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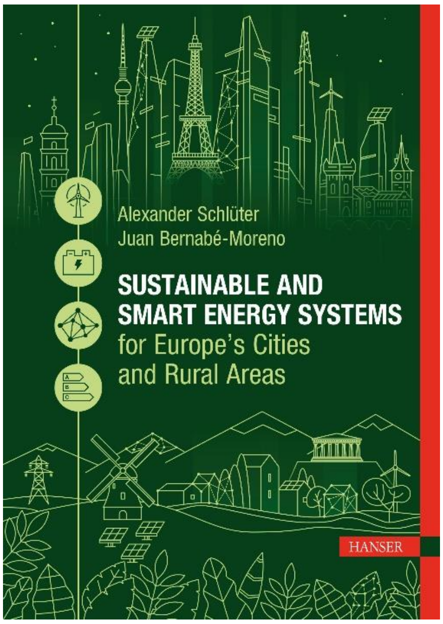

Sample Pages

Sustainable and Smart Energy Systems for Europe's Cities and Rural Areas

Alexander Schlüter and Juan Bernabé-Moreno

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Foreword by Fabrizio Rossi

Fabrizio Rossi, Secretary General of the Council of European Municipalities and Regions (CEMR)

We live in exceptional times, where changes happen at a pace just not imaginable only a few decades ago. The constant movement of transformation across Europe we are witnessing reflects trends and innovations often coming from other parts of the world, sometimes being conceived and developed in our continent. This great transformation has modified the way we interact and communicate, move people and transport goods, make payments, produce and stock energy. And in turn, this silent revolution has become increasingly evident in the space we live in, our cities, towns, villages.

If today there is an element that more and more unites large metropolises with small rural centres, it is precisely this transformation. All our communities want to be smarter in the way they use their resources and provide services to their citizens. This is a silent revolution not only because electric buses produce less noise pollution than petrol ones or because an e-mail is less noisy than fax! It is silent because through a transversal approach, we are transforming our economies and, therefore, our communities.

In fact, being a smart city or a smart rural area today means trying to obtain an integrated approach to services. It is a triple gain if it improves the quality of life of citizens, increases the competitiveness of our economies, and pave the way for a sustainable low-carbon economy. The local transport system cannot ignore the way the energy necessary to make it work is produced, just as public buildings or the house in which we live must respect energy criteria that are growingly attentive to sustainability, and productive activities are reconverting towards a model with a lower impact on the environment and natural resources. And all this would be impossible without the ability to store, analyse and manage huge amounts of data that allow us to optimise production processes and provide more accurate and rapid services to citizens.

The role of municipalities has therefore become crucial to manage and steer a change that is as profound as it is irreversible. A good local administration is, in fact, what can make the difference between a territorial development without order and growth for the benefit of all. For these reasons, the book edited by Alexander Schlüter and Juan Bernabé-Moreno represents a rare opportunity to learn more about the state of the art of this transformation in Europe and how the municipalities across the continent face this great challenge.

All people living in the European territory today should enjoy what Henri Lefebvre called the ‘right to the city’, which perhaps today we should call the ‘right to the community’, since cities and rural areas are united by similar problems and solutions. The right to the community is, therefore, not only the right of every person to access the resources and services of their own territory but also, and possibly above all, to contribute to this transformation so that it takes place in a way that is respectful of all. In fact, no change can make sense for European municipalities if not aimed at the well-being of their citizens, the inclusion of disadvantaged ones, the development of everyone's potential. This is probably the real and pivotal challenge that awaits all of us, both citizens and public administrators.

Brussels in February 2022

Fabrizio Rossi

Foreword by the Editors

Congratulations! You are one of the few people who read and pay attention to forewords. For this book, it makes sense to do so because we explain how you can use it most effectively to your advantage. This is because we don't just want to report on technologies and challenges but encourage you and give you tangible recommendations for action.

But who are we – over 40 established international experts – actually writing this book for? It is, of course, intended for all those interested in smart cities and rural areas. We are directing it in particular to those responsible in cities, towns, villages and districts. They are crucially important to ensure that further development in energy, mobility and digitalisation succeeds. They have begun to gather experience in their local areas. We want to supplement this with scientific insights and forecasts while explaining technical terms and contexts in detail. Our aim throughout these chapters is to make you realise the challenges and take interesting approaches on board to enrich the lives of residents. Your municipality can contribute to the success of the energy transition while benefiting from it at the same time. Of course, experts in the field, students and those in the issues covered are invited to advance their education by reading this publication.

But what makes the transformation into a smart municipality worthwhile at all? It's because smart municipalities permit a more sustainable way of living and are therefore an answer to the major challenges, such as climate change, facing our society. Our environment is changing at an extraordinarily rapid pace – unfortunately, to our disadvantage. The systematic destruction of our planet worsens living conditions and increases the risks to human health, entailing high economic and social costs and leading to species extinction. We are currently living through some of the dangers that face us when the relations between humans, nature and wildlife are thrown off balance – for example, an increased risk of pandemic.

Wouldn't it be clever to combine the necessary changes with an improvement of our quality of life? And that's precisely what smart city projects are all about. In this book, we start off with the basics and encourage you to create your own vision and strategy for your smart municipality of the future and to understand your own role and responsibility in shaping it. After that, you will read about the numerous challenges and opportunities presented by energy systems and digitalisation. For the focus areas you will have formulated on this basis, we will point you toward selected funding and subsidy options.

Last but not least, we want to thank all those involved in this project, which has been driven and implemented with great enthusiasm right from the start by E.ON internally as well as by the many external authors. We hope you enjoy the book and the subsequent implementation.

Munich in spring 2021

Alexander Schlüter and *Juan Bernabé-Moreno*

Foreword to the European Edition

The feedback on the first book has shown that we seem to have hit the spot with the subject and type of presentation. For this reason, and in response to further climate-linked disasters, we have decided to publish an English edition to cater for a European framework. Compared with the first book, which contained many examples and data from Germany, we have replaced these with references to Europe and the European Union in this edition. And of course we have updated the information in general wherever possible. What's more, the team has been expanded, and Greenwich, London has made itself available for interview. We are very grateful for this. OK, enough of the foreword. Now it's time to read, plan and act!

Munich in February 2022

Alexander Schlüter and *Juan Bernabé-Moreno*

Contents

Editors and Authors

Editors and Authors

Dr.-Ing. Alexander Schlüter

Innovation Manager, New Business, E.ON Digital Technology GmbH.

Lecturer, Technical University Munich (Guest) & REMENA-Programme of the Universities Cairo, Kassel and Monastir.

Dr. Juan Bernabé-Moreno

Chief Data Officer, E.ON; Global Head of Data and Analytics, E.ON Digital Technology GmbH.

Research Fellow, University of Oxford & Universidad de Granada.

■ Authors

Dr. Nikoletta Athanassopoulou

Head of Solution Development, IfM Engage, Institute for Manufacturing, University of Cambridge.

Angel K. Batalla, MBA, MA Design

MSc Energy & Sustainability Student, Technical University Munich.

Climate Tech & Sustainability Strategy, Hellenic Republic Asset Development Fund.

Peder Berne, MSc

Project Manager Sustainable City, E.ON City Energy Solutions.

Hagen Braas, MSc

Research Associate, Institute for Thermal Energy Technology, University of Kassel.

Bernadette Brandner, MSc

Former Working Student, E.ON Digital Technology GmbH.

Scholarship recipient, UnternehmerTUM GmbH.

Dr.-Ing. Markus Bücherl

Expert Engineer, E.ON Energy Solutions GmbH.

Philipp Bugs, MSc

Venture Manager, New Business, E.ON Digital Technology GmbH.

Dr. Giorgio Cortiana

Head of Advanced Analytics – Energy Intelligence, E.ON Digital Technology GmbH.

Garance Emmerich-Bundel, MSc, MBA

Senior Manager Technology Enablement, E.ON Energy Infrastructure Solutions.

Prof. PhD Theodoros Evgeniou

Professor of Decision Sciences and Technology Management, INSEAD.

Artificial Intelligence Academic Partner, World Economic Forum.

Dipl.-Pol. Laura Antonia Färber, MSc

Venture Manager, New Business, E.ON Digital Technology GmbH.

Prof. Ing. Petronilla Fragiacomo

Associate Professor of Energy Systems and Power Generation.

Research Head of Fuel Cell and Hydrogen Team, University of Calabria.

Dr. rer. pol. Maria Garbuzova-Schlifter

Global Data Governance Manager & Senior Expert Digital Innovation, E.ON Digital Technology GmbH.

Dr.-Eng. Matteo Genovese

Postdoc and Research Fellow, Fuel Cell & Hydrogen Research Group, University of Calabria.

Dr.-Ing. Ron-Hendrik Hechelmann

Postdoc, Department of Sustainable Products and Processes, University of Kassel.

Prof. Dr. Svetlana Ikonnikova

Associate Professor, Chair for Resource Economics, Center for Energy Markets, TUM School of Management, Technical University Munich.

Dr. Imoh Ilevbare

Principal Solution Development Specialist, IfM Engage, Institute for Manufacturing, University of Cambridge.

Dipl.-Ing. Alexander Jäger

Advisor for Strategic Special Projects and Policy Issues, Bayernwerk AG.

Dr.-Ing. Diana Khripko

Senior Solution Development Specialist, IfM Engage, Institute for Manufacturing, University of Cambridge.

Dr. Andreas Kießling

Head of Associations and Quality Assurance, Bayernwerk AG.

Dipl.-Ing. Simon Köppl

Project Leader, FfE.

Alexandra Krumm, MSc

Research Associate, Europa-Universität Flensburg.

Doctoral Candidate, The Reiner Lemoine Institute.

Jakob Kulawik, MSc

Research Associate, Chair for Energy System Economics, E.ON Energy Research Center, RWTH Aachen University.

Dr.-Ing., Dipl. Math. Manuel Lindauer

Product Development, Calcon Deutschland GmbH.

Freelancer, Fraunhofer Institute for Building Physics.

Eva Meschede, MSc

Research Associate, Institute for Networked Energy Systems, German Aerospace Centre (DLR).

Prof. Dr.-Ing. Henning Meschede

Chair for Energy Systems Technology, Paderborn University.

Prof. Dr. Pao-Yu Oei

Professor for Economics of Energy System Transformation, Europa-Universität Flensburg.

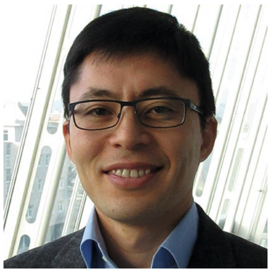
Head of “CoalExit” research group, Europa-Universität Flensburg, Technische Universität Berlin, and DIW Berlin.

Nicholas Ord, MBA, Tech Eng. (Computer Science and Electronics Systems)

Venture Manager, New Business, E.ON Digital Technology GmbH.

Dr.-Ing. Janybek Orozaliev

Group Lead Thermal Components and Systems, Institute for Thermal Energy Technology, University of Kassel.



Dr. Victoria Ossadnik

Board member, E.ON SE.

Member of the supervisory boards of Linde plc. & Commerzbank AG.

Dr.-Ing. Christoph Pellinger

Managing Director, FfE

Dr. Rob Phaal

Director of Research (STIM, CUED), Institute for Manufacturing, University of Cambridge.

Dr.-Ing. Matthias Philipp

Project Manager Product- and Solution Development, Bayernwerk Natur GmbH.

Prof. Dr.-Ing. Aaron Praktiknjo
Chair of the Department for Energy Systems Economics, E.ON Energy Research Center, RWTH Aachen University.

Vincenz Regener, MSc

Research Associate, FfE.

Dipl.-Chem. Katherina Reiche

Chief Executive Officer, Westenergie AG.

Chair, National Hydrogen Council of the German Federal Government.

Dr.-Ing. Florian Schlosser

Postdoc, Department for Energy Systems Technology, Paderborn University.

Eugenio Scionti, MSc

Venture Manager, New Business, E.ON Digital Technology GmbH.

Kuldip Singh, Drs., CMA, CFM

Head of Digital Transformation CS, E.ON Digital Technology GmbH.

Prof. Dr.-Ing. Rita Streblow

Professor for Digital Networking of Buildings, Energy Supply Systems and Users, Einstein Center Digital Future, Technische Universität Berlin.

Chief Engineer, Institute for Energy Efficient Buildings and Indoor Climate, E.ON Energy Research Center, RWTH Aachen University.

Matthew Timms, BSc

Industry Advisor, Advent International

Independent Non-Executive Digital Advisory Board Member, Cabinet Office, UKE.

Dr. Jens Weibezahn

Postdoctoral Research Fellow and Marie Skłodowska-Curie Fellow, Copenhagen School of Energy Infrastructure (CSEI), Copenhagen Business School.

Dr.-Ing. Egon Leo Westphal

Chief Executive Officer, Bayernwerk AG.

3 How to Make Your Municipality Smart and Sustainable

Alexander Schlüter

To make it easier for you to read this book, we are presenting three model municipalities, as shown in Figure 3.1. They are based on Eurostat's definitions (cf. Part I, Chapter 1). Throughout this book, we use these categories to highlight the different challenges and opportunities the three types of municipalities, i.e. large, medium and small, each face.

	Metropolis 1.5 m Inhabitants	Medio Town 60 k Inhabitants	Villago 10 k Inhabitants
Structure	Industry, retail, active business environment, good and readily available public transport, high building density, large hospitals, care centres	Some industry, retail, public transport connection to nearest big city, mainly residential areas, medium building density, small hospitals, care centres	Agrarian economy, seldom industry and retail, scarce public transport, private transport reliance, low building density, few care centres, doctors' offices

Figure 3.1 Model municipalities used throughout this book

The transition between the model municipalities is fluid. Villago, for example, can be understood as a rural area, or as a village or as a small town.

As described earlier, there is no standard definition of smart city or smart rural area that explores individual issues in any detail. In larger projects involving several organisations, this may soon lead to disputes among the parties. Therefore, you should first work on developing your own definition and objectives. If you don't know what you are aiming at, you will never get there. Away from the focus of this book, examples could include transparency in political projects and creation of a cooperative, digital administration, industry and commerce, educational and health facilities, safety in public places, science and culture.

Here are a few suggestions for the main issues of this book.

(1) This first list concerns **municipalities of any size:**

- Our primary energy demand per head is to be 25 % lower than that of comparable municipalities by 2030. We want to be climate-neutral by as early as 2035.
- We are tightening the requirements for planning permission so that buildings will have to be constructed as low-energy houses from now on, and as passive houses from 2030. For existing buildings, integration into the energy use plan and local energy concepts will be required and incentivised.
- To this end, we will use at least 20 % of available roof space for photovoltaics to generate electricity.
- We want significantly cleaner air and less traffic noise. To achieve that, we will continually expand the facilities offered to cyclists and limit passenger car traffic. From 2025 onwards, no diesel or petrol-powered cars will be allowed to drive in our central district.
- When constructing new buildings, we must provide an adequate number of parking spaces for bicycles and cargo bikes: one space for a standard bicycle per person.
- We will expand the local public transport infrastructure. Starting immediately, we will gradually convert our buses to silent drive types without climate-relevant emissions by 2030.
- We will promote car sharing with modern, low-emission drives and offer dedicated parking in convenient locations for such vehicles.
- We will apply the top runner principle, which is used successfully in other parts of the world. When making new acquisitions, only the three most innovative and sustainable technologies will be considered, which will where possible, also provide added value for the energy transition.
- The indirect costs of a product, such as the energy costs incurred during its useful life, are often significantly higher than the initial cost. Energy efficiency will therefore become an essential part of our procurement process. Contracts will be awarded to the most sustainable quotation with the lowest total cost of ownership.
- Our website will provide information on how residents can increase their energy efficiency, including with the help of energy experts, whose services we will arrange on an agency basis.
- Our digital infrastructure will be ultra-modern.
- We will provide WiFi hotspots free of charge.

(2a) For the **Metropolis** model city, you could additionally specify the following:

- Car-free zones in and around the city centre will be expanded to encourage visitors to look at buildings and parks rather than cars and roads.
- Throughout the city, motorised deliveries can only be made with silent drive types, which have significantly lower emissions. To facilitate deliveries, reloading terminals will be set up close to railway stations.
- We will network the energy flows in and around industrial areas. Factories, swimming pools, greenhouses, etc. offer good opportunities for exchanging thermal energy. In a best-case scenario, we will achieve a circular economy. We want to reduce our specific heating demand, i.e. kWh per person or tonne of product, for example, by 50 % by 2030 and by 70 % by 2050.
- We will encourage urban gardening and offer workshops for this purpose.
- We will provide Internet of Things (IoT) technology and plan 15 pilot projects in this context.

(2b) **Medio Town**'s administration could plan to do the following, in addition to (1):

- We will campaign for an even better connection of local public transport to the nearest major city and the other towns nearby.
- We will bundle our industries in a well-thought-out industrial area.
- We will provide IoT technology and are planning two specific pilot projects in this context.
- We are providing a cycling network.
- We have established traffic-calmed zones and cycling streets in our residential areas and the town centre. Motor traffic is guided around the town centre.

(2c) And **Villago** will plan to do the following in addition to (1):

- We provide local public transport, even if use rates are very low at times. We do so, for example, by providing on-demand ride services.
- We organise a weekly market in the area and offer a bring-to-market service linked to the local public transport system.
- We want to generate the energy we consume ourselves and create a smart grid (together with neighbouring municipalities, if appropriate).
- We are open to renewable energies, such as wind farms. However, local people and the municipality should get a fair share of the profit. We organise public information events, shadow the information- and will-forming process and support the establishment of cooperatives.
- We encourage the formation of carpools with an appropriate internet platform.

A Few Energetic Basics

The authors collaborating on this book are aware that you may not always be familiar with the subject of energy. This is why we paraphrase the terms and sometimes even use colloquial terms – such as power for electrical energy or storage for energy storage. But it can be interesting to pay attention to detail in the public debate. Take note of what the newspapers say or the terms politicians use when they speak on television: electricity, heating or energy? Energy also includes fossil fuels for mobility, for example. In other words: electricity is not the only form of energy. It is merely an important part of it. However, as all three forms are of interest to the people on the ground – including you – this book deals with all three.

In this context, you should be careful not to confuse the type of energy medium on its way to you (referred to as secondary or final energy) with its use on-site. As you can see, you have to pay attention to the right terminology when talking about energy, primarily to ensure comparability. The chain is as follows:

- primary energy, e.g. natural gas at the source,
- secondary energy, e.g. electrical power *en route* from the power station to the end customer,
- final energy, e.g. electrical power from the socket at home,
- useful energy, e.g. heat or movement.

2.2 How Can the Electricity Grid Be Turned into a Future-capable Smart Grid?

In its definition of smart grids, the IEEE singles out, in particular, the use of new communications and information technologies, which characterise the energy system of the future:

> *"The Smart Grid (SG) has come to describe a next-generation electrical power system that is typified by the increased use of communications and information technology in the generation, delivery and consumption of electrical energy."*
>
> *Yu (2010)*

Of crucial importance here are the measurement, control/balancing and IT components, which can record the grid status in real-time and communicate with each other.

Ultimately, this will produce much more than just a digital version of the conventional power grid: it will be enhanced by innovative grid operating resources, and new intelligent operating strategies will be enabled. At the same time, smart meters will digitalise and network households and decentralised systems. Bidirectional communication and new balancing interfaces will allow the flexible integration of many additional power producers and consumers. In this way, smart grids are expected to ensure that sustainable, economically viable and secure power supplies can continue in the future (Ali, 2013, p. 25).

It will not be possible to meet the needs of the future power by merely adding ICT components. Based on the above points that make today's grid ready for the future, the formula to define smart grids could be as follows:

Conventional power grid + new grid operating resources & networking
\+ smart meters + intelligent flexible integration of generation & consumption
= smart grid

What does this kind of future-capable smart grid look like in concrete terms? What is behind words such as smart meter? What will change for customers, and how will consumers become flexumers? You will find out shortly.

2.2.1 New, Digital Grid Operating Resources and Networking

The energy transition makes the expansion and digitalisation of the grid infrastructure unavoidable. In this context, we are not referring only to new operating resources such as innovative transformers and switchgear, which will guarantee secure grid operation in the future, but also to the networking of components. In this way, the power grid will be extended by adding a digital information network, with measurement technology and sensors on the lines (Limbacher, 2018). Several different channels will be available to exchange data between the grid operating resources. Firstly, there are dedicated fibre connections, and secondly, medium voltage lines can also be used for data communications using powerline technology. Wireless communications via the common mobile communications standards LTE or 5G are also possible. The data is collated in the grid operators' control centres. They develop an optimised operating strategy to maintain grid voltage and efficiently manage energy flows based on the information gathered.

DSO 2.0: Greater Responsibility for Distribution System Operators

It is infinitely more complex to operate a smart grid than the grids we used to have. Since the energy transition is taking place almost entirely in the distribution system, the coordination requirements for distribution system operators have increased considerably. The greater responsibility and enlarged range of tasks have resulted in the term "DSO 2.0" being coined (see Colle et al., 2018). It is used to explain that distribution system operators do not develop incrementally but that their role is changing fundamentally in a short space of time.

However, only a few medium- and low-voltage grids have the required metering and balancing technologiy today, which leads to difficulties determining the actual grid status. What is more, most transformers have a constant turns ratio. This means that when larger volumes of power are temporarily fed in from renewable sources, unacceptably high grid voltages may result. The problem can be remedied with adjustable local grid transformers with a variable turns ratio, which decouple the voltage levels. Therefore, flexible local grid transformers can provide a constant voltage from the substation on the low-voltage side.

In addition, linear regulators are used to balance locally caused fluctuations in longer low-voltage lines. These regulators do not have to be connected locally to the transformer station but are ideally installed as close as possible to the consumer or power supplier (Hoppert and Krüger, 2014).

2.2.2 Transparency for Households: What Do Smart Meters Do?

To achieve the intended transparency in the smart grid and allow customers to participate, intelligent electricity meters have been developed that, in addition to recording data, are integrated into a communications network to transfer this data. Under the Third European Energy Liberalization Package, they will replace 80 % of the existing analogue meter equipment throughout Europe by 2020 (Giglioli, 2010). In practice, regulatory uncertainty and IT security concerns mean that the rollout in some countries has so far fallen short of the set targets (Bogensperger et al., 2018).

Through their connection to the Internet of Things (IoT), smart meters use complementary software to visualise your power consumption, which can lead to savings simply by making consumers more aware (Auer et al., 2019). In addition, the billing breakdown based on time means that variable rates and fluctuating electricity prices can also be passed on to consumers. The smart meter concept is not necessarily limited to electrical energy. Still, one can also apply it to gas, water and heating meters, and this could offer added benefits for monitoring malfunctions or leaks.

Moreover, smart meters offer secure 2-way communication, which in addition to new remote maintenance work, also provides control options for grid operators, for example, to adjust the feed-in power of prosumer equipment in grid-critical situations. In many cases, this newly gained transparency and the new options to take action can help accommodate consumers with high peak loads, such as electric charging points, in the grid without upgrading the power grid "to the last kilowatt".

IT Security of Smart Meters

Due to data protection and security concerns, digitalisation is often a hot topic in many European countries. Therefore, before intelligent electricity meters can be approved, they have to meet stringent product security requirements (CEN et al., 2014). The security standards intended to protect from hacker attacks sometimes even exceed those for online banking. Also, intelligent grid operation does not necessarily require personal data. It is also possible to use anonymised or aggregated data based on measurements in the grid. For many applications, smart meters also bring benefits to customers and are needed to allow individual participation.

Figure 2.3 shows the smart meter in its operational environment and the interfaces involved.

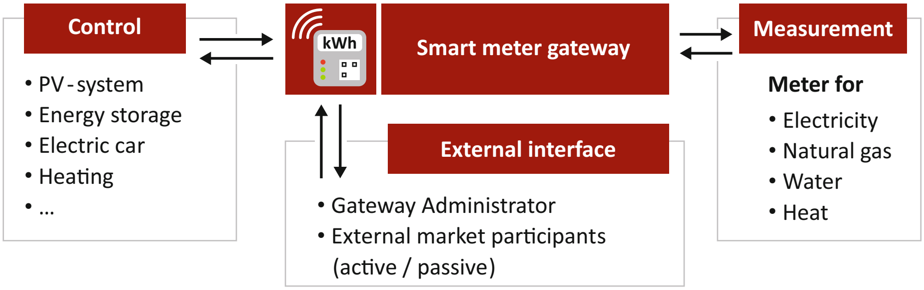


Figure 2.3 Diagram showing the smart meter in its operational environment

2.2.3 Flexibilisation of Generation and Consumption: to Support, or at Least Be Compatible with the Grid!

The locations of many of the new generation systems, such as photovoltaic systems or combined heat and power plants, are decentralised. But the power fed into the grid from these systems still has to be coordinated to be compatible with the grid. This means that the power fed in reacts flexibly to the requirements of the grid to a certain extent, either by using additional storage or through control limits. Part IV, Chapter 2 explains the various options.

The same applies to systems from the heating and transport sector, whose increasing electrification turns them into consumers in the power grid. Classic examples include electric heat pumps or electric vehicles. To ensure that the advancing cross-sector linkage can be accommodated in the future, a certain degree of flexibility in the load curves must also be planned for at the time of integration. Suppose all players optimise the operation of these systems only according to their criteria (e.g. to increase their consumption). In that case, the grid will sooner or later reach the limits of its capacity. Find out more about flexibilisation of the load side in Part IV, Chapter 5.

If we continue the thought of a grid-compatible way of operating, this will lead us to the next step: grid support. Prosumers with generation and consumption systems make their flexibility options available to the grid operators in exchange for remuneration incentives and become flexumers in the process. In this way, private combined heat and power plants or the battery storage in electric vehicles could be accessed to provide balancing power to offset fluctuations in power generated from renewable sources. This, in turn, requires consistent horizontal and vertical networking of the components as well as universal control interfaces. Figure 2.4 shows the target model of a smart grid.

2 Saving Energy in Industry and Commerce

Florian Schlosser, Ron-Hendrik Hechelmann,
Henning Meschede, Alexander Schlüter

Many companies are now aware of the significance of energy efficiency. What's more, a growing number of companies are keen to commit to climate neutrality (SBTi, 2021). One of the top priorities in this respect is exploiting existing potential to increase energy efficiency. With this aim in mind, the European industry initially increased its efficiency rates by 1.6 % per year until 2008. However, from 2008 onwards, the rate of progress has slowed down to 1 % (Ademe, 2021). As Figure 1.4 of the previous chapter shows, there is still a lot of untapped potential for efficiency gains.

2.1 What Can Industry and Commerce Do in Concrete Terms?

There is a wealth of energy-saving opportunities available to companies, enabling them, on the one hand, to strengthen the sustainability, and on the other, to save money. As we read in Part III, Chapter 1, the core question when considering any changes is: what does my process need, and how have I been providing this so far?

Here are a few examples:

- You have to move something, so you use compressed air to do so.
- You have to heat a process or room, so you use a natural-gas- or oil-fired boiler to do so.
- You have to keep a process or room below room temperature, so you cool the whole production hall down to do so.

You can probably see where this is leading. For example, lighting systems started to be integrated with movement detectors at some point in time – as lighting is only necessary in certain rooms and when people are present. In addition, the illuminance required also depends on the type of work activity. However, the reality in production buildings is quite different. Walking through a factory building outside production times, it is not uncommon to hear the hissing sound of compressed air – a costly medium – leaking. In other words, the sound of pure money escaping through the cracks. At the start of a shift, very often all machines are set to operating mode: All machines are ramping up. But not all machinery is usually required, or at least not in the first couple of hours. So the plant and machinery consume energy, even though this energy is not used in a value-adding way for quite a while. This is another example of inefficiency, and its impact is not to be ignored (Goy, 2016, p. 143).

Unlike in households, energy supply in industrial companies is complicated. The above examples show that many forms of useful energy are used in many locations, in various departments and at different times. As a result, energy efficiency needs to become structurally embedded in the corporate culture so that a holistic approach is adopted when unlocking energy efficiency potential.

Organisational Framework

What sort of framework can small and large companies create to be able to leverage this efficiency potential and establish a more energy-efficient organisational structure? At this point, we can initially make a distinction between internal and external organisational approaches:

Internal:

- Building up knowledge and creating a culture of improvement, for instance, encouraging suggestions for improvement, which are rewarded if they are subsequently implemented.
- Obtaining certification to ISO 50001: setting up an energy management system involves instilling the drive for continuous improvement in the corporate culture. Apart from reducing energy costs, this can also lead to tax advantages or government subsidies.

External:

- Using specialist networks and experts: There is no shame in calling external consulting services for assistance.
- Energy contracting: shifting the pressure onto external service providers, who will also benefit from the savings generated.

Without establishing such an infrastructure, processing companies will have a hard time ahead. After all, their main focus does not tend to be on the issue of *energy,* so they often lack the relevant knowledge.

If you hear people saying, “But that’s how we’ve always done it”, then you know you are on the right path. But that’s an observation independent of the issue of energy.

Integrating an energy management system in accordance with ISO 50001 as referred to above will ultimately lead to establishing a database and developing employees' knowledge. In some cases, companies will then go on to reassess and restructure their procedures and processes.

Methodical Approach

A key step in the process of sustainably improving energy efficiency is to carry out a systemic assessment of efficiency. Analysing individual problems and measures takes little time or effort. However, by comprehensively evaluating all relevant points, it is possible to identify real potential and generate optimum results. It also prevents errors in dimensioning and negative feedback effects, as explained at the beginning of this part based on the onion layer model. Figure 2.1 sets out the methodical approach to be adopted for developing measures.

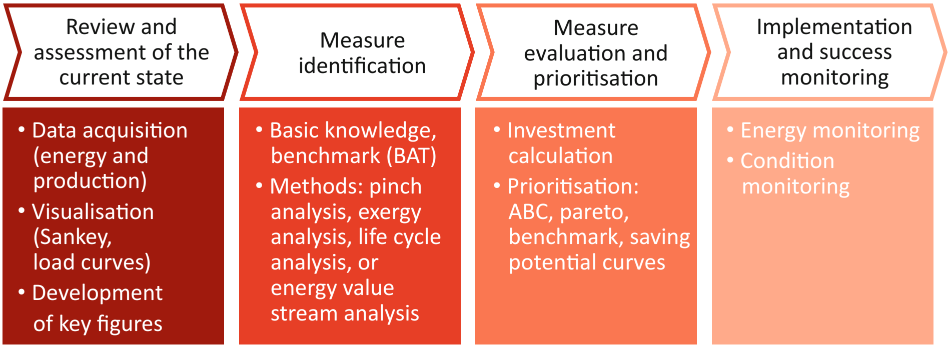


Figure 2.1 Methodical approach for developing measures (Source: based on Hesselbach, 2012)

The first step to achieving greater energy efficiency is always to record and assess the current situation. This can be done with the help of energy monitoring systems. Without this information, companies will only be groping in the dark for potential efficiencies. For assessment purposes, it can be helpful to visualise the data with suitable diagrams and establish critical figures. We will not go into further detail about this specific subject, but examples of assessing the energy efficiency of buildings can be found in Part III, Chapter 3. Efficiency potential exists if the relevant key figure deviates from the sector- or process-specific benchmark.

Measures can be identified using checklists and guidelines for certain cross-cutting technologies – such as the guidelines published by the German Energy Agency (dena, 2015). Sector-specific energy concepts often incorporate the best available technology (BAT) (e.g. Blesl and Kessler, 2018). Further assistance can be sought from databases compiling reliable figures on efficiency measures resulting from completed assessments. The energy savings and costs of such efforts need to be measured and documented. Databases such as this can be used to identify technical, economic, and practical potentials for increasing efficiency specific to a particular sector or technology, as shown by Ebersold et al. (2020) using a US database.

Analysing more complex systems with multiple energy flows requires the use of holistic methods, such as a pinch analysis[1]. The identified measures must then be assessed for their economic (and ecological) benefits and a meaningful sequence in which they can be implemented needs to be derived. In doing so, make sure you take possible interdependencies between individual steps into due consideration! Implementing the measures does not mean they can now be immediately forgotten. Their effectiveness still needs to be checked by setting up a suitable means of monitoring, observing any impact of changing framework conditions, and feeding data into the databases referred to above. In this way, you can continuously map the current state of the art and keep increasing energy efficiency.

Energy Efficiency Using the Example of an Electroplating Plant

Having established the organisational and methodical framework for unlocking energy efficiency potential, we now want to look at the systematic identification and implementation of efficiency measures based on an example from the electroplating industry. Electroplating is understood as the surface treatment of components (e. g. in the automotive sector) via electrochemical metal deposition. Electroplating process chains typically entail many processing tanks in proximity and succession. Electroplating procedures generally comprise three treatment steps: pre-treatment, metal deposition and post-treatment. The aim of the individual tanks is to clean and coat the workpieces in line with specific design and resistance requirements. As shown in Figure 2.2, the various processing tanks require heating and cooling energy at different temperature levels.

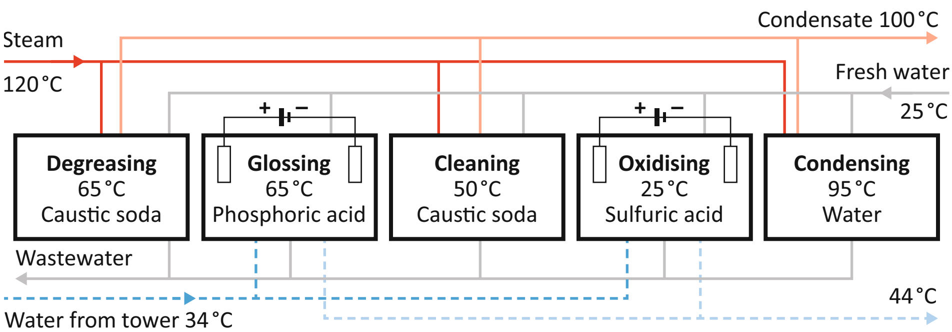


Figure 2.2 Extract from a typical supply circuit of an anodising process (Source: Schlosser, 2021, p. 136)

[1] Pinch analysis is a methodology for calculating thermodynamically feasible energy targets to ascertain the potential for recovering heat and minimising the energy consumption of a process.

In existing processes, steam is typically used as a source of energy, making it difficult to ascertain the energy demands of the individual tanks and integrate a heat recovery system and heat pump into the setup.

Given a large number of tanks, an energy monitoring system is an ideal solution for identifying the individual energy flows. As it is expensive to measure steam, only the volume of natural gas consumed is generally recorded for billing purposes. However, it is possible to measure the consumption of electrical (direct) current in an electrolytic bath without any problems. As the electric current is ultimately converted into heat while ensuring that the temperature in the tank does not exceed a certain threshold, this heat has to be dissipated from the tank via cooling, with the dissipated heat output correlating with the incoming electrical output. Any missing measured values can be added via energy balancing (i. e. based on calculations) around the individual tanks and via temporary spot measurements – for example, using ultrasonic measuring instruments.

The next step involves establishing suitable key figures. In the case of electroplating, the energy requirements are particularly dependent on the surface to be treated, so this can be used as a basis for establishing the key figures. If deviations are identified compared with results from sector guidelines, it is first necessary to check the efficiency potential at process level. This includes evaluating electrolytes that permit lower process temperatures. In addition to applying thermal insulation, the electrolyte surfaces should be covered to reduce loss of waste heat and minimise volumes of exhaust air. It is also possible to use energy-efficient rectifiers to reduce current heat losses (LfU, 2003).

Once the efficiency measures have been implemented in the process, it is necessary to assess efficiency again, this time in terms of cross-cutting technologies. It may have occurred to many to recover the waste heat volumes and integrate them back in the process, in the sense of a closed-loop system. Although this is, without doubt, desirable, it is anything but simple to identify and integrate heat recovery measures, given the large number of thermal flows and the presence of steam heat exchangers. A pinch analysis can provide a solution in this respect. It sorts all thermal flows by load and temperature and outputs the maximum potential heat recovery value as a target parameter. In the present example, this method was used to tap 95 % of the proven potential. The reduction in heating and cooling effort amounted to 24 % and 34 %, respectively. Excess heat in the form of residual cooling demands can be used directly in the process via a heat pump, covering a further 32 % of the heat demands. Based on the onion layer model, it was possible to use the residual waste heat potential to preheat the space heating air during the heating season. Switching energy sources from steam to hot water (necessary for the heat recovery system and heat pump) reduces waste heat losses though requieres the cost-intensive conversion of heat exchangers from steam to hot water.

Only in the following step in the process, we can focus on improving the efficiency of the cooling unit and boiler to cover the remaining heat requirements. As can be seen in the example, the efficiency measures in the process and closed-loop solution have reduced demand for operating energy and, in turn, made it possible to reduce the dimensions of the installations. This illustrates that the sequence in which the measures are implemented is an essential factor, and changing the sequence could result in the clear oversizing of the supply installations. The energy cost savings[2] arising from the measures taken in the various layers of the onion layer are shown in Figure 2.3.

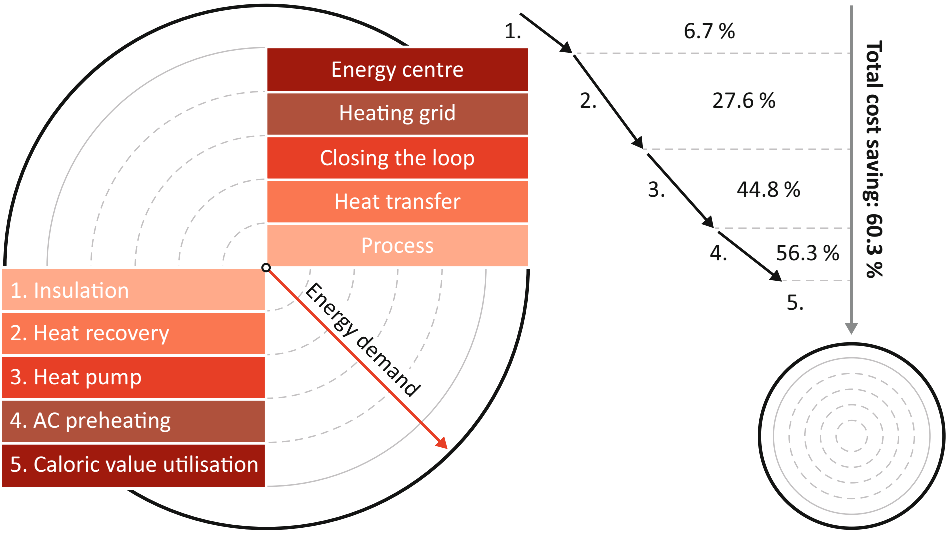


Figure 2.3 Total cost reductions for process heating and cooling energy as well as space heating energy (Source: Schlosser, 2021)

■ 2.2 Where Does Energy Efficiency in the Industry Reach its Limits?

Burning fossil fuels are responsible for the majority of greenhouse gas emissions in the industry. Companies primarily use these fuels to supply process heat, i.e. thermal energy at temperatures from 100 °C to over 1500 °C. For climate targets to be met, the efficiency potential described in this chapter should be exploited until a technically and economically viable threshold is reached. The threshold is set

[2] Electricity price = €0.16/kWh; natural gas price = €0.033/kWh; efficiency of steam boiler = 0.83; annual performance factor of cooling tower = 17.4

based on technical (production-related) restrictions and basic economic parameters. However, these efforts alone are not enough to meet the specified climate targets. Companies need to convert their processes as far as possible to power-based techniques (power-to-heat) by 2050. In some processes, it is not possible to make direct use of electrical energy. In such cases, companies should switch over to renewable fuels originating from power-to-liquid (PtL) or power-to-gas (PtG) processes (UBA, 2019, p. 33). This is particularly applicable for energy-intensive sectors. Several examples illustrating how this can be done are provided below. The corresponding cross-sector linkage concepts are described in detail in Part IV.

In the *steel industry,* furnaces (usually coke-fired) are first used to convert iron ore into raw steel, which releases very high levels of CO_2 emissions. A possible alternative is to switch over to a gas-based direct reduction system followed by a smelting process in an electric arc furnace, for which hydrogen can be used as the fuel. However, in realistic terms, companies will want to wait until the end of the useful life of their respective installations before making such a switch. As this could take over 20 years, it creates yet another obstacle to the speed of progress in improving efficiency levels. The next step in producing the end product of steel is processing raw steel plus additional steel scrap in electric arc furnaces using electric steel production. Companies are, therefore, already using electricity in this second step of the process, so there would be little need to make changes apart from increasing the volume of scrap (UBA, 2019, p. 34). For the *non-ferrous metals industry*, the UBA study assumes that greenhouse gas emissions on the energy side will reduce to zero – although production volumes are expected to increase. This assumption is based on several reasons and measures, such as the use of fuels (PtG) or electricity generated from green power, greater energy efficiency, and a larger share of secondary production (from 56 % to 90 %) (UBA, 2019, p. 34).

2.3 Conclusion and Courses of Action for Smart Municipalities

Part III, Chapter 1 presents a range of options for making our everyday lives and industrial activities significantly more energy-efficient. This concerns deploying cross-cutting technologies – such as lighting, compressed air and heat supply – in households and in industrial plants. Based on the onion layer model, the requirements in terms of energy supply are determined by the application concerned. Starting with the application, we provide various handy information to systematically guide you on your path towards achieving a more efficient energy supply.

Efficiency networks in particular have proven to be a valuable means of exchanging information on funding options and measures. Advice on efficiency and funding mechanisms can become a permanent fixture of the municipality's climate protection and energy management department, making it the first port of call for residents and companies.

There are different factors of relevance for our model town and city than there are for our model village. Depending on a company's quite specific corporate structure, there will be a potential for saving energy in industry, trade and business in Metropolis as well as Medio Town. It is imperative to analyse the use of industrial waste heat flows, and make use of these flows, where possible. However, this requires long-term planning. Each metre of distance between a waste heat source and a waste heat sink is harmful in terms of cost efficiency – and this applies to municipal buildings and households alike. This issue is less relevant in Villago. This is partly due to the low density of processing companies and partly to options for using heat.

However, all regions can support private households. Residents should be able to access low-cost energy advice within their municipality. The landlord-tenant dilemma plays a role in terms of rented accommodation, in that energy costs in rented buildings are passed on by the landlord to the tenant. It is the landlord's responsibility to invest in improvements, but they are not the ones feeling any direct cost pressure. The same applies for the industry. For example, industrial plants could pass on cost pressure to their contracted provider.

It would be desirable for energy-efficient behaviour and purchase to be included in the school curriculum. Many problems in the energy sector could be resolved and savings generated by adopting the systematic methods set out above. What's more, it would encourage a structured approach, which would also be beneficial in many areas of life. However, for energy education to be offered in schools, we would first need expertise in the municipality. According to a study conducted by Roland Berger, the market for energy-efficiency services in Germany will grow to around EUR 50 million by 2025. Growth in this sector lies at 8 % in Europe and 7 % in Germany (Roland Berger, 2019). What could be more evident than the municipality encouraging energy-efficiency service providers to settle locally? It won't take long for contracts to come in, with short distances and trust based on its regional presence.

Just remember there won't be any climate neutrality without energy efficiency.

Checklist

- Ensure adequate information and guidance are available and provide residents and companies with access to specialists in energy efficiency.
- A sufficient number of highly successful energy efficiency networks are now emerging. Join them, or encourage companies based in your region to join them.
- Monitor their energy requirements and relevant temperatures, pressures, etc.
- Set an example and implement efficiency measures in cross-cutting technologies in municipal buildings. And publicise these measures, following up with results.
- Look into energy contracting.
- Integrate lifecycle energy costs into your purchase decisions. These costs often amount to many times the investment costs if inefficient technologies are deployed.

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In "Vision", a joint pilot project conducted in 2017 (BCG, 2019; VW, 2017; TenneT, 2017), the car manufacturing company *Volkswagen* and electricity transmission system operator *TenneT* investigated the possibility of improving short-term solar energy feed-in forecasts using sensor data from vehicle fleets. Although brightness, temperature, humidity, rain and air pressure measurements from car-mounted sensors are primarily used to enhance the safety and comfort of drivers, this data could also be used as an additional, granular and local source of weather information.

To compensate for discrepancies between the predicted and actual volumes of renewable energy generated and guarantee the security of supply, grid operators are forced to intervene at short notice and high cost, for example by ramping additional ancillary generators up or down. The more precise the forecast data, the lower the costs incurred by subsequent grid balancing measures are, which translates into lower grid fees in end-consumer energy bills.

Large-scale, low-cost, and non-intrusive IoT devices can be used to enhance knowledge while enabling online access to previously unconnected systems and sectors. For example, if IoT technology were used to equip transformers in low-voltage grids, this would provide unprecedented transparency about the capacity and flexibility in the power grid. There are many geographically dispersed systems – around 4 million distribution transformers in Europe alone –, the vast majority of which are not equipped with sensors (BdEW, 2020). Not only could interconnected sensors provide insight into the real-time load of the transformers, but – in a similar fashion as in the above "Vision" project – sensors measuring brightness, humidity, temperature and pressure could be mounted on multi-purpose IoT boards (E.ON, 2020a) to deliver hyper-local proxy values for weather conditions. This would enhance standard weather information and improve estimates of feed-in volumes from local renewable generation systems. Finally, complemented by AI-powered load and renewable generation forecasts at each location, real-time condition measurements of low-voltage transformers will provide data-driven support for optimising energy usage, prompt accommodation of peak loads from e-vehicle charging, and the option of activating and initiating efficient demand-side-response mechanisms.

■ 4.3 Data from and to IoT Devices for Controllable Remote Operation

So far in this chapter, we have focused on situations in which data primarily flows from the IoT devices to a central platform, where it is processed and analysed. But what if we enable the bidirectional exchange of information from and to these devices?

The possibility of bidirectionally communicating with IoT devices and remotely controlling and operating the underlying systems opens an entirely new set of opportunities for optimising systems.

Standard IoT data acquisition and IoT controller solutions within households, local renewable energy sources, storage systems and e-mobility charging infrastructure would make it possible to optimise the operation of local energy systems. The standard IoT controllers developed and piloted by E.ON in the village of Simris (Simris, 2020) in the southwest of Sweden were integrated with an advanced suite of forecast and optimisation algorithms, making it possible to:

- increase the village's self-consumption,
- improve its resilience to possible power outages and offer the possibility of running independently from the power grid,
- reduce its energy-related carbon footprint, and
- decrease overall electricity costs.

An overview of the solution is provided in Figure 4.3, showing how local generation and storage systems are utilised to their maximum capacity, enabling the village to optimise its energy exchange with the power grid based on energy market signals and energy prices.

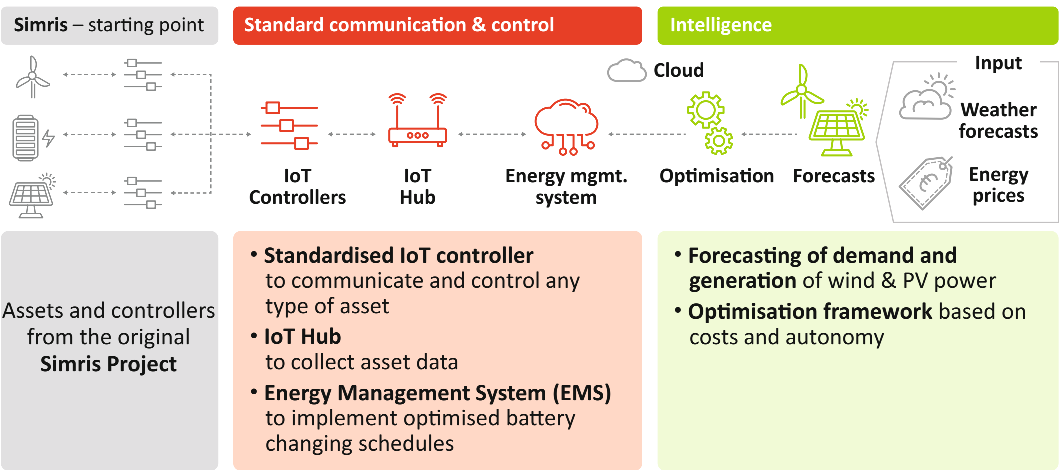

Figure 4.3 Schematic view of the Simris solution developed using standard IoT technology (Source: based on Simris, 2020)

As you can see from the figure, data from various systems, households, wind turbines, the solar farm, and stationary batteries are integrated with weather and energy price forecasts in a holistic and flexible intelligence module. This module then determines the best charging and discharging times for the energy storage system. The application is structured on a modular and scalable basis. It can be deployed in more than one municipality and used to create energy pools, in which ad-hoc surplus volumes of energy can be shared and balanced among different local energy systems or sold on the energy markets.

Given the expected growth in e-mobility, solutions like Simris could be extended and adjusted for use with fleets of electric vehicles to leverage the flexibility provided by vehicle-to-grid options (E.ON, 2020b; E.ON, 2021) – see Part IV, Chapter 4 for further information. Applications such as these – in conjunction with time-based variables that define usage patterns – are based on

- real-time data from the charging infrastructure and battery (state of charge),
- typical plug-in times (arrival and departure), in the case of commercial or private e-vehicle fleets,
- desired charge levels, and
- location-specific load profiles and grid capacity constraints.

Concerning e-vehicle fleets, it is possible to use dynamic load management algorithms so that the available energy can be optimally distributed among the various cars. For those e-cars able to do so, it is possible to exchange energy bi-directionally with the grid (cf. Fig 4.4).

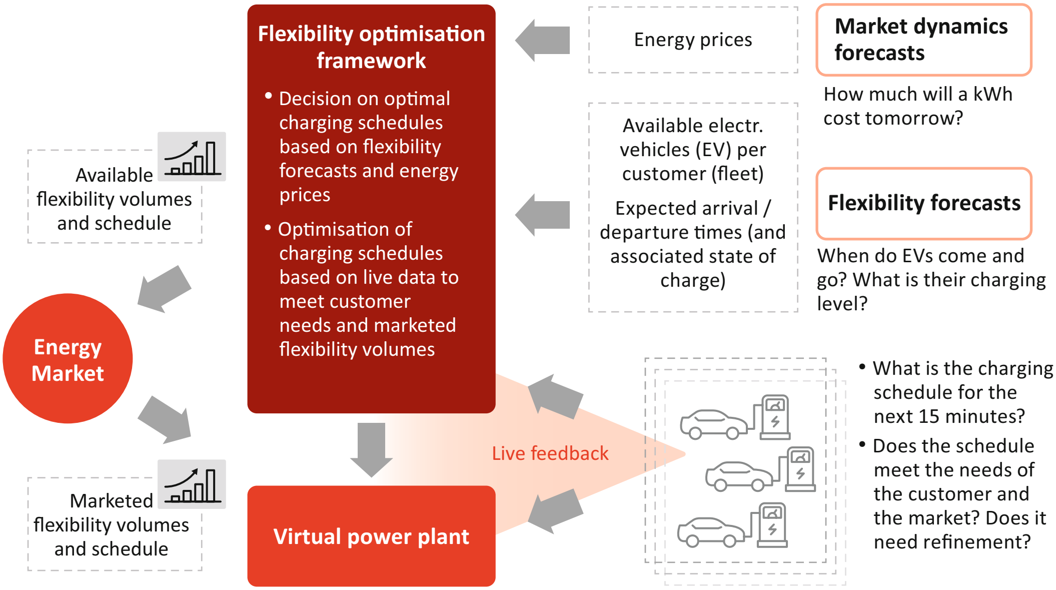

Figure 4.4 Process of optimising vehicle-to-grid flexibility using a combination of energy market and grid information with e-vehicle data

Finally, in the heating and cooling sector, IoT technologies can be used to develop innovative solutions to minimise thermal losses and leverage the balancing potential in nearby buildings. Within certain limits, the thermal inertia of buildings can be utilised in combination with heat pumps to act similarly as e-mobility batteries, in other words, as a means of storing ad-hoc surplus energy volumes and absorbing peaks in demand.

4.4 Conclusion and Courses of Action for Smart Municipalities

Summarising the above shows that IoT technologies can be used to achieve rapid object-to-object communication. On this basis, advanced analytical and digital solutions can be developed to form the beating heart of future smart cities, smart towns and smart rural areas. Over the next few years, IoT devices will increasingly build up connectivity to the real world via a wide range of sensors, creating a rich source of contextual data and knowledge and linking previously unconnected domains and sectors (BCG, 2019). Municipalities need to plan their digitalisation process correctly and in good time so that data coverage, security and ownership can be ensured across the critical infrastructures of cities, districts, towns, villages and communities.

The possibility of bidirectionally communicating with IoT devices and remotely controlling and operating the underlying systems opens an entirely new set of opportunities for optimising systems. The key to unleashing the full potential of smart cities, towns and rural areas rests on the possibility of merging, blending and combining various types of IoT data and data sources to deliver valuable and actionable insights. High-quality, real-time data and smart machine-learning algorithms will digitally link the mobility, power, heating and cooling sectors, enabling unprecedented synergies and potential for optimisation. This, in turn, will create opportunities to use energy more efficiently and sustainably, and in turn, reduce costs, losses and waste.

Checklist

- Check whether you have sufficient information relating to the critical infrastructure of your municipality and whether you need to invest in sensor technology.
- Review your IoT systems and assess the potential for using other IoT devices.
- Check IoT data ownership and bring stakeholders around the same table to understand how data can be used and shared in synergy with each other.
- Raise citizens' awareness about the advantages of IoT technology and the beneficial impact of sharing their data.
- Think about using IoT data beyond its specific domains. Create the option of owning and sharing data outside its original application/platforms.

4.5 Literature

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