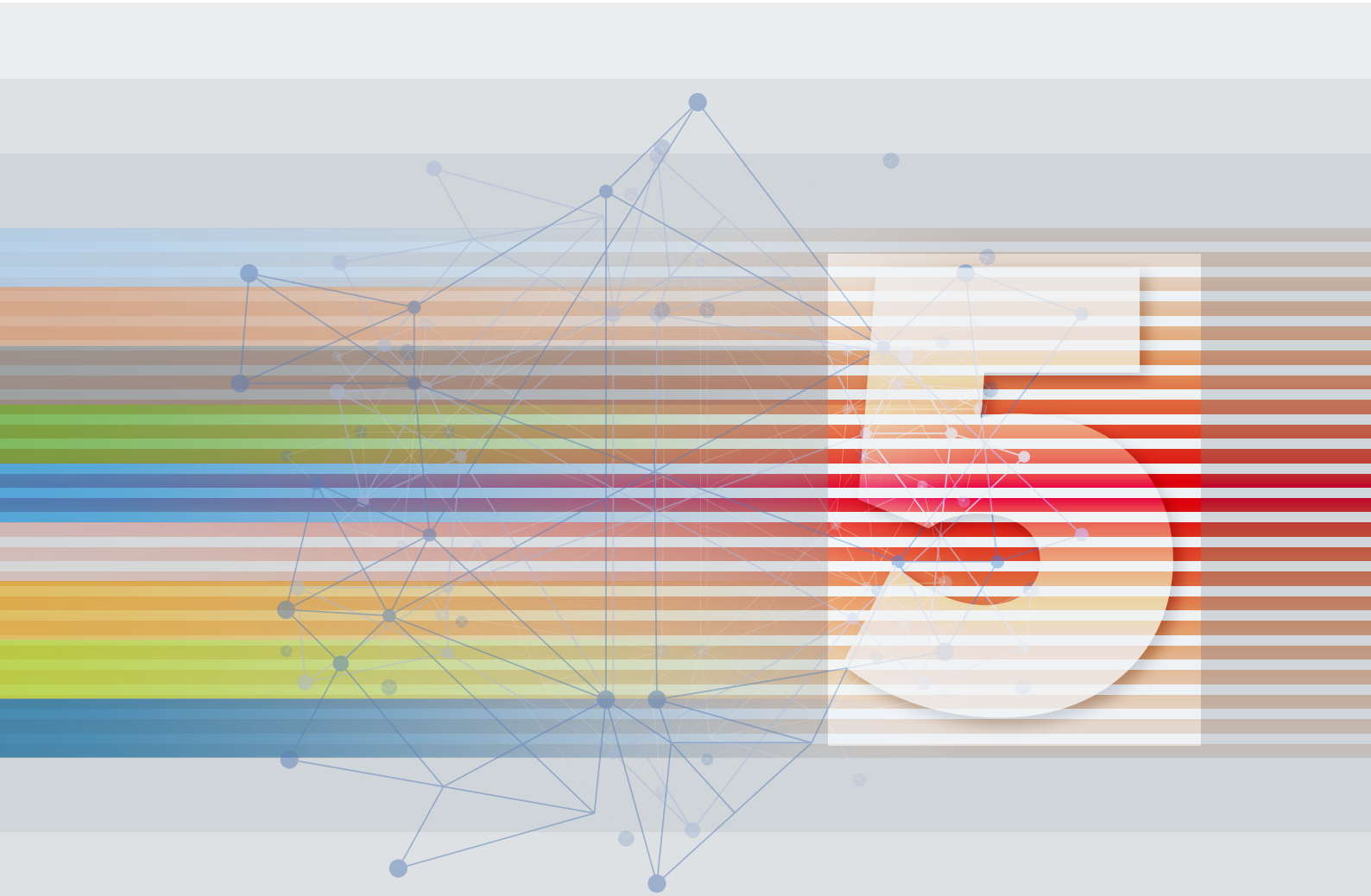


Source: eco, Arthur D. Little

Cities are the places where the majority of people live in the 21st century. They must therefore be pioneers for a green transformation of the economy and society and real laboratories for carbon neutrality. The Smart City Study shows that this will only be possible with the intelligent use of digital technologies. If we succeed in raising the potential of digitalisation in cities worldwide, this will not only lead to a better quality of life, but also make a significant contribution to climate and environmental protection.

Inger Paus,
CEO Vodafone Foundation

Vodafone Institute for Society and Communications



5. Conclusion and Outlook

The growth trend that was already indicated in 2017 is confirmed in our current study and it will continue until 2026. According to eco and Arthur D. Little, the Smart City market in Germany will have revenues of around 38.5 billion Euro in 2021. By 2026, the market volume is expected to more than double to around 84.7 billion Euro. With a projected growth of over 17 per cent, Smart Cities represent an attractive market – and not only for companies in the Internet industry.

Based on the forecast market development and considering the current influencing factors, eco and Arthur D. Little see defining trends in the coming years – both on the part of the providers and on the part of German cities:

- The enormous increase in data points and their interlinking in German cities is giving rise to a multitude of new business models in the Smart City market.
- Driven by the scope for expandable digitalisation and the ongoing pandemic, the healthcare and education sectors will see strong growth in the market – despite high requirements for investments.
- The German federal government's ambitious climate targets require a stronger focus to be placed on sustainability and energy efficiency, both for companies in the Internet industry and for companies in other industries, and at the same time increase the pressure on German cities and decision-makers.

Beyond the aspects already mentioned, the following general recommendations for further development actions in the area of sustainability can be derived for German cities from the trends and Smart City challenges:

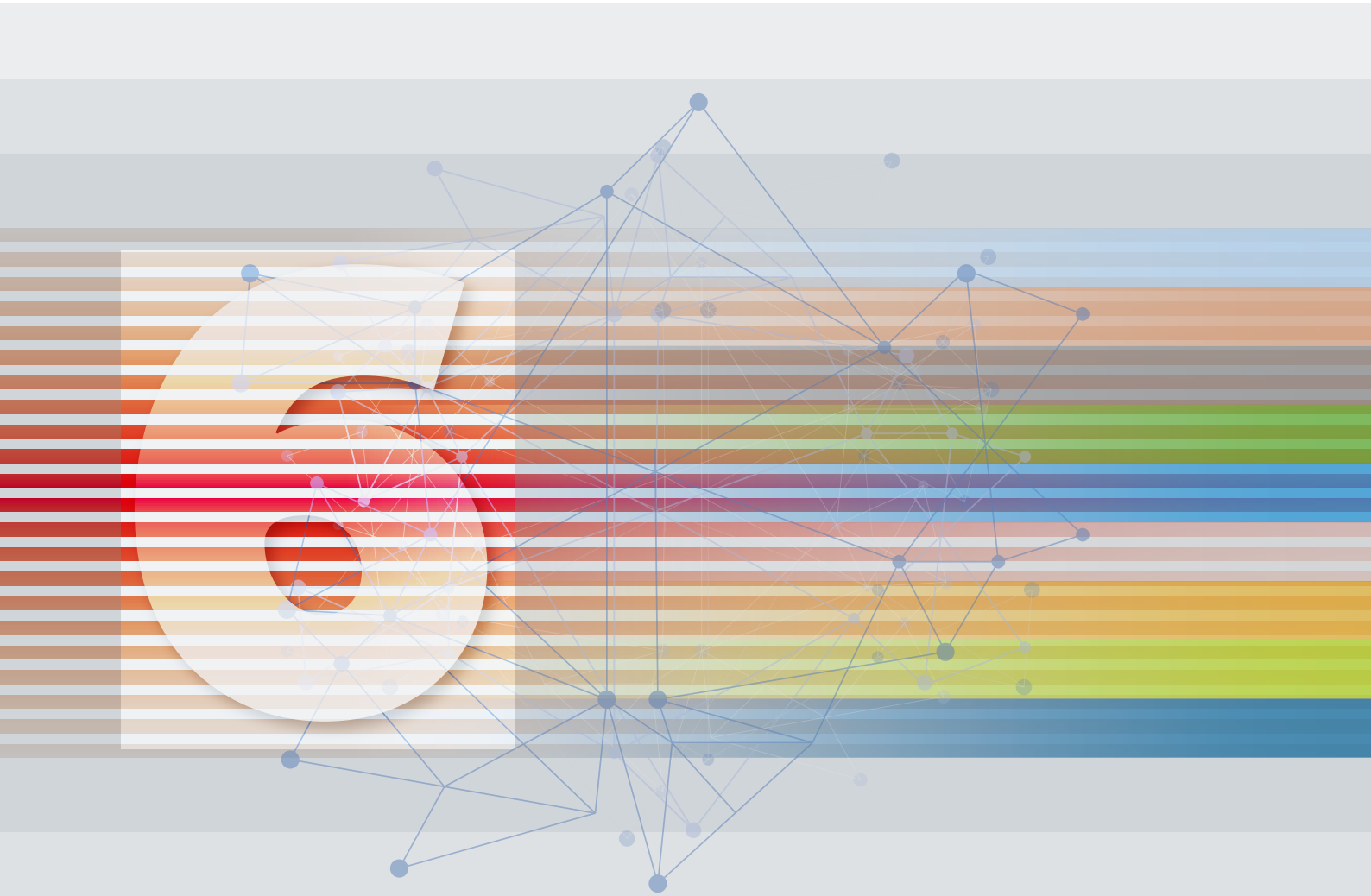
- All Smart City initiatives should be built on open platforms, with a prerequisite being access to open and easy-to-use interfaces. This allows synergies and economies of scale that arise between segments to be realised. Data integration in a database or a foundational framework such as Gaia-X also forms the basis for analytical services and optimisation potential with regard to sustainability effects. The legislator must provide the appropriate framework and standards.
- A clear understanding and case-by-case selection of new business and monetisation options in the area of the Smart City is required. Cities need attractive and flexible financing options for the implementation of Smart City solutions. This includes innovative concepts beyond the traditional Public-Private Partnerships (PPP), where the private party not only finances but also puts together the partnerships to design, build and operate the solution.

- Urban alliances and industry partnerships allow urban actors to learn from best practices, share development costs (avoiding redundancy) and achieve economies of scale and synergies at a cross-city level. Within the framework of cooperative workshops and co-creation sessions, cities can build up the required knowledge and expertise. Within regions, solutions and standards must be developed holistically across cities and municipalities and rolled out across the board. Individual stand-alone solutions cannot be maintained and scaled in the long term.

- Clear prioritisation based on the business case must be carried out to identify the most important initiatives. For cities, the business case should include both traditional financial measures (e.g. profitability), and further dimensions such as climate effects and quality of life.

- Success depends crucially on the information provided to the users of Smart City services. A clear communication strategy needs to be developed across different modes and platforms to create awareness among users of the services available in the city. In this context, Smart Cities must create incentives for sustainable consumption and sustainable mobility profiles. Otherwise, negative rebound and induction effects will outweigh the efficiency gains.

Overall, eco and Arthur D. Little see good momentum in the Smart City market in Germany. The high complexity resulting from the interdependencies and the long-term nature of measures should not deter decision-makers from taking the necessary further steps, from implementing initiatives dynamically, and from establishing an open cooperative design model.



6. Methods, Definitions and Market Description

The figures on the size of the market, the individual market segments and the further segmentation on which the study is based are grounded on data from eco and Arthur D. Little as well as various secondary sources from associations (VATM, BIU, etc.), publications from the German Federal Statistical Office and other services (for example Statista, Destatis).

Market description

Exclusively components that would not exist in a "traditional, non-Smart" city form a part of the calculation and thus part of the market. If a traditional service is merely upgraded, the incorporated and existing hardware and software are not part of the calculation and therefore not part of the Smart City market. The following examples illustrate the demarcation:

"Intelligent lighting": The cost of the light pole is not part of the Smart City market, as the light pole is usually only upgraded. Thus, only new components such as sensors, gateway, software, connectivity and platform are part of the Smart City market.

Electric charging stations: The costs along the value chain (investment and operating expenses) are entirely a part of the Smart City market. Electric charging stations are ordinarily products which are completely newly designed and produced, and not mere upgrades of traditional charging stations.

Sustainability model

In order to quantify sustainability effects, the existing initial situation (i.e. the baseline) was first determined. For example, for the evaluation of Smart Lighting initiatives, existing energy consumption was registered and the CO_2 emissions were derived from the corresponding electricity mix. Subsequently, reduction potentials were determined by means of different sources. Finally, the overall sustainability effect was determined on the basis of the degree of implementation. In the calculation model, a Germany-wide consideration of energy requirements was used as a basis.

The degree of implementation was modelled by means of the market penetration of the respective building blocks. Resource consumption through production, use and disposal of the technologies was not taken into account. Likewise, for reasons of complexity, induction and rebound effects were not integrated into the model.

Definitions

Smart City

A Smart City is a city, municipality or coherent region that seeks to continuously improve the lives of its citizens and visitors and the conditions for successful economic activity. In the process, it becomes more efficient, technologically advanced, greener and more socially inclusive. The focus for eco and Arthur D. Little is on promoting ICT-based urban innovation.

Smart City platform

A Smart City platform brings together urban data, services and applications in a technical and organisational sense, functions as a link between the applications of different segments, aggregates the data of all solutions, and enables exchange between all of these – it offers developers access in order to plan applications.

Smart City ecosystem

With the term Smart City ecosystem, eco and Arthur D. Little refer to the strategic cooperation of companies to identify specifics and requirements of a city and their ability to offer products and services as a total solution.

Digital twin

The digital twin is considered a central building block of Industry 4.0. It reproduces real production systems, buildings and their equivalent in a digital copy. With the help of the digital twin, processes can be optimised and production steps can be planned in advance to check whether a plant would even be capable of producing a desired product in a desired quality. For Smart Cities, this digital copy offers many use cases in the areas of "Mobility", "Energy" and "Building Automation".

Sustainability effects

Type	Description	Examples
Direct effects	The implementation of service modules generates direct positive and negative environmental effects.	Saving CO_2 emissions through the use of electrically powered city buses. The production, use, maintenance and disposal of sensors uses resources and produces CO_2 emissions.
Indirect effects	The elements of the Smart City change behavioural and production patterns that influence the environment.	Traffic jams are avoided through intelligent traffic control. An ecosystem of charging stations promotes e-mobility and thus indirectly saves CO_2.
Rebound effects	Higher efficiency can lead to an increase in the need for resources.	Smart fridges are more energy efficient, so households buy bigger fridges. Energy-efficient 5G networks allow even more high-definition videos to be streamed.
Induction effects	Digital services can stimulate additional consumption, which in turn leads to emissions.	Digital marketing generates the desire for additional consumer goods.

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eco shapes the Internet

With more than 1,100 member companies from over 70 countries, eco is the largest Internet industry association in Europe. Since 1995, eco has been instrumental in shaping the Internet, fostering new technologies, forming framework conditions, and representing the interests of members in politics and international committees.

Together with our members, we advocate for a free, technology-neutral, and high-performance Internet. In so doing, our focus is on promoting trust in the Internet as well as its security and reliability. The aim is to shape the digital transformation of society and the economy in the best possible way so that successful economic activity can be based on our democratic values. As the voice of the Internet industry, we assume societal responsibility for ethically-oriented digitalisation.

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