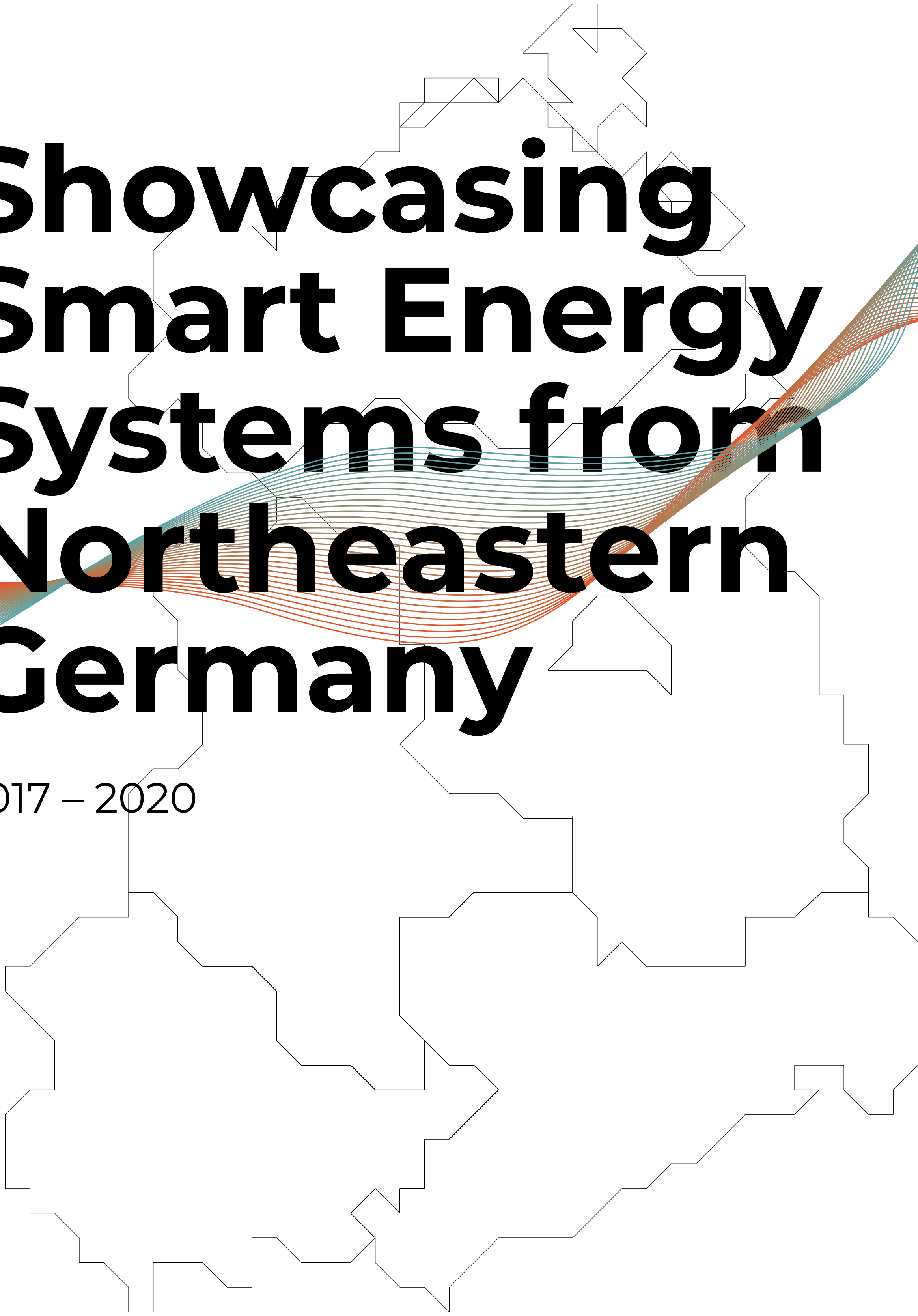
Showcasing Smart Energy Systems from Northeastern Germany

2017 – 2020



#WindNODE**report2020**

#WindNODE**report2020**

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Table of Contents

WindNODE Report 2020

WindNODE is a pluralistic project – not only at the administrative level, but especially with regard to those participating and our target audience. We care about people, independent of gender. Therefore, to the best of our ability, we have used gender-neutral language.

Zoom In

A detailed table of contents for the subprojects is provided on the following page. →

Zoom In

Overview of the subprojects and the project partners involved

* Associated partner.

WindNODE is looking into a future in which our electrical energy demand is completely covered by renewable sources.

#WindNODE**report2020**

Editorial

Germany has ambitious plans for the next stage of its energy transition: a dual phase-out that will shut down the country's last nuclear power plant by 2022 and its last coal-fired power plant by 2038. On the path towards a low-carbon future, Germany has already achieved important milestones. It now meets nearly half of its electricity demand with renewable energy; this figure is closer to two thirds in the northeastern states that make up the WindNODE region. Still, as the transition advances to the next phase, crucial questions lie ahead. For example, how can we efficiently and securely integrate a 100 % renewable energy supply – primarily from wind power and photovoltaics – into our energy system? Will our efforts at sector coupling succeed, i. e. to decarbonise applications in heating, mobility and industry that rely on fossil fuels? How can we craft a regulatory framework that will catalyse the energy transition instead of standing in its way? And what role does digitalisation play in all of this?

Four years ago, WindNODE set out to develop model solutions that would help build the energy system of the future. From 2017 through early 2021, more than 70 partners from six German states collaborated on this task at locations throughout eastern Germany and Berlin. Our research approached energy system transformation from multiple perspectives, examining it not only as a driver of innovation in energy and information technology, but also as a transition taking place within a broader legal, economic and social context. The primary focus of our project was on increasing flexibility, specifically by investigating the potential of a concept called "using instead of curtailing" to adapt our electricity consumption to renewables as intelligently as possible. WindNODE created the largest 'reality lab' in northeastern Germany, made possible by an agile network of hundreds of experts. The project succeeded not only in inviting dialogue and public participation, but also in presenting a highly visible advertisement for the skills and know-how of our energy region. Thanks to the regulatory experimentation clause, it also offered creative freedom. And last but certainly not least, it reminded us that the energy transition opens up many opportunities – for innovation, for new jobs and for exports.

WindNODE is coming to a close in the midst of the global COVID-19 pandemic. Thus far, our society has responded to this crisis with remarkable determination. We must now demonstrate that same resolve to achieve German and European climate targets and increase the share of renewable energy in our energy mix to 100 % over the next few years. Our joint project and supporting partners will continue to pursue this goal passionately, even after the formal conclusion of the WindNODE project. After all, the path to 100 % renewables is not only an ecological imperative; it is also an officially stated industrial strategy for Germany.

Many people have contributed to the success of the WindNODE project. First and foremost, we would like to thank the Federal Ministry for Economic Affairs and Energy (BMWi), which made our work possible with the programme Intelligent Energy Showcases – Digital Agenda for the Energy Transition (SINTEG). We are also grateful to the project management company Projektträger Jülich (PtJ), a reliable partner that provided professional assistance on every funding question. In addition, we would like to express our gratitude to the six participating federal states and their leaders – all of whom were key WindNODE sponsors who offered support as well as invaluable input. More than 400 people were involved in WindNODE project work: some devoted all of their working hours to the project; others provided expertise as needed. We thank all of these participants for their outstanding contributions. Finally, we would like to extend a special thank you to the members of the steering committee and the workstream coordinators, who supported WindNODE on a voluntary basis and demonstrated tremendous dedication to the project. It was a fantastic and very enriching experience for 50Hertz to coordinate a joint project with so many partners and stakeholders and assume overall management of WindNODE – under the umbrella of 50Hertz, but also as an independent entity in the service of the project.

We now invite you to learn more about us and our work. We hope to stay in touch and continue the dialogue – even after the WindNODE project comes to an end.

Dr Dirk Biermann
50Hertz Chief Markets & System Operations Officer / Joint Project Coordinator

Markus Graebig
WindNODE Project Director

Lab Notes: 'Reality Lab' for the Second Phase of the Energy Transition

Over a period of more than four years, running from 1 January 2017 to 31 March 2021, we at WindNODE have developed model solutions for the energy transition and gave visibility to our reality lab. The work was preceeded by two years of project development, starting in 2015. In the Lab Notes, we take a look back on our history and our milestones. To learn more about our extensive international activities, please refer to 'WindNODE worldwide' on page 216.

← OUR MILESTONES

2020

2019

2018

2017

OUR MILESTONES

Vattenfall Wärme lays the foundations for Germany's largest PtH plant

Berlin State Secretary Stefan Tidow and the General Manager of Vattenfall Wärme Berlin, Gunther Müller, lead the groundbreaking ceremony. The Power-to-Heat (PtH) plant at the Reuter West district heating power station in Berlin, the largest of its kind in Europe, is expected to achieve a thermal output of 120 MW, making it one of the main providers of flexibility in the WindNODE project. ► p. 148

6 Nov 2017 | Berlin

2017 annual meeting: WindNODE project kick-off in Berlin

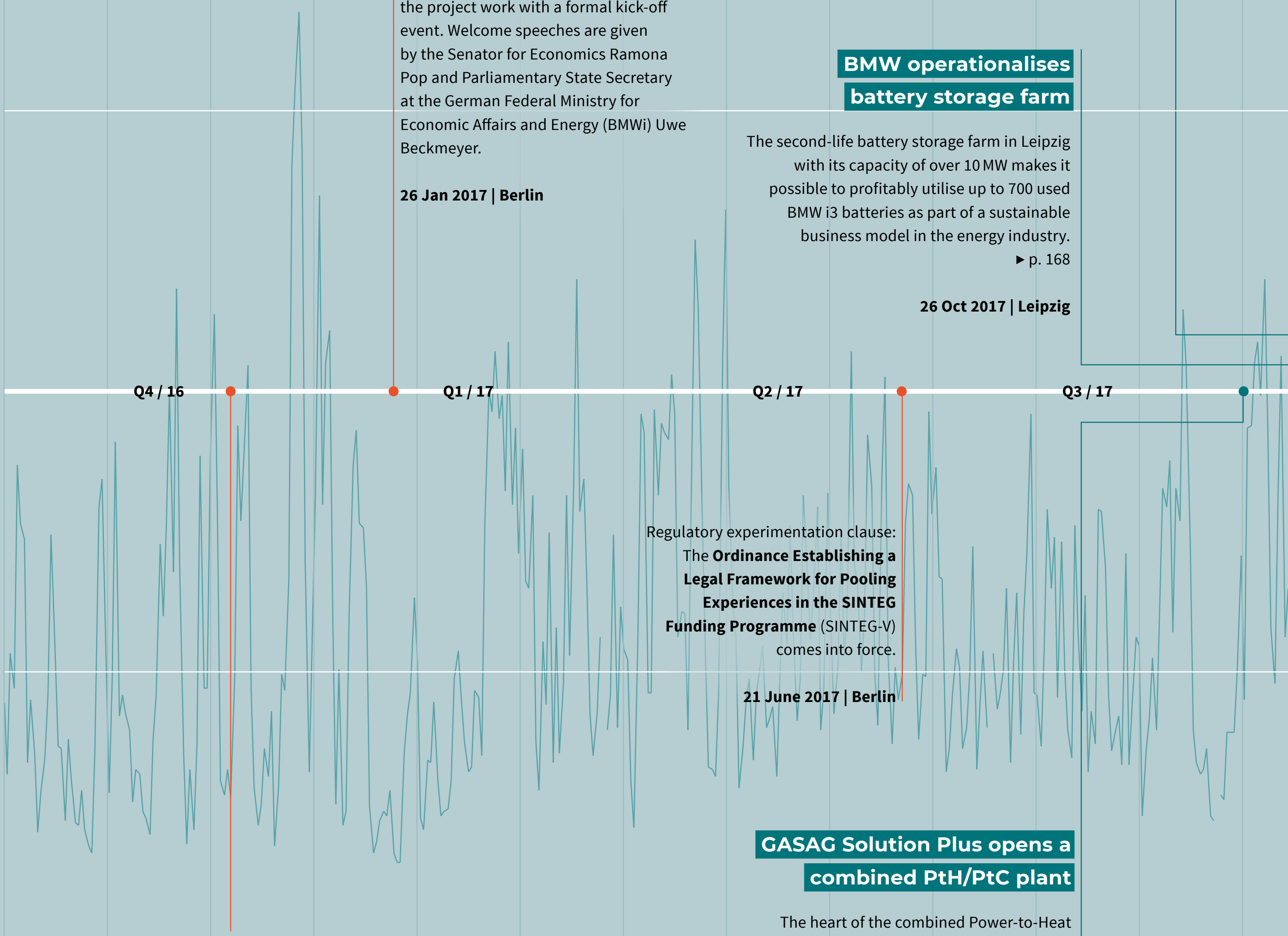
At the invitation of project coordinator 50Hertz, the WindNODE partners start the project work with a formal kick-off event. Welcome speeches are given by the Senator for Economics Ramona Pop and Parliamentary State Secretary at the German Federal Ministry for Economic Affairs and Energy (BMWi) Uwe Beckmeyer.

26 Jan 2017 | Berlin

BMW operationalises battery storage farm

The second-life battery storage farm in Leipzig with its capacity of over 10 MW makes it possible to profitably utilise up to 700 used BMW i3 batteries as part of a sustainable business model in the energy industry. ► p. 168

26 Oct 2017 | Leipzig



Regulatory experimentation clause: The **Ordinance Establishing a Legal Framework for Pooling Experiences in the SINTEG Funding Programme** (SINTEG-V) comes into force.

21 June 2017 | Berlin

GASAG Solution Plus opens a combined PtH/PtC plant

The heart of the combined Power-to-Heat (PtH)/Power-to-Cold (PtC) plant on the EUREF campus in Berlin is made up of two water tanks, each with a storage capacity of 22 m³. GASAG offers tours of the Energy Workshop for those interested. ► p. 144

13 Oct 2017 | Berlin

Share of renewable energy in the 50Hertz control area as ratio of daily renewable energy generation and total electricity consumption.

Source: BNetzA – German Federal Network Agency/SMARD.de (BNetzA electricity market information platform)

Opening of the WindNODE Energy Transition Showroom at 50Hertz

This exhibition at 50Hertz is meant to offer visitors an insight into the technical and physical challenges involved in the energy transition. In addition, the showroom illustrates the challenges and duties of a transmission grid operator. ► p. 192

30 Nov 2017 | Berlin

Kick-off for WindNODE Live!

Berlin State Secretary Christian Rickerts and the General Manager of Berlin Partner, Dr Stefan Franzke, open the travelling exhibition where visitors can learn about the challenges, research questions and solutions associated with the WindNODE subprojects. ► p. 194

12 Feb 2018 | Berlin

Opening of a visitor site: the GridLab grid simulator

GridLab's grid simulator gives visitors an insight into grid and system management, challenges during times of disruption and faults as well as procedures to restore grids after failure. ► p. 122

9 March 2018 | Schönefeld

2018 annual meeting: An intelligent energy transition in northeastern Germany

At the Leuna chemical site, around 200 participants discuss the first year of the project and the milestones for the work ahead. Keynote speakers include the Minister for the Environment, Agriculture and Energy in Saxony-Anhalt, Prof. Dr Claudia Dalbert, and Albrecht Gerber, Minister for Economic Affairs and Energy in Brandenburg.

14 – 15 March 2018 | Leuna

Opening of the Lidl showcase store

Berlin Senator for Economics Ramona Pop opens the Lidl showcase store. In addition to a 100-kW/250-kWh battery storage system for testing grid-friendly operations, there is an interactive 3D model demonstrating how the store's technology will work. ► p. 104

10 April 2018 | Berlin

The Westsächsische Hochschule Zwickau (West Saxon University of Applied Sciences Zwickau) begins field tests in the Marienthal neighbourhood. ► p. 176

24 May 2018 | Zwickau

Smart energy transition: WindNODE is selected as one of the 2018 Landmarks in the Land of Ideas

The project is one of only 100 recipients to be selected by an independent jury for this distinction from among just under 1,500 entries in a nationwide competition.

4 June 2018 | Berlin

SINTEG 2018 annual conference
The Schaufenster Intelligente Energie – Digitale Agenda für die Energiewende (SINTEG – Intelligent Energy Showcase – Digital Agenda for the Energy Transition) annual conference, featuring contributions from all showcases, is held at the BMWi.

5 – 6 June 2018 | Berlin

Opening of the Industry Energy Hub at the Virtual Development and Training Centre (VDTC)

Strategic planning and the intelligent operation of technical systems require the comprehensive design, monitoring and control of multiple energy media. This is demonstrated at the innovative multi-sector control room of the Fraunhofer Institute for Factory Operation and Automation (IFF). The presented solutions can be used to identify, modelled and make economical the industrial flexibilities at any given site. ► p. 160

20 June 2018 | Magdeburg

Zwickauer Energieversorgung (ZEV) erects an intelligent transformer substation and an innovative battery storage system in the Marienthal neighbourhood. ► p. 176

26 June 2018 | Zwickau

Lumenion, GEWOBAG and Vattenfall Wärme launch a high-temperature steel storage system ► p. 188

23 Sep 2018 | Berlin

Q4 / 17 · 2018 · Q1 / 18 · Q2 / 18 · Q3 / 18 · Q4 / 18

Start of the test run for the WindNODE flexibility platform

50Hertz, E.DIS, ENSO NETZ, Stromnetz Berlin and WEMAG Netz start the test run for the WindNODE flexibility platform. Providers of flexible power generation resources or electricity consumers can submit bids with a geographical attribute. Grid operators anticipating congestion on their grids can then accept the most affordable bids for their region, in consultation with distribution system operators and the transmission system operator. ► p. 66

20 Nov 2018 | Berlin

Opening of the Municipal Energy Management System (KEMS) visitor site

The Municipal Energy Management System (KEMS) showcases the intelligent networking of energy generation and consumption as well as the use of innovative grid technologies and grid operating concepts. ► p. 82

30 Nov 2018 | Berlin

2019

Q1 / 19

2019 annual meeting

More than 150 participants meet in Zwickau to take stock. The developmental work that has been going on for 24 months has now started bearing fruit, with many subprojects having achieved exciting results. Martin Dulig, Saxony's State Minister of Economic Affairs, Labour and Transport, opens the event.

19 – 20 March 2019 | Zwickau

Visitor site ZUKUNFTSRAUM*ENERGIE* showroom

In Siemens' **ZUKUNFTSRAUM***ENERGIE* showroom (Energy of the Future space), visitors can explore interactive scenarios designed to illustrate how manufacturing processes contribute to the integration of renewables into the system, and what it takes to optimise the energy system of the future. ► p. 158

14 May 2019 | Berlin

Q2 / 19

Opening of WindNODE partner Technische Universität Berlin's Energy in Motion exhibition

Energy in Motion, a 300-m² space providing a window into the world of energy, offers a feast for all senses with five themed islands featuring audio stations, films and interactive experiences and highlights interesting, significant and often surprising relationships and pieces of information. ► p. 210

18 June 2019 | Berlin

Q3 / 19

Opening of a new visitor site: the Stadtwerke Hennigsdorf grid buffer storage system

The new heat storage system, which has a volume of around 1,000 m³, forms part of the Hennigsdorf heating hub, which is intended to usher district heating to 80 % climate-neutral generation. ► p. 152

28 Aug 2019 | Hennigsdorf

Visitor site now also at Stromnetz Berlin

At the Eichenstraße site, visitors can experience charging infrastructure available at over 30 parking spaces. ► p. 205

3 Sep 2019 | Berlin

First Lusatia Conference: 'Structural Change and Energy Transition – Together for the Lusatian Region of Excellence'

Around 200 participants from business, science, politics and society came together in Schwarze Pumpe (Spremberg) to discuss the region of Lusatia's pathway to becoming a European model region for successful structural change. Ten companies, including WindNODE partners 50Hertz, enersis, ENERTRAG, IBAR Systemtechnik, the ILK Dresden, Vattenfall and Lumenion, present to Brandenburg ministers Prof. Dr Jörg Steinbach (Economic Affairs, Labour and Energy) and Dr Martina Münch (Science, Research and Culture) the Lusatian Memorandum for Sustainability, Innovation and Employment.

9 Sep 2019 | Spremberg

Q4 / 19

2020 | Q1 / 20 | Q2 / 20 | Q3 / 20 | Q4 / 20 | Time

Opening of a visitor site at the experimental neighbourhood in Prenzlauer Berg

An energy transition solution has been developed in a Berlin residential area built in the 1960s: building automation increases the use of renewable energy as well as energy efficiency in buildings. Visitors can learn that flexibility is capable of making a vital contribution to reducing CO_2 emissions in the building sector, without affecting comfort levels.

► p. 180

6 Nov 2019 | Berlin

ENERTRAG operationalises the wind-powered heat storage system in the energy village of Nechlin in Brandenburg

At Nechlin, 17 wind turbines generate around 70 million kilowatt-hours of emission-free electricity annually. On particularly windy days, more energy is generated than can be fed in, so that it has to be curtailed several times a month. As the wind-powered heat storage system in Nechlin illustrates, this electricity can be used effectively to generate heat in situations with generation overcapacity.

► p. 76

6 March 2020 | Nechlin

Stadtwerke Frankfurt an der Oder opens up a district heating power station and a heat exchange station as visitor sites

Based on its experience in operating power plants and cross-border district heating with the neighbouring Polish town of Słubice, the municipal utility Stadtwerke Frankfurt an der Oder develops IT solutions for fully automatic control of all the required processes in the power plants. This ensures the most efficient possible operation of the power plants and hence the best possible use of renewable energy. This can be experienced at the two visitor sites. ► p. 80

13 Aug 2020 | Frankfurt an der Oder

Best Practice Manual: Identifying Flexibility Options is published

The WindNODE partners' Best Practice Manual: Identifying Flexibility Options provides a practice-oriented contribution to the discussion about the use of flexibility in the energy transition. The manual focuses on the individual options for identifying and using flexibility and summarises the project's findings in terms of identifying potential flexibility. ► p. 41

24 Aug 2020 | Berlin

Flexibility, Markets and Regulation: Insights from the WindNODE Reality Lab is published

This publication showcases the WindNODE partners' experience with marketing flexibility. There is a particular focus on the innovative WindNODE flexibility platform for market-based grid congestion management. The project's experience with the SINTEG-V (SINTEG Ordinance) regulatory experimentation clause is also examined. ► p. 42

16 November 2020 | Berlin

1866

Werner von Siemens discovers the dynamo-electric principle, laying the foundation for modern electrical engineering.

1938

Konrad Zuse introduces the Z1, a mechanical computer.

The Model Region: Pioneering Energy and Transition

Facts and Figures

The WindNODE region, which stretches from the Baltic Sea to the Thuringian forest, is home to more than 16 million people. The area also features every component of a complete electrical energy system, including every individual link in the value chain and all grid levels, market roles and stakeholders. All of these elements take part in the WindNODE project. Sixty percent of the region's electricity needs are met by renewables, with volatile wind and solar power accounting for the largest share. This makes the region a unique pioneer of the energy transition – and offers a glimpse of our future energy system.

Committed to tradition

The history of the modern energy system began roughly 150 years ago in the centre of today's WindNODE region. It was here that Werner von Siemens presented his electric generator, laying the foundation for the breakthrough of electrification. Some 70 years later, Konrad Zuse introduced the world's first functional computer. Both innovations now culminate into what is called the 'digitalisation of the energy industry' – in the middle of an energy region that is steeped in tradition and home to one of the most vibrant start-up scenes in Europe. In the WindNODE region, energy innovation fuels our past, our present – and our future.

Experienced in transformation

Perhaps the most exciting chapter in Germany's post-war history began in our region 30 years ago: the political transition, or 'Wende', that led to the country's reunification. As a result, when it comes to processes of transformation, the people of our region have more experience than most – which means that they are particularly well-positioned to meet the challenges of this next transformation. After all, like the original 'Wende', the energy transition is ushering in changes that will touch every aspect of society for a literary take (see e-stories, p. 240).

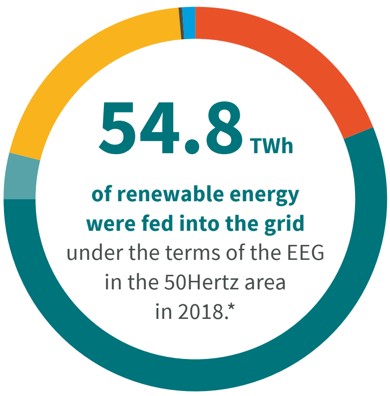
108,946 km²
total area of the WindNODE region

16.2 million
residents

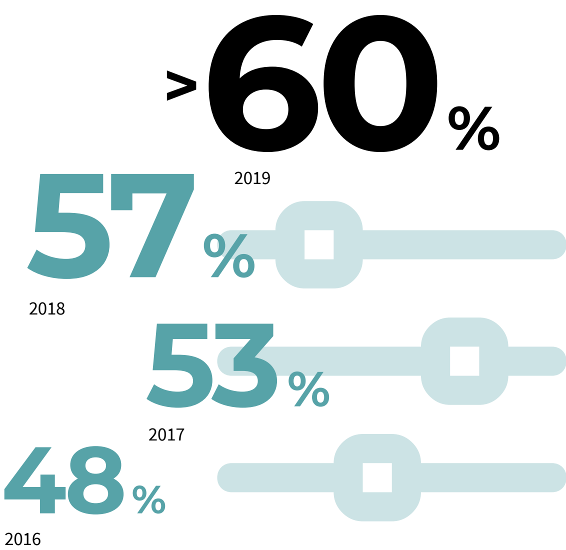
WindNODE works in a context that is characterised by challenges such as the structural change in Lusatia and other coal regions, questions of acceptance for wind farms and grid expansion, and finally discussions with the 'electrical neighbours' Poland and the Czech Republic about cross-border challenges like 'loop flows'.

Approx. 87,000
full-time employees in the field of renewable energy (as of 2016)

In 2018, 54.8 TWh of renewable energy was fed into the grid – significantly more than the 46.0 TWh recorded in 2016.*



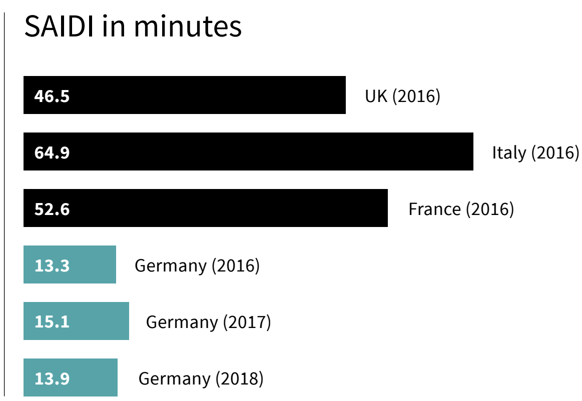
Security of supply with wind and sun
Renewable energy sources account for more than half of the electricity consumed in the WindNODE region. Most of this 'green' electricity comes from volatile sources (sun and especially wind), whose actual feed-in depends on the time of day and the weather. Nevertheless, electricity consumers in our region enjoy world-class security of supply – even during periods of extremely high or low winds.



Share of electricity consumption that could be covered by renewable energy in the 50Hertz area between 2016 and 2019.*

Security of supply

The System Average Interruption Duration Index (SAIDI) is a measure of the reliability of a country's energy supply. The statistic indicates the average number of minutes of unplanned power outage per customer in one calendar year. Germany is generally one of the best-performing countries in the index.



* Refers to the 50Hertz control area (including Hamburg). The WindNODE region consists of Berlin and the five new federal states, i.e. the federal states re-established after Germany's reunification. Sources: Federal Network Agency (BNetzA), Federal Statistical Office, Institute of Economic Structures Research (GWS), 50Hertz, Council of European Energy Regulators.

A regional prototype for the energy transition

The WindNODE region is the ideal environment to develop and test solutions for the energy transition because, with regard to energy, it is today where many other regions will be in the future. The model region comprises the entire control area of transmission system operator 50Hertz (with the exception of Hamburg) and includes all levels and stakeholders that make up a complete large-scale energy system. This encompasses populated areas with abundant wind power capacities as well as urban centres with high power demand.

1.81 2016 **1.94** 2017 **2.06** 2018

ratio of installed renewable capacity to peak load*

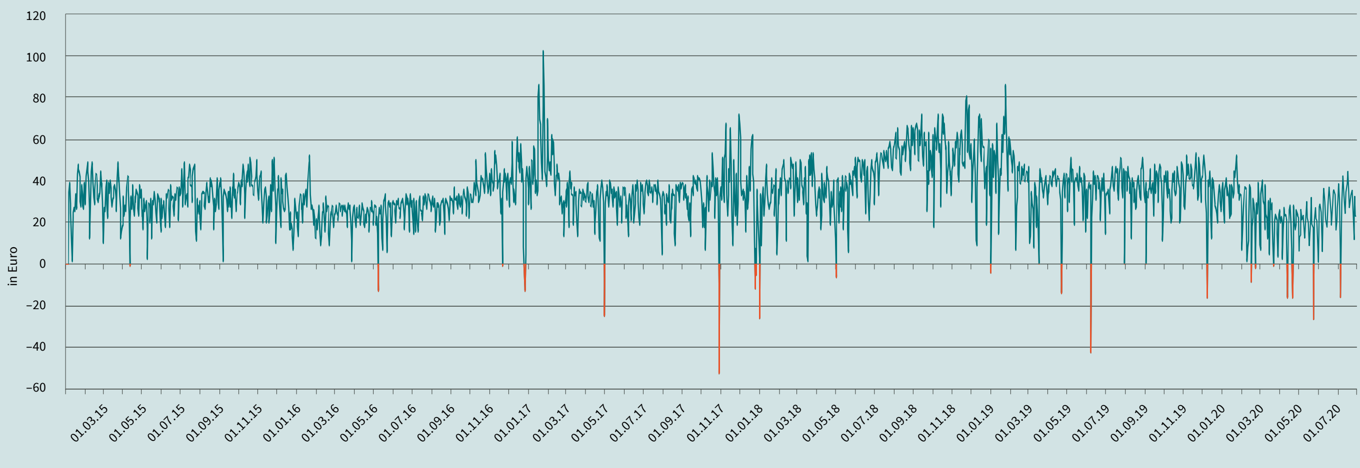
This means that renewables could theoretically cover more than twice the annual peak load in the model region, given optimal conditions for wind and solar energy. This value will never be reached in practice. However, in January 2019, a new record was set in the 50Hertz control area: for the first time, wind turbines fed more than 16 GW of power into the grid simultaneously – enough to cover even the region's peak demand.

16 GW

peak load*

Consumers in the region draw a maximum of around 16 GW power from the grid at the same time.

Wholesale spot-market prices in the 50Hertz control area, 2015–2020	2015	2016	2017	2018	2019	2020**
Hours with negative prices	110	97	146	134	211	236
Days with negative prices	25	19	24	25	39	37
Days with at least 6 hours of negative prices	12	7	12	10	18	23



* Refers to the 50Hertz control area (including Hamburg). The WindNODE region consists of Berlin and the five new federal states. ** Data through July 2020.

Sources: Federal Network Agency (BNetzA), 50Hertz, ENTSO-E.

2018 **33.0 GW**

2017 **31.3 GW**

2016 **29.5 GW**

installed generation capacity from renewables

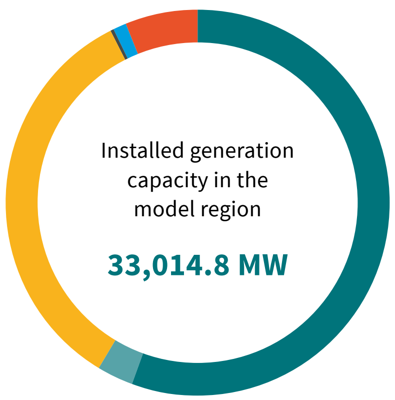
This is the sum of the installed generation capacities of all renewable power plants (as defined in the EEG) in the region from 2016 to 2018.

> 1.2 %

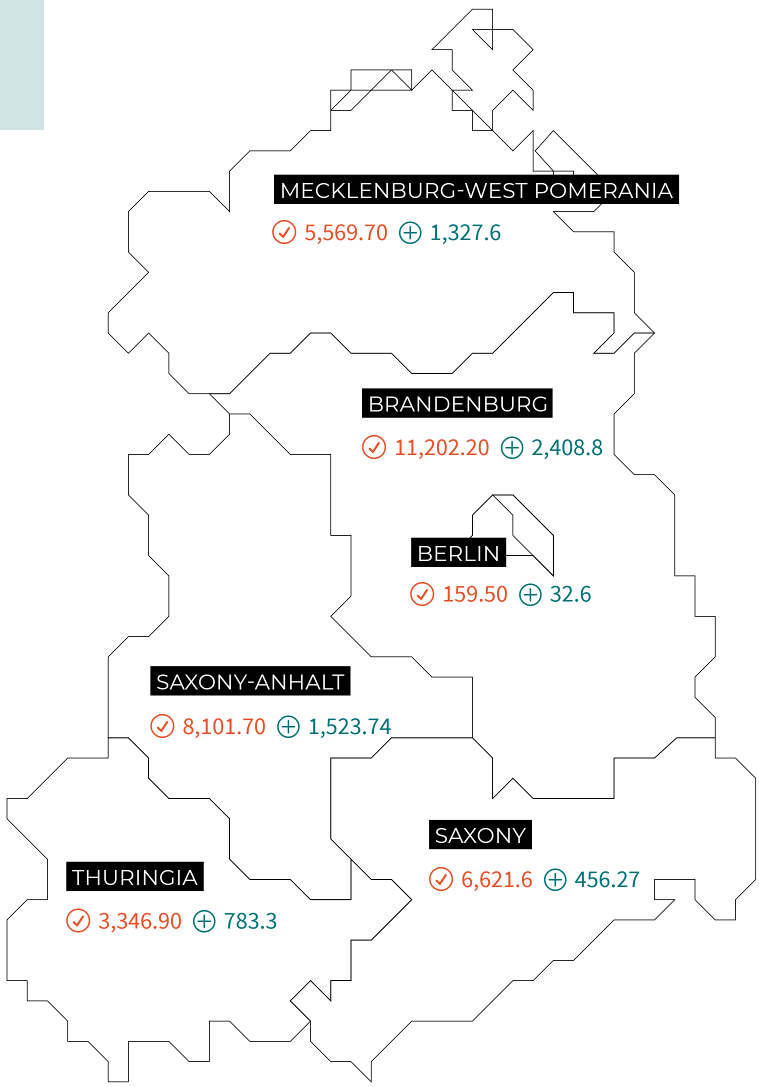
of total generation from renewable energy sources was curtailed due to physical limitations of the grid (grid congestion) in accordance with section 13.2 of the German Energy Industry Act (EnWG) in 2018. This left 686 GWh of electrical energy unused.

A look into the future of the energy system

The high proportion of fluctuating feed-in regularly pushes electricity grids to their limits and requires frequent intervention by the transmission system operator: a challenge that other regions will have to face increasingly, too. The strength of WindNODE thus also arises from the uniqueness of its model region, where the energy future is already present in many respects.



► **Renewable means volatile:** wind and solar power dominate the supply of renewable energy in the model region. Above: shares of installed capacity by technology in 2018.

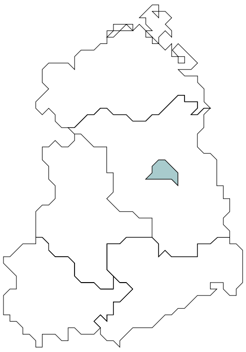


► **Steady growth:** installed generation capacity from renewable sources in the model region as of 2018.

Installed generation capacity (MW)

Net expansion of generation capacity, 2015 – 2018 (MW)

Sources: 50Hertz, Federal Network Agency (BNetzA)



Berlin – Energy Transition in the Capital City

‘The WindNODE project, a collaboration between several German states, has rightly made clear that the energy transition can only succeed if the regions stand shoulder to shoulder: intelligent, renewable generation and flexible but reliable consumption are the cornerstones of our strong, future-oriented energy region.’

Michael Müller
Governing Mayor of Berlin

In the Berlin Energy Transition Act, Berlin set the ambitious goal of achieving climate-neutrality by 2050 at the latest. In order to meet this target, we must focus, first and foremost, on shifting Berlin’s energy supply to a decentralised, flexible, secure and socially responsible model that is based on renewable energy. This new system will link electricity, heat and mobility, and citizens will participate in its success through access to affordable energy and opportunities for public input. Rapid decarbonisation of the energy supply plays an important role in this process:

→ Berlin discontinued electricity generation based on lignite as early as 2017. Hard coal will be phased out by 2030, provided that security of supply is guaranteed.

→ The feasibility study ‘Carbon Exit and Sustainable District Heating Supply Berlin 2030’ shows how the heat supply of Berlin can be transformed by 2030. Instead of coal, innovative, low-emission technologies like combined heat and power stations, biomass plants, industrial waste heat and heat pumps will be used to supply heat for the city. As a first step, operations began at Europe’s largest power-to-heat plant as part of the WindNODE project. This 120 MW plant uses excess wind power to provide sustainable heat in Berlin.

→ One of the objectives of the Berlin Energy and Climate Protection Programme is to supply 25 % of the city’s electricity from solar power. To achieve this goal, scientists and experts developed the ‘Solarcity Master Plan’ after extensive consultation with stakeholders. The plan identifies Berlin’s solar capacity and proposes measures to mobilise these resources by providing support to

Climate-neutral by

2050

25 % of electricity from solar power by 2050

▲ Vision of Karl-Marx-Allee, Berlin, in 2035.

market players and initiatives, eliminating barriers and offering target-group-specific advice and information.

→ In addition to a large number of innovative energy service providers and energy technology companies, the newly established municipal utility Berliner Stadtwerke has provided the impetus for increased solar production on the city's rooftops, especially those of public buildings.

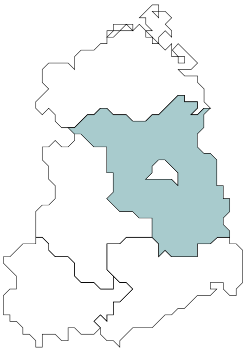
As an energy consumer, Berlin is both reliable and innovative, and renewable generation in the surrounding areas often exceeds local electricity demand. The metropolis is making a decisive contribution to the success of the energy transition in the entire region with intelligent, energy-related solutions for supply- and demand-oriented distribution. Storage, load flexibilisation, sector coupling and the electrification of urban transport contribute to this. Organisations in the Berlin-Brandenburg Cluster Energy Technology – specifically those specialised in energy management, energy technology, science and research – played a key role in initiating the WindNODE joint project.

Addressing the technical, economic and social challenges of energy system transformation, such as intelligent management of the energy system, will require cooperation across state borders. The Berlin Senate has expressed support for the WindNODE joint project's approach, which is based on intelligent interconnections between specific energy system transformation projects on a range of topics, from renewable generation to distribution and innovative use. The WindNODE project demonstrates the technical and economic feasibility of the energy transition.

For more information:
www.berlin.de/sen/energie

'I am pleased that – thanks to WindNODE – we have exciting energy transition locations in Berlin that demonstrate how cities can make a vital contribution to the success of the transition through digitalisation, sector coupling and participation.'

Ramona Pop
Mayor of Berlin and Senator for Economics, Energy and Public Enterprises



Brandenburg is Pushing the Energy Transition Forward

'For Brandenburg, one of the leading states in renewable energy expansion, it's vital to take the energy transition to the next level. Over the past several years, the WindNODE project has provided new insight and developed innovative solutions in the field of sector coupling. We must now implement these on a large scale to make the energy transition a success.'

Dr Dietmar Woidke
Minister President of Brandenburg

Brandenburg is widely known as an 'energy state', but this designation is often only associated with the industrial culture that has historically revolved around the local energy carrier, lignite, as well as the refinery in Schwedt. Uckermark and Lusatia have always provided the energy supply for our economy. Since the beginning of this century, both regions – along with others, like Prignitz and Havelland – have been leaders in renewable energy expansion.

Uckermark has emerged as the frontrunner among these regions thanks to ENERTRAG, which has played a pioneering role in the energy transition. After all, the world's first hybrid power plant to use wind energy, electrolysis and batteries began operation in Prenzlau as early as 2011, and a heat storage unit powered by wind was recently opened in Nechlin.

Lusatia is also moving towards renewables, away from its 'old' energy model. In Brandenburg, the Lusatia-Spreewald planning region is the leader in wind power, with approximately 1,700 MW of installed capacity. This represents around a quarter of the wind power installed in the entire state. The planning region also accounts for roughly a quarter of photovoltaic capacity in Brandenburg.

Although these developments provide a solid foundation for the energy transition, we must not ignore the challenges facing the state of Brandenburg. These challenges are related not only to the decision to phase out lignite, but also to the large installed capacity of fluctuating renewable energy. In addition, thus far the energy transition in Germany has focused primarily on the electricity sector. In

35.6 billion kWh

of electricity exported (2017): Brandenburg is Germany's largest exporter of electricity

▲ A sustainable and innovative master plan implemented in Feldheim, a district in the Brandenburg city of Treuenbrietzen, created a decentralised renewable energy system that supplies electricity to companies, private households and municipalities.

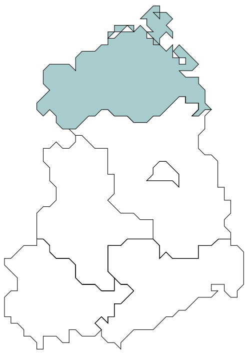
2018, however, the heating sector – primarily non-electrical consumption –accounted for over 53 % of the state final energy demand; mechanical applications mainly in industrial drives and above all in the mobility sector, made up roughly 39 %. The energy transition can only be successful if there is a dramatic reduction in CO_2 emissions – not only in the electricity sector, but also in mobility and heating.

That is why, for years, Brandenburg has done all it can to ensure that what was once known as the 'electricity transition' finally becomes a transition across all sectors and all energy carriers. Sector coupling is essential to the success of the energy transition, which is why Brandenburg made it a central component of its Energy Strategy 2030 as early as 2012. Sector coupling also opens up enormous opportunities for our energy regions through Power-to-X technologies and the creation of a hydrogen economy. Power-to-X technologies that produce green hydrogen from renewable energy may be the key to a successful energy transition. Green hydrogen enables sector coupling between the electricity, heating and transport sectors and can thus provide solutions for a low-carbon industry. Given the significant opportunities for industrial policy, Brandenburg is committed to implementing new and innovative concepts to supply industrial sites with renewable energy produced in the state. This can create greater added value and job growth in the region – exactly what is so urgently needed for structural development in Lusatia. These opportunities can also benefit the entire state.

For more information:
www.mwae.brandenburg.de/de/energiestrategie-2030/bb1.c.478377.de
(German only)

'Without comprehensive sector coupling and energy storage, Germany will not achieve its energy policy goal of reducing greenhouse gases by 80 – 90 % by 2050. Hydrogen has the potential to play a key role in the energy transition. That's why we urgently need a market for renewable hydrogen: only sustainable business models will trigger the investments we need now to ramp up hydrogen production.'

Prof. Dr Jörg Steinbach
Minister for Economic Affairs and Energy
of the State of Brandenburg



Energy from Mecklenburg-West Pomerania

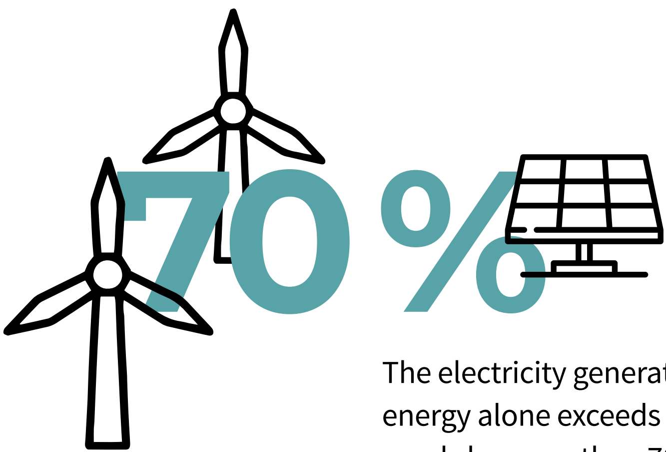
‘Mecklenburg-West Pomerania is at the forefront of Germany’s renewable energy production and technical innovation in this growing market. We want to continue this success story. I very much hope that insights from WindNODE will allow renewable energy to be integrated into the energy system even more efficiently in the future.’

Manuela Schwesig
Minister President of Mecklenburg-West Pomerania

Renewable energy expansion is a central pillar of the energy transition in Mecklenburg-West Pomerania. In 2013, we became the first German state to produce enough renewable energy to meet all of our electricity needs.

One of our main priorities is to ensure that the clean energy we produce is fully utilised. Only then can we gain the public acceptance we need for further renewable energy expansion. Accomplishing this goal will require us to develop storage technologies and convert electricity from clean sources into forms that can be used in transport, in buildings for heating and hot water, and in industry as an alternative to energy storage.

We want to strengthen the connections between these sectors. This interlinking, called ‘sector coupling’, opens up opportunities to combine strategies for economic growth and climate change as part of a holistic approach to the energy transition. Hydrogen plays a crucial role in enabling electricity use in other areas: it can be deployed in all sectors and can transfer energy between sectors. The Hydrogen Strategy for North Germany, which we prepared in collaboration with Germany’s other northern federal states, encourages advancements in the production of hydrogen as the energy carrier of the future. Our goal is to establish a large-scale hydrogen economy in northern Germany; however, we do not anticipate any real breakthroughs in



The electricity generated from renewable energy alone exceeds the state’s electricity needs by more than 70 %.

▲ Wind farm in Mecklenburg-West Pomerania.

'For a successful energy transition, it is vital that we convert electricity from clean sources into forms that can be used in transport, in buildings for heating and hot water, and in industry as an alternative to energy storage. Creating a flexible relationship between supply and demand will require a smart interlinking of all sectors. The WindNODE project has made an important contribution to this goal.'

Christian Pegel
Minister for Energy, Infrastructure and Digitalisation of Mecklenburg-West Pomerania

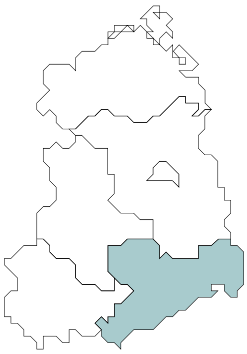
hydrogen and sector coupling technology until a more robust regulatory framework is in place. We have submitted proposals for an experimentation clause that would create more favourable economic conditions for electricity use in the heating, transport, industrial and chemical sectors.

Digitalisation is bringing about other important changes in the energy industry – requiring the management of large flows of feed-in data, the use of smart meters, and process automation.

One of the main energy policy goals of Mecklenburg-West Pomerania, as a federal state that produces a significant amount of energy from renewable sources, is increasing the added value of renewable energy generation. That is what made WindNODE such an exciting opportunity for us: it provided a showcase for intelligent regional electricity solutions that link load and generation centres in northeastern Germany. The implementation of innovative pilot projects has shown how a comprehensive and sustainable energy transition can be achieved in all sectors.

Moving forward, the success of the energy transition will remain dependent on close cooperation between all stakeholders: consumers, businesses, policy-makers, citizen groups and – last but not least – experts in research and development. We want to achieve the energy transition – together.

For more information:
www.government-mv.de/The-Ministries/Ministry-of-Energy%2c-Infrastructure-and-Digitalization/



Energy Transition in Saxony

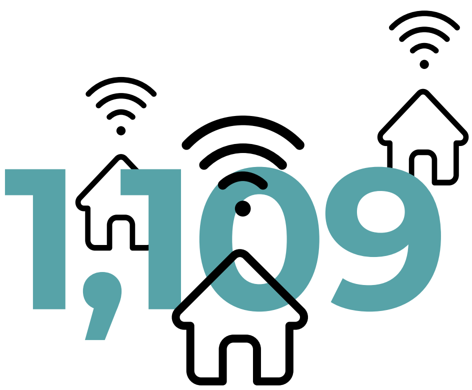
'WindNODE has shown that the use of energy storage and the integration of renewable energy into the grid contribute to a secure energy supply. Now we need a fundamental revision of the tax and allocation system in the energy sector. That is the only way we can achieve the goal of an inexpensive and competitive energy supply.'

Michael Kretschmer
Minister President of the Free State of Saxony

The state of Saxony is committed to remain an 'energy state'. This will require it to supply energy that is affordable and sustainably generated. Public enthusiasm for measures addressing climate- and energy-related issues has spread across the state and demands concrete action, especially at a political level. The energy transition is a historic once-in-a-generation challenge.

The current Coalition Agreement outlines plans for determined action in the Free State of Saxony over the next five years. The state's goals are deliberately ambitious: Saxony will phase out coal-fired power generation by 2038 at the latest and will be carbon-neutral by 2050. Such changes offer opportunities to introduce new technologies and business models – even beyond the energy sector – that can secure long-term regional prosperity, especially for lignite mining areas. We have already seen the first positive results.

As the renewable energy expansion in the state accelerates, the Free State will set an example with its own properties and vehicle fleet. In 2020, it will also update its energy and climate protection programme, which will serve as a guiding principle for future energy and climate policies at the state level. The results of WindNODE will be incorporated into this process.



residential units connected to the intelligent grid

▲ E^3- Research Factory at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz.

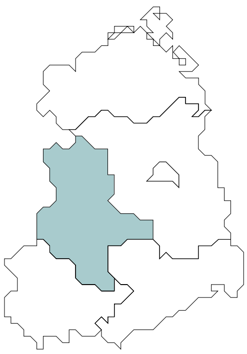
Saxon participants in the WindNODE joint project have demonstrated their capacity for innovation and contributed their know-how to the project, especially in the areas of neighbourhood concepts and (industrial) load shifting. At the same time, they have benefitted from cross-sectoral exchange between industry and research within the showcase region. Visitor sites present the energy system of the future and show the visitor how plants participate in the electricity market in real time. From the battery storage facility in Leipzig, over the E^3 Research Factory for Resource-efficient Production, to the ubineum competence centre for the development and presentation of products and services on 'smart living': the results of WindNODE are visible across Saxony.

The next step is to refine the tried-and-tested business models from the showcase in preparation for the mass market, and to translate what we have learned into future action. Project results will help to identify gaps and obstacles in the regulatory framework that have hindered flexible systems from operating economically thus far. This framework must now be addressed and changed.

For more information:
www.energie.sachsen.de

'WindNODE has demonstrated the potential for flexible exchange between power generators and consumers. The joint project partners from Saxony always led the way in developing concrete applications and business models. We must now translate these valuable insights and results into a new regulatory framework so that we can continue to have a reliable, decarbonised energy system.'

Wolfram Günther
Saxon State Minister of Energy, Climate Protection, Environment and Agriculture



Energy System of the Future for Saxony-Anhalt

'The stability of the energy system in Saxony-Anhalt is of great importance in the context of the energy transition and the coal phase-out. WindNODE developed potential solutions and practical examples that show how load management potential can be identified, evaluated and marketed as an instrument to integrate renewable energy into the energy system. This is very significant for the industrial state of Saxony-Anhalt because it provides a way for large-scale industrial consumers to contribute to a stable renewable energy system.'

Dr Reiner Haseloff
Minister President of Saxony Anhalt

The federal state of Saxony-Anhalt wants to continue to play a pioneering role in the expansion of renewable energies. In keeping with this goal, the state aims to increase the share of renewable energy sources in primary energy consumption to 100 % by 2050. This will require a cross-sector approach to electricity, heating and transport, as well as an ambitious expansion of renewable energy. Renewable energy must also be integrated successfully into the energy system.

Saxony-Anhalt's climate and energy concept, which was adopted in 2019, outlines and evaluates 72 measures to reduce greenhouse gas emissions. In order to meet targets, the energy system of the future will need to satisfy certain requirements. Issues like the intelligent integration of renewable energy, energy storage, sector coupling and increased flexibility are therefore especially important. In combination with the digitalisation of the grid, new models for more intelligent and decentralised grid operations management present innovative options for improving flexibility. The grid expansion required in the course of the energy transition will depend, in turn, on the feasibility and use of these options. The phase-out of coal-based electricity generation also makes it necessary to tap the existing potential and implement new technologies and concepts throughout the energy system.

The results of WindNODE can demonstrate possible solutions and courses of action on many relevant topics. The projects of greatest interest to Saxony-Anhalt include those focused on identifying, evaluating and marketing load shifting potential. Energy-intensive industries

100 %

share of renewable energy in the primary energy consumption of Saxony-Anhalt **by 2050** account for a large share of the state's electricity consumption and thus offer considerable potential for testing and implementing reasonable measures for load management. Industrial and commercial companies in the chemical, cement, paper and wood, food, metal, and glass industries are relevant in this context. Apart from the possible implementation of load management measures in households or during the smart charging of electric vehicles, the industrial sector holds the greatest potential.

The WindNODE projects show how digitalising the energy system can provide flexibility options in energy production and consumption. Approaches that apply ICT and digitalisation in the field of networking and grid operations management also provide valuable insight that can inform the development of Saxony-Anhalt's future energy system.

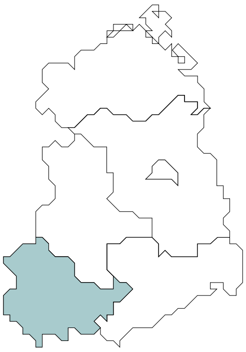
After potential solutions and courses of action are established, an important step will be to raise awareness of existing options – among the public and in the fields of economics, politics and science – and then to implement a variety of measures.

For more information:
www.mule.sachsen-anhalt.de/energie

'Saxony-Anhalt has set a goal to use renewable energy to supply all of the energy used in the electricity, heat and transport sectors. The results of WindNODE can make a valuable contribution to the use of flexibility options and the integration of renewable energy into the energy system in all sectors. The WindNODE visitor sites offer everyone insight into the world of the energy transition. This is important in order to increase understanding of the need for renewable energy expansion as well as to boost acceptance of the energy transition.'

Prof. Dr Claudia Dalbert
Minister for Environment, Agriculture and Energy of Saxony-Anhalt

▼ Overhead power lines near Wolmirstedt, a town in the Börde district.



Thuringia: Shaping the Energy Transition – Seizing Opportunities

‘Thanks to its central geographical location, Thuringia plays a special role in the energy transition. For the future, it’s important to create a networked, intelligent and cross-sector energy system that does not end at national borders. WindNODE is already testing innovative technological applications for smart grids, flexibility and energy storage. These innovations will help Thuringia prepare for the challenges that the energy transition presents.’

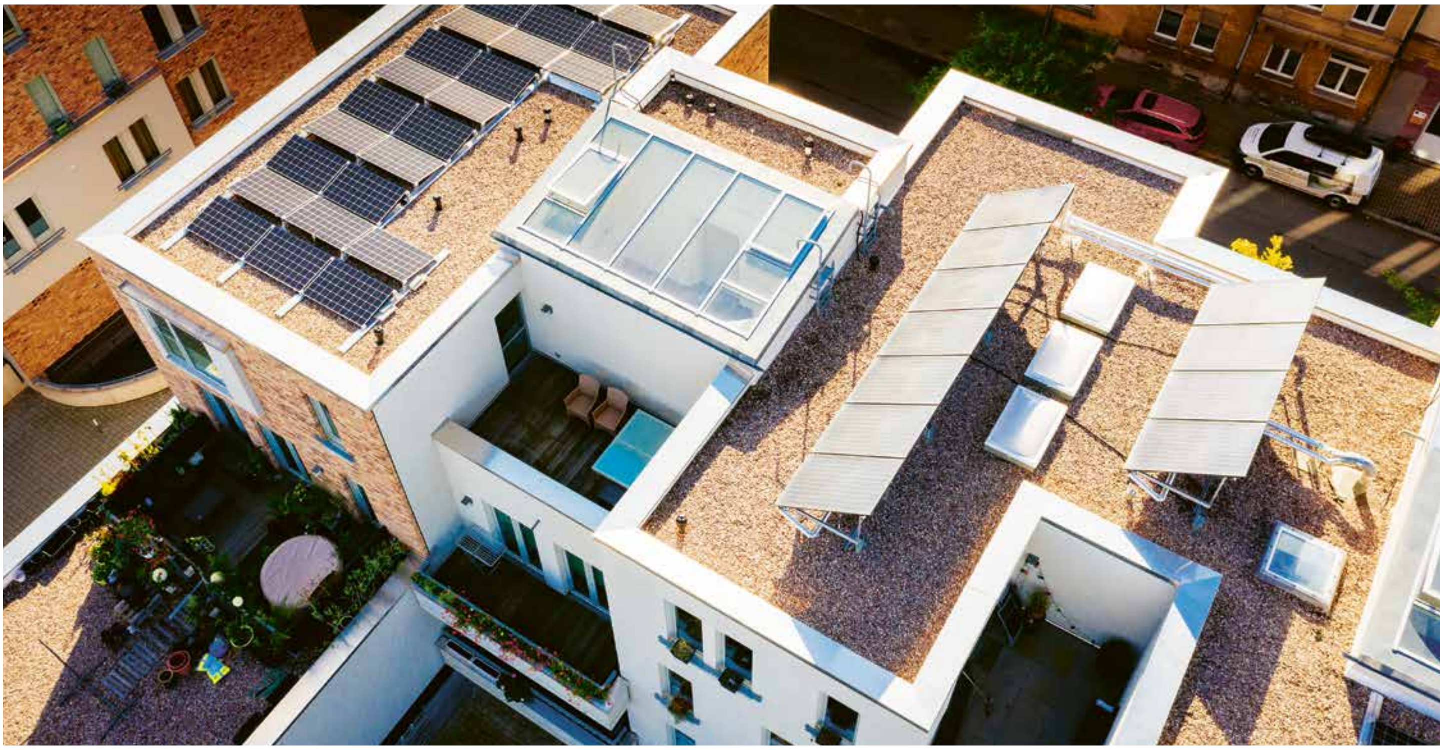
Bodo Ramelow
Minister President of the Free State of Thuringia

Thuringia is committed to a decentralised, regional and renewable energy transition. Its ambitious energy target underscores this commitment: Thuringia aims to cover all of its energy needs with a mix of renewables produced from its own resources by 2040. Achieving this objective will require an expansion of renewable energy, improvements in energy efficiency, greater energy conservation, and measures for sector coupling. The energy supply must play a decisive role in achieving climate goals. In order to gain broad public support, the future energy system must be environmentally sustainable, secure and affordable. Thuringia was the first federal state in eastern Germany to pass a climate law; the legislation supports the state’s central energy goals and took effect at the end of 2018. In 2019, the state government adopted an integrated energy and climate mitigation strategy, which proposes concrete measures to achieve the energy and climate targets defined in the state’s climate law. The climate law and strategy provide the framework for state energy and climate policy and will set guidelines and establish binding commitments.

Thuringia introduced intelligent energy and climate policy to ensure that the state is well-positioned for the future. To achieve this goal, the state must tap the potential for value creation from climate mitigation and the energy transition. The energy transition also provides opportunities for innovation, competitive jobs and increased participation. The Thuringian state government is using its room to manoeuvre to offer various forms of support for citizens, local authorities and companies. State programmes promote initiatives including energy efficiency measures in companies and municipalities, thermal analyses and studies of potentials, landlord-to-tenant electricity supply

The goal:
100 % renewable energy by 2040

2040



▲ Auenhöfe landlord-to-tenant electricity installation in Erfurt.

models, and demonstration projects. In addition, the state energy agency ThEGA provides a range of services for consultation and support in implementing specific projects. The state government's goal is to ensure that the energy transition benefits as many stakeholders as possible. This builds support and increases acceptance.

A broad research landscape has developed in Thuringia to study the transformation of the energy system. The state government supports this research and the implementation of best practices. Universities are collaborating with research institutes and companies to research and evaluate the current challenges of the energy transition. The research projects focus on the integration of renewable energy into the market; on measures to increase the flexibility of supply and demand; and on intelligent coupling of the electricity, heating, transport and industry sectors. The joint project ZO.RRO (Zero Carbon Cross Energy System), for example, is researching and developing systemic solutions for a carbon-free energy supply with support from the state and federal government. The integration of hydrogen into the energy system of the future also shows great promise; the H_2-Well project is testing the prerequisites for a regional hydrogen economy. JenErgieReal, Thuringia's reality lab, is a testing ground for methods to improve energy system flexibility. Experience gained in the course of the broader WindNODE project can contribute to the development of innovative energy transition system projects in Thuringia.

For more information:
www.umwelt.thueringen.de

'We are designing an energy system based on renewable energy. This offers many opportunities for economic growth. The WindNODE project has generated significant momentum for the energy transition, and I am certain that the results can have an impact beyond the project period – and beyond the project partners.'

Anja Siegesmund
Minister for the Environment, Energy and Nature Conservation of the Free State of Thuringia

Pluralism as a Principle

Steering committee The steering committee is the decision-making and supervisory body of WindNODE.

Project partners Project partners receive financial support within the framework of the SINTEG funding programme.

Associated partners Associated partners do not receive any financial support from SINTEG.

Subcontractors Subcontractors are assigned specific tasks by individual project partners but do not receive direct funding from SINTEG.

More than 70 Partners in One Joint Project

Stromnetz Berlin

Wirtschaftsförderung Brandenburg | WFBB

BMW GROUP

Borderstep Institut für Innovation und Nachhaltigkeit

BOSCH Technik fürs Leben

b-tu Brandenburgische Technische Universität Cottbus - Senftenberg

DECKEL MAHO Seebach GmbH

Fraunhofer IFF

Fraunhofer IWU

GASAG SOLUTION +

SCHWARZ LIDL Kaufland

Stadtwerke Cottbus Heizkraftwerksgesellschaft

PUMACY TECHNOLOGIES

RL REINER LEMOINE INSTITUT

SENERTEC

SOLANDEO

stadtwerke FRANKFURT (ODER)

STADTWERKE HENNIGSDORF

Westsächsische Hochschule Zwickau University of Applied Sciences

zev strom erdgas wärme

ENERSTORAGE POWER TO HEAT. INDUSTRIAL SCALE.

enso NETZ

enviaM

envia THERM

e+ Zeit Ingenieure ganzheitlich · energieoptimiert · nachhaltig

eit InnoEnergy Knowledge Innovation Community

LEAG

LUMENION

MITNETZ STROM

RADEBERGER GRUPPE

ThEGA Thüringer Energie- und GreenTech-Agentur

ubitricity

VHP READY Virtual Heat & Power

VSB

WEWOBAU Bei uns wohnt die Zukunft.

Zere

EUREF Consulting

GRIDLAB

htw Hochschule für Technik und Wirtschaft Berlin University of Applied Sciences

i ö w INSTITUT FÜR ÖKOLOGISCHE WIRTSCHAFTSFORSCHUNG

E

Our Focus

50 subprojects working on 4 major focus areas

50
subprojects

WindNODE is a pluralistic project, with over 70 partners working in 50 subprojects to provide a detailed insight into the various aspects of the 100 % renewable, smart energy system of the future. In every subproject, individual perspectives and approaches are employed to develop model solutions for the energy transition.

The results of WindNODE's individual subprojects are detailed on pages 60 – 190.

9
workstreams

The 50 subprojects are divided into nine workstreams, each with a particular thematic focus. This gives structure to the overall project, with each workstream beeing represented by a voluntary workstream coordinator. The inevitable and sometimes intentional overlapping of workstreams are perfect opportunities for networking and an exchange of expertise.

4
focus areas

All nine workstreams and their 50 subprojects contribute to the overall WindNODE story, which covers four overarching focus areas. On the following pages, we present aggregated findings from the subprojects, grouped by these focus areas, and provide a condensed overview of our results. Much of the work has been done by volunteers in our Coordination Commitees, which will be featured as well.

Areas

34–211

Our Focus Areas

WindNODE develops model solutions for the second phase of the energy transition – to create a smart energy system of the future that receives 100 % of its power from renewable sources. We pursued this goal in 50 subprojects (presented in detail on pages 60 – 211). Some of these are interlinked; others are organised independently. This pluralism is a key feature of WindNODE – and we are convinced that it will also characterise the energy system of the future. Although our model solutions are diverse, they can be grouped into four overarching focus area:

1

Identifying flexibility,
i.e. recognising and describing technical potential for load shifting and sector coupling;

2

Activating flexibility,
i. e. facilitating the economical use of technical flexibility potential in new and existing flexibility markets;

3

Digitalising the energy system,
to make the energy transition possible and maximise the benefits of energy data;

4

Developing a reality lab,
a concept that yielded a series of methodological blueprints on a range of topics – from managing a network of more than 70 partners, to diversifying approaches to public engagement, to a 'show and tell' about the opportunities of the energy transition.

The following pages present an overview of our findings in these four focus areas. For research conducted in the first two focus areas, cross-workstream Coordination Committees (CoCos) have worked together for nearly two years to synthesise results. We would like to thank the WindNODE colleagues who participated in this process for their voluntary contribution to this effort.

After introducing the four focus areas, this report briefly outlines the significance of the SINTEG Ordinance (SINTEG-V), the regulatory experimentation clause that provided the framework for WindNODE's research on innovative concepts. This 'regulatory sandbox' is a novel tool in energy research, and we believe that it should remain an integral component of reality labs and similar projects in the future.

1

Focus area 1:

Identifying Flexibility

What is flexibility?

The WindNODE Coordination Committees developed the following definition:

> ‘Flexibility refers to the ability of elements in the energy system to adjust their power output or input as an active response to an external signal that reflects the variability of electricity generation and consumption.’

Why is flexibility needed?

The need for flexibility in the power system stems from an important property of electrical systems: production must always be equal to consumption. Conventional power plants can adapt generation to consumption and thus provide flexibility. Due to the fluctuating nature of renewable energy sources, there is a growing need for flexibility on the consumption side. Demand for flexibility in the energy system can originate from wholesale markets (day-ahead, intraday) or from efforts to eliminate grid congestion. Flexibility can also be requested on the balancing markets or be required for the provision of ancillary services.

At a minimum, the following parameters must be determined in order to quantify the technical potential of flexibility:

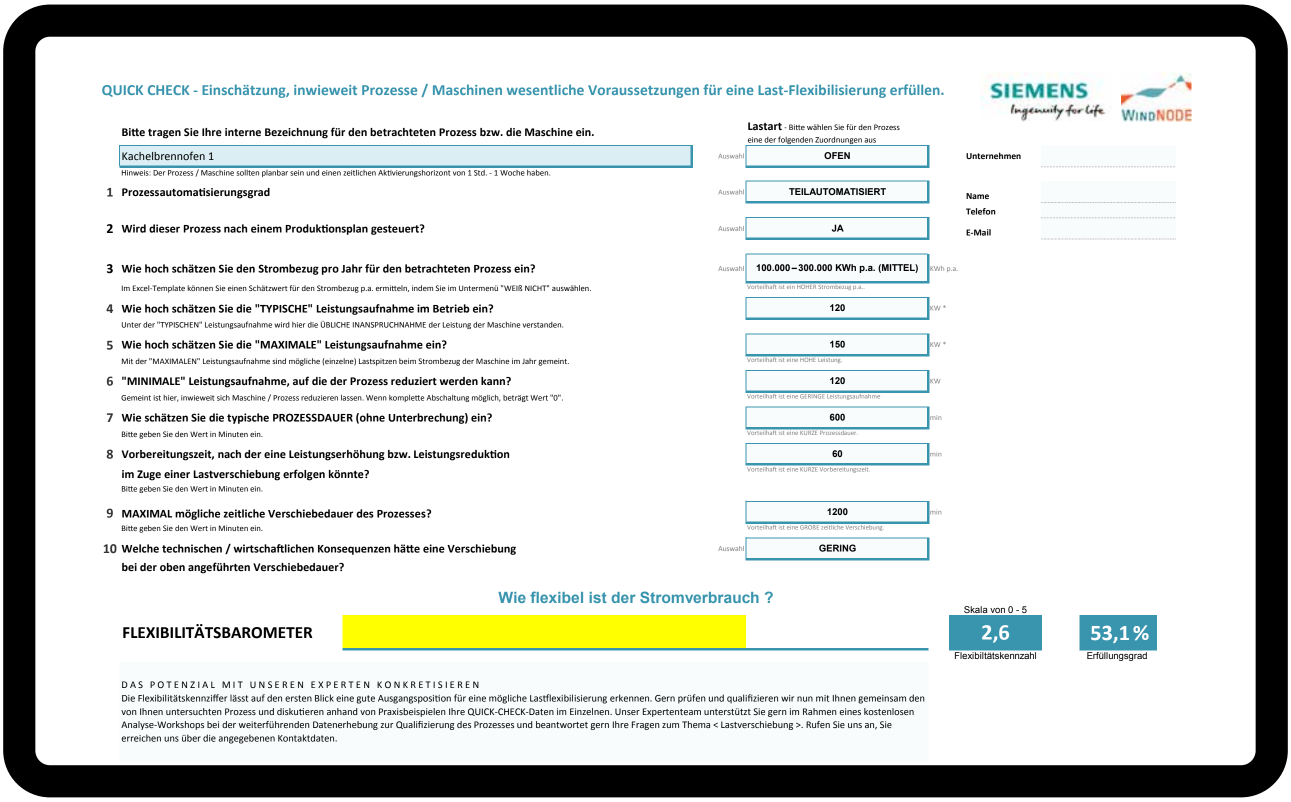
- Value range of the change of power input or output,
- Duration of the change,
- Lead time until the change can be effected.

The supply and demand sides determine the level of technical flexibility potential in an energy system. When calculating the economic flexibility potential, it is important to consider the costs and benefits achieved by providing flexibility, as well as the existing regulatory framework.

How can flexibility be characterised?

The table provides an overview of the key parameters useful when identifying flexibility potential: prerequisites, market participation, technical and hardware requirements. It also facilitates the decision on whether flexibility potential can be activated and indicates the necessary steps to take. The overview covers four sectors: the tertiary sector (trade, commerce and services), industry, transport, and neighbourhood solutions.

	Tertiary sector (trade, commerce and services)	(Energy-intensive) industry	Mobility and transport sector	Neighbourhood solutions
Prerequisites for the provision of flexibility	Compliance with customer requirements / fulfilment of customer preferences / no influence on customer experience	No negative influence on production or manufacturing / fulfilment of customer preferences, compliance with peak load limits	Guarantee of required transport capacity	No adverse effect on living comfort
Previous market participation	Generally none (only via choice of power utility)	Generally flexible procurement of electricity, in certain cases balancing power market	Generally none (charging stations supplied by power utilities)	Generally none (only via choice of power utility)
Typical annual energy consumption	400 – 1,600 MWh	Starting at 100 MWh	Depending on fleet size	Approx. 3 – 8 MWh per household
Technical status quo	Mainly non-controllable loads, occasionally controllable or shiftable loads or processes, potentially emergency power generators	Controllable loads and generating units, occasional ability for (temporary) autonomous operation	Controllable charging stations, no higher-level coordination or control, no grid or system services	Occasional CHP and PV plants but generally low generation capacity, mainly non-controllable loads, small heat and electricity storage systems
Monitoring, control and information technology for flexibility	Partially to widely available, but not designed for flexibility	Energy monitoring and management available	Energy monitoring and management available	Available to some degree via networked central heating systems and smart building technology
Technical measures required	Installation of system-specific smart meters and devices for intelligent control and networking	Installation of measurement and control technology as needed	Installation and operation of a mobility control centre for the coordinated management of energy flows	Installation of smart building technology and smart meters, system-specific control technology
Organisational measures required	Transparent tracking of energy flows	Integration of flexibility into the value chain	Controlled charging	Transparent tracking of energy flows



▲ 'Quick check' tool of flexible loads (German only).[1]

A tool to identify flexibility potential in individual companies

As part of the 'Meine Energie für Meine Stadt' (My Energy for My City) initiative, Siemens created a 'quick check' tool that helps to record and assess individual parameters (e. g. for machines, plants, storage systems) that are important in identifying flexible systems. By working through the checklist, users can compare available flexibility options and determine whether the flexibility can be mobilised. Our work has shown that it is insufficient to look at power values when evaluating flexibility options since organisational factors and the process enviroment are equally important. For an initial analysis of flexibility potential, however, it is crucial to introduce relatively simple evaluation criteria that can be assessed quickly. The data are analysed using a pre-defined set of evaluation criteria, resulting in the calculation of a 'flexibility value' and the degree of current flexibility mobilisation. The set of parameters and criteria are the result of approximately 100 evaluations in industrial manufacturing environments.

[1] Available online at http://mems.berlin/quick-check.

Examples of flexibility

In the WindNODE project, we identified several 'types' of flexibility options. The following list is a selection of examples that could easily be expanded by including sector coupling options like Power-to-Heat and, in the future, Power-to-Gas.

- **Flexible supermarket:**
  Two branches of the Schwarz Group-owned supermarkets Lidl and Kaufland were designated as 'showcase stores' (subproject 4.2 Controlling and Marketing Flexibility in a Company Group with Retail and Production, p. 104). In these stores, tests were performed to evaluate the potential for a battery storage system to relieve the grid by storing energy during times of peak renewable production. In addition, a decentralised energy management system in the store can be used to control electricity consumers – particularly cooling units – and thus increase or decrease their power consumption. In 2019, the battery storage system at the Lidl store in the district of Berlin-Schöneberg was connected to and autonomously participated in the day-ahead and intraday energy markets. The storage facility was also included in the test operation of the WindNODE flexibility platform (subproject 1.2 Innovative Process Platform, p. 66) and successfully provided flexibility.

- **Intelligent load management:**
  At its Berlin plants (subproject 7.2 Intelligent Industrial Load Management in Berlin, p. 158), Siemens was able to demonstrate that monitoring and categorising industrial processes through the use of modern measuring devices, coupled with an energy management system enable using flexibility options in accordance with various optimisation goals. These goals may include maximising the share of renewables in the energy consumption, observing limits to peak power consumption or those imposed by peak load time windows. In addition, as part of the WindNODE flexibility platform, these flexibility options were successfully brought to market.

- **Smart software:**
  The Smart Energy and Load Management (ZIEL) system, which was developed by the Fraunhofer Institute for Machine Tools and Forming Technology (IWU) in cooperation with Deckel Maho Seebach (subproject 7.1, p. 156), shifts the timing of energy-intensive production orders depending on energy price and actively controls the decentralised energy infrastructure in factories. This allows manufacturing companies to design future-proof production processes that can adapt their energy consumption depending on different factors.

- **Optimised charging:**
  For its fleet of electrically operated vehicles – still mainly consisting of passenger cars – Berliner Stadtreinigung (BSR) uses the EnEffCo® energy management software, developed by WindNODE partner ÖKOTEC. BSR used the software to analyse optimisation potentials leveraging flexibility options with the aim of integrating a prototype process into its day-to-day operations. This allowed for a reduction in energy costs and made it possible to test three applications: supply optimisation on the electricity market, dynamic charging management on-site, and the use of the WindNODE flexibility platform.

- **Networked neighbourhood:**
  In cooperation with partners in the Prenzlauer Berg model neighbourhood (subproject 8.2 Model Region Berlin / Prenzlauer Berg Neighbourhood, p. 180), which is equipped with smart building technology, the Borderstep Institute tested the potential for market-oriented and grid-oriented operation of a combined heat and power (CHP) plant and Power-to-Heat elements. The building stock as well as the local heat and heating networks were used as thermal storage. The resulting flexibility could be made available via the WindNODE flexibility platform (subproject 1.2 Innovative Process Platform, p. 102) or, by being connected to the virtual power plant of WindNODE partner Energy2Market, even be offered on the energy markets (subproject 4.1 Orchestration of Flexibility on the Market as a New Service, p. 66).

We found significantly more technical flexibility potential than expected

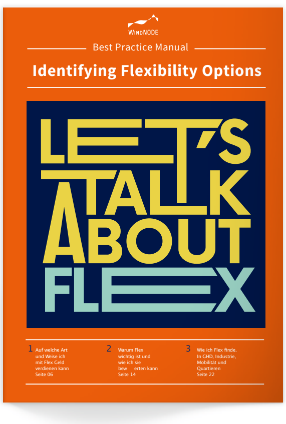
In our experience, many people react cautiously or even negatively to the search for flexibility. But good communication and visible success can facilitate a more positive stance: interest in the search for flexibility increased significantly among all participants over the course of the project. The search for flexibility even had some unexpected positive side effects and produced important insights. For example, in a Siemens plant, the voltage quality could be improved and a defect in semiconductor production eliminated – which, though not in itself a flexibility issue, was resolved thanks to a chance discovery made during the systematic search for flexibility. The search also confirmed the significant potential for flexibility in supermarkets, specifically in the freezing of food, albeit with some limitations: experiments conducted by our project partners from the Schwarz Group showed that, although frozen foods are not negatively affected by cooling below temperatures in the usual temperature range (–18 to –24° C), occupational health and safety requirements make it very difficult for employees to work at temperatures below –24° C. Therefore, cooling below this threshold is possible only outside of operating hours (e. g. at night or on Sundays). And in the case of the neighbourhood concepts introduced by the Borderstep Institute, careful initial communication paid off: residents were more willing than expected to participate in the project and have their homes upgraded to enable flexible use.

All in all, we discovered significantly more technical flexibility potential than anticipated. More than 200 MW of flexibility were identified in WindNODE. Nevertheless, the search for flexibility is only just beginning. The University of Leipzig estimates the total theoretical potential for flexibility (generation and consumption) in the WindNODE region to be over 32 GW. Our work in the focus area Identifying Flexibility demonstrated how this potential can be identified, and the 'Best Practice Manual: Identifying Flexibility Options' summarises our findings and can serve as a guide for companies and organisations that want to put theory into practice.

We would like to thank the following people for their voluntary participation in the Identifying Flexibility Coordination Committee:
Dr Severin Beucker (Borderstep Institute)
Jörn Hartung (Siemens)
Christian Heyken (BSR)
Andreas Hüttner (Siemens)
Dr Christopher Koch (formerly of TU Berlin)
Dr Sandra Maeding (Stromnetz Berlin)
Dr Henning Medert (formerly of WindNODE-PMO)
Christina Over (GreenCycle)
Dr Marc Richter (Fraunhofer IFF)
Mark Richter (Fraunhofer IWU)
Niko Rogler (WindNODE-PMO)
Fabian Stein (formerly of GreenCycle)
Dr Alexander Weber (Ökotec)

>200 MW

flexibility potential identified in WindNODE.



Further reading

The Identifying Flexibility Coordination Committee summarised its findings in the summary report *Best Practice Manual: Identifying Flexibility Options.* The report provides case studies from industry, commerce and neighbourhoods.

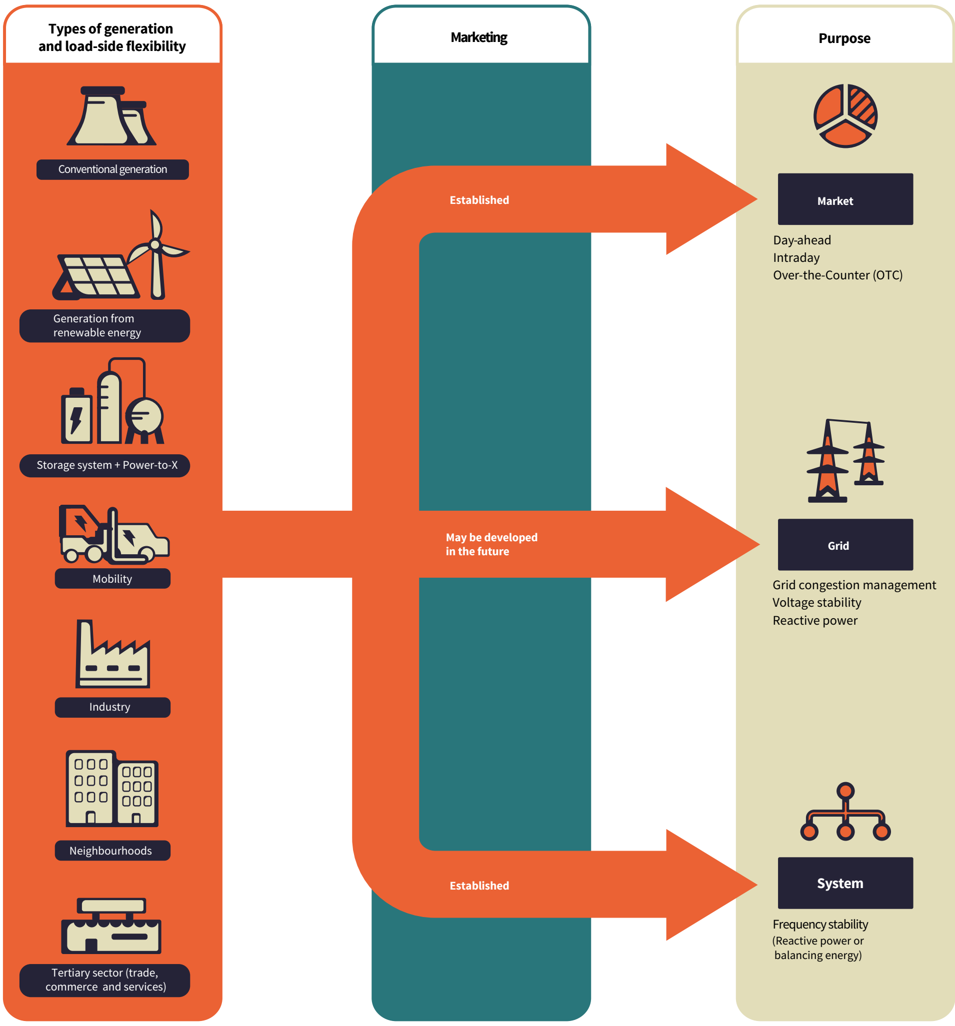
2

Focus area 2:

Activating Flexibility

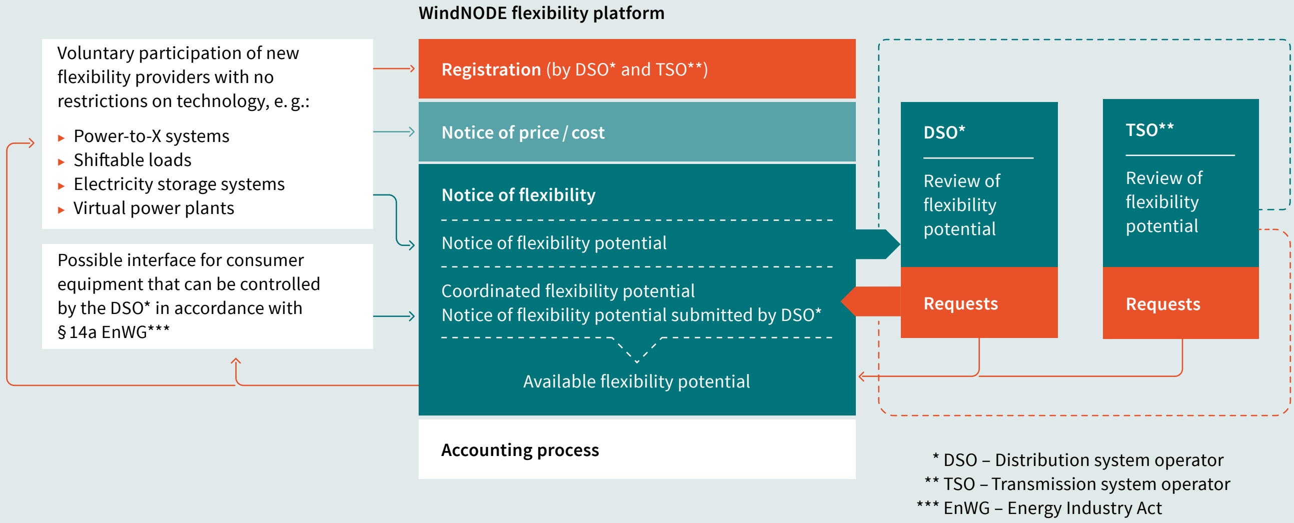
How do we put a price tag on flexibility potential?

After identifying types of technical flexibility potential, a key question becomes whether and how it can be activated in an economical manner. We define the activation of flexibility potential as the use of flexibility in ecologically and economically expedient ways, both for individual companies and for the energy system as a whole. For this to succeed, the right market and regulatory framework conditions must be in place. There are three basic channels for marketing flexibility: first, the very liquid electricity market (e. g. via the electricity exchange), on which competitive trading has taken place for a long time; second, the procurement of balancing power as a system service, provided by flexible systems – also an established marketplace that functions effectively; and third, the use of flexibility to support the grid, i. e. the flexible control of systems to relieve the grid and avoid grid congestion, for which there is currently no market mechanism. Thanks to the regulatory experimentation clause SINTEG-V (see SINTEG Ordinance, p. 55), and as a first in energy research, the WindNODE partners have had the opportunity to test systemic solutions to this challenge, some of which go beyond the boundaries of the current regulatory framework.



◂ Areas of application and marketing channels for flexibility in the electricity system.

Source: Best Practice Manual: Identifying Flexibility Options
Illustration: Ellery Studio.



▲ Overview: how the flexibility platform works.

Basic economic considerations: flexibility must pay off

From the perspective of flexibility providers, business considerations like process optimisation or profit maximisation on potential markets play a decisive role in activating flexibility. Tapping flexibility potential often requires investments as well as equipment upgrades to acquire metering technology that can collect data on the load profile of individual components. Experience has shown that, in general, revenue from ‘peak shaving’ (i. e. smoothing out the peak load) or from marketing balancing power is currently insufficient to justify the necessary investments within the company and thus provide an economically sensible incentive to increase flexibility. To tackle this issue, it may be advisable to design targeted investment incentives for potential flexibility providers. It is conceivable that, in the future, an incentive will be provided to promote flexible systems that benefit the grid, as has been done to promote energy- and resource-efficient systems. This could significantly increase the supply of usable flexibility.

From a systemic perspective, flexibility should be used if it creates ecological added value, for example in the form of reduced life-cycle resource consumption and emissions. If a company is considering increasing the flexibility of systems today, then from an ecological point of view it should ideally focus its efforts on those that provide flexibility for the energy system with little to no additional resource consumption.

Flexibility platform: the technology and processes are there, but the environment is not

The WindNODE project developed and tested a new solution: a market-based approach to procure flexibility for grid congestion management. Use of this additional potential is intended to allow for greater utilisation of renewable energy generation in the event of grid congestion (‘using instead of curtailing’). Concept development included the design of a web platform that establishes communication between the grid operators and flexibility providers. The first step calls for providers to register with the platform and let their systems be pre-qualified in a joint process conducted by 50Hertz and the relevant distribution system operators (DSOs).

Actual use of the flexibility platform (subproject 1.2 Innovative Process Platform, p. 66) – including bidding, coordination and requests – has been tested several times in the WindNODE project. As part of the procedure for designing processes and products, the specific requirements that have to be met by flexible loads, storage and virtual power plants were discussed and implemented in joint workshops. On days with grid congestion, flexibility potential was offered on the platform, procured by the system operator and used to reduce the necessary curtailment of renewables. In short, the flexibility platform demonstrated its technical, procedural and systemic usefulness.

A particular challenge is the fact that the voltage level at which grid 'bottlenecks' occur does not necessarily coincide with the voltage level of flexibility options that are available. This makes it necessary for the transmission system operator (TSO) and DSO to coordinate their processes. Thanks to the close and constructive collaboration between 50Hertz, Stromnetz Berlin, E.DIS Netz, ENSO NETZ and WEMAG Netz, it was possible to implement and test a solution for these processes in WindNODE using the flexibility platform. In the future, a coordination mechanism of this kind will become increasingly important, for example in the context of the redispatch process that will take effect in October 2021 as part of Grid Expansion Acceleration Act (NABEG) 2.0.

At the same time, the NABEG Amendment, which was passed during the WindNODE project period, partially undermined the purpose of the flexibility platform. The amendment extends the regulatory redispatch process to include generators and electricity storage systems with a capacity of 100 kW and above; consumption systems are still not legally obligated to participate. As a result, a large portion of the potential that was to be traded on the flexibility platform is now subject to regulated, non-market-based mechanisms.

A further, fundamental problem of the flexibility platform is that market-based procurement of flexibility for grid congestion management could encourage market participants to engage in behaviour that worsens congestion. This behaviour, also known as strategic bidding or 'increase-decrease gaming' (inc-dec gaming), occurs when a player that is up- or downstream from the bottleneck adjusts its output to intensify the congestion, then uses a second system to relieve the bottleneck, reaping monetary rewards. This practice is currently not prohibited, and there is still no reliable way to prevent it.

Due to the dual challenges presented by the NABEG Amendment and inc-dec gaming, a permanent use of the flexibility platform after the project period seems unlikely. The concept of 'using instead of curtailing' remains fundamentally sensible, however – from both an economic and an ecological point of view. Hence, over time, it is likely that the opportunities and drawbacks of market-based mechanisms will be reassessed. The concept of the flexibility platform is a technically and operationally proven approach that can establish spatially differentiated incentives for the use of flexibility, especially with future increases in redispatch volumes and times of negative residual load. It remains a viable option for congestion management.

Small-scale flexibility potential in the distribution grid: transparency and control

The transmission and distribution grids have long been characterised by a high level of transparency at the extra-high- and high-voltage levels due to the existing actuator and sensor technology. This allows grid operators to assess the grid state with a high degree of accuracy. In the past, electricity flowed from these higher levels to the ones below, so there was no operational need to monitor other voltage levels in this way. This may change in the future, especially since few grid operators have their own communication network that extends all the way to the distribution transformer substations. Because flexibility at the low-voltage level is much smaller in scale, however, it is necessary to consider groups of consumers. Technologies must therefore be highly scalable and suitable for the mass market.

In the WindNODE project, further refinement of the electricity pager (e-pager) yielded a practical solution to control electricity consumers at the low-voltage level. Several project partners conducted joint tests of Strompager DX control boxes (subproject 4.6 EE-Stalker – Low-Voltage Swarm Control for Improved Grid Operations, p. 114). The new devices will be used in different neighbourhoods to test the applications developed by the respective partners. In one such application, a relay is used to convey a signal that can be interpreted by energy management systems on site. This would make it possible to align plant operation based on external signals like the renewable energy forecast deviation at the TSO level. Consumption systems could then be switched on when feed-in is higher (positive deviation) or switched off when feed-in is lower (negative deviation) than predicted. New regulations on technical and procedural requirements are needed, especially in view of the fact that electromobility and heat pump use are expected to expand significantly. When this time has come, e-pager technology can help make flexibility usable at the low-voltage level.

Marketing flexibility: some highlights

Using automation and digitalisation, the WindNODE partners have successfully conducted field tests to develop new applications for flexibility in key areas.

- **Optimised grid use and day-ahead procurement for industry:**
  The implementation of a suitable metering system and the detailed evaluation of individual processes opened up new opportunities for flexibility marketing at the Siemens industrial site (subproject 5.1 Evaluation of the Overall System Efficiency, p. 118). The identified flexibilities are primarily suitable to decrease day-ahead procurement costs and to shave peak loads: in the current regulatory framework, peak shaving minimises grid fees even when cheaper renewable energy is available.

- **Mastering the challenges associated with the dynamic integration of storage systems:**
  The BMW Group (subproject 7.6 Combined Use of a Battery Storage Farm for Grid Services and Intelligent Energy Management at a Large Industrial Manufacturing Site, p. 168) built a second-life storage farm from used and new vehicle batteries. The storage farm is active on the electricity and primary balancing power markets and, in the future, will be used to synchronise generation and consumption at the plant. Load peaks can be avoided, thus optimising grid charges and increasing own consumption. The dynamic integration of battery storage systems into plant networks or households continues to be difficult in the current regulatory framework. The effect is that some use cases remain unprofitable due to the burden of charges and levies. Switching balancing groups is also a hurdle and should be made possible in shorter time frames.

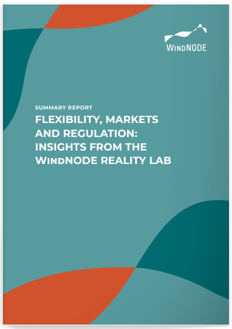
- **Intelligent and forecast-based control and optimisation of energy systems:**
  Algorithms developed by the GASAG Group (subproject 6.3c Supplying the EUREF Campus with Combined PtH / PtC, p. 144) for intelligent and forecast-based control of energy systems benefit the new Power-to-Heat / Power-to-Cold storage system, significantly increasing its opportunities for optimisation. When electricity on the intraday market is cheap enough and the marginal price for heat generation with the electric boiler falls below the heat production costs of another running unit, it makes sense to activate the electric boiler. However, a cost advantage compared to the biomethane CHP is very rare. A few years ago the marketing prospects in the balancing energy market were still significantly more attractive. GASAG's facility now focuses on the intraday market, where increasing volatility due to the growing share of renewables is expected to make offering flexibility more cost-effective. A key finding of the project is that a reduction in the fixed cost element in the consumer electricity price will lead to demand behaviour that is more beneficial to the overall energy system.

- **In neighbourhoods, all of the challenges of the energy transition are brought together under one roof:**
  Work by the Borderstep Institute (subproject 8.2 Model Region Berlin / Prenzlauer Berg Neighbourhood, p. 180) has shown that buildings and neighbourhoods can operate in ways that benefit the grid and the markets while maintaining a high level of comfort for residents. The conversion and storage of renewable energy peaks in buildings or the targeted feed-in of heat and electricity from own generation into the public grids are feasible today with the help of intelligent technology. Flexibility options in urban neighbourhoods are comparatively small-scale (in the two to three-digit kilowatt range), which makes marketing under today's conditions with high connection and transaction costs difficult. In the future, marketing flexibility via an aggregator is conceivable. This can be done either on the electricity spot market or as balancing power for frequency maintenance.

The ‘rules of the game’ for flexibility must be modernised

With the successful identification of flexibility, a first important step is taken. Without effective integration into the overall system, however, flexibility can play only a limited role in reducing system load or mitigating climate change. It is therefore important to take the second step as soon as possible and make the necessary adjustments to the regulatory framework. The creation of incentives that are market-oriented, ecologically sustainable, non-discriminatory and open to different kinds of technology will be one of the central political and regulatory challenges in the second phase of the energy transition. The challenge is to make the existing flexibility potential usable on a large scale – because the principle of ‘using instead of curtailing’ is and will remain a vital factor in the successful development of a 100 % renewable energy system.

We would like to thank the following people for their voluntary work as part of the Flexibility, Market and Regulation Coordination Committee:
Dr Severin Beucker (Borderstep Institute)
Hannes Doderer (IKEM)
Alexander Funke (BMW)
Jörn Hartung (Siemens)
Andreas Hüttner (Siemens)
Dr Christopher Koch (formerly of TU Berlin)
Dr Hendrik Kondziella (Leipzig University)
Dr Sandra Maeding (Stromnetz Berlin)
Dr Henning Medert (formerly of WindNODE-PMO)
Dr Georg Meyer-Braune (50Hertz)
Dr Michael Rath (GASAG Solution Plus)
Niko Rogler (WindNODE-PMO)



Further reading

The Flexibility, Market and Regulation Coordination Committee has prepared the summary of findings in the publication *Flexibility, Markets and Regulation: Insights from the WindNODE Reality Lab.* Analyzing the flexibility options that were identified in the project, the report dives into different marketing opportunities and the regulatory challenges associated with them both in the WindNODE region and beyond.

3

Focus area 3:

Digitalising the Energy System

What does it mean to digitalise the energy industry?

The SINTEG programme is an initiative to advance the federal government's 'digital agenda'. As a result, the digitalisation of the energy industry played a central role in our work. We discovered that 'digitalisation' is a buzzword that is not sharply defined – which led to many misunderstandings, even among the experts in the WindNODE community. We learned that digitalisation is not the subject of control by a single entity, but the result of many decentralised solutions – and that its progress is less 'disruptive' than often claimed.

In the energy industry, the term 'digitalisation' primarily refers to the automated collection, processing and secure transmission of information that is carried out in order to efficiently achieve the goals of security of supply, environmental sustainability, economic efficiency and increasingly also public acceptance. Work conducted in the WindNODE project has shown that consistently digitalised processes have three main advantages.

1. Software makes the energy industry flexible
First, digital solutions allow for a more flexible use of existing infrastructure. This addresses a basic problem in the energy industry: the often long investment cycles that traditionally set the pace for innovation. For example, an amendment to a law may make a particular new service attractive, or a good idea may open up a new business field. In the past, reacting to such opportunities has typically required expensive technical upgrades or conversions. Digitalisation, by establishing stable interfaces and allowing hardware to be upgraded via software, allows innovation at a faster pace.

In the digital energy industry, promising future applications can be implemented with little effort. An intelligent digital meter can be used today to read electricity – and tomorrow to support detailed consumption forecasts in the energy system (subproject 4.4 Production Forecasts for Solar and Wind Systems with Real-Time Smart Meter Data, p. 110). Reactive power compensation was previously provided only by a few specially equipped systems. Now digital communication in the grid – which takes place almost in real time – allows decentralised generation systems to be used for this purpose (subproject 3.3b Dynamic Reactive Power, 110-kV-Voltage-Level, p. 90). Production processes operated in combination with digital data collection tools can provide flexibility at the push of a button. In short: in the digital energy industry, stakeholders can take over a range of tasks 'via software update' as soon as doing so becomes economically feasible and legally permissible.

2. Digitalisation makes sector coupling possible
The energy system, with all of its interconnected generators and consumers, is among the most complex systems built by humans. And as it evolves into a decentralised, renewable and flexible version of itself, this 'organism' is only becoming more complex. Out-of-domain information like weather forecasts (subproject 4.4 Production Forecasts for Solar and Wind Systems with Real-Time Smart Meter Data, p. 110), predictions for the use of charging points in the transport sector, and current dynamic data from industrial processes are suddenly playing a significant role.

The energy transition therefore requires not only a physical coupling of sectors, such as by converting electricity into heat as needed; it also requires a more abstract coupling: an integration in terms of information and technology (IT).

This is where the second advantage of digitalisation becomes clear. Once a process has been digitalised – whether inside or outside the energy industry – a machine-readable (i. e. common) language is created. The consistent use of norms, standardisation and open interfaces (subproject 9.7 Standardisation in the Intelligent Energy System, p. 208) can integrate information across industries and sectors. This lays the groundwork for a system within which more and more components can be integrated, situations analysed at high speed and automated decisions made.

3. Digital transparency helps to optimise energy industry processes
In light of rising costs and the rapidly growing complexity of the system, the optimisation of energy management processes is a key priority. Digital solutions, such as the WindNODE energy cockpit (subproject 8.1b WindNODE Energy Cockpit – Making the Energy Transition Visible, p. 178) and the market and consumer platform (subproject 1.4 Market and Consumer Platform, p. 70), play a role at every level. In the planning phase, digital simulations enable the optimal design of components and equipment. Relevant data from all systems are collected and monitored during operation so that the optimal process can be selected in every case (subproject 2.4 Municipal Energy Management System, p. 82). These data also ensure that equipment can be used more efficiently and for longer, which in turn reduces the need for expansion and new construction and avoids redundancies.

In all of these cases, digitalised processes increase the availability of data, allowing for greater transparency and easier comparison between the set and actual values of key parameters. Automatic processing of these huge volumes of data finally enables equally automated decision-making and control via common interfaces. In a digitalised energy system, this can take place across different locations, throughout an entire region and in near real time for a large number of facilities and systems. Projects like the Open Data Portal (subproject 1.3 Open Data Portal, p. 68) demonstrate that transparency also has the potential to help build trust and improve public participation.

Lessons from the reality lab: digitalisation with a sense of proportion

Based on our project work, WindNODE has reached the following three conclusions about the nature of successful digitalisation projects:

1. Successful digitalisation is modular
At first glance, it seems reasonable to assume that digitalisation requires a centralised, systemic approach – for example, a central platform for the efficient orchestration of the entire system. In practice, however, such projects are extremely difficult to implement. First of all, the high level of complexity presents an obstacle: because even experts are generally only familiar with certain areas of the energy system, it quickly becomes difficult to manage industry-wide solutions, let alone those involving multiple sectors. The traditionally heterogeneous stakeholder landscape is rapidly evolving and changing, which creates sizable hurdles to coordination; in addition to different perspectives, there can also be competing business models to accomodate.

In order to bring promising digital technologies to the market despite these challenges, it is helpful to focus on specific industry problems. Even if this small-scale strategy initially appears less ambitious, it is successful in the medium term. Modular systems with standards-based communication are key factors for success in meeting the need for a holistic approach and addressing the multiple interdependencies in the system. A value creation network like WindNODE offers excellent opportunities to accomplish this task: close cooperation between project partners opens up opportunities to discuss, iterate and implement new ideas.

2. Successful digitalisation can be an evolutionary process
There is currently much talk of 'disruption' in the digitalisation discourse, but we believe evolutionary approaches are more promising in the energy industry for a number of reasons. First, it is unclear whether

business models aimed at disruption and 'market capture' also lead to optimal results from the perspective of a national economy. Second, the often lamented strong institutional inertia in the energy industry is certainly justified in an industry with inherent needs for security and stability. In addition, the interconnectedness between the regulatory framework, the markets, and the physical reality of energy systems, create difficult conditions for revolutionary approaches. At the same time, these interrelationships serve to guarantee a reliable energy supply and a balance between private and public interests.

Due to its critical infrastructure, the energy industry is a heavily regulated environment; digital innovations are therefore first implemented within relatively narrowly defined fields of application and are used to improve and optimise established processes in these specific areas. New ideas and business models (subproject 1.2 WindNODE Flexibility Platform, p. 66) are developed incrementally from these collaborations and are then implemented in accordance with national and European data protection law, the regulatory framework and agreements between the broadest possible range of partners. Good ideas are not primarily intended to generate short-term profits, but to provide robust, socially sustainable solutions. This 'digitalisation with a sense of proportion' also makes it easier to manage the risks associated with an increase in digital networking, automation and standardisation.

3. Successful digitalisation is a tool, not an end in itself

Platform economy, artificial intelligence, blockchain – digitalisation suffers from a glut of buzzwords, which conceal ideas that are often simple, sometimes vague and occasionally entirely unsuitable to the problem at hand. What is justified in marketing is often a hindrance in the context of research, where clear language is an advantage, especially when communication must be carried out across industries and sectors. Many of the concepts addressed in the WindNODE project can be described using terms like 'digital twin', 'machine learning', 'predictive maintenance' or 'Internet of Things'. But our most successful projects view technologies as a means to an end – a tool to solve concrete problems within the energy industry.

The key to success is the right fit between the problem and the solution. It is unlikely that the energy industry will be revolutionised by blockchain, for example; but this technology can be used successfully under certain circumstances, as Fraunhofer FOKUS and 50Hertz demonstrated (subproject 1.1 Basic Services for Networking in the Digitalised Energy System, p. 62). This is how digitalisation succeeds and creates added value for the economy and the energy sector. Once this first step has been taken, the leap from small, isolated solutions to large-scale innovations is contingent on the kind of regulatory 'leeway' offered by the SINTEG experimentation clause, future-proof digital infrastructure and open interfaces.

The aforementioned practical digitalisation projects – which often start with small-scale questions but can develop significant economic value through widespread application – were complemented in WindNODE by a number of studies, including:

a) The study 'Weiße Flecken in der digitalen Vernetzung der Energiewirtschaft' (English: '"White areas" in the Digital Networking of the Energy Industry') by the Fraunhofer Institutes IEE and FOKUS has identified areas in which there is still a lack of modern, digital information and communication technology (ICT) for future information flows in the energy industry. The study found that the conventional value chain will no longer be sufficient to map energy industry processes in the future. A more suitable model is the 'value creation network' that spans 10 value-added fields between the stages of production, transport, trade and consumption. Researchers concluded that sound ICT to manage these information flows is largely in place today but must be adapted to meet the needs of the future energy industry.

b) In its study 'Information and Communication Technology in the Intelligent Energy System', the TU Berlin took a holistic approach to evaluating the digitalisation in the energy industry. The study focuses on three key challenges: identifying and activating flexibility, grid congestion management, and grid planning. The investigations show that the use of ICT can make processes in all three areas more efficient. This makes it possible to improve individual dimensions of the energy policy triangle for specific problems without negatively affecting the others.

c) The TU Berlin study 'Eine Marktübersicht der Blockchain in der Energiewirtschaft' (English: 'A Market Overview of Blockchain in the Energy Industry') divides blockchain technology into technical modules and classifies existing solutions according to a specially-developed methodology. Researchers concluded that a large number of blockchain projects exist throughout the energy industry´s value chain. None of these applications are disruptive; in fact, individual modules or individual features of blockchain technology (e. g. smart contracts) have the potential to deliver very specific, customised solutions. And while many solutions have been developed theoretically, few have been deployed in the real world and are thus difficult to evaluate.

Digital solutions from WindNODE

A review of the reports from the WindNODE subprojects reveals that digital innovations play an important role in almost every solution. The following non-exhaustive overview provides a list of highlights:

- In local and distribution grids, digital measurement technology is used to obtain better insight into the grid state and take appropriate action through early interventions. The project pursued approaches to predictive maintenance, i. e. close monitoring of equipment for improved planning of repair measures (subproject 3.3e Online Measuring Technology for Distribution Transformer Substations, p. 98, and subproject 8.1 Model Region Zwickau/Marienthal Neighbourhood, p. 176).

- In the distribution grid, decentralised generating units can be integrated into an intelligent reactive power management system to provide ancillary services formerly reserved for large power plants (subproject 3.3b Dynamic Reactive Power, 110-KV Voltage Level, p. 90).

- A comprehensive software solution allows for the consistent collection of data from municipal energy systems across sector boundaries. This 'digital twin' helps in planning and dimensioning as well as in monitoring and in the provision of decision-making support in real time (subproject 2.4 Municipal Energy Management System, p. 82).

- In the future, automated control in large battery storage facilities will make it possible to use virtual 'sub-blocks' independently of each other for different operating scenarios, with advantages for the provision of ancillary services and the marketing of primary balancing power (subproject 2.1 Future Storage of the Energy Transition – Ancillary Services of the Energy Transition, p. 74).

- The innovative process platform defines selected digital interfaces and models coordination processes between grid levels and flexibility providers for efficient management of grid congestion (subproject 1.2 WindNODE Flexibility Platform, p. 66).

- Bidirectional connection of decentralised small-scale installations for demand-side management is achieved in several subprojects using various technologies, including modernised pager-based ripple control (subproject 4.6 Strompager DX, p. 114, and subproject 8.2 Model Region Berlin/Prenzlauer Berg Neighbourhood, p. 180) and telecontrol (subproject 6.3a Distributed Small-Scale Systems – Wind Storage Instead of Night Storage Heaters, p. 140).

- The combination of self-learning algorithms and 'digital twin' technology for high-precision generation forecasts shows promising results for applications in green electricity trading and in the optimisation of grid operation (subproject 4.4 Production Forecasts for Solar and Wind Systems with Real-Time Smart Meter Data, p. 110).

- Efficient algorithms and methods for energy and load management in an industrial context are researched academically (subproject 7.1 'ZIEL' – Algorithms and Methods for the Intelligent Energy and Load Management of the Future, p. 156, and subproject 7.3 Load Shifting Potential in Energy-Intensive Industries, p. 160) and implemented in practice (subproject 7.2 Intelligent Industrial Load Management in Berlin, p. 158, and subproject 7.4 Market Integration of Industrial Flexibility via an Interface Between Energy Controlling and Market Platforms, p. 164). Their application relies on extensive collection of master and dynamic data from the examined processes.

- Smart building technology is used to combine greater comfort with energy optimisation and make it possible to reduce energy consumption in existing buildings while keeping investment costs low. In addition, many data from many small-scale systems can be digitally collected and centrally orchestrated as flexibility via a virtual power plant (subproject 8.2 Model Region Berlin/Prenzlauer Berg Neighbourhood, p. 180).

The following people contributed to this section:
Dr Severin Beucker (Borderstep Institute)
Andreas Corusa (TU Berlin)
Benjamin Dittwald (Fraunhofer FOKUS)
Lisa Hankel (Stromnetz Berlin)
Christoph July (devolo)
Thomas Koller (enersis europe)
Philipp Lämmel (Fraunhofer FOKUS)
Dr Philipp Mahr (Bosch.IO)
Dr Georg Meyer-Braune (50Hertz)
Mark Nigge-Uricher (Bosch.IO)
Malte Viefhues (WindNODE-PMO)
Marcus Voß (TU Berlin)
Dr Armin Wolf (Fraunhofer FOKUS)

4 Focus area 4: Developing a Reality Lab

Creation of WindNODE: the unexpected power of pluralism

At the beginning of 2015, Germany's Federal Ministry for Economic Affairs and Energy (BMWi) published the long-awaited funding announcement for the project 'Intelligent Energy Showcase – Digital Agenda for the Energy Transition' ('Schaufenster Intelligente Energie – Digitale Agenda für die Energiewende' (SINTEG)). This called for large-scale showcase projects that would demonstrate how large quantities of renewable energy – potentially up to 100 % – could be integrated into the energy system. This scope was a perfect fit for northeastern Germany, where the share of renewables was already well above the national average at the time. One topic was a discussion on 'using instead of curtailing' to avoid the need for temporary shutdowns of wind and solar power plants due to grid bottlenecks ('feed-in management'). Moreover, digital platforms would bring 'wind into the cities' by connecting rural wind power and photovoltaic systems more intelligently to the urban load centres.

Together with a number of energy companies, the Cluster Energietechnik Berlin-Brandenburg (Energy Technology Cluster Berlin-Brandenburg) seized on the initiative and supplied valuable preparatory work for a joint project entitled 'Wind Energy as the Contribution of Northeastern Germany to the Energy Transition' ('Windenergie als Beitrag Nordostdeutschlands zur Energiewende', or WindNODE). There was not yet a project organisation or a defined WindNODE narrative at the time, and not everyone in Berlin and Brandenburg believed that WindNODE's application to SINTEG would be successful. Above all, the heterogeneity of the group appeared to be a challenge: around 30 companies, universities and research institutions were initially interested in WindNODE. What was the shared vision beyond a goal to raise funds? Would it be possible to compete against the strong and well-organised competition within SINTEG from northern, western and southern Germany without an established management structure?

The partners showed remarkable pragmatism and focus. They quickly agreed to set up a steering committee, initially consisting of members from 50Hertz, Berlin Partner, Siemens, Stromnetz Berlin and ZAB (Zukunftsagentur Brandenburg, today WFBB). The committee appointed an overarching project leadership team and collaborated with it to steer the development of the project over the next four months under considerable time pressure. There was no single narrative prescribed from above. Rather, the emerging WindNODE governance structure reflected a hybrid top-down/bottom-up approach. The partners brought in their individual project ideas and retained the greatest possible degree of autonomy for their projects; the steering committee and the project leadership fitted these components together like pieces of a puzzle to develop an overall story, completed the partner structure (partly through targeted acquisition of new partners, partly by saying goodbye to existing ones), and created a common organisational, strategic and communicative framework. At first glance, the 50 subprojects may not appear to be 'cast in the same mould' (top-down), but over time this broad pool of ideas (bottom-up) has proven to be a particular strength of WindNODE.

What started as a sprint in February 2015 eventually turned out to be a marathon. The two SINTEG application phases ran for almost two years until WindNODE finally received the funding decision from State Secretary Baake on 6 December 2016. The first phase, in early 2015, involved a number of important strategic decisions. This included the expansion of WindNODE to the territory of all eastern German federal states, which thankfully led the heads of government in all of the federal states involved to position themselves behind WindNODE as key sponsors. Energy Saxony and later also Fraunhofer FOKUS became steering committee members. And, finally, 50Hertz, as primus inter pares, took on the fiduciary role as project coordinator and set up an independent project office when work began on 1 January 2017.

Pluralism proved to be an unexpectedly strong foundation for collaboration – even in the early days of WindNODE, when there was no contractual basis for it. The partners involved raised a mid-six-figure sum voluntarily, and without any public funding, to finance the joint tasks of project development that would be required to create the SINTEG showcase. Decisions with far-reaching effects, such as the distribution of limited financial resources among the many proposed projects, were resolved by consensus. Only at the beginning of the actual project work, in early 2017, did the project partners sign a formal cooperation agreement.

From the early phase of the application process, we learned that, when compared with other regions, we lacked neither quality nor substance, but only self-confidence and a coordinated approach. One of the most important lessons from WindNODE has been just how much can be achieved by collaborating within a network.

WindNODE governance: about *moving targets* and *carrots* without *sticks*

There are not exactly many pre-existing models to follow when implementing joint R&D projects that involve over 70 partners. Conventional publicly funded projects in R&D usually have a handful of full and associated partners, one of whom takes on the relatively manageable, primarily administrative tasks involved in project coordination. This role is usually adopted by a partner with a high ratio of public to private funding (e. g. a university) and its coordination effort is reimbursed by the funding provider as part of the eligible personnel costs. But things were different with WindNODE. First, the project was much bigger and more complex – in the words of one of the founders, it was 'like herding cats'. Second, WindNODE always saw itself as an initiative from the business world and placed great value on project coordination that would be highly professional and pluralistic. Third, the project coordination would by no means entail only administrative tasks, but would serve to push the whole project forward, broaden the network and represent the partners on several levels, both internally and externally. All of this enabled us at WindNODE to break new ground in project management while learning a great deal:

- **Publicly funded projects are not high-speed endeavours.** Two long years and a multi-stage application process lay between the SINTEG funding call and the start of WindNODE. This process would first require a 40-page project outline, then an in-person presentation, and finally an overall project description (OPD) of some 80 pages and an estimated 2,000 pages of subproject descriptions (SPDs) from all project partners – as well as countless additional rounds of fine-tuning. The large-scale showcase project format was new for everyone involved, which understandably led to occasional uncertainties regarding the process and planning. In fact, for the partners, this long application phase proved to be a 'dry spell' in terms of both funding and morale, as well as an ongoing acid test for the still-young organisation. Above all, it was challenging to keep the project idea up to date while the energy industry continued to evolve at a rapid pace. Terms like 'sector coupling' or 'blockchain' really only became part of the conversation after our application process was already underway – too late to be incorporated into the OPD or SPDs. The project management agency (Projektträger Jülich or PtJ) always supported us to the best of its ability, fostering the agility required and helping us adapt the project design to the latest developments, even though existing public funding law is not exactly designed with *moving targets* in mind.

- **Governance by strong, neutral trustees.** Proposals to entrust project coordination to a new, independent legal entity, such as a dedicated limited-liability company or registered association, were floated and rejected for practical reasons, as well as for reasons related to public funding law. Instead, we decided that an existing partner would be given the task of coordinating the organisation in a way that was neutral, practical and highly professional, acting in the interests of all members and covering its costs through a management fee paid by all partners (i. e. funding recipients). 50Hertz took on the job and hired a dedicated six-person team that became entirely responsible for the overall WindNODE project direction.

- **Multi-stakeholder management: *carrots* without *sticks.*** There was an unusual triangular relationship between the project partners, the project coordinator (overall project leadership) and PtJ. The actual core business under public funding law – application, disbursement, reporting and progress monitoring – took place in a bilateral relationship between PtJ and each project partner (funding recipient). In all of this, the project coordinator was merely a spectator and sometimes not even entitled to be informed, unless the project partners voluntarily chose to share information. Conventional principles of project management were taken to the *point of absurdity* here, and it became clear how difficult it was to steer a project without access to the budget, without binding reporting rules and largely without the possibility of formal sanctions. In fact, the project coordination worked less through tight, metrics-based control of the project as a whole, and more through positive incentives: it paid off for the partners to take part, and they recognised that cooperation was rewarded through a variety of opportunities to network and raise their public profile. The project coordination was the mechanism through which the project became more than just a loose interest group. Instead of dictating goals, the project coordinator organised pluralities and coalitions of willing participants. This created a powerful, positive group dynamic among the partners. Ultimately, the project coordinator also had options for sanctions in cooperation with PtJ. These were almost never needed, as we were mostly surprised by the high level of constructive willingness to participate without any formal obligations. But it was also true that not every goal could be achieved, not every one of the more than 70 partners provided top-notch performance, and not every last one of the 50 subprojects was a big success.

- **Focus on synthesising the results.** Normally, in publicly financed projects, each individual project partner describes their own project results in their SPDs. To make sure that the work of the joint project becomes more than the sum of its parts, however, all of the results must be synthesised into a coherent whole. This was defined as a continuous process from the start. Within WindNODE, the task was entrusted to Coordination Committees (CoCos) which carried out internal committee work on major key issues. This work proved its worth and led to several highly praised publications, such as the Best Practice Manual: Identifying Flexibility Options. Unfortunately, the CoCos were not set up at the start, but were created as a reaction to a temporary discontinuation of comprehensive accompanying research by SINTEG. As a result, none of the partners had originally planned a budget for the work of the CoCos, which consequently had to rely entirely on voluntary contributions.

- **Developing prospects for follow-up projects.** Time limits are part and parcel of project work. It was to be expected that, after a certain time, there would be signs of fragmentation – that is, that partner organisations and individuals would begin to direct their focus away from WindNODE and towards new projects. Fortunately, this never occurred, and most WindNODE partners showed very high morale and willingness to participate right into the last months of the project. Even so, it was a challenge to retain staff, especially in the final year. This was exacerbated by the outbreak of the COVID-19 pandemic, which caused many partners to have to adapt their priorities. This external disruption notwithstanding, it was necessary to identify potential follow-up projects quickly so as to maintain the momentum of a project like WindNODE up to the very last day and beyond. This may have been achieved for at least part of the WindNODE community through the First Lusatia Conference on 9 September 2019, which focused on the shaping of structural change in coal regions.

WindNODE as a showcase for eastern German energy and transition competence

WindNODE primarily targeted a specialist audience. Our work therefore did not focus on organising broad participation in the form of civil society co-determination, nor on the development of specific products or services for end customers. Activating and involving a wide variety of target groups, however, was the subject of the diverse, partly experimental approaches in our workstream 9 (Participation and Dissemination), which was supported by the communication and public relations work of the project coordination structure. A major field of activity entitled ‘Energy and Society’ emerged within WindNODE, encompassing the following themes:

- **WindNODE narrative: competence in energy and transition.** We worked to develop an overall narrative for the project that would focus on the special features of our region and highlight the opportunities offered by the energy transition. With over 60 % renewable sources in the electricity mix (as of 2019), we are Germany’s pioneers when it comes to the energy transition; we are also well-positioned to lead on this issue thanks to our region’s unique experience with transformations. The energy transition is not only a necessity motivated by climate policy, but also and especially an opportunity in terms of industrial policy. This was the spirit of our big-picture project communication and public relations, as well as our highly active endeavours to raise the international profile of northeastern Germany as a model region for the energy transition – efforts that were quite successful in several countries, such as Japan. Our project communication (e. g. website, yearbook, summary reports and prominent formats such as the ‘WindNODE Spotlight’ series) was consistently bilingual in German and English.

- **Visitor sites: show & tell for our energy transition skills.** The concept of the visitor site was a key element of WindNODE’s communication activities. Many of our demonstrators and model solutions were showcased at the roughly 30 sites throughout the WindNODE region. We invited all interested members of the public (especially schools) to share in our fascination for the energy transition and explore the subject of ‘flexibility’ at various locations – an energy transition as a tourist attraction. A visible ‘competence network’ for the energy transition was created for national and international specialist audiences, which served to raise the profile of the entire region. Both approaches proved valuable and were well received. The link among our visitor sites was the touring exhibition *WindNODE Live!,* which was organised by Berlin Partner and made stops throughout the model region as well as at various trade exhibitions and national events.

- **Invitations to participate.** Even though WindNODE was not explicitly a public-facing project, we invited the public to participate on a number of occasions. In addition to the visitor sites and the wide range of information on offer (for example, our magazine-like project presentations 'WindNODE Spotlight'), the highlights included: the 'energy hackathons' hosted by Stromnetz Berlin, where IT developers and thinkers could get involved and work together on a more sustainable power supply and digital future strategies; the idea and technology competition at Berlin Partner's WindNODE Challenge; the citizen's report on CO_2 pricing from the TU Berlin and the educational game Hertzschlag (heart beat) by Stromnetz Berlin.

- **The cultural aesthetics of energy.** Admittedly, at first glance, this subject is not at the heart of WindNODE – yet its significance to the project reveals that deeply held convictions motivate many in the WindNODE community to search for answers to key questions: how can we pass on our passion for the energy transition to broader groups? How can we work on energy transition narratives that are based not only on the need to react to climate change, but also on the opportunities for industry – perhaps even producing a 'man-on-the-moon' moment (to echo Peter Altmaier's comparison of the German energy transition with the American moon landing)? There have of course been no conclusive answers to these questions. However, we have explored them in a range of experiments, such as in the project 'Energy and Art', in which 50 paintings on the future energy system were created based on a discourse between energy experts and artists; in the initiative 'Energy Meets Art', which encompasses a broad range of activities, from scenario studies for the future energy system to creative visualisation and broad stakeholder dialogue; and in the 'e-stories', which examined the literary reception of energy technology topics across two centuries. For more information on these projects, see our special feature starting on page 220.

More than just an R&D project: network and reality lab for energy system transformation

The purpose of the SINTEG programme is primarily to promote application-oriented energy research. Around € 37 million of the programme funding was granted to WindNODE. This financial support was crucial, but the amount of funding appears more limited when measured against the challenges associated with the energy transition. The project partners had several idealistic reasons for participating in WindNODE, which may have been weighted differently in each case, but in their totality were certainly at least as important as the financial support. These reasons included:

- **A scaffolding for the energy transition in northeastern Germany.** One partner described WindNODE as *'an excellent competence network which has shown that the energy transition works when partners from a range of disciplines join forces to develop solutions'.* This is the first such ecosystem to encompass all of northeastern Germany. WindNODE made use of large, practical value creation networks in which concrete demonstrators could be developed on topics related to technology, market and regulation – for example, by using innovative IT platforms to link our flexibility options with the various flexibility markets. As one partner remarked: *'The tailwind from WindNODE has brought the integration of the various energy sectors […] one step forward.'*

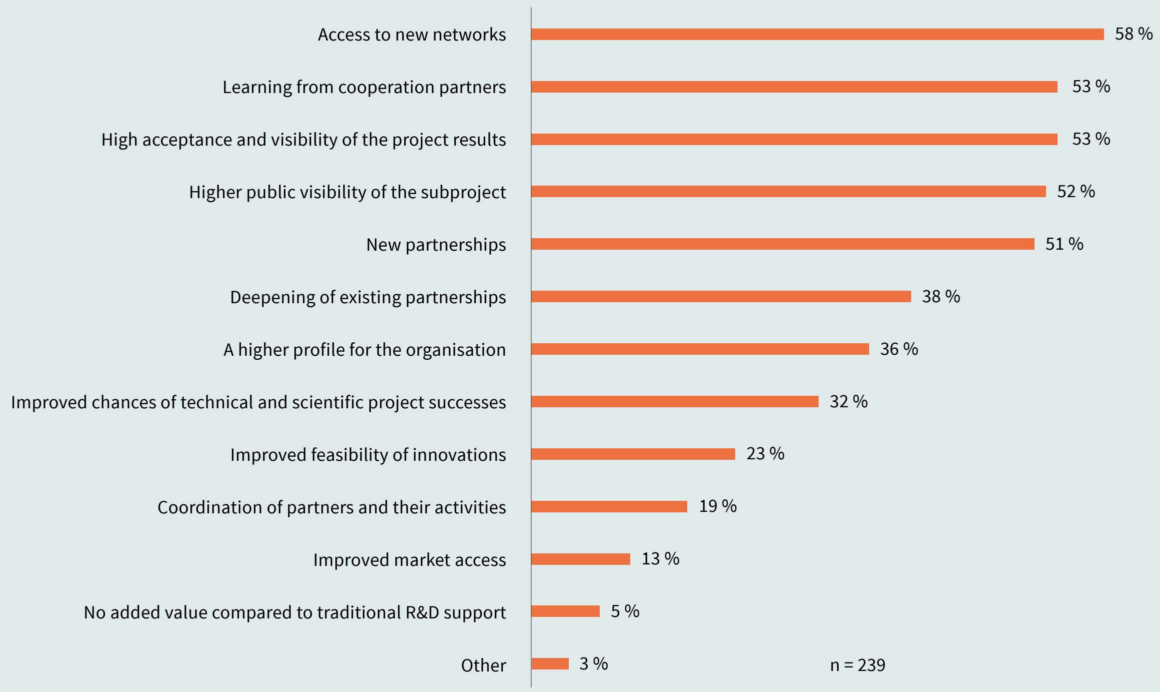
- **Regulatory sandbox.** This was the first time that an energy research programme included the regulatory framework as part of the experiment (see page 55 on the SINTEG Ordinance). That alone was reason enough for several partners to choose to join WindNODE – some (associated) partners even took part without any financial support. The freedom to innovate provided by the 'regulatory sandbox' in SINTEG was a strong incentive to participate, especially as there would be an opportunity to exchange ideas with federal and state politicians as direct recipients of the conclusions reached in WindNODE.

- **Fertile network.** One project partner wrote: *'WindNODE is the starting point for numerous new project ideas and plans for the energy transition, such as the inclusion of data centres in flexibility concepts or the use of AI-based platforms for steering and supply in residential areas.'* WindNODE has produced results that go beyond its findings on specific research topics; it has created a network that, for many partners, has proven to be an outstanding source of added value (see also the results of the SINTEG evaluation, below). One partner praised the *'pull of a large-scale showcase project providing a feeling of togetherness in our region and a lively network of partners who will continue to cooperate in innovative contexts in the future'.* Another noted that there was *'greater trust among the various actors in the process of finding common solutions'.*

- **Reputation.** The effects of WindNODE extend far beyond regional boundaries. The visibility of such a large showcase project is undoubtedly an incentive to participate. It gave partners the opportunity to present themselves to local stakeholders in the best possible light and to introduce themselves to national and international specialist audiences. Our online presence, the visitor sites, attendance at trade exhibitions (e. g. multiple times at E-World), political dialogues, international road shows and much more have all contributed to this. Partners spoke of *'demonstrators that can increase the visibility and importance of the energy transition […]'.* Especially among our small and medium-sized enterprise partners, there are many successful examples of how the visibility fostered by participation in the WindNODE network led to new business and follow-up projects.

These experiences offer a methodological blueprint that can be invoked when discussing future 'reality labs of the energy transition' or structural change in former coal regions. Reality labs provide more than just model solutions with a high 'technology readiness level', and structural change will not be achieved with grant funding alone. In our experience, the proven success factors and defining features of reality labs are the strong networks, the excellent framework-forming management structure, the regulatory freedom and the establishment of attractive beacon projects in a model region that is visible from afar.

Author: Markus Graebig (WindNODE-PMO)

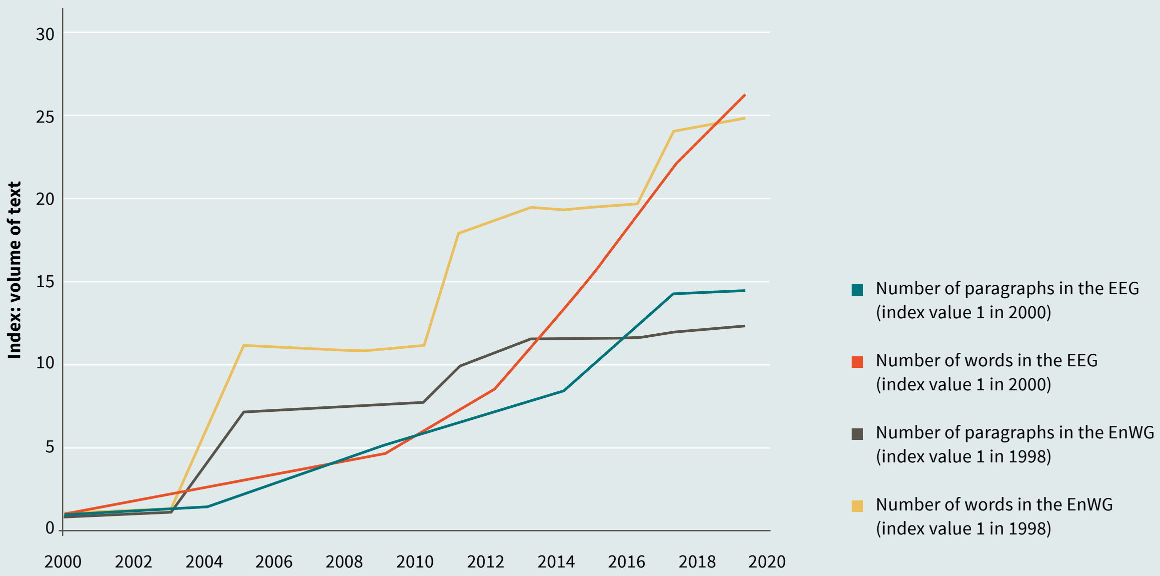


▲ The added value of the showcase approach. Survey of all SINTEG showcases:
'So far, what added value have you derived from integrating your project into a showcase?'
Source: Kerlen Evaluation 2019.

SPOTLIGHT
The Regulatory Sandbox SINTEG-V ('SINTEG Ordinance')

Energy law as a catalyst or inhibitor of the energy transition

The energy industry is highly regulated, and the energy law framework is closely aligned with business models in the energy sector. People new to the industry are often stunned by the complexity of energy law – and the effect it has on innovation. For example, the Renewable Energy Sources Act (EEG) unleashed a real innovation boost around 20 years ago, helping make Germany the world leader in renewable energy expansion for years.



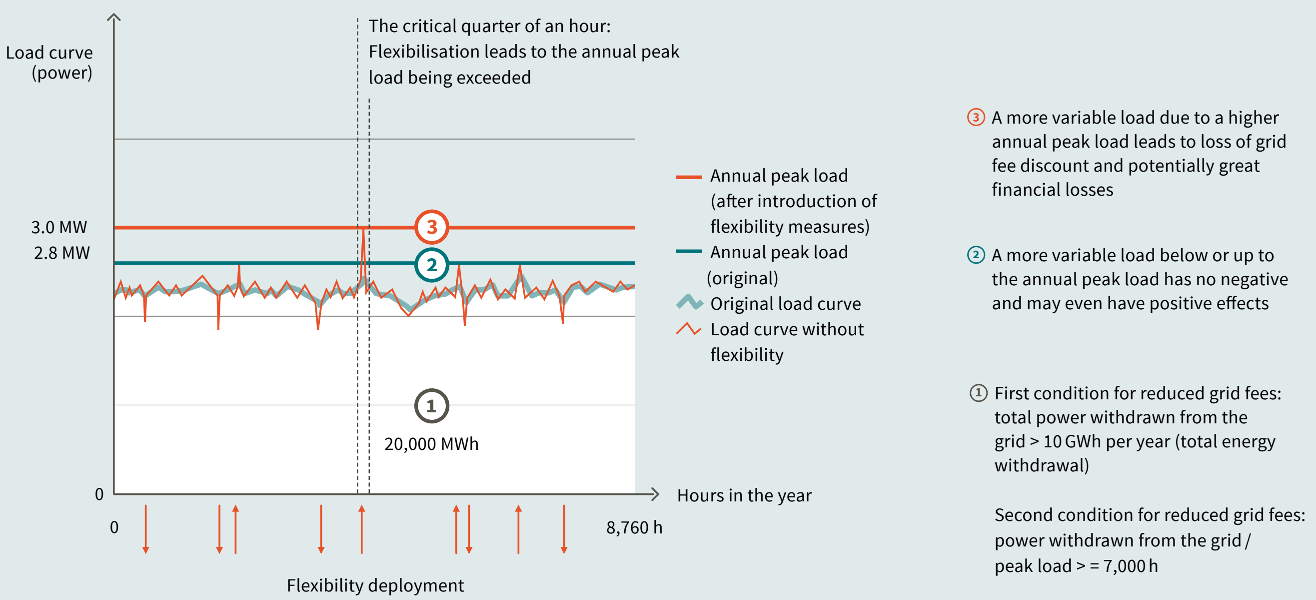
▲ Complexity has increased tremendously as the volume of energy law has grown over the course of two decades. For example, the scope of the EEG, measured in the number of words, has almost doubled over the past 20 years.
Source: Kalis/Dittmar: Quo vadis Energiewenderecht? TaTuP 28/3 (2019) with further references.

Of course, delays in the modernisation of energy law can also act as a brake on innovation, as illustrated by the following example. The Ordinance on Electricity Grid Fees (Stromnetzentgeltverordnung (StromNEV)) regulates the electricity grid fees paid by customers as part of their electricity bill. For consumers whose load is metered – that is, a large number of industrial and commercial consumers whose actual electricity consumption is recorded every quarter hour – StromNEV can lead to significant discounts on the grid fees.

An example is the 'individual grid fee' provided for in § 19 (2) (2) StromNEV, according to which anyone who uses at least 10 GWh of electricity per calendar year spread over at least 7,000 hours of use (for comparison, one whole calendar year comprises 8,760 hours) pays a reduced grid fee that can be as low as 20 % of the standard cost. With 8,000 hours of use, this minimum is further reduced to 10 %. The number of consumption hours is calculated from the amount of energy consumed per year (in GWh) divided by the annual peak load (in MW).

This means that StromNEV incentivises continuous and uniform consumption. A consumer who increases their electricity consumption significantly in a single quarter of an hour to a point that increases the annual peak load would run the risk of falling below the threshold of 7,000 or 8,000 hours of use, and thus of losing their grid fee discount. This is illustrated in the diagram below, which shows a theoretical consumer with a total annual consumption of 20 GWh (the area ① in the power-time-diagram corresponds to the amount of energy). If the annual maximum load ② is 2.8 MW, the number of consumption hours is 20,000 MWh / 2.8 MW ≈ 7,143. This meets both conditions of the StromNEV: total energy consumption exceeds 10 GWh and there are more than 7,000 consumption hours, meaning that the individual grid fee will be reduced to 20 %.

The introduction of flexibility measures can, however, change the load profile at certain times of the year. In the example diagram, there is a new annual peak load of 3 MW in a single quarter hour due to especially high wind power supply (the red load curve and its maximum ③ show the deviation from the original grey load curve). As a result, usage hours drop to 20,000 MWh / 3 MW ≈ 6,667 hours, which is below the threshold of 7,000 hours, leading to an increase from a minimum of 20 % of the regular grid fee to a new level of 100 %. This can lead to considerable additional costs, which consumers would naturally like to avoid – and existing energy management systems are optimised to allow for just that.



▲ Potential loss of the grid fee reduction under the 7,000-hour rule due to more variable loads.
Source: Own work.

In contrast to this, a currently widespread form of regulation-driven optimisation is the 'using instead of curtailing' principle, which aims to consume the power produced by renewable generation peaks at the moment they occur instead of throttling generation in response to grid bottlenecks (which is why wind turbines sometimes stand idle despite strong wind). If, for instance, the operator of cold storage warehouses switches cooling units to maximum when there is a high volume of wind so that they can store the abundant and inexpensive wind power as cold, in the worst case they may lose their grid fee reduction and thus incur financial losses.

Another example is the EEG surcharge, which is included in the electricity price and normally amounts to almost seven cents per kilowatt-hour – that is, more than the total price of one kilowatt-hour of natural gas. In many cases, the fee makes it economically unattractive to replace gas heating with electrical heating (via Power-to-Heat applications or PtH). Even in cases where PtH applications are technically simple and ecologically sensible for green energy generation peaks that would otherwise have to be curtailed and remain unused.

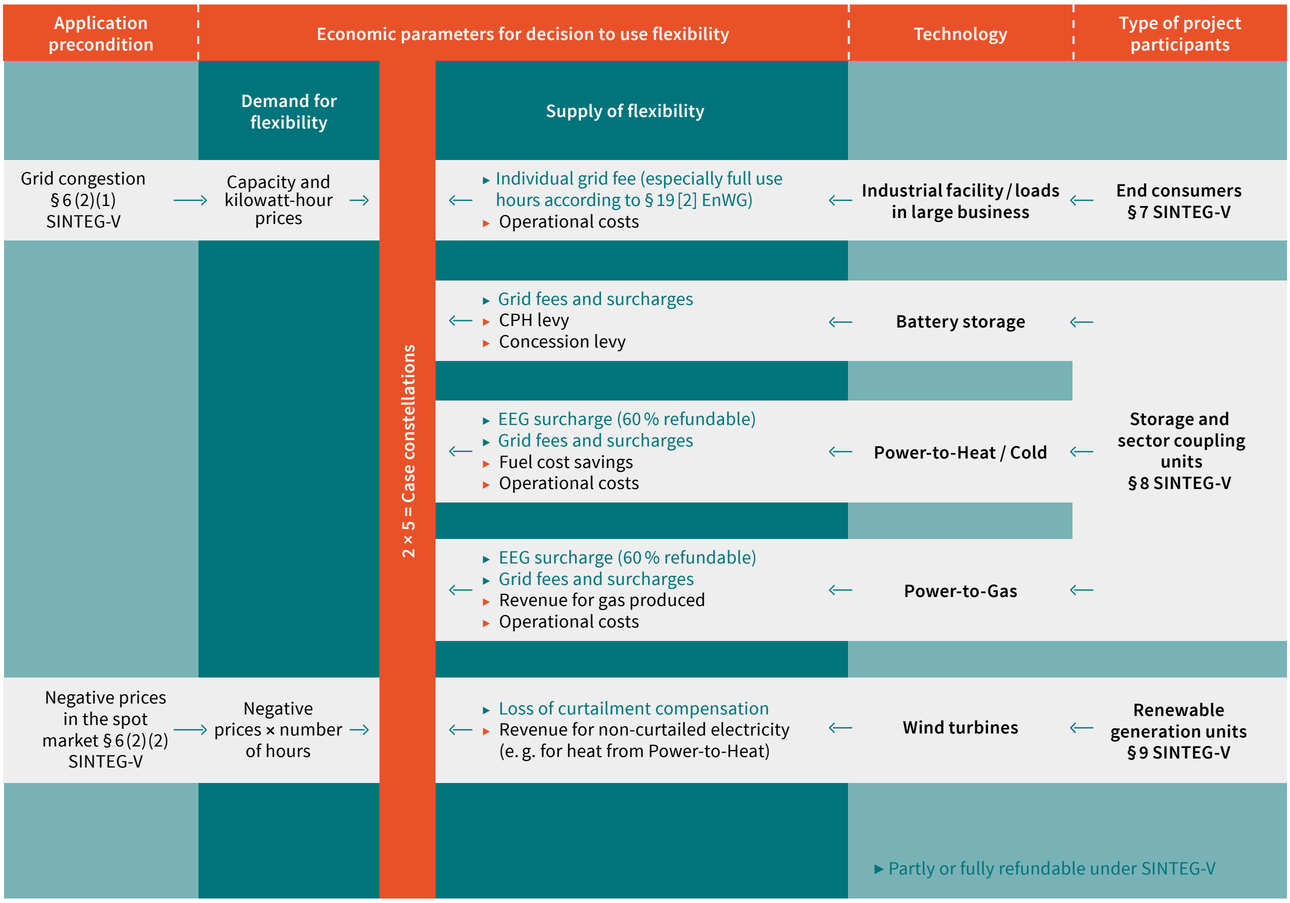
Both examples show that the current regulatory framework can become an obstacle to systemically meaningful and technically available solutions enabling the energy system of the future. And while these problems have long been known in specialist circles and are in fact discussed by politicians, the modernisation of the energy law framework remains a slow and arduous process.

The regulatory sandbox provides leeway for energy system innovation

The slow pace of modernisation has direct effects on R&D projects like SINTEG, because regulatory obstacles can be so severe that certain innovations are not even implemented as model projects. Examples include processes to make industrial loads more flexible in a way that is beneficial to the grid and the system, or sector coupling applications (Power-to-Heat, Power-to-Gas, Power-to-X): they are all technically feasible, systemically sensible, even eligible for financial support during construction – but a regulatory burden in operation.

At the end of 2016, the German Bundestag provided a way out of this dilemma with § 119 of the Energy Industry Act (Energiewirtschaftsgesetz (EnWG)), which created an authorisation to issue ordinances. This enabled the Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie (BMWi)) to issue an 'Ordinance to create a legal framework for collecting experience within the funding programme Intelligent Energy Showcase – Digital Agenda for the Energy Transition' (SINTEG-V) in early 2017. This is also known as a 'regulatory sandbox' because it allowed the players involved in the SINTEG showcase to test use cases which were not feasible within the existing legal framework. Two specific problem cases, which the SINTEG-V partially solved, were outlined at the beginning; the figure (p. 58) provides an overview of other case constellations for which the SINTEG-V is relevant.

In essence, the SINTEG-V compensates for disadvantages. Companies and organisations which increase flexibility in the system and thereby behave in a way that serves the system and grid initially accept monetary disadvantages in the form of having to pay the EEG surcharge or losing grid fee discounts. The SINTEG-V remedies this by guaranteeing SINTEG participants subsequent compensation for those disadvantages, which is paid out by the relevant grid operator at the end of a year after an application to the Federal Network Agency (Bundesnetzagentur, BNetzA).



▲ Possible applications for the application of the SINTEG Ordinance.
Source: Ecologic Institute 2020.

SINTEG-V should thus effectively enable operators to disregard any increases in grid fees or the EEG surcharge that result from increased flexibility. While any grid fees in excess of those due in the reference state initially do need to be paid, they are eventually fully refundable. The same applies to the EEG surcharge of which 60 % can be reimbursed, provided that the flexibility was used in a way beneficial to grid or system operation.

SINTEG-V explicitly does not allow an economic advantage either. Therefore it is entirely forbidden to make any extra profit by exploiting its provisions (see § 10 SINTEG-V). This means that it is not a true 'regulatory sandbox' in the strict sense, but rather a mechanism to compensate for disadvantages. In one important respect, however, SINTEG-V does expressly create space for new possibilities: according to the exemption clause in § 5 SINTEG-V, which modifies § 13 (6) EnWG, a distribution system operator is allowed to create and coordinate flexibility platforms without involving all other distribution system operators. This was an important basis for the creation of flexibility platforms within SINTEG.

SINTEG-V was successful – but not perfect

Many project partners were motivated to participate in WindNODE solely because of the prospect of using the compensation for disadvantages provided by SINTEG-V – in some cases even when they were not allocated any funding (these were 'associated partnerships'). SINTEG-V has regularly been met with great interest even abroad, where similar regulatory sandboxes are being discussed in many places. One specific application example comes from the WindNODE project partner ENERTRAG, which provides heating for the town of Nechlin in northern Brandenburg (subproject 2.2, page 76). This process takes place practically without any CO_2 emissions through the use of electricity produced by a neighbouring wind farm during generation peaks – power that would otherwise have been curtailed due to grid bottlenecks. The electricity is stored as heat in a specially constructed heat storage facility (this is a WindNODE visitor site). This activity was made possible by SINTEG-V.

SINTEG-V was important for the constitution of WindNODE, even if it later became apparent that its effect fell short of expectations and that it could therefore only be used in a few cases. The following difficulties were noted:

1. Relatively short period of validity of the ordinance: The text was adopted in 2017 and its duration was limited to mid-2022. For many partners, this already short term was reduced in practice to a useful life of less than three or in some cases even one to two years, since the first years of the project had to be spent on preparation and planning processes. Longer time periods are required for cost-intensive capital goods to pay back their investment costs. In the aforementioned example from Nechlin, the economic future of the plant once SINTEG-V expires is uncertain.

2. Administrative effort: The application process for using SINTEG-V requires a major bureaucratic effort. First, a project activity must be reported to the Federal Network Agency (BNetzA). Then an application must be submitted for a compensation of financial disadvantages – but this can only be done in the calendar year following the project activity. All creditable benefits must be included in the application and the accuracy of the information must be confirmed by an auditor, to whom the applicant must make an advance payment; auditor costs can be fully deducted from the economic benefits.

3. No profitability despite privileged treatment: SINTEG-V can only be used to compensate for disadvantages after the fact. In other words, operators initially take on a risk because they must run their systems without knowing whether their application will be approved or what the amount of the compensation will be. SINTEG-V does not provide positive economic incentives, instead it even explicitly deducts any profit that was made from the compensation for economic disadvantages. As a result, because no profits are permitted to arise from the use of SINTEG-V, they cannot offset any potential losses on the balance sheet.

4. Narrow scope of application: The prerequisites for participation and the high bureaucratic obstacles mean that the use of SINTEG-V is not practical for smaller consumers or households. In addition, not all of the technologies in the SINTEG showcase are covered. To make matters worse, the compensation for disadvantage under SINTEG-V is limited to the periods in which the narrow conditions of use apply today which is, in the case of negative wholesale electricity prices, rare today but might be common in the future.

Modern rules of the game can be more powerful than public funding

By introducing SINTEG-V, the legislature showed boldness and created something truly original. Despite the ways in which it can be improved, SINTEG-V remains an important success factor in the genesis of the SINTEG showcases. 'Regulatory learning' now also means drawing lessons from our experiences with the use of the SINTEG-V. Regulatory sandboxes are a powerful tool – they provide leeway to explore systemically meaningful solutions and are more effective innovation catalysts than millions of euros spent on project funding. This knowledge should be taken into account in future reality labs and in shaping the major structural change that will result from the impending coal phase-out.

With contributions by:
Hannes Doderer (IKEM)
Markus Graebig (WindNODE-PMO)
Niko Rogler (WindNODE-PMO)

Participating partners

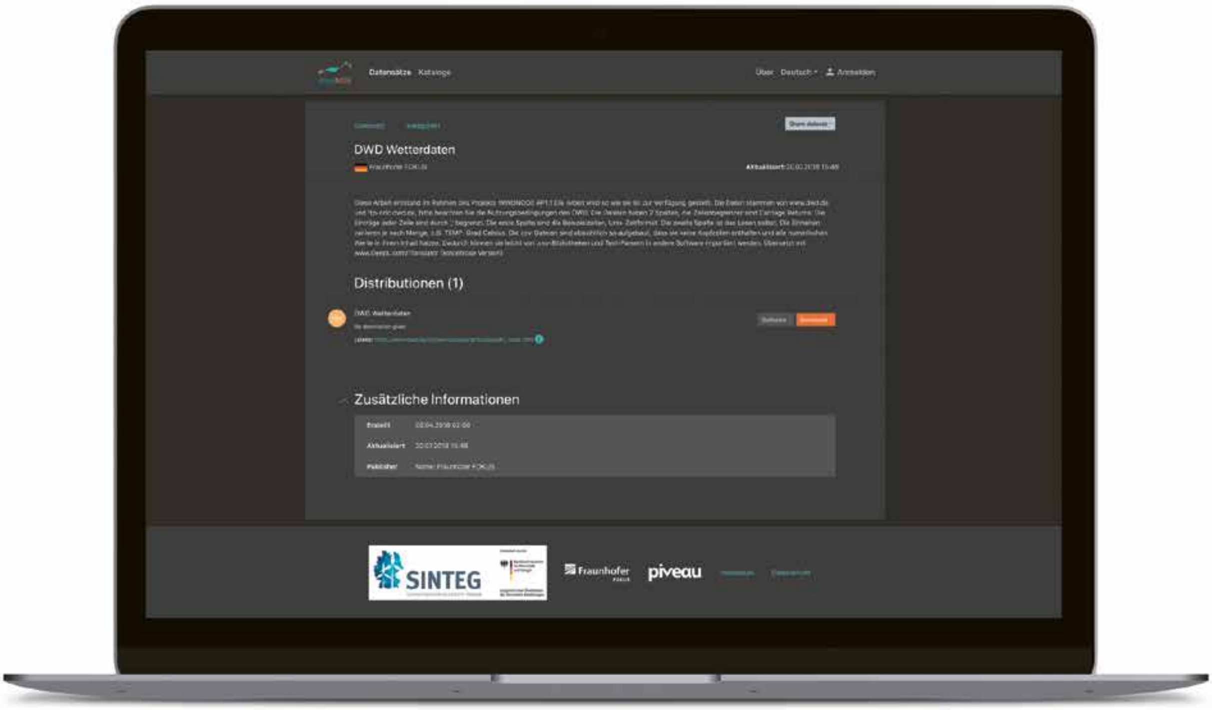
50hertz | Elia Group
BES Riva Group
e.dis
energiequelle ENERGIE MIT ZUKUNFT.
ENERSTORAGE POWER TO HEAT. INDUSTRIAL SCALE.
enso NETZ
Fraunhofer FOKUS
HES Hennigsdorfer Elektrostahlwerke GmbH
IBERDROLA
OPEN KNOWLEDGE GERMANY
PUMACY TECHNOLOGIES
stadtwerke energie jena-pößneck STADTWERKE JENA GRUPPE
Stromnetz Berlin
SWT STAHLWERK THÜRINGEN
T-Systems
ubitricity
WEMAG NETZ GmbH

ICT Networking Platform

The energy transition requires information and communication technologies (ICT) based on standardised interfaces within an increasingly decentralised energy system.

Using these solutions, we can connect the various stakeholders in a secure and intelligent way while making efficient use of the data generated. In this workstream, we are developing an energy data and energy service platform, opening up market access for new flexibility providers and making data flows transparent for start-ups and consumers.

Workstream 1 is coordinated by Dr Alexander Willner (Fraunhofer Institute for Open Communication Systems (FOKUS)) on a voluntary basis.



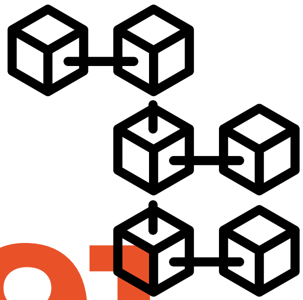
▲ Detail view of a dataset from the energy data marketplace.

Networking in the Digitalised Energy System

Networking in the digitalised energy system requires flexible ICT infrastructures. The Fraunhofer Institute for Open Communication Systems (FOKUS) aimed to address this issue by carrying out the design, implementation and pilot operation of a platform for energy data and energy services, as well as by providing a private blockchain network. In keeping with the concepts of marketplace and platform economy, the solutions made available to WindNODE partners as part of this project are technical building blocks based on open standards. This will enable stakeholders to exchange data in an interoperable and secure way while keeping integration costs low.

▷ CHALLENGES AND SOLUTIONS // **Distributed data exchange makes the energy transition possible**

Existing data exchange systems are often based on bilateral agreements and proprietary interfaces as well as data models that are generally either inaccessible to third parties or only usable at great expense. As a result, data and data-based services are not intelligently networked to meet the demands of a platform economy, which impedes the progress of the energy transition. Fraunhofer FOKUS has therefore set a goal to develop a platform that can provide the necessary building blocks (i. e. basic services) to network energy data – and energy-related services requiring such data – in an open, standardised, supported, interoperable, secure, flexible and scalable manner. This approach can be expanded, advancing the construction of platforms for energy data and laying the groundwork for future process and business models of energy industry stakeholders, which were initiated as pilots in WindNODE. The technological concept behind the GAIA-X project – the current initiative for 'European data sovereignty' – also emphasises the importance of these aspects, providing additional evidence that the approach to architecture applied in subproject 1.1 is indeed a future-proof solution.



91

potential use cases for blockchain technology in the energy industry

'The energy transition is an important building block in sustainable development, enabling us to create an ecologically intact, economically successful and socially balanced world. We feel committed to this responsibility, and our work contributes to open networking of all stakeholders – a crucial element in the digital transformation of the energy system.'

Dr Alexander Willner
Fraunhofer Institute for
Open Communication Systems FOKUS

▶ Guests at the Fraunhofer FOKUS visitor site in Berlin.

10

areas of value creation

A map with ten potentially bidirectional interaction paths can be drawn between the value creation stages of production, transport, trade and consumption, the form and dynamics of which are increasingly influenced by the digital networking of the energy industry.

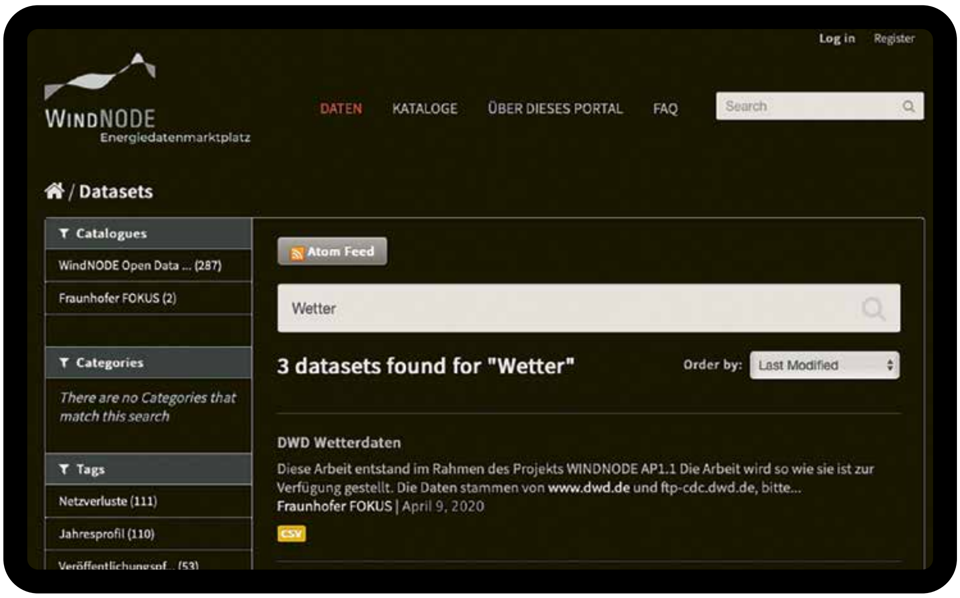
▷ RESULTS // Prototypes for blockchain-based trading and publication and anonymisation of energy data

The two most significant results of the subproject are, first, the design and development of technical components for an energy data and services marketplace, as well as its pilot operation; and, second, the evaluation of the blockchain technology in the context of smart energy, particularly with regard to its application in flexibility trading.

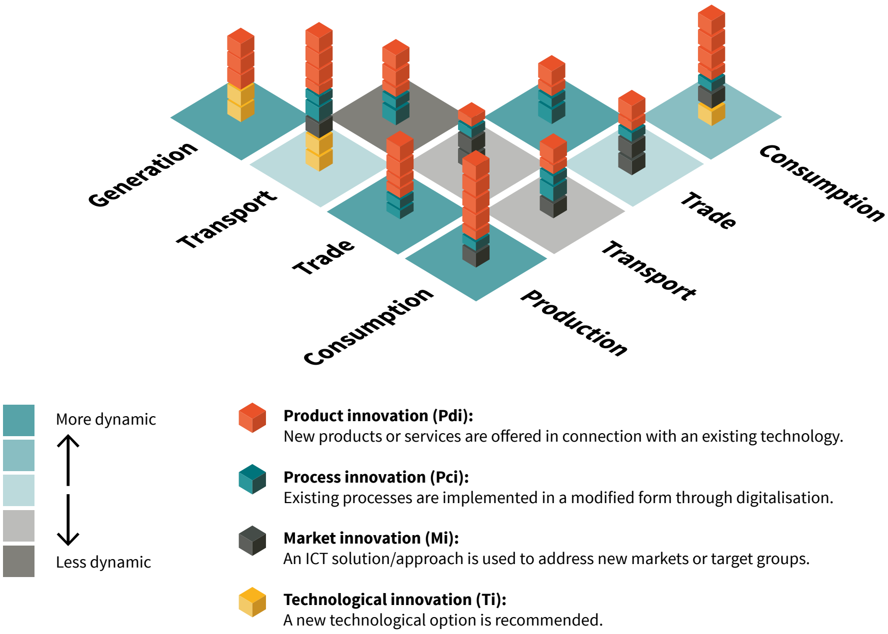
For example, in the course of the project, the energy data marketplace provided access to energy-related data: feed-in data from Stromnetz Berlin, weather data from the German weather service (DWD) and load data from the Siemens plant in Berlin. WindNODE partners could then further use and process these data. In order to guarantee a secure data exchange, a prototype for rights management and communication was implemented, based on the security measures developed. State-of-the-art technology was examined and evaluated to ensure that the process would produce an interoperable solution. Specifically, OAuth2, an established open standard, was selected to secure the authentication and authorisation processes for evaluating user credentials before access is granted to the energy data marketplace. The energy data marketplace was also extended in such a way that data can be stored and made available via well-defined user interfaces. The objective of high interoperability was achieved by using open standards interoperability, which could be ensured by using open standards and applying programming principles like HTTPv2, JSON and REST.

In collaboration with participants of the subproject 1.3, methods were developed to ensure anonymisation, a basic service that makes it possible to anonymise data using various algorithms and to classify anonymisation potentials. This means that data can be analysed with regard to their anonymisation needs; the end user is then given a recommendation as to whether anonymisation should be performed. In concrete terms, this basic service supports the following algorithms: k-anonymity, l-diversity and t-closeness. These algorithms make it possible to aggregate data sets on the basis of a detailed geographical reference to neighbourhoods, streets or city districts; these datasets can then be made available to interested partners, as the level of abstraction guarantees the protection of personal data. The basic service can easily be integrated into existing infrastructures via open interfaces, which helps to meet the need for anonymised data.

In the study *Weiße Flecken in der digitalen Vernetzung der Energiewirtschaft* (English: *'White spots' in the digital networking of the energy industry*), Fraunhofer Institutes IEE and FOKUS identified areas in the energy industry that still lack modern, digital information and communication technology (ICT) for future information flows. Based on the study's findings, the conventional value chain will no longer be sufficient to map energy industry processes in the future. In light of new develop-



▸ Screenshot of the search mask for locating data in the energy data marketplace.



▲ Digital Dynamics Map with ICT solutions for each type of innovation. The map was first created by the German Energy Agency (dena) and developed further by experts in WindNODE.

ments, a more suitable model will be a 'value-added network' that spans 10 value-added areas between the stages of production, transport, trade and consumption. The study comes to the conclusion that ICT technology for managing these information flows is already largely in place today but must be adapted to meet the needs of the future energy industry.

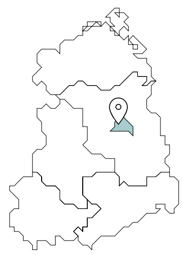
The Forschungsgesellschaft für Energiewirtschaft (FfE) has identified 91 potential use cases for the blockchain technology, one of which is in the flexibility trade. Because this topic is particularly relevant to the WindNODE project, a prototype was developed in cooperation with other WindNODE partners (primarily 50Hertz) to evaluate the use of blockchain technology in the context of flexibility trading via the WindNODE flexibility platform. A private Ethereum network was set up for the participating partners, and relevant business processes (bidding and acceptance) were developed into smart contracts using the programming language Solidity to ensure that automated flexibility trading could be carried out securely. Experimental data were collected on general performance and access to the network. This allowed researchers to conclude, for example, that the performance of the prototype would be more than sufficient for the use case, confirming its technical feasibility. Further findings concerning the prototype are documented in a concept paper on the use of blockchain technology in the context of smart energy, which is available to interested WindNODE partners.

▷ CONCLUSION AND OUTLOOK // **Open standards for open ecosystems**

The digitalisation of the energy transition can only be successful if all stakeholders work together towards the same goal. In the context of ICT, relevant interfaces and data models must be open and standardised to allow for the creation of interoperable ecosystems. The results achieved and basic services developed in the WindNODE project represent the first – and thus fundamentally important – findings and building blocks for this development. They constitute a platform based on open standards for secure, interoperable data exchange and a basis for the creation of a common, decentralised space that is based on mutual trust and requires no central authority. After the project ends, the technology developed by Fraunhofer FOKUS will be further used and updated as part of various research and industrial projects. This option is also available to WindNODE partners.

SP 1.1

FOCUS AREA
Digitalising the Energy System



▸ **Title of the subproject**
Basic Services for Networking in the Digitalised Energy System

▸ **Funding code**
03SIN514

▸ **Subproject partner**

▷ PROJECT PARTNER
Fraunhofer FOKUS

▸ **Contact**
Dr Alexander Willner
T +49 30 3463-7116
alexander.willner@fokus.fraunhofer.de

▸ **Visitor site**
eGovernment Laboratory and IT4Energy Centre
Kaiserin-Augusta-Allee 31
10589 Berlin

Registration required

▷ INQUIRIES TO
Dr Armin Wolf
armin.wolf@fokus.fraunhofer.de

For more information
datenmarkt.windnode.de

▲ Extra-high-voltage lines with wind turbines in the 50Hertz control area.

The WindNODE Flexibility Platform

The WindNODE flexibility platform project was developed and tested by transmission and distribution system operators (TSOs and DSOs) to provide additional flexibility for grid congestion management. In the future, due to changes to the regulatory framework resulting from the NABEG amendment, a large share of the available flexibility will be part of the regulated redispatch process. This alleviates the pressure for marked-based grid congestion management in the short term. However, the concept "using instead of curtailing" continues to make sense and its integration into the regulatory framework should be reassessed in due time.

‘The successful cooperation between grid operators at different voltage levels is an especially positive development. Bottlenecks in the grid and the flexibility potential required to eliminate them can be on different voltage levels, and coordinated processes are necessary to bring them together.’

Dr Georg Meyer-Braune
WindNODE Project Manager, 50Hertz Transmission GmbH

Lisa Hankel
Project Manager Business Development, Stromnetz Berlin GmbH

▷ CHALLENGES AND SOLUTIONS // **Efficient management of grid congestion**

The electricity markets bring together supply and demand under the assumption that there is no physical congestion in the grid. This is meant to increase liquidity and foster efficiency. Limitations in grid capacity lead to temporary, generation-driven congestion, which could previously be resolved by redispatch and feed-in management. These measures mean that renewable energy sources can, as a last resort, be curtailed in the interest of grid congestion management. The idea behind this subproject was to use innovative flexibility options as comprehensively as possible before curtailing renewable power plants. From an economic point of view, more flexibility in the grid congestion management process is especially interesting if it can replace existing, more expensive flexibility options or increase the use of renewable electricity. For this to be true, the costs saved must at least compensate for the price of developing and operating a given flexibility platform. The frequency with which the new flexibility is used and the capacity required can be very different depending on the location of a facility and the local situation in the power grid, and must be assessed individually in each case. The original goal was to design a process which would include facilities that are not already legally obliged to participate in the redispatch, allowing them to participate on a voluntary basis and in a way that is open to new technologies. All the grid operators involved should be able to use the flexibility in question, with robust coordination across different voltage levels. The use of this additional potential was intended to enable greater use of renewable electricity in cases of grid congestion – often called 'using instead of curtailing'.

▷ RESULTS // Tried and tested

The close cooperation between TSOs, DSOs and various flexibility providers made it possible to design processes, platform functions, interfaces and products that lower entry barriers as much as possible and allow interested parties to participate in the flexibility platform regardless of the technology employed. By defining products and processes, the requirements of the different grid operators could be brought in line with the offerings of the flexibility providers. Other products and variants might be accomodated using the same concepts in the future. The deployment of the platform with submission of bids, coordination and retrieval was successfully tested in practice during the project period. To make our solutions publicly available and foster harmonisation, the partners of this subproject worked with DIN and other WindNODE partners to develop and publish the standardisation project DIN SPEC 91410 1.

Energy industry processes in

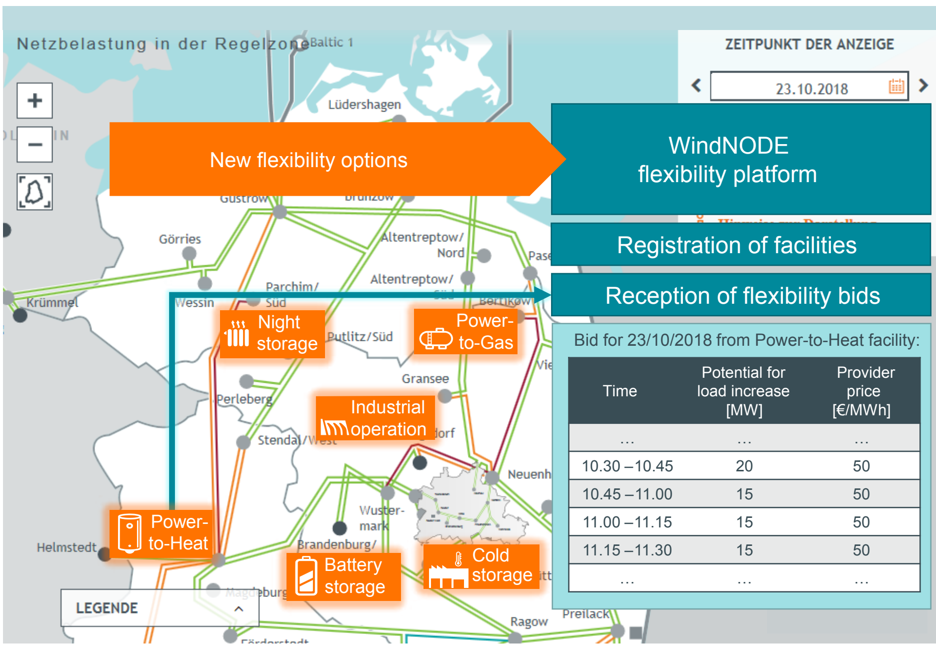
26,000

lines of code

▷ CONCLUSION AND OUTLOOK // New framework conditions

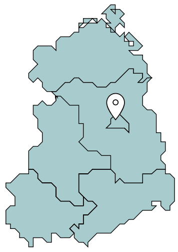
The procedural and technical feasibility of the flexibility platform was successfully confirmed by real tests. The NABEG amendment, introduced in 2019, however, specifies that much of the flexibility potential in Germany will now be obliged to participate in the regulated redispatch, which translates into less additional use of the platform. The unused potential not covered by the redispatch process now consists almost exclusively of flexible loads. This particular type of flexibility is affected by the problem of strategic bidding ('inc-dec gaming'), in which flexibility providers artificially reinforce or create a bottleneck and then eliminate it with their own resources to generate profits. One regulatory solution to this problem could be a mandatory integration of this unused flexibility potential as part of a voluntary mechanism for managing grid congestion. Regardless, the concept of the flexibility platform is and remains fundamentally well-suited to creating spatially differentiated incentives for making greater use of flexibility, especially in light of future increases in redispatch volumes and periods of negative residual load.

▼ Decentralised providers can submit their flexibility bids via the flexibility platform.



SP 1.2

FOCUS AREA
Activating Flexibility
Digitalising the Energy System



▶ **Title of the subproject**
Innovative Process Platform

▶ **Funding code**
03SIN500

▶ **Project partners**

▷ SUBPROJECT PARTNERS
50Hertz Transmission GmbH
Stromnetz Berlin GmbH
WEMAG Netz GmbH

▷ ASSOCIATED PARTNERS
E.DIS AG
ENSO NETZ GmbH

▷ FLEXIBILITY PROVIDERS
Brandenburger Elektrostahlwerke GmbH
Energiequelle GmbH
ENERSTORAGE GmbH
Hennigsdorfer Elektrostahlwerke GmbH
Siemens AG
Vattenfall Wärme Berlin AG
Schwarz Gruppe
Energy2market GmbH
BMW Group
GASAG Solution Plus GmbH
Stahlwerk Thüringen GmbH

▶ **Contact**
Dr Georg Meyer-Braune
T +49 30 5150-2133
georg.meyer-braune@50hertz.com

For more information
www.50hertz.com

◂ The series of hackathons brings together members of the public and stakeholders from the energy and supply industry to network, compare notes and develop exciting ideas.

Energyhack – Open Data Leads to Good Ideas for the Energy Transition

Stromnetz Berlin, Fraunhofer FOKUS and the Open Knowledge Foundation are cooperating to expand the publication and utilisation of energy data. The goal of 'hackathons' is to collaborate with young developers to generate new ideas for a sustainable power supply and digital strategies of the future. The WindNODE partners hosted three hackathons between 2017 and 2020.

'Stromnetz Berlin stands for transparency. We are the first grid operator in Germany to offer open data. Our energy hacks bring all kinds of people together to find innovative solutions for the city of Berlin and the energy transition.'

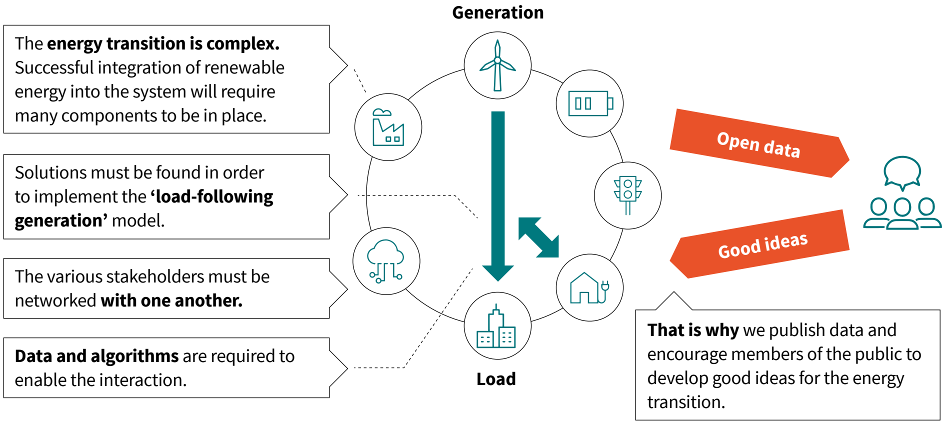
Claudia Rathfux
Head of Customer and Market Relations, Stromnetz Berlin GmbH

▹ CHALLENGES AND SOLUTIONS // **Open data as a success factor**

Open data offer great potential for innovative developments. Refining, analysing and evaluating data can inspire visions for the future and new approaches to solving problems. In collaboration with Fraunhofer FOKUS, the grid operator Stromnetz Berlin is expanding its grid data portal http://daten.windnode.de, and continuously works to acquire, release and integrate new data sources. In order to lower the barriers to data publication, further development continues on a data anonymisation service. Throughout the course of the WindNODE project, the subproject partners have worked to build excitement for the opportunities associated with open data and succeeded in recruiting more partners to publish datasets on the portal. The companies and organisations that have joined the open data initiative include Berliner Wasserbetriebe, Deutsche Bahn, Vattenfall Wärme and Schneider Electric.

▹ RESULTS // **Energyhack³ – a successful event series**

The 'Energyhacks', which were held in cooperation with the Open Knowledge Foundation in September 2017, October 2018 and a final event planned in 2020, are highlights of this subproject. The goal of these events was to develop projects



that would increase public awareness of the issues surrounding electricity, energy grids and the energy transition. As a partner of the WindNODE project, Stromnetz Berlin was and is able to use its budget to support and develop individual ideas that show potential to facilitate the energy transition, even outside of the hackathon. On the infrastructure side, Fraunhofer FOKUS completed the new version of the open data portal and released it along with the service for data anonymisation.

2017

The choice is yours!

Winners: Strombär (coupling and sharing of data on electricity production and consumption), EnergyDiversity (sharing of information for consumers about sources and prices of electricity), EVCount (how many electric vehicle charging points do we need?), Abwasser as a Service (how does a wastewater pumping station work and what kind of energy does it consume?)

After an initial brainstorming session, EVCount evolved into an augmented reality project that supplied live data on the electricity grid in select areas of Berlin. A pilot project was successfully developed.

2018

For the city, for the energy

Winners: Internet of Bears (IoT learning platform for schoolchildren), Simspeicher (optimisation of electricity consumption using storage), Wer oder was bin ich? (visual quiz about data), SmartCity Services (data request feedback concept)

Special prize:
Simulation der Berliner Klärwerke und Stromnetze (simulation of the Berlin wastewater treatment plants and power grids; elaboration of a concept from 2017)

2020

City, energy, mobility

At the Energyhack 2020, the networking of different sectors of energy and transport will be more central than ever. Due to the unique circumstances resulting from the 2020 COVID crisis, much of this year's hackathon will take place online. The challenges and results will be displayed at www.energyhack.de.

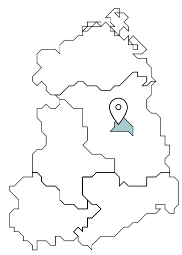
313 open data sets

Three events with more than 100 participants each, 313 open datasets available at **daten.windnode.de** (German only).

▷ CONCLUSION AND OUTLOOK // **The grand finale**

Stromnetz Berlin is holding the final hackathon in the summer of 2020. By then, the WindNODE partners will have brought even more partners on board to support the concept of open data. This will allow the event series to culminate in a large and valuable compilation of open data – a fitting conclusion. Alongside new data, the final Energyhack will also give space to present a follow-up of the winning ideas from previous competitions: their creators are invited to present the further development and pilot projects that resulted from their work, underlining the potential of hackathons in the energy sphere.

SP 1.3
FOCUS AREA
Digitalising the Energy System



▸ **Title of the subproject**
Open Data Portal

▸ **Funding code**
03SIN530

▸ **Subproject partners**

▷ PROJECT PARTNERS
Fraunhofer FOKUS

Stromnetz Berlin GmbH

▷ SUBCONTRACTOR
Open Knowledge Foundation Deutschland e. V.

▸ **Contact**
Christian Jacob
T +49 30 492028542
christian.jacob@stromnetz-berlin.de

For more information
www.energyhack.de

▲ Correlation of performance and energy consumption data in metal processing

Big Data Analytics for Market and Consumer Data

Pumacy has created a market and consumer platform and, in order to evaluate its practical application, has implemented use cases that can be used as a basis for new consumer and operator models. The technological core of the platform is search-based applications (SBA) that index, aggregate, normalise and visualise structured, semi-structured and unstructured data.

‘The WindNODE project brings us a good step closer to the goal of using powerful data analyses to stimulate new business models throughout the energy value chain. At the same time, we are helping consumers actively shape their energy consumption.’

Dr Toralf Kahlert
CEO,
Pumacy Technologies AG

▷ CHALLENGES AND SOLUTIONS **// Search Based Applications (SBA)**

Data are among the decisive accelerators of the ongoing energy transition. Merging, combining and visualising of large amounts of data from different sources makes an essential contribution to the development of new applications and business models within the framework of WindNODE as well. ‘Big data’ emerging in the energy industry are characterised not only by their sheer volume and the need for quick processing, but also and above all by their highly varied structure, which makes the task of merging them challenging. This subproject combines current research approaches in the field of SBA with applications in the field of energy economics that target both consumers and producers.

▷ RESULTS **// Big data use cases for energy producers and consumers**

The first half of the project established the technological platform for the market and consumer applications. Pumacy used open-source applications to develop a complete SBA framework. This resulted in a powerful core system for the analysis of all types of data correlations, which is available for use cases from the energy sector and beyond.

The second half of the project focused on the implementation of concrete data applications. This included the forecasting of the theoretical maximum power generation through solar and wind energy by postcode. This function will eventu-

7,325,978 data sets

15 GB of information,
10,918 hours of process data

ally be made available to end users. In addition, it is possible to upload consumption values to the market and consumer platform via smart meters in order to calculate an individual energy and CO_2 balance. Other applications involve data analysis for industrial plants. For instance, a scenario for production planning was formulated which made it possible to postpone certain energy-intensive process steps to periods of high renewable electricity availability.

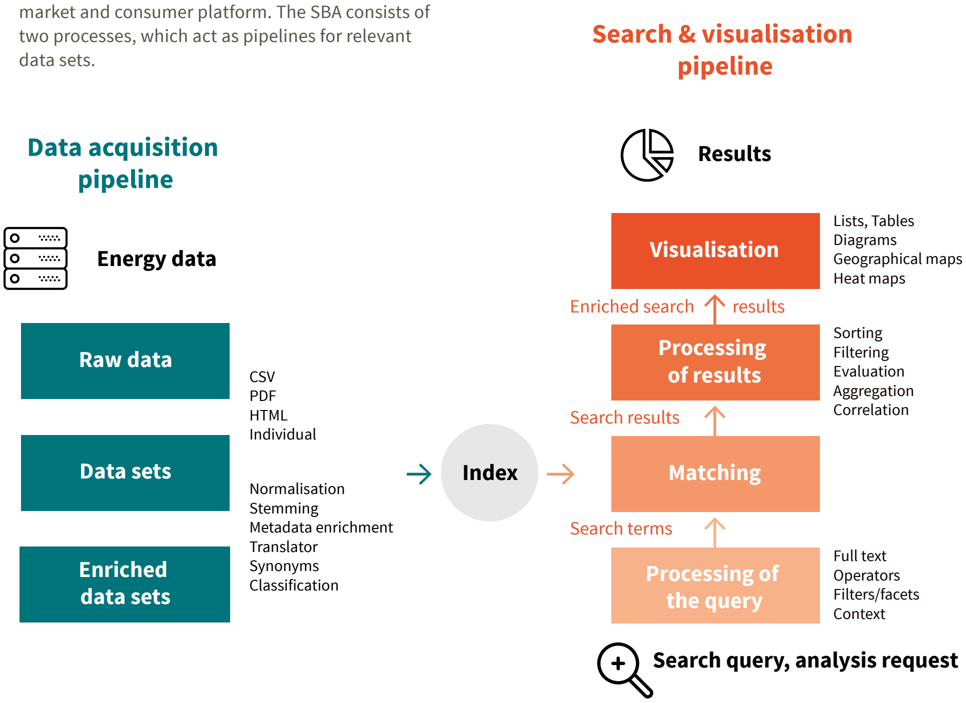
In the second half of 2019, three major use cases were developed and advanced to the extent that their analysis and processing functions can be regarded as complete. Of course, it is possible to further refine the methods and increase the quality of the results; however, this will require significantly more data over longer periods of time, meaning that continuous improvement can be expected as the systems run and integrate more data.

▷ CONCLUSION AND OUTLOOK **// Scenarios for data-driven business models**

A number of lessons were learned in the course of the project. For instance, the original idea to base the system on commercial SBA software was discarded early on, as the need for an open architecture that could be used without additional costs ultimately required the in-house development to take place on an open-source basis. Another lesson concerned data quality and availability: there were often major gaps in data provision, both temporally and spatially.

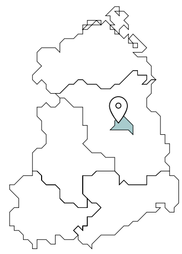
By the end of the project, concrete scenarios will have been developed that will allow producers and consumers to define starting points for individual implementation and new business models.

▼ SBA (search-based application) architecture of the market and consumer platform. The SBA consists of two processes, which act as pipelines for relevant data sets.



SP 1.4

FOCUS AREA
Digitalising the Energy System



▸ **Title of the subproject**
Market and Consumer Platform

▸ **Funding code**
03SIN524

▸ **Subproject partner**

▷ PROJECT PARTNER
Pumacy Technologies AG

▸ **Contact**
Manuel de Melo
T +49 30 22161280
info@pumacy.de

▸ **Visitor site**
Pumacy Technologies Solution Center,
Pumacy Technologies AG
Bartningallee 27
10557 Berlin

Visits by appointment every Monday – Friday from 10 am to 5 pm. The visits are individual and primarily intended for business and public users.

▷ INQUIRIES TO
info@pumacy.de

For more information
www.pumacy.de

Participating partners

BELECTRIC

b-tu Brandenburgische Technische Universität Cottbus - Senftenberg

ENERGIEAVANTGARDE ANHALT

ENERTRAG Eine Energie voraus

Fraunhofer IEE

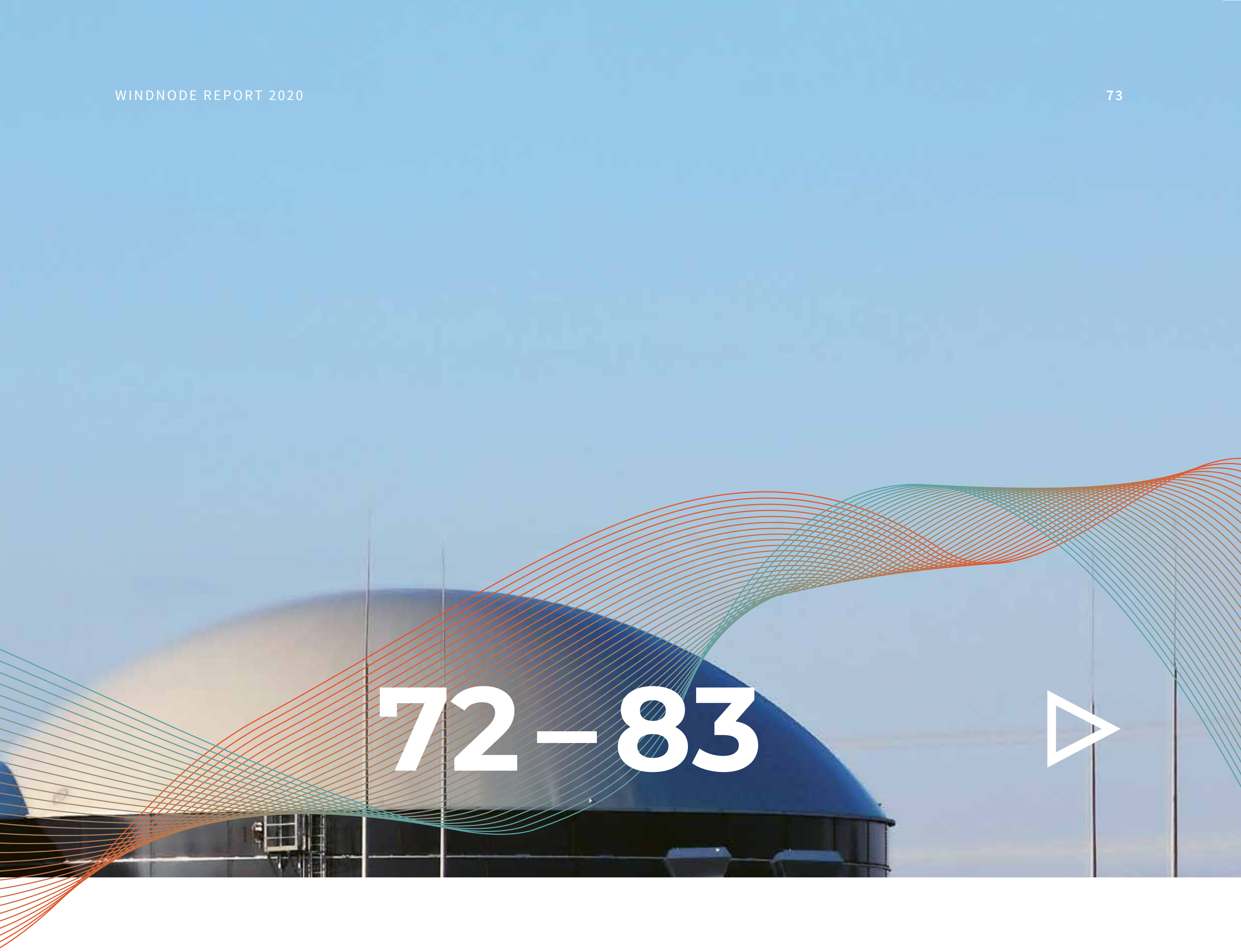
Stadtwerke Cottbus Heizkraftwerksgesellschaft

IBAR

i ö w INSTITUT FÜR ÖKOLOGISCHE WIRTSCHAFTSFORSCHUNG

RLI REINER LEMOINE INSTITUT

stadtwerke FRANKFURT (ODER)



72–83

Flexible Generation and Regional Power Plants

In this workstream, WindNODE demonstrates how generators, storage facilities as well as power and heating grids in close geographical proximity can be connected to each other to regionalise load flows and make feed-in flexible and beneficial to the grid.

For the first time, multiple power plants are being coordinated and controlled within a regional network in a way that supports the grid and the overall energy system. This has led regional ancillary services to emerge as a new revenue model for flexibility providers.

Workstream 2 is coordinated by Martin Beckmann (ENERTRAG AG) and René Markgraf (IBAR Systemtechnik GmbH) on a voluntary basis.

▲ Vehicle batteries in use as part of a large-scale battery storage system in a shipping container. Batteries are operated with modern control technology via radio.

Future Storage of the Energy Transition – New Markets and Solutions

Until now, large-scale battery storage systems have mainly been used for primary balancing power (PRL). New concepts were needed to increase their market share and tap into the numerous possibilities that this technology has to offer. These take the form of additional services such as flexibility and faster control, optimisation for applications, and hybrid power plants.

‘Battery storage systems offer diverse applications that are making them a key technology in the development of renewable energy production.’

Dr Tim Müller
CTO,
BELECTRIC Solar & Battery GmbH

▷ CHALLENGES AND SOLUTIONS // **Key technology with market barriers**

Large-scale battery storage systems are emerging as a key technology in the energy transition. They can address many of the emerging challenges associated with the transition: they counteract volatile generation in cases of imbalance in supply and demand, are designed to operate in a decentralised manner, reduce the need for grid expansion and provide the fastest control services of any technology. To achieve unsubsidised construction and leverage the opportunities created by these systems, further adjustments to existing markets, entirely new market concepts and falling battery prices are needed.

With large parts of the preliminary research completed and a virtual hybrid plant composed of various units operational, new challenges could be tackled. These included the identification and analysis of new market opportunities, the simulation of innovative operating concepts in different contexts, and the development and testing of technical solutions. We managed to pair new ideas for control services with different combinations of batteries with generator technologies such as wind or photovoltaics. Together, they form an effective hybrid power plant that is able to open up existing as well as soon-to-be markets.

▷ RESULTS // **Help large-scale storage systems to achieve an economic breakthrough**

Various approaches were taken to solve the central problem, i. e. to increase the profitability of large-scale battery storage systems. Different practical concepts for economic integration with other generators – such as wind farms, combined heat and power (CHP) plants and run-of-river power stations – were presented. In addition, the subproject explored using these solutions to increase the share of renewables in end-user energy supply. The battery as part of a hybrid plant was found promising due to its flexibility, fast provision of services, and ability to smooth or shift energy generation and consumption. Concepts were developed for a cost-effective application of the battery that would simultaneously leverage the plant´s other components and the connection to the grid.

A second avenue of research was the development of new energy services and the necessary adaptations to the battery storage systems. Differences in the capacities of the battery storage systems, and in the flexibility of their use to meet customer requirements, proved to be a central challenge. In the future, very fast reaction times – on the order of 150 milliseconds – and the capability to directly set the grid voltage will be key factors in gaining a competitive edge. Making this cost-effective requires modified hardware concepts, cooling and optimised software. In order to achieve reliable system control, new redundancy concepts were developed. These employ Spanning Tree Protocols (STPs) on multiple processing units with redundant communication paths as well as over-provisioning of the power units based on the N-1 principle to safeguard against single component failure.

▷ CONCLUSION AND OUTLOOK // **Practical opportunities and outlook for large-scale battery storage systems**

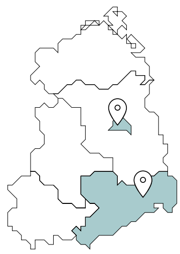
The work carried out in this subproject advances new concepts and market opportunities for economically optimised battery storage systems, which will play an important role in making the EU climate neutral by 2050. In the medium term, it is expected that battery storage systems will increasingly be combined directly with other generators and consumers to increase their cost-effectiveness under the changed market conditions. Projects for faster control services and hybrid systems are now in the pipeline. In order to continue on this path in the long term, the experience gained is leveraged for further development work on virtual synchronous machines that can provide momentary reserves and be used to optimise DC-coupled systems.

32 % is the amount that the price of battery storage has fallen in three years. Coupled with the right innovations, few technologies will be able to compete.

▼ User interface of the energy management system for data display and management of a battery storage power plant.

SP
2.1

FOCUS AREA
Identifying Flexibility



▸ **Title of the subproject**
Future Storage of the Energy Transition – Ancillary Services of the Energy Transition

▸ **Funding code**
03SIN502

▸ **Subproject partner**

▷ PROJECT PARTNER
Belectric Solar & Battery GmbH

▸ **Contact**
Robert van Treeck
T +49 351 2574-9091
robert.vantreeck@belectric.com

▸ **Visitor site**
Audi Power Storage
EUREF-Campus
Energiezentrale (Haus 9)
Torgauer Straße 15
10829 Berlin

▷ INQUIRIES TO
Robert van Treeck
robert.vantreeck@belectric.com

For more information
www.belectric.com/battery-storage

▲ Hybrid power plant of ENERTRAG in Prenzlau.

Renewable Energy Takes Over Functions from Conventional Power Plants

With the integrated renewable power plant in Uckermark, ENERTRAG is demonstrating how combining renewable energy resources, storage facilities and Power-to-X (PtX) systems can completely replace some of the functions of conventional power plants in the future. The Uckermark plant has its own feed-in grid that connects wind energy, solar and biogas facilities, a 20 MW battery and a hydrogen electrolyser within a 25-km radius. In addition, the PowerSystem software developed by ENERTRAG ensures the coupling and uniform control of all elements in the plant.

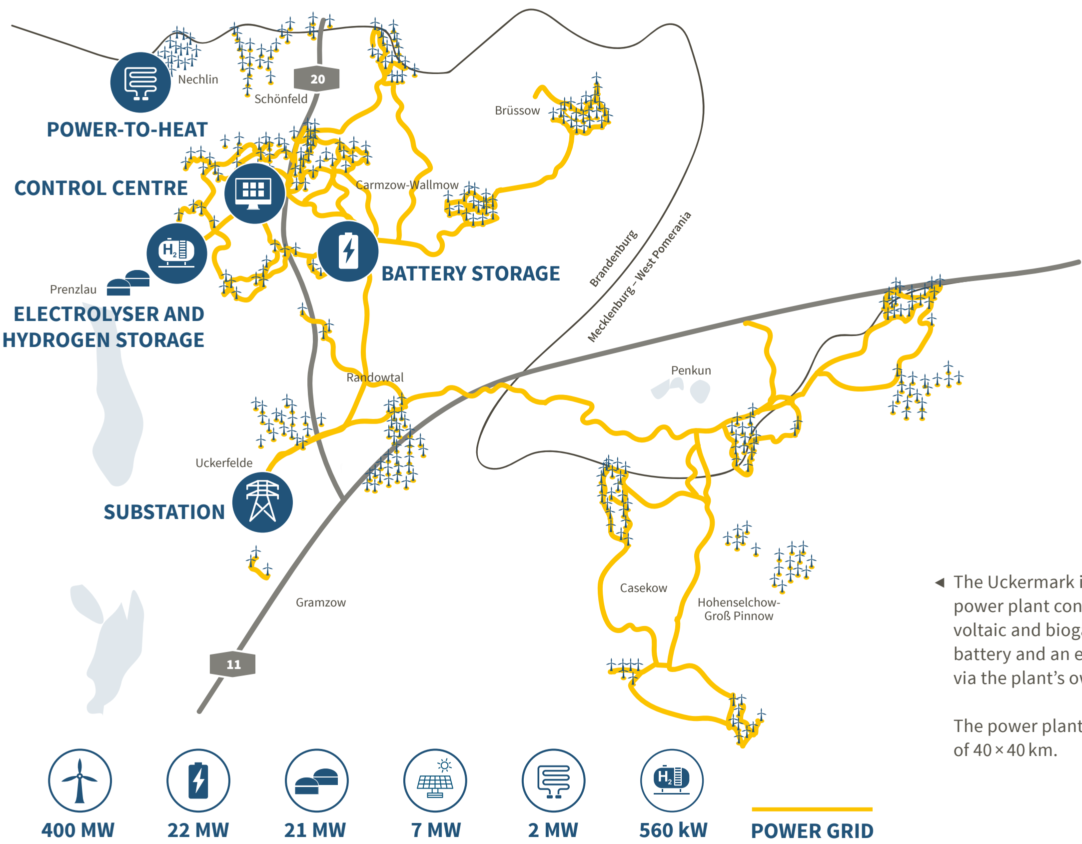
Through their participation in WindNODE, the Reiner Lemoine Institute (RLI), the Fraunhofer Institute for Energy Economics and Energy System Technology (IEE) and ENERTRAG have gained important scientific knowledge and practical experience that can be applied on the way to an energy system based entirely on renewables. In the future, renewable power sources will not only satisfy all of society's primary energy needs; they will also be fully responsible for system stability. By refining the integrated renewable power plant through research and practical development, RLI, IEE and ENERTRAG have taken steps to improve economic efficiency and increase potential benefits to the system and grid.

▷ CHALLENGES AND SOLUTIONS // IT solution improves data security and controllability in the integrated power plant

All components of the integrated power plant are electrically and digitally linked, and their operation coordinated. The ENERTRAG PowerSystem IT platform helps to integrate all facilities, unifying the decentralised and heterogeneous structures. It is used to monitor and control each of the components in the integrated power plant and group them into large power generating units. The reliable controllability and security of infrastructures like the integrated power plant will have a decisive influence on Germany's system security in the future. The WindNODE project partners therefore aimed to strengthen the links within integrated power plants, making them even more secure against external attacks. In addition, rapid technological development has dramatically changed the technical requirements on software used to regulate and control components. Support from WindNODE enabled further development of the ENERTRAG PowerSystem software which is designed to facilitate the creation of renewable power plants, and is now well-suited for monitoring and controlling the large number of linked components within integrated power plants.

The PowerSystem software controls a total of 2.7 GW of renewable plant capacity

ENERTRAG PowerSystem allows for central management and precise unified control of the individual components despite the fact that there is significant technical diversity due to a large variety of manufacturers and construction dates of the technical units. ISO 27001 certification was an important milestone that further confirmed the information security of the integrated power plant.



◂ The Uckermark integrated renewable power plant consists of wind, photovoltaic and biogas units as well as a battery and an electrolyser, all linked via the plant's own feed-in grid.

The power plant extends over an area of 40 × 40 km.

‘A wind power heat storage system like the one in Nechlin could supply numerous communities and cities with renewable heating in the future. However, before millions of people can get access to cheap, carbon-free heat, changes need to be made to the EEG and the electricity tax.’

Jörg Müller
Founder and Chairman of the Board, ENERTRAG

During the course of the project, penetration tests on the PowerSystem conducted by Fraunhofer IEE revealed security vulnerabilities, making it possible to eliminate them systematically. These simulated attacks on the data transmission software and the related scientific exchange between the partners provided the impetus for further security tests.

▷ RESULTS **// Converting instead of curtailing: renewable heating for a whole village**

ENERTRAG’s wind-heat storage system in Nechlin is bringing the ‘SINTEG Ordinance’ or SINTEG-V, a regulatory sandbox introduced by the Federal Ministry for Economic Affairs and Energy, to life. Since March 2020, this Power-to-Heat (PtH) model project has demonstrated how an entire village can be heated at low cost, and with little technical effort, using wind power that would otherwise have been curtailed. The wind farm is directly connected to a wind power heat storage tank by means of an electric cable. As soon as the grid operator gives a curtailment signal, the heating rods are activated in the heat storage system. The storage system contains one million litres of water, which is heated, stored and delivered to the local heat network in the village as required. When there is a lot of wind, the storage unit only needs a few hours to fully heat up and can subsequently supply the village with heat for up to two weeks – 100 % carbon-free. Moreover, in the right conditions, wind heating from Nechlin is significantly cheaper than oil heating. In the future, this type of wind-heat storage system could supply hundreds of municipalities and cities in northeastern Germany with renewable heat at a low cost.

▷ CONCLUSION AND OUTLOOK **// The legal framework prevents PtH plants from being economically efficient**

The Reiner Lemoine Institute has investigated the possibility of using surplus wind energy to supply district heating networks in the cities of Schwedt and Prenzlau in the Uckermark region. The annual heat demand in the district heating networks of these two cities amounted to a total of around 190,000 MWh in the year 2016, which was the study period. During periods of curtailment, electricity from wind turbines is not used or not generated at all, despite the fact that electricity consumers still pay grid fees. In the same year, some 190,000 MWh from wind turbines were cur-

▼ The wind power heat storage is a WindNODE visitor site located directly on the bicycle path from Berlin to Usedom. Short open-air tours inform visitors about the concept behind the facility and provide a concrete example of sector coupling.

200,000 MWh

Almost 200,000 MWh of electricity from wind turbines are curtailed in the Uckermark region every year. In Nechlin, ENERTRAG is showing how this electricity can instead be used to generate carbon-free heating.

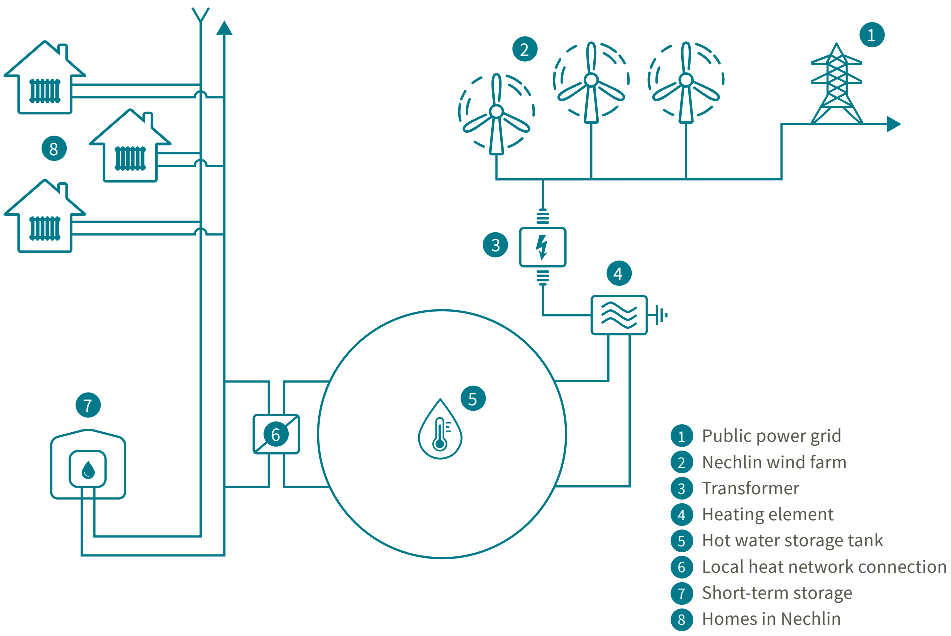
tailed in Uckermark. As the wind-heat storage system in Nechlin shows, a large portion of this electricity could be used to generate heat locally instead. This is because wind turbines are curtailed especially frequently in winter, when heating demand is highest.

The studies by RLI show that an economically efficient use of wind power that would otherwise be curtailed is technically possible with PtH plants. However, under the current regulatory framework, wind power used to generate heat is subject to an additional €136/MWh in taxes, duties and levies. This means that it is not currently viable to deploy this type of solution outside the terms of the SINTEG Ordinance.

Investigations into targeted ways to adapt the regulatory framework imply that the special regulations in the SINTEG Ordinance generally point in the right direction. Sector coupling with PtH remains economically difficult, however, even with the regulatory sandbox approach of the SINTEG Ordinance. Enabling sector coupling and thus a more effective use of renewable power sources requires charges, taxes and levies for the electricity, heat and gas sectors to be adapted. Uniform carbon pricing would be one suitable regulatory option, as it would provide the necessary incentives to use wind energy that would otherwise be curtailed instead of natural gas for heat generation.

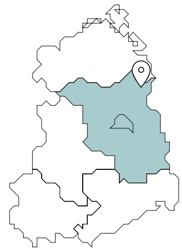
The study can be downloaded from the RLI website: www.reiner-lemoine-institut.de.

▼ ENERTRAG uses renewable energy to heat an entire village in Brandenburg. Wind power from the nearby wind farm is used to heat water in a heat storage facility which feeds directly into the local heat network.



SP 2.2

FOCUS AREA
Activating Flexibility



▸ **Title of the subproject**
Uckermark Regional Power Plant

▸ **Funding code**
03SIN513

▸ **Subproject partners**

▹ PROJECT PARTNERS
ENERTRAG AG

Fraunhofer IEE

Reiner Lemoine Institute gGmbH

▹ SUBCONTRACTORS
Energieavantgarde Anhalt e. V.

Institut für ökologische Wirtschaftsforschung gGmbH

▸ **Contact**
Martin Beckmann
Martin.beckmann@enertrag.com

▸ **Visitor sites**
Control Centre of the Uckermark Integrated Power Plant
Gut Dauerthal
17291 Dauerthal

Registration required. Visits limited due to ongoing operations; visitor conference room available

Hybrid Power Plant with Power-to-Gas Plant
17291 Wittenhof

Registration required. Visits limited in the summer months

Wind Heat Storage/ Power-to-Heat Plant
17337 Nechlin

Freely accessible tour

▹ INQUIRIES TO
Dr Nadine Haase
nadine.haase@enertrag.com

For more information
www.enertrag.com/windwaerme

▲ Gas engine in the combined heat and power (CHP) plant in Frankfurt (Oder). The engine can generate 2,000 kW of electricity and 2,400 kW of heat.

Flexible Operation at Short Notice

The district heating power station operated by the municipal utility Stadtwerke Frankfurt supplies the city of Frankfurt (Oder) with electricity and heat. Our district heating grid crosses international borders since 2015. In this project, flexible modes of operation were developed at a total of six generation plants in order to supply both heat and electricity. Once the resource planning model was completed, it became clear that only plants with short start-up and shut-down times were suitable for a flexible power generation strategy.

‘To us, participation in the WindNODE project means developing new solutions for the coal phase-out and further renewable energy expansion and integrating these solutions into electricity and heat generation. At the same time, we are relying on modern management systems to ensure a secure supply for our customers.’

Harald Wolf
WindNODE Project Manager,
Stadtwerke Frankfurt (Oder) GmbH

▷ CHALLENGES AND SOLUTIONS // **Economical and ecological operation of the power plants**

When the project was launched, our power plants and distribution grids for electricity and district heating were operated in a way that required a great deal of manual and administrative effort. By making the operation of the district heating power station, the heating plant and the CHP plant ‘Süd’ more efficient and flexible, and by securing mutual delivery of heat with our Polish partners, we aimed to achieve an economically optimal operation of all plants while simultaneously offering the CHP plants as controllable loads.

The district heating grid has had a cross-border element since 2015, when a connection to Słubice was commissioned: this represented a bold and technically sophisticated construction project and opened a new chapter in the cooperation between the two cities across national borders.

A newly developed software solution will allow all of the components involved in the generation and distribution process to be linked and controlled in a modular fashion. This is intended to optimise plant operation, ensure flexible load management, provide fuel savings and minimise CO_2 emissions. This new flexibility will make it possible to efficiently adapt the operation of the power plants used to supply Frankfurt with heat and power to the available renewable energy from wind and solar in the surrounding region.

▷ RESULTS // Achieving high flexibility

During the project period, we worked hard with our partners to develop an implementation concept. The necessary steps were defined, translated into concrete tasks and then implemented. One such step was the acquisition of additional metering data from the district heating grid. These are necessary to determine the current amount of energy available in the district heating grid and enable the use of the grid for energy storage. These better insights proved to be invaluable to accurately gauge the effects of heat-based operation of the participating plants.

We have decided to implement the software-related aspects of the project with the EMS-EDM Prophet® system developed by our partner, the Fraunhofer Institute IOSB. A series of workshops was conducted to elaborate simulation models and resource planning components, providing the foundation for the development of resource planning models. We then proved the effectiveness of these models through extensive tests.

▷ CONCLUSION AND OUTLOOK // Efficient start to the energy transition

Beginning with the 2019/20 heating period, the entire system was tested in day-to-day operations. It was not only used to inform the energy procurement with dispatch planning data, but also to support dispatchers deciding on the best choice of operating principle when facing unforeseen circumstances.

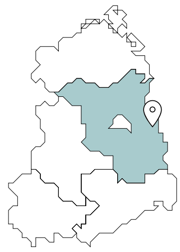
Our visitor sites – the Frankfurt (Oder) district heating power station and Heat Exchanger Station (WÜST) 8.0 – will remain open beyond the project period. Interested parties can register to visit online via the homepage of Stadtwerke Frankfurt (Oder). We will also provide further information to the public in an exhibition featuring the overall project.

During the project period, 28 participants were actively involved in developing the new software solution and integrating it into our processes.

▲ Heat distribution unit in the Frankfurt (Oder) district heating grid.

SP 2.3

FOCUS AREA
Identifying Flexibility



▸ **Title of the subproject**
Cross-Border System Integration

▸ **Funding code**
03SIN532

▸ **Subproject partner**

▷ PROJECT PARTNER
Stadtwerke Frankfurt (Oder) GmbH

▸ **Contact**
Harald Wolf
T +49 335 5533517
harald.wolf@stadtwerke-ffo.de

▸ **Visitor sites**

Heat Exchanger Station (WÜST) 8.0
Slubicer Straße
15230 Frankfurt (Oder)

Registration required

Frankfurt (Oder) District Heating Power Station
Am hohen Feld 4
15236 Frankfurt (Oder)

Registration required

▷ INQUIRIES TO
windnode@stadtwerke-ffo.de

For more information
www.stadtwerke-ffo.de

▲ René Markgraf, Managing Director of IBAR Systemtechnik GmbH, at the company headquarters.

KEMS – the Municipal Energy Management System

As the energy transition progresses, it is becoming increasingly important to maintain an energy supply that can be planned while remaining secure and economical. It is therefore crucial to integrate additional and sometimes completely new stakeholders into municipal supply structures and all grid levels, as well as to optimise existing networks. A Municipal Energy Management System (KEMS) will show how and under what conditions this can be achieved.

‘As a medium-sized company, IBAR gains unique business perspectives from participating in a cross-regional and cross-industry network like WindNODE.’

René Markgraf
Managing Director,
IBAR Systemtechnik GmbH

▷ CHALLENGES AND SOLUTIONS // **Smart energy grids**

As part of the ongoing energy transition process, utilities can and must take a much more active role in establishing future-oriented digitalisation processes, and thus in developing new business models and energy-related services, especially at the municipal level.

This WindNODE subproject focuses on the growing integration of decentralised flexibilities (i.e. generation plants, consumers and energy converters) into regional, cross-sector supply structures. A crucial part of this integration is digitally connecting the relevant infrastructure components.

The Municipal Energy Management System (KEMS) created by IBAR Systemtechnik GmbH enables municipal utilities, and municipal institutions in general, to make effective use of previously untapped resources. The power management system collects and visualises data and supply structures (e. g. for electricity, heat and gas) on a common platform. In addition, it offers a simulation environment that allows to economically analyse the potential integration of further operating resources into the system another promising use case of KEMS is the testing of new, cross-technology operating concepts and business models for energy marketing. Interfaces to integrate market and forecast data are planned for this purpose.

10 million process variables in the system

up to 2,048 servers

Scalable: from small single-user application to networked, redundant high-end system with more than ten million process variables and tags.

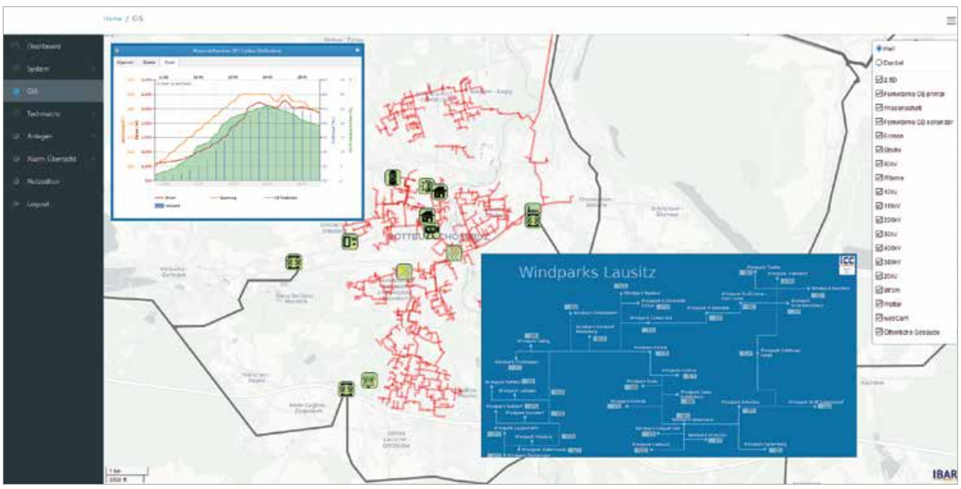
▷ RESULTS // **Everything on one dynamic map**

The process of defining objectives, functionality and target groups began with the creation of a basic structure for KEMS. From the very beginning, a key focus was the development of a geographic information system (GIS) for an informative and interactive user experience. The GIS is based on a robust development environment and database designed for critical infrastructures, and its functionality, performance and operation are continuously improved. An efficient software interface and a compatible, standardised, but flexible data model were designed to ensure the connection and representation of various grid participants and structures. This makes it possible to visualise the individual participants in a regional supply infrastructure within the GIS and to provide status information related to these participants and the grid infrastructure in real time. Throughout development, special attention was paid to data security.

In order to promote market acceptance and public interest, it was important to create a product that was not only functional, but also visually appealing and intuitive to use. As a result, the development of the user interface and detailed visualisations continue to be a high priority. In terms of functionality, KEMS was given a new dimension with the development of cross-sector grid simulation capability called the dynamic grid editor DNE. In combination with the corresponding simulation tools, the DNE makes a significant contribution to economic feasibility studies at the neighbourhood level and beyond.

▷ CONCLUSION AND OUTLOOK // **Effective management of public services**

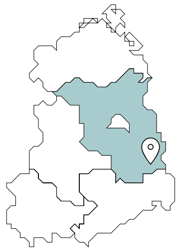
The purpose of the energy management centre is to enable the comprehensive monitoring and control of municipal supply infrastructures with a consistent approach that is based on scalability and standardised, modular expandability. The GIS provides a real, geocorrect image of the respective municipality and its associated supply infrastructure. A central data centre and special web solutions are used to transfer the necessary amounts of data. In addition to intelligent real-time management that leverages the possibilities offered by artificial intelligence (AI), KEMS should also be able to simulate entire operational management scenarios and strategy concepts in the future.



▲ The municipal energy management system in use at IBAR Systemtechnik GmbH in Cottbus.

SP 2.4

FOCUS AREA
Activating Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
The Municipal Energy Management System (KEMS) in Cottbus

▸ **Funding code**
03SIN518

▸ **Subproject partners**

▷ PROJECT PARTNERS
Brandenburg University of Technology Cottbus-Senftenberg Department of Power Plant Engineering

HKWG Heizkraftwerksgesellschaft Cottbus mbH

IBAR Systemtechnik GmbH

▸ **Contact**
IBAR Systemtechnik GmbH
René Markgraf
Ewald-Haase-Straße 18
03044 Cottbus
ibar-gmbh@ibar.de

▸ **Visitor site**
Municipal Energy Control Centre & Municipal Energy Management System (KEMS) Demonstrator
Ewald-Haase-Straße 18
03044 Cottbus

Registration required

▷ INQUIRIES TO
ibar-gmbh@ibar.de

For more information
www.ibar.de

Participating partners

- b-tu Brandenburgische Technische Universität Cottbus - Senftenberg
- e.dis
- envia THERM
- MITNETZ STROM
- Stromnetz Berlin
- TU berlin
- Universität Rostock
- VSB
- WEMAG NETZ GmbH

Efficient Operating Concepts for Power Grids

Medium- and high-voltage grids face considerable challenges due to the feed-in of large amounts of renewable energy.

To ensure efficient operation of existing power grids and reduce the need for further grid expansion, this WindNODE workstream takes a systematic look at the transmission and distribution grids and develops new technical components and processes to ensure efficient operation.

Workstream 3 was coordinated by Prof. Dr Harald Schwarz and Dr Erik Blasius (Chair of Energy Distribution and High Voltage Engineering of the Brandenburg University of Technology Cottbus-Senftenberg) on a voluntary basis until 31 December 2018. On 1 January 2019, this task was taken over by Prof. Dr Kai Strunz and Despina Koraki (Department for Sustainable Electric Networks and Sources of Energy (SENSE) of the Technical University of Berlin).

◂ The visualisation platform of the Real-Time Lab for the Energy Transition as it appears in the web app.

Real-Time Lab for the Energy Transition

The Real-Time Lab for the Energy Transition is a visitor site that gives visitors an interactive, real-time look at the current and future energy system with a high share of renewable energy. To target as many groups as possible and accommodate varying levels of knowledge, the site adopts an integrative approach that guides users through separate modules for learning, experiencing and researching.

‘Our models provide a behind-the-scenes look at the energy transition and transfer knowledge and information to the largest possible audience in a playful form. Communication of this kind is an important task, especially in today’s world, and makes it possible to successfully support progress on important topics like the energy transition.’

Despina Koraki
Research Associate and WindNODE Coordinator Workstream 3, TU Berlin

Prof. Dr Kai Strunz
Director of the SENSE Department, TU Berlin

▷ CHALLENGES AND SOLUTIONS // **Not a problem! Or is it?**

The energy transition is fundamentally changing the interactions between energy generation and consumption. On the generation side, the relatively few conventional power plants are being replaced by a large number of smaller weather-dependent resources. At the same time, consumption is diversifying, especially through the coupling of the electricity, heating and mobility sectors. In this new situation, it is the responsibility of the power grid operators to maintain the quality and security of the power supply at a high level. A prerequisite is making power generation and consumption more flexible, which can be achieved by introducing new technologies and increasing the number of active participants in the energy supply system as much as possible.

To increase the acceptance of these far-reaching changes, the technical innovations and economic incentives necessary for the sustainable energy supply of the future must be made more tangible to a broad audience. TU Berlin’s SENSE department researches topics covering modern grid operation management and sector coupling; it also conducts experiments in its own smart grid laboratory in which physical and virtual components interact in real time. In the WindNODE project, an interactive visualisation platform was developed as a web application (see illustration above) to display and demonstrate the interactions between power generation, consumption and distribution.

More than **150** students and experts from 10 different countries have already visited the Real-Time Lab for the Energy Transition.

▷ RESULTS // **Becoming an energy expert in three steps**

The Real-Time Lab for the Energy Transition includes a web-based visualisation platform that communicates and interacts directly with the laboratory hardware. The platform is used to run simulations of virtual energy systems as well as to control laboratory components, including inverters, batteries, and a power-to-heat plant. This linking of virtual and physical components enables practice-oriented research without the need to recreate a complete power grid in the laboratory. In order to monitor and control the virtual grid models, the user interface, and the laboratory components, an open-source SCADA system developed at CERN[1], called C2MON[2], was adapted to meet the special requirements of a smart grid.

The visualisation platform aims to address different user groups, from interested members of the public and students to researchers and experts in the energy sector. It is therefore divided into the three areas ‘learn’, ‘experience’ and ‘research’, which build on each other and examine relevant topics in progressively greater detail and complexity.

The ‘learn’ section teaches the technical and economic fundamentals of the energy system. For example, the ‘market phase’ shows how power is traded on the electricity exchange. In the ‘flexibility phase’, the trading results are explained in terms of their implementation in the technical aspects of grid operation.

These topics are further explored in the ‘experience’ section with the help of interactive games. Here, users can trade flexibilities – that is, increased or decreased generation or consumption of particularly flexible electricity generation or consumption systems – in the ‘market phase’ and use them for congestion management in the ‘flexibility phase’.

In the ‘research’ section, physical laboratory components become part of the simulation in order to test innovative concepts of grid operation on a laboratory scale and in real time. These innovations are based on the latest research in the field. Featured innovations include the sector coupling areas Power-to-Heat and Power-to-Mobility, as well as integrated market and grid operation management, which makes it possible to make more efficient use of flexibilities.

◂ The Real-Time Lab for the Energy Transition is presented to a group of students in a live demonstration.

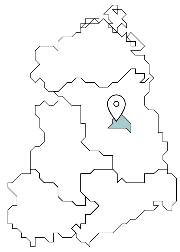
▷ CONCLUSION AND OUTLOOK // **Creating knowledge together**

The Real-Time Lab for the Energy Transition has taken the showcase character of WindNODE literally and brought it to life with the help of a visualisation platform. This platform allows user groups with different levels of knowledge to familiarise themselves with the topic – and, if they are interested, to deepen their understanding. The visualisation platform was designed to enable the continuous integration of new results from research and industry. The results of the projects OptNetzE and EchtEWende, which are supported by the German Federal Ministry for Economic Affairs and Energy, have already been integrated successfully.

[1] The European Organization for Nuclear Research.
[2] The Open Source solution to your data and process monitoring needs, https://c2mon.web.cern.ch/c2mon

SP **3.1**

FOCUS AREA
Activating Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
Real-Time Lab for the Energy Transition

▸ **Funding code**
03SIN539

▸ **Subproject partners**

▷ PROJECT PARTNER
Technische Universität Berlin, Department of Sustainable Electric Networks and Sources of Energy (SENSE)

▷ ASSOCIATED PARTNER
VSB Neue Energien Deutschland GmbH

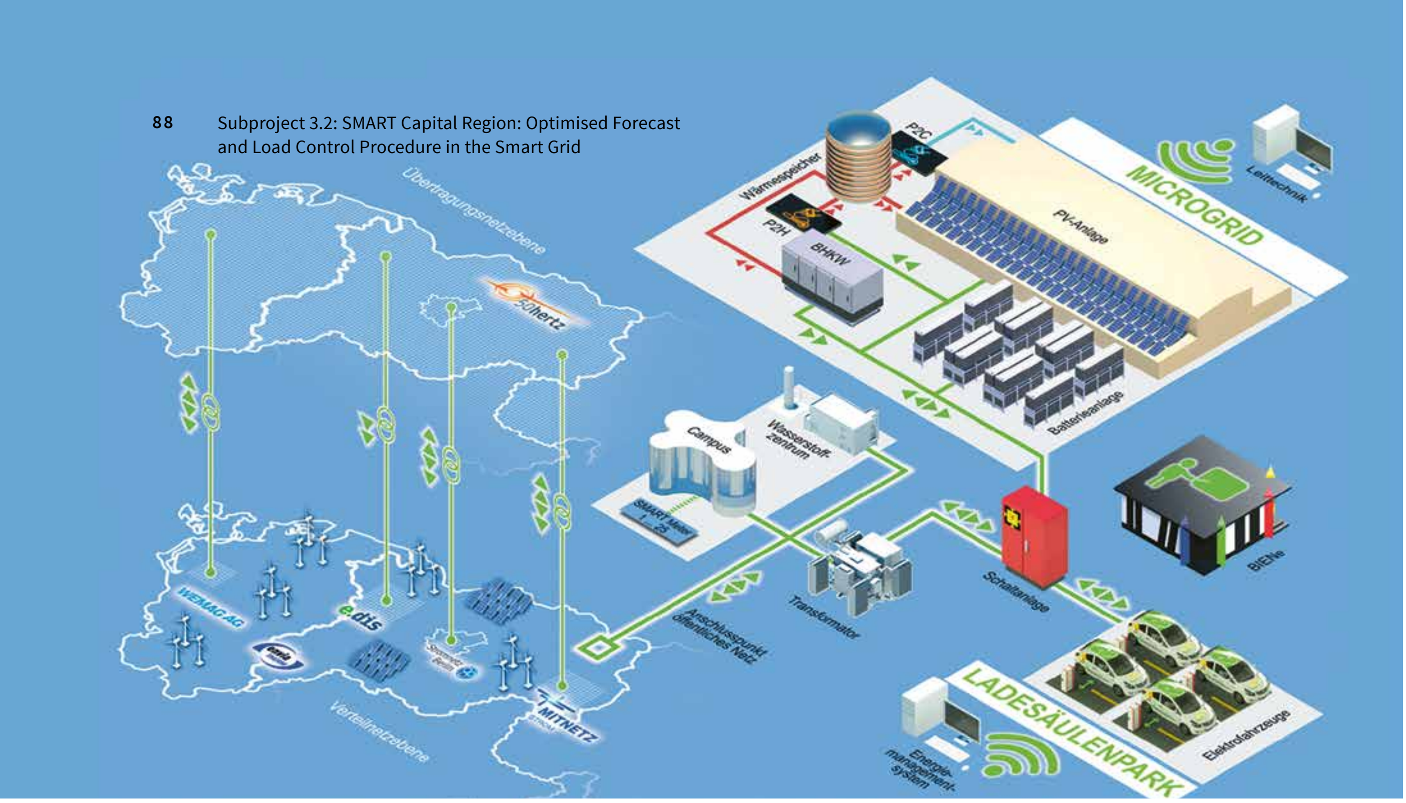
▸ **Contact**
Prof. Dr Kai Strunz

▸ **Visitor sites**
Real-Time Lab for the Energy Transition
Technische Universität Berlin
Einsteinufer 11 (EMH-1)
10587 Berlin

Registration required

▷ INQUIRIES TO
sekretariat@sense.tu-berlin.de

For more information
www.sense.tu-berlin.de



▲ The BTU smart grid consists of a photovoltaic system, a CHP plant, a battery storage unit, a charging station with electric vehicles, and a Power-to-Gas, Power-to-Heat and Power-to-Cold system

Smart Capital Region 2.0: Intelligent Energy from Northeastern Germany

SMART Capital Region 2.0 (SCR 2.0) is examining the use of controllable loads and storage systems to facilitate better local use of the renewable power surpluses that are increasingly common in northeastern Germany. The subproject demonstrates how the distribution of renewable power production and residual load in a web application functions on a supra-regional level.

‘Our smart grid is a miniature version of a possible power supply system of the future.’

Prof. Dr Harald Schwarz
Chair of Energy Distribution and High-Voltage Engineering, BTU Cottbus-Senftenberg

▷ CHALLENGES AND SOLUTIONS **// From fossil fuel to green energy**

The driving force behind our work in this WindNODE subproject is the transformation of today’s energy supply system brought on by the energy transition. This system, which was originally based on fossil fuels, is transitioning to renewable power sources. We are working at the interface of politics, business and science to develop solutions for the power supply of the future.

In some areas of the Brandenburg grid, the energy supply from renewable sources already exceeds the total electricity demand. However, this does not mean that there is a full supply on a continuous basis; there are days with extreme overproduction and days when almost no green electricity is generated at all. The management of this increasingly weather-dependent electricity supply and fluctuating demand is becoming more complex and presents new challenges for the energy supply system. We are addressing these new requirements by improving the conventional grid infrastructure of our microgrid through innovative information and communications technology. This smart grid model can be used to control a growing number of decentralised power generators, storage units and consumers.

▷ RESULTS // **Visualising the BTU load curve**

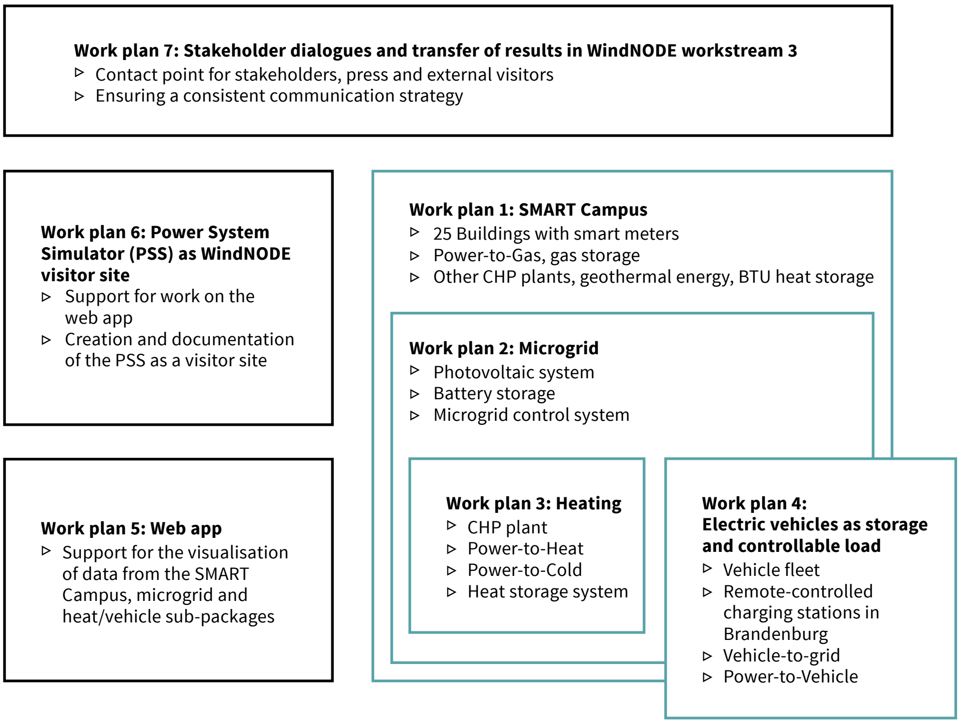
The research conducted by BTU in WindNODE subproject 3.2 was divided into seven work plans. In work plan 1, BTU examined, clustered and systematised its load curve data using an algorithm developed in-house. Next, a standard load profile (SLP) was developed and compared with the load profiles of other universities. The BTU SLP was used for a forecasting and optimisation approach that was also developed in-house. This was examined in the microgrid (work plan 2) for practical suitability and visualised in the context of the visitor site. The third work plan focused on developing operation strategies that would enable components of the heating and cooling plant network to function in a way that benefits the grid. The main consideration in this context was sector coupling. In work plan 4, researchers successfully investigated the use of electric vehicles as storage and a controllable load, which makes it possible to deploy electric vehicles for frequency stabilisation. A number of strategies were developed and investigated for this purpose. The grid operator data were successfully visualised as part of work plan 5, providing an enriched overview of the latest data within approximately 24 hours of their acquisition. The Power System Simulator (work plan 6) was set up as a visitor site for this purpose.

Over **1,800,000,000**

data sets are currently being evaluated or have been evaluated over the course of the project.

▷ CONCLUSION AND OUTLOOK // **E-mobility tested in practice**

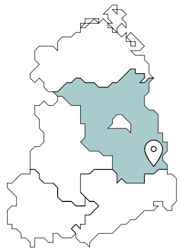
We will use the findings from WindNODE to investigate how, in the specific case of our smart grid, battery electric vehicles can be charged in a way that benefits the grid without restricting mobility services for end customers. Next, we will develop software that allows users to plan their individual preferences and journeys. Finally, these effects will be analysed in the microgrid and scaled to the real grids.



▲ This schematic overview shows how the individual work plans are connected with each other within the project. The focus is on work plans 1 – 4.

SP 3.2

FOCUS AREA
Digitalising the Energy System



▸ **Title of the subproject**
SMART Capital Region: Optimised Forecast and Load Control Procedure in the Smart Grid

▸ **Funding code**
03SIN507

▸ **Subproject partners**

▷ PROJECT PARTNERS
Brandenburg University of Technology Cottbus-Senftenberg

Stromnetz Berlin GmbH

WEMAG Netz GmbH

▷ ASSOCIATED PARTNERS
E.DIS AG

envia THERM GmbH

Mitteldeutsche Netzgesellschaft Strom mbH

▸ **Contact**
BTU Cottbus-Senftenberg
Dipl.-Ing. Bastian Garnitz
T +49 355 695578
bastian.garnitz@b-tu.de

▸ **Visitor sites**

Visitor Centre Smart Energy Grids (BIENe)
Konrad-Wachsmann-Allee
03046 Cottbus

Registration required

Power System Simulator (PSS)
Siemens-Halske-Ring 13
03046 Cottbus

Registration required

▷ INQUIRIES TO
marika.scholz@b-tu.de

For more information
www.smartcapitalregion.de

▲ View of the WEMAG Netz GmbH grid control centre, where the Intelligent Reactive Power Management System (IRPMS) is deployed.

Voltage Control with Distributed Energy Resources – A Tool for the Distribution Grid

The displacement of large power plants from the energy system and the grid expansion required for this purpose are increasingly causing changes in ancillary service provision. The reactive power demand of the grids required to ensure voltage stability has previously been met primarily by large power plants and compensation facilities in the transmission grid, but in the future this task will increasingly be performed in a decentralised manner in the lower-voltage distribution grids.
In the approach developed by distribution grid operator WEMAG Netz GmbH, the targeted use of distributed energy resources (DER) in the distribution grid allows voltage and reactive power to be controlled in accordance with the requirements of the distribution and transmission grid.

150 MW

of feed-in capacity could be used to raise or lower the voltage at the extra-high voltage junction by 7.9 kV or 5.7 kV, respectively.

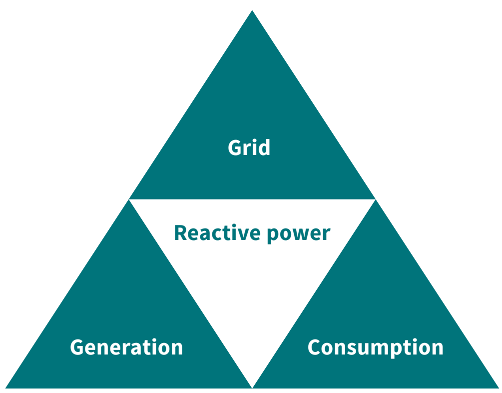
▷ CHALLENGES AND SOLUTIONS // **Decentralisation of power generation requires more system services from the distribution grid**

Renewable energy sources have priority in the distribution grids, so bringing more of them online requires not only an expansion of transmission capacity, but also adjustments to the operation strategies in the distribution and transmission grids. At the same time, the decentralisation of the power generation structure also has a direct effect on the need for, and provision of, ancillary services. The displacement of conventional power generation and the increase in line lengths at all grid levels result in higher requirements for voltage control.

An essential factor in voltage control is the provision of reactive power from generating units and grid operating equipment. The large-scale fluctuations in the provision of power and the associated rapid changes in grid conditions also require more flexibility in reactive power compensation.

To ensure a more flexible provision of reactive power from the distribution grid, it is necessary to create both open- and closed-loop control options for wind and solar power systems. In its contribution to the WindNODE project, WEMAG aims to implement such control options directly in the grid control system. This allows for a quick reaction to current requirements in the distribution and transmission grids, including demand for reactive power at particular grid junctions. In addition, the system is desigend to stabilise target voltages via fully automated reactive power dispatch. This creates advantages not only in terms of voltage quality, energy losses and grid utilisation, but also for end consumers and generating units. While the optimal use of grid infrastructure lowers grid fees, the provision of reactive power dependent on the status of the grid can lead to a reduction in losses in the generating units. The aim is to make reactive power more

▼ The target triangle of the project:
dynamic reactive power in the distribution grid.



Grid operation
- ▷ Maximising integration capacity
- ▷ Minimising grid losses
- ▷ Fulfilling the requirements of lower-level grids
- ▶ **Optimising voltage quality and grid utilisation**

Generation plants
- ▷ Maximising active power feed-in
- ▷ Minimising system losses
- ▶ **Optimising the profitability of generating units**

Grid users
- ▷ Minimising grid fees for end consumers
- ▷ Maximising the utilisation of resources
- ▶ **Optimising costs of the supply grid**

> ‘The phase-out of nuclear energy and coal-fired electricity means that new concepts for ancillary services are becoming more and more important. The decentralised generating capacity connected to the distribution grid can make a major contribution to the safe operation of the overall system.’

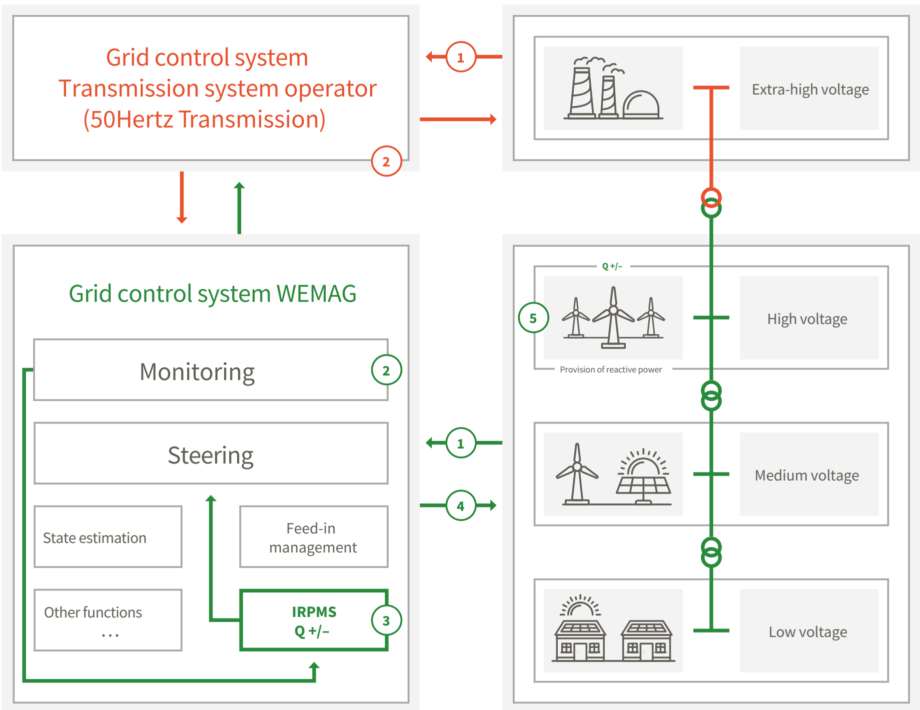
Tim Stieger
WindNODE Project Manager,
WEMAG Netz GmbH

flexible in order to influence all relevant target variables and to achieve a common optimum. For this reason, the project works directly with several plant operators in high-, medium- and low-voltage grid applications as well as with the control system manufacturer.

▷ RESULTS // Active control of reactive power via the control system

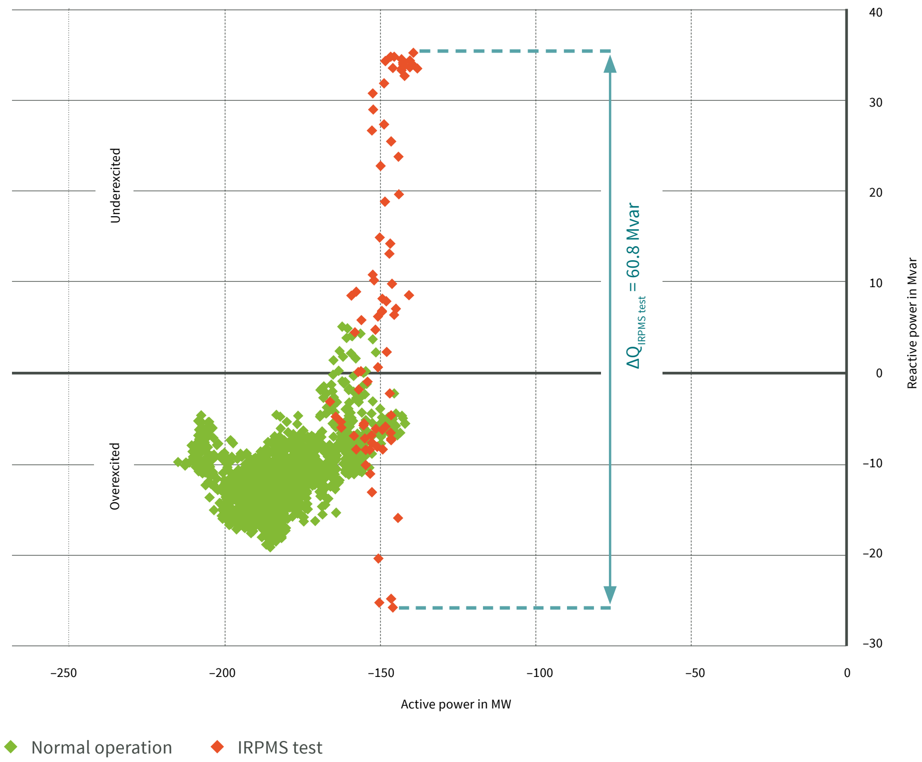
WEMAG Netz GmbH is working on the automation of reactive power provision and the optimisation of connection criteria for DER in the distribution grid. An essential part of the project is the functional expansion of the grid control system with an Intelligent Reactive Power Management System (IRPMS). The various functions of the IRPMS include integration of generators via telecontrol, calculation of reactive power potential at every node, transmission of direct reactive power control commands (specified target values) in response to requests from the distribution or transmission grid, and visualisation of the current controllable capacity. The available adjustment potential in the grid can be controlled at the plant level as well as with regard to its effect on a given connection to the transmission grid.

▼ Process flow in the Intelligent Reactive Power Management System (IRPMS) within the WEMAG grid control system.



1. Monitoring of grid operation
2. Determination of requirements for reactive power control from the distribution and transmission grids
3. Continuous calculation of reactive power adjustment potential for each power plan
4. Transmission of control commands to generation systems in the high-voltage grid
5. Provision of reactive power in the high-voltage grid through individual plants

▼ IRPMS field test: representation of the values measured by the extra-high-voltage/high-voltage converter in a PQ diagram



◀ The diagram shows the dependent variables of active and reactive power in an extra-high-voltage/high-voltage converter in one-minute intervals. Green dots were recorded during normal operation in the grid with standard Q characteristic curve specifications. Over a period of one hour, the generation plants involved in the IRPMS were given underexcited and overexcited target values for reactive power (red dots). With an active power feed-in of around 150 MW at that particular moment, the system was able to provide a reactive power difference of around 61 Mvar.

For generating units to participate in the IRPMS's reactive power control, the individual connection users need to prequalify. The pool of units is currently being expanded through intensive tests of potential candidates. By the end of the project, all generating units in the WEMAG Netz high-voltage grid will be included in the system, making the most of the adjustment potential in the distribution grid.

Several field tests provided a striking demonstration of the power factor adjustment capacity. The diagram shows the results of one such trial using selected operating points at the 380/110 kV grid junction. Changing the power factor by around 61 Mvar led to a considerable change in the operating voltage in the high-voltage grid of up to 7.9 % and in the extra-high-voltage grid of some 5 %.

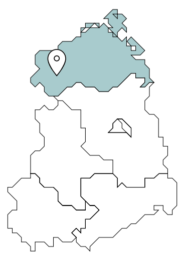
▷ CONCLUSION AND OUTLOOK **// The system works – scaling and deployment are next**

In its next phases, the project will build on the already implemented functions of the IRPMS to increase the adjustment potential of the system by prequalifying additional generation plants and optimising the methods of the IRPMS. The overall goal is to increase the system's degree of automation. Until the end of the project, regular field tests will complement the knowledge gained so far, and the integration of the system into day-to-day operations will be tackled.

Integration into the live systems requires an especially close cooperation with the transmission system operator 50Hertz. At the same time, the reactive power behaviour of generation plants in standard operation (without a target value set by the IRPMS) needs to be further investigated, in order to optimise plant operations at all grid levels - creating advantages for the grid and its customers alike.

SP **3.3b**

FOCUS AREA
Identifying Flexibility
Activating Flexibility



▸ Title of the subproject
Components for Optimised Network Operation ... Dynamic Reactive Power, 110-kV Voltage Level

▸ Funding code
03SIN544

▸ Subproject partner

▷ PROJECT PARTNER
WEMAG Netz GmbH

▸ Contact
WEMAG Netz GmbH
Obotritenring 40
19053 Schwerin

Philipp Kertscher
philipp.kertscher@wemag-netz.de

▸ Visitor site
Lankow Battery Storage
Neumühler Weg 8
19057 Schwerin

Registration required

▷ INQUIRIES TO
kontakt@wemag-netz.de

For more information
www.wemag-netz.de

▲ Laying of E.DIS Netz GmbH's 110-kV Oderland cable

New Possibilities in Planning Power Lines for Renewable Electricity

Working as a WindNODE partner, Technische Universität Berlin has developed Cable Earth, a new method to calculate the heating of underground power lines. This opens up new possibilities for planning such lines. Within the scope of WindNODE, the method was used and tested on a 110-kV underground power line belonging to E.DIS Netz GmbH. The 36 km long line was equipped with fibre optic technology. Cable temperature measurements, which are high resolution in terms of both time and space, were used to calibrate and validate the Cable Earth method.

'The energy transition creates new technical and economic challenges for cable grids. We must therefore find new possibilities in the planning, laying and operation of power lines.'

Prof. Dr Gerd Wessolek
WindNODE Project Manager,
TU Berlin

▷ CHALLENGES AND SOLUTIONS // **Intelligent calculation of the current-carrying capacity of underground cables**

To calculate the heating of underground cables and thus determine the maximum current-carrying capacity of an underground power line, scientists at TU Berlin developed the Cable Earth method. The calculation models that had previously been used in the energy industry only allowed reliable observations to be made for quasi-stationary power loads. The new method is based on a numerical simulation model that can model even volatile power flows realistically. It also takes into account relevant effects of soil, climate, and land use.

This WindNODE subproject proved the reliability of the new method, laying the groundwork for the acceptance of new calculation methods in energy industry practice.

Because the location- and climate-related conditions affecting an underground power line are highly variable in reality, the method was first tested on a 110-kV example line for feeding wind energy into the transmission grid.

130 km 110 kV

E.DIS in Brandenburg planned and built 130 km of power lines for feeding renewable power into the transmission grid with the support of the Cable Earth method.

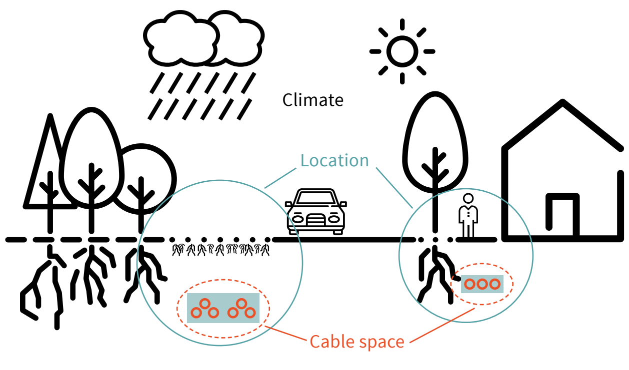
The 36 km long line was equipped with fibre optic technology, which allowed cable temperature to be measured in high resolution with respect to time and space. In conjunction with extensive information on the technical execution and on the geological, hydrological and usage-specific site conditions along the line, these observations made it possible to calibrate and validate the Cable Earth method.

In addition, the Cable Earth method was used in sensitivity studies to identify optimisation potential for the laying and operation of underground power lines and to detect the environmental effects of the lines.

▷ RESULTS // **Relevant innovations**

A particular challenge for the chosen approach is the enormous amount of data generated by the monitoring system. Special software was developed to process the data for calibration. A problem that affected the test phase was the fact that, during the project period, only some of the planned wind turbines were connected to the power line, which meant that the method could only be calibrated at low cable temperatures. Additional laboratory measurements were therefore carried out with special soil containers.

Project results show that the Cable Earth method can be used to map all processes relevant to the heat balance of an underground power line and to calculate cable temperature, even with a highly volatile power load. Analysing the environmental effects of the underground power lines showed that the Cable Earth method is very well suited to map the warming of the topsoil. However, the effects caused by underground power lines with volatile power loads are small. Use of the cable increases soil temperature in the primary space occupied by plant roots on the underground power line by two to three kelvins. Two to three metres away from the cable, the temperature increase is only very slight (1 – 1.5 K) and at even greater distance a change is hardly detectable. In other words, the underground power line is like a heat band in the landscape.



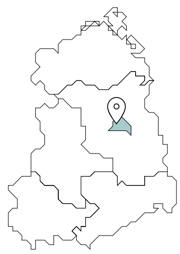
◂ Principle of the Cable Earth method: numerous influencing factors are taken into account to calculate cable heating

▷ CONCLUSION AND OUTLOOK // **Practical application**

Based on the knowledge gained in WindNODE, the Cable Earth method was prepared for application in the planning and laying of underground power lines. Cooperation with project partners significantly accelerated acceptance, and the procedure is now being used in several power line laying projects in the context of the energy transition.

SP 3.3c

FOCUS AREA
Digitalising the Energy System



▸ **Title of the subproject**
Components for Optimised Grid Operations … Cable Earth for 110-kV Underground Power Lines

▸ **Funding code**
03SIN538

▸ **Subproject partners**

▷ PROJECT PARTNER
Technische Universität Berlin, Department of Site Science/ Soil Protection Ecology

▷ ASSOCIATED PARTNER
E.DIS AG

▸ **Contact**
Technische Universität Berlin
Prof. Dr Gerd Wessolek
Gerd.Wessolek@tu-berlin.de

Project collaborator
Dr Steffen Trinks
steffen.trinks@tu-berlin.de

For more information
www.boden.tu-berlin.de

‘Must-run Units’ in WindNODE

In the future, the share of renewable energy in the electricity mix will increase. However, renewable energy plants are not yet able to provide all system services required for secure grid operation. It is thus still necessary for conventional power plants to supply enough energy to maintain a minimum load on the grid at all times (‘must-run units’). The University of Rostock is researching how to keep these minimum requirements as low as possible.

‘WindNODE enables us to examine the complete transformation of the electrical energy supply using an existing energy supply grid. This makes it possible to illustrate advantages (CO_2) as well as disadvantages (security of supply).’

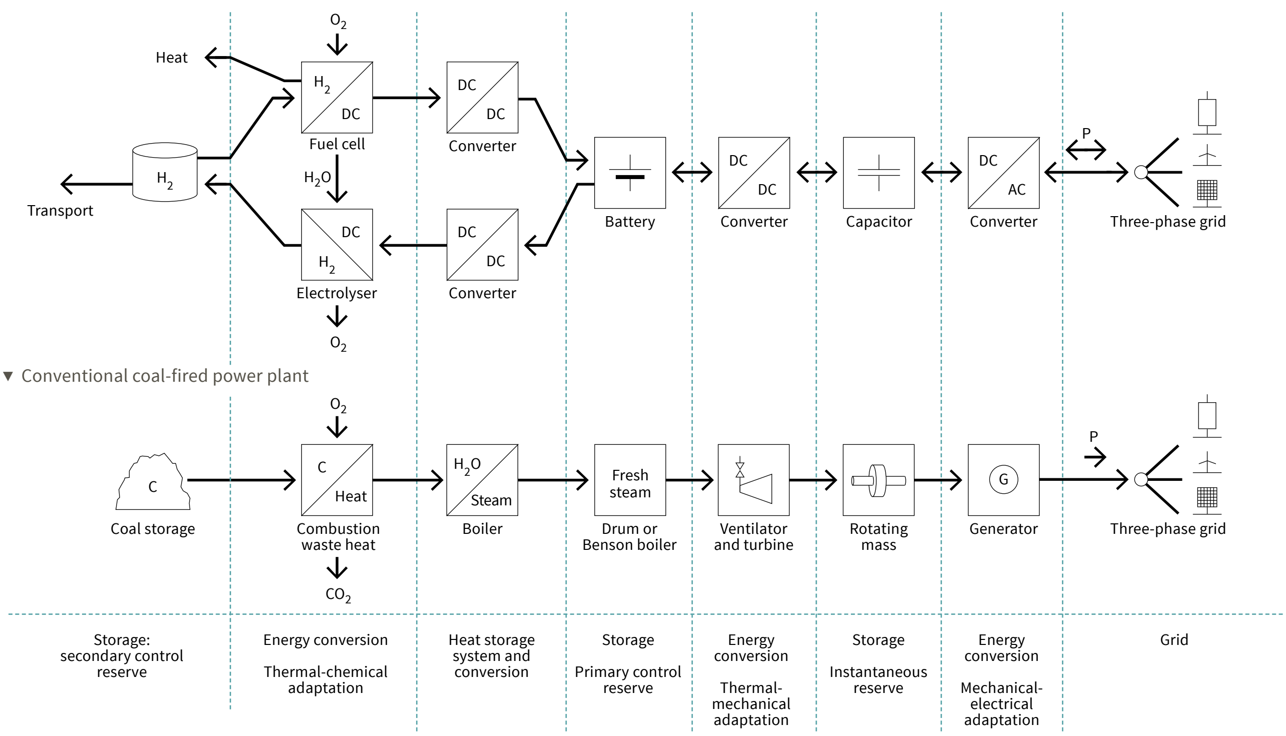
Prof. Dr Harald Weber
Chair of Electrical Energy Supply,
University of Rostock

▷ CHALLENGES AND SOLUTIONS // **Electricity supply without thermal power plants**

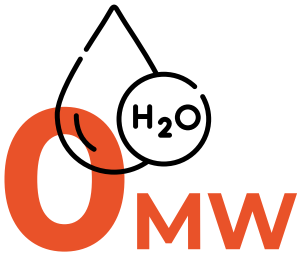
The investigations examine a core topic of the energy transition: how can secure and stable grid operation be ensured even with an increasing share of renewable energy in the grid? Maintaining secure and stable operations requires a balance between generated and consumed power at all times. The voltage must also meet the requirements of the grid operators at every point in the grid. This cannot currently be achieved by renewable energy alone: it is dependent on the supply of primary energy (e.g. from the wind and sun), which cannot be influenced. As a result, conventional power plants must remain connected to the grid in order to supply a minimum generation capacity – even during periods in which sufficient feed-in from renewable energy is available. This is due to the start-up and shutdown times of conventional power plants and to the limited ability of renewable energy to supply balancing power that could compensate for deviations from the load forecast. For environmental reasons, however, the use of conventional power plants should be reduced or avoided entirely in the future. This was the motivation for investigating whether renewable energy and storage technologies can emulate the grid-forming function of conventional power plants.

▼ New hydrogen storage power plant

▼ Schematic diagram of a hydrogen storage power plant. The energy storage systems of a conventional power plant are replaced by electrical and electrochemical storage systems.



▲ A simulation was used to model the transmission grid of the WindNODE region and the surrounding European interconnected grid.



Hydrogen storage power plants make it possible to reduce conventional must-run capacity to 0 MW.

▷ RESULTS // **From coal to hydrogen**

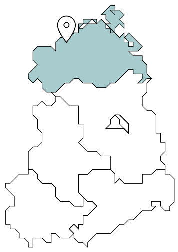
In order to operate a grid without conventional power plants, it is first necessary to understand what functions they perform for grid control and why they have been indispensable thus far. One advantage of conventional power plants is their ability to run according to a predefined schedule and compensate for load changes or generation failures without delay and over any length of time. In the future, other players in the grid will need to take over this function. Hydrogen storage power plants were selected to fill this role. These consist of a battery and capacitor in addition to a hydrogen storage unit. In combination with a special inverter control system, these components make it possible to emulate the grid-forming function of conventional power plants. In this subproject, researchers used simulations to investigate whether and how hydrogen storage power plants could be used to reduce the must-run capacities of conventional plants. An electromechanical model was created to simulate a hydrogen storage power plant embedded into the European interconnected grid at the transmission level; this simulation was used to examine various scenarios in the grid. The analysis focused on the grid of the so-called 'new' federal states, i. e. the states re-established after Germany's reunification. The results of the study provide evidence that secure and stable grid operation is possible even without conventional power plants – provided that hydrogen storage power plants are built in sufficient quantities.

▷ CONCLUSION AND OUTLOOK // **On the way to 100 % green electricity**

Based on individual load cases, previous investigations have shown that, in principle, secure and stable operation of the grid serving the WindNODE showcase region is possible using only wind turbines and hydrogen storage power plants. This raises a new question: is it also possible to provide an electricity supply based entirely on renewable energy? Further research should investigate this possibility, particularly with regard to the expansion of renewable energy and the dimensioning of storage elements that would be necessary to realise this goal.

SP 3.3d

FOCUS AREA
Identifying Flexibility



▸ **Title of the subprojects**
Components for Optimised Grid Operations … Must-Run Capacities in WindNODE

▸ **Funding code**
03SIN541

▸ **Subproject partner**

▷ PROJECT PARTNER
University of Rostock

▸ **Contact**
University of Rostock
Prof. Dr Harald Weber
T +49 0381 4987101
harald.weber@uni-rostock.de

For more information
www.iee.uni-rostock.de

Monitoring the Low-voltage Level Using Online Data Collection

Distribution system operators see both challenges and potential in the greater digitalisation of low-voltage systems. Today, it is relatively easy to determine the requirements posed on low-voltage grids with statistical methods and, for example, standard load profiles. This will change as new loads are added (e. g. from electro-mobility), customers modify their behaviour in response to load-based pricing or consumers demand becomes more synchronised: more consumers may use electricity at the same time because green electricity is available at a much lower price or because everyone plugs in their electric vehicle after work. In short, the load curves of the future will be significantly different from those observed today.

Modern online measuring technology is already helping to visualise consumption at the 400-volt low-voltage level and to transfer data to the grid control centre and in-house IT systems of system operators. This makes it possible to adapt grid planning and operational management sustainably and efficiently.

'The secure and reliable provision of information about the state in local grids is already an essential building block for future low-voltage grid management.'

Thomas Röstel
Head of Asset Strategy,
Stromnetz Berlin GmbH

▷ CHALLENGES AND SOLUTIONS **// Low voltage – safely increasing flexibility requires better monitoring**

Methods for monitoring low-voltage grids have thus far been rudimentary. Stromnetz Berlin is currently deploying communication and measuring technology in its grid substations to improve status monitoring in the urban low-voltage grid. The goal is to optimise grid expansion and grid management. The increasingly dynamic environment requires more accurate and up-to-date state information from the grid. Such information is also essential for future operational management in the low-voltage grid. This is important, for example, in order to efficiently integrate electromobility into the Berlin power grid. In addition, monitoring the low-voltage grid is crucial when providing flexibility services from components connected to this voltage level.

Approximately

1,150

of Stromnetz Berlin's distribution transformer substations are now equipped with permanently installed measuring devices.

2,460 measurements

Seventy mobile measuring kits are deployed and have been used to carry out 2,460 readings at distribution transformer substations which do not yet have permanently installed measuring devices.

▷ RESULTS // **Data from roughly 3,600 distribution transformer substations**

Innovative measuring technology has been systematically installed in the grid substations of the Berlin power grid. In February 2020, the Stromnetz Berlin measurement database contained data from approximately 3,600 distribution transformer substations. This means that roughly 45 % of the total data collected during operational monitoring are available in the form of load profile measurements. In 1,148 transformer substations, measuring instruments were permanently installed and now record the annual load profile. In addition, the weekly load profile of around 2,460 transformer substations is recorded with the help of a mobile measuring kit that was developed on the basis of existing technology.

Using the new measuring technology has enabled Stromnetz Berlin to collect much more detailed information on load conditions. All recorded time series are centrally available to grid planners in a ‘grid information system’. This means that new insights into the ongoing changes and increasing volatility of grid usage can be taken into account when planning the grid of the future.

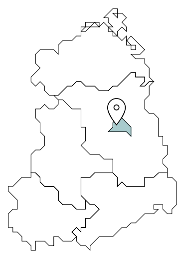
▷ CONCLUSION AND OUTLOOK // **A building block for low-voltage grid management in Berlin**

In the next step, Stromnetz Berlin will investigate whether the measuring devices can also be used for fault detection as part of future low-voltage grid management. Suitable criteria for fault detection were derived from an analysis of current patterns. Once the device software has been adapted, these entirely new functions can be tested to determine whether faults can be localised and repaired more quickly and efficiently. Finally, an increasing number of distribution transformer substations are scheduled to transmit measurements digitally to the Advanced Distribution Management System (ADMS).

▼ Mobile measuring kit: quick readings of load situations require mobile measuring devices, which provide the same range of functionality as permanently installed devices.

SP 3.3e

FOCUS AREA
Digitalising the Energy System



▶ **Title of the subproject**
Components for Optimised Grid Operations … Online Measuring Technology for Distribution Transformer Substations

▶ **Funding code**
03SIN530

▶ **Subproject partner**

▷ PROJECT PARTNER
Stromnetz Berlin GmbH

▶ **Contact**
Thomas Röstel
thomas.roestel@stromnetz-berlin.de

For more information
www.stromnetz.berlin/fur-berlin/energiewende/energiewende-erleben

Participating partners

BLS ENERGIEPLAN

BOSCH

devolo

e2m

EUREF Consulting

Fraunhofer IEE

Fraunhofer FOKUS

SCHWARZ
LIDL
Kaufland

SOLANDEO

Stromnetz Berlin

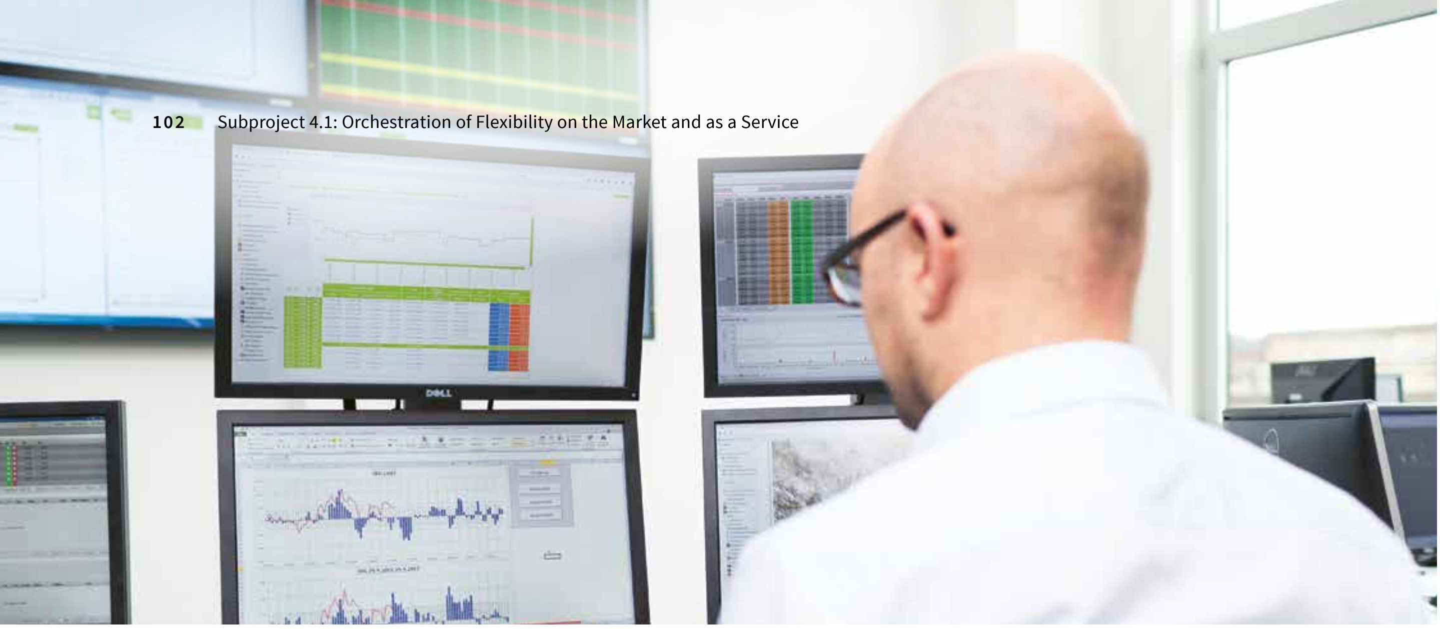
VHP READY
Virtual Heat & Power

Connected End Customer

Connecting controllable loads from households and businesses offers a wide range of opportunities. Numerous new services and business models are emerging around the supply-oriented utilisation of energy fed in from volatile sources.

This WindNODE workstream creates the technical basis for this process and organises the necessary data flows. In addition to giving every end customer an economic advantage, this also opens up further potential for efficiency in the entire energy system.

Workstream 4 was coordinated by Dr Sandra Maeding (Stromnetz Berlin GmbH) on a voluntary basis until the spring of 2020, when Lisa Hankel (Stromnetz Berlin) took over.



Flexibility, Securely Connected and Marketed

In this WindNODE subproject, the partners Energy2market GmbH (e2m) and Fraunhofer FOKUS are collaborating with the Industry Alliance VHPready e. V. as associated partner in order to promote the standardised and market-driven use of decentralised flexibility. Within the scope of the project, the partners therefore paid special attention to the investigation and further development of technical control and connection standards as well as the integration of prosumer flexibility into the electricity market.

‘A standardised platform economy in the form of virtual power plants will be the answer to the challenges of tomorrow’s small-scale and decentralised energy paradigm. The technical and regulatory requirements linked to secure grid operation and the need for low-cost and effective market access for individual players can only be met through aggregation.’

Kurt Kretschmer
WindNODE Project Manager,
Energy2market GmbH

▷ CHALLENGES AND SOLUTIONS // **Prosumer flexibility creates optimisation potential for energy procurement**

The aim of Fraunhofer FOKUS was to facilitate the exchange of flexibility data, specifically to develop models for energy flexibility in decentralised electrical systems in such a way that they would accurately depict these systems while providing maximum freedom in the use of flexibility. The primary challenge was to design standardised models for flexibility so that the models of individual systems could be aggregated easily. If flexibility is marketed, these systems can then be controlled as one group – as if part of a single large (virtual) plant – to provide services such as grid congestion management. Compared to existing techniques, the selected modelling approach offers a major advantage: it accounts for the effects of utilised flexibility potential on future potential – for instance, if discharging a battery increases its charging capacity but reduces its discharging capacity.

E2m focused on identifying flexibility in and outside the project environment as well as facilitating its technical and market integration. The challenge was to make flexibility from so-called ‘prosumers’ – which had not yet been used in a market-based manner – accessible to the electricity markets, thus promoting sector coupling. Solutions to connect with these systems as well as ideas to market them needed to be developed for this purpose.

The focus of our previous optimisation approaches also had to be reconsidered. This is because to many prosumers, the objective of optimisation is not necessarily to achieve the highest possible electricity market revenues; instead, their priority is reducing the overall energy procurement costs at a given site.

Solutions for the connection of very small systems to virtual power plants in the form of sub-aggregations were also designed and tested in practice.

Another research focus for e2m was the use of the acquired knowledge to help refine the regulatory framework. For this purpose, know-how was shared with relevant stakeholders while important regulatory standardisation projects – such as the implementation of redispatch from decentralised plants and remote control in combination with smart meter gateways – were closely monitored. These are based on a regulatory recognition of decentralised prosumers as an integral part of the new energy paradigm. The technical possibilities provided by a virtual power plant can help connect these small-scale providers to the grid and the market, so long as the technical and regulatory requirements do not create insurmountable barriers to market access.

▷ RESULTS // New players are entering the market

In addition to creating a conceptual classification of different approaches to the exchange of information on, and the use of, flexibilities, Fraunhofer FOKUS collaborated with partners from Industry Alliance VHPready e. V. to develop use cases, define the requirements for an ICT extension of the VHPready standard, and document these in a specification sheet. This specification provided the basis for an ICT extension proposal for the use of flexibility in decentralised systems, which was developed and coordinated with the partners from Industry Alliance VHPready e. V. The main results are a data model based on 'flexibility corridors' and a protocol for data exchange which was implemented as a prototype for demonstration purposes.

Within the framework of the project, e2m identified and analysed a wide range of flexibility potentials. It then worked with project partners to connect selected plants and sites to the virtual power plant, for example in the modern residential quarter of Prenzlauer Berg (see p. 160). In the case of the BMW battery storage facility in Leipzig (see p. 118), a market-ready application was created and the facility now actively participates in the primary balancing power market of the German transmission system operators via e2m. In cooperation with BMW, the fan technology at the Leipzig site was also integrated into the e2m virtual power plant, and thus the electricity markets, as one of the first sub-aggregation solutions. This makes it possible to combine many micro units into a virtual plant, enabling more efficient connection standards and marketing approaches that are easier to plan. The experience gained is incorporated into the project work and thus benefits other project partners.

More than

5,000

decentralised plants have been successfully integrated into e2m's virtual power plant. All technology groups are represented, from biogas to emergency power supplies and Power-to-Heat plants.

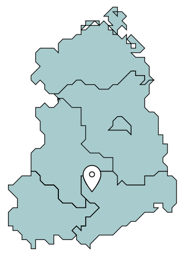
▷ CONCLUSION AND OUTLOOK // Market opportunities depend on technical scaling and the removal of regulatory hurdles

An adequate data model for flexibility in connection with a communication protocol is a prerequisite for the standardised, digitally supported use of decentralised flexibility. Utilising this potential will require certain technical preconditions as well as enough room to experiment, new business models and economic incentives.

In addition to providing evidence of technical feasibility, e2m's project approaches have, above all, increased awareness of the need for standardised connectivity solutions and simplified requirements to participate in the market. It has been shown that the connection costs, which are still quite high compared to expected returns, are a major obstacle to the integration of small-scale flexibility. Lawmakers have made considerable progress in terms of standardisation over the project period. At the same time, the newly organised Redispatch 2.0 in the NABEG act, a German law designated to accelerate the grid expansion, has chosen a state-controlled concept that makes liberal market approaches, such as a local flexibility market, unnecessary. This eliminates a potential source of revenue and thus restricts the integration of decentralised flexibility providers into the electricity market.

SP 4.1

FOCUS AREA
Activating Flexibility
Digitalising the Energy System



▸ Title of the subproject
Orchestration of Flexibility on the Market and as a Service

▸ Funding code
03SIN514 / 03SIN517

▸ Subproject partners

▷ PROJECT PARTNERS
Energy2market GmbH

Fraunhofer Institute for Open Communication Systems FOKUS

▷ ASSOCIATED PARTNER
VHPready Services GmbH

▸ Contact
Energy2market GmbH (e2m)
Kurt Kretschmer
kurt.kretschmer@e2m.energy

▸ Visitor site
Trading Room and Virtual Power Station Control Centre
Energy2market GmbH
Weißenfelser Straße 84
04229 Leipzig

Registration required

▷ INQUIRIES TO
kundencenter@e2m.energy

For more information
www.e2m.energy

▲ Battery storage in front of the Lidl showcase store in Berlin.

Innovative Ideas to Increase Flexible Energy Use in Retail

In collaboration with Lidl, Kaufland and MEG, GreenCycle, a subsidiary of the Schwarz Group, worked on the smart interconnection of technical systems in order to react to volatile feed-in from renewables. Increasing their flexibility shifts electricity consumption and makes it possible to store electricity when there is a large supply of renewable energy. The gist: use electricity from renewables and reduce their curtailment.

‘WindNODE offers an excellent opportunity to play an active role in the energy transition. Thanks to the Schwarz Group’s many branches and logistics centres, it will be possible to scale up flexibility potential quickly in the future and use it to stabilise electricity grids.’

Thomas Tappertzhofen
Managing Director,
GreenCycle Umweltmanagement GmbH

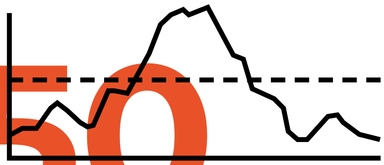
▷ CHALLENGES AND SOLUTIONS **// Making the most of available flexibility**

The intermittent production of solar and wind energy makes it more difficult to balance supply and demand in the power grid. If electricity production is higher than necessary, consumption cannot be flexibly adjusted to take advantage of the excess supply. As a result, grid operators must increasingly curtail generation from power plants to avoid overloading the grid.

How can the Schwarz Group use this excess electricity? What load shifting potentials are tapped? What is a standardised method to assess flexible loads and the requirements with regard to their control? Answering these questions will help identify new flexibility in the retail sector and develop innovative concepts to utilise its potential.

In Berlin, two branches of the retail brands Lidl and Kaufland have been designated as showcase stores. At these locations, 3D models, posters and displays supply information on WindNODE and the Schwarz Group’s contributions to the project. The Lidl showcase also includes an energy storage system that provides a practical demonstration of flexibility. This allows customers to experience the energy transition in real life.

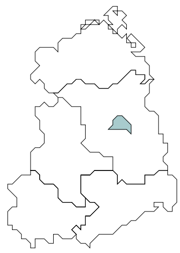
More than **1,250**



load peaks could be shaved with the help of the energy storage system at the Lidl showcase store in Berlin in 2019.

SP 4.2

FOCUS AREA
Identifying Flexibility



▸ Title of the subproject
Controlling and Marketing Flexibility in a Company Group with Retail and Production

▸ Funding code
03SIN527

▸ Subproject partners

▹ PROJECT PARTNER
GreenCycle Umweltmanagement GmbH (Lidl, Kaufland, MEG)

▹ SUBCONTRACTORS
BLS Energieplan GmbH

EUREF-Consulting Gesellschaft von Architekten und Ingenieuren mbH

▸ Contact
GreenCycle Umweltmanagement GmbH
Stiftsbergstraße 1
74172 Neckarsulm

Christina Over
christina.over@greencycle.de oder
energie@greencycle.de

▸ Visitor sites

Lidl Showcase Store & Battery Storage System
Hauptstraße 122
10827 Berlin

Kaufland Showcase Store
Karl-Liebknecht-Straße 7 – 13
10178 Berlin

For more information
www.greencycle.de

▹ RESULTS // Load shifting as an effective tool

A baseline study has shown that cooling systems, batteries and charging infrastructure for electric vehicles have the greatest potential to increase flexibility. Theoretically, the cooling systems of all stores in the WindNODE project area could provide a switchable load of approximately 50 MW by temporarily cooling food to lower temperatures in order to store cold.

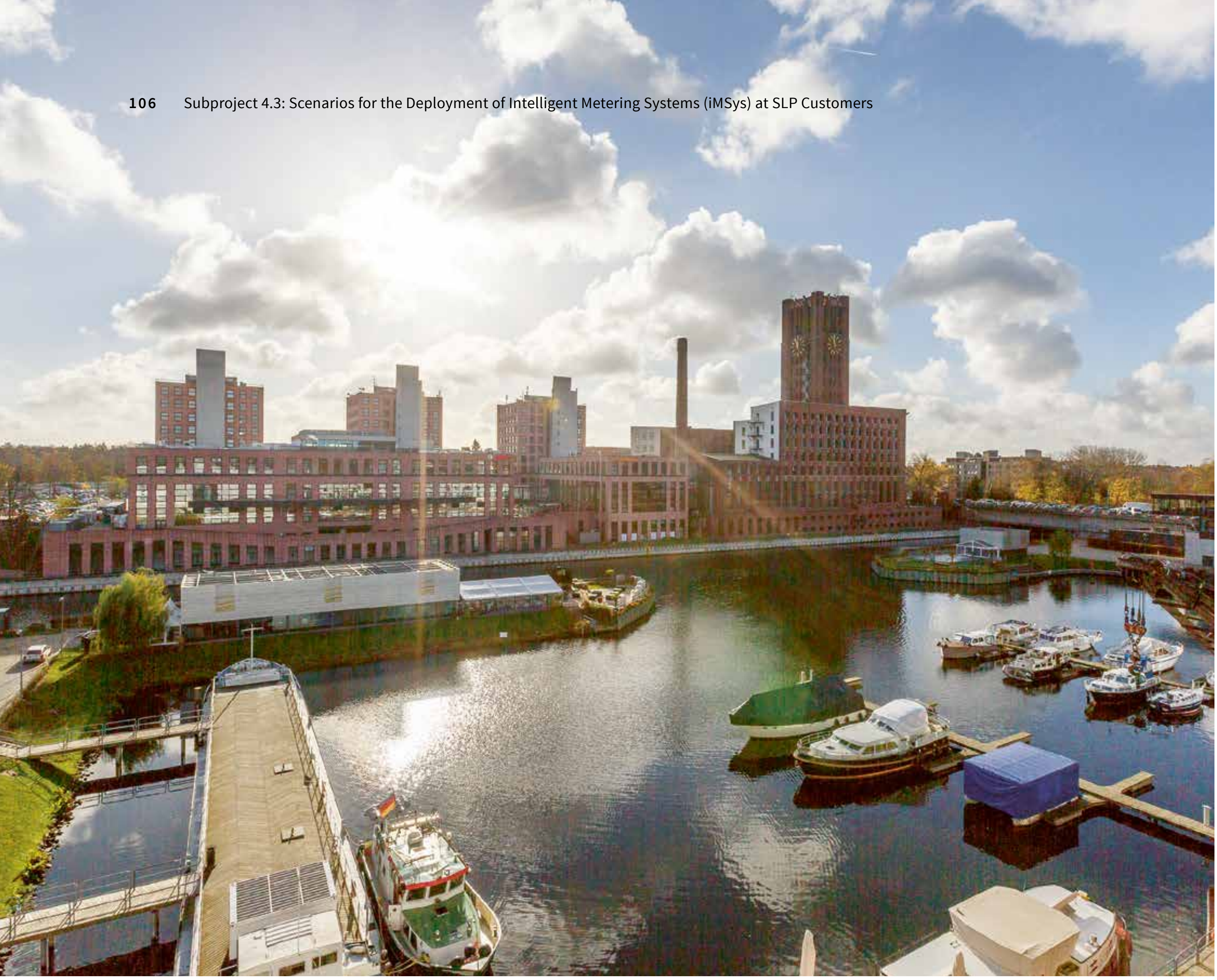
However, the flexibility of consumers varies based on a range of physical properties, such as the availability of adjustable capacity and power as well as the practical duration of on/off periods. In order to collect the individual characteristics of consumers with a standardised methodology, a SINTEG-ready standard was developed as a documentation tool. This standard was tested at the Lidl showcase store in the context of marketing the flexibility of the storage system. The storage was used for peak shaving, generated revenues of over €2,100 on short-term electricity exchanges in 2019, and was one of the first technical units active on the WindNODE flexibility platform.

The SINTEG-ready standard was also used to study other applications, such as charging stations for industrial trucks in logistics centres that might shift their energy demand depending on grid conditions. However, there is currently no off-the-shelf solution available that can integrate the heterogeneous charging infrastructure into the grid and increase its flexibility.

▲ View of the Kaufland showcase store in Berlin.

▹ CONCLUSION AND OUTLOOK // Economies of scale for the energy transition

The Schwarz Group has been involved in four years of exciting research. Electricity markets are evolving, and flexibility will become an increasingly important part of future energy systems. The Schwarz Group intends to apply the knowledge it has gained to foster flexibility across its locations. An important step in this process is the development of inclusive networking solutions that can bundle consumers effectively regardless of their characteristics, such as manufacturer and model.



▲ The Ullsteinhaus creative district at the Tempelhofer Hafen in Berlin.

Experiences from the Smart Meter Reality Lab: The Long Way from Cellar to Data Centre

The main goal of digitalising the power grid is to better track energy flows and make grids easier to monitor and control. The amount of power used by a consumer is generally recorded by an electricity meter at the site of consumption. Transmitting and processing the metered data is a particular challenge. The current state of the art for metering technology and the corresponding communication links are intelligent metering systems (iMSys) installed on the customer's premises. These systems combine a digital meter with a communication unit, called a Smart Meter Gateway (SMGW).

7,200

readings from the field tests are made available, checked for plausibility and processed every day

The SMGW guarantees safe data transmission. According to rules issued by the German Federal Office for Information Technology (BSI), only authorised SMGW administrators may configure the gateway using administration software. The gateway transmits meter data to market partners, such as metering service providers or suppliers, who can process them in their systems. This WindNODE subproject tests the end-to-end communication from a smart meter to a grid operator's data centre using power-line communication infrastructure in a series of different application scenarios.

▷ CHALLENGES AND SOLUTIONS // **95 % accessibility – even without mobile coverage**

The roll-out of intelligent metering systems is an important step in digitalising the energy transition. The new metering technology is a basic technical prerequisite for the reliable, real-time tracking of power drawn from and fed into the grids. In the future, this will allow end customers to be networked using smart meters and will facilitate the development of new products and services. Stromnetz Berlin, Bosch.IO, devolo and Fraunhofer IEE are showcasing secure, robust and powerful communication technology and software in the various iMSys application scenarios. In addition to the communication technology, they have also demonstrated seamless interaction between the hardware and software used in the smart grid.

The technical components of the iMSys include a meter and an SMGW, which is securely configured via the administration software GWA. The SMGW forms a digital gate that securely sends the data from the meters to the authorised market participants. By law, electricity grids qualify as 'critical infrastructure', whose failure or incapacitation would have dramatic consequences. For critical infrastructure, cybersecurity requirements are more stringent. As a result, the BSI has defined high standards for the gateways. In addition to the transmission of meter data, the secure SMGW connection can also be used in other application scenarios, such as to control local systems like charging points or streetlamps, or to enable additional value-added services for customers.

In each of the various application scenarios using iMSys, a basic requirement is the connection of the Smart Meter Gateway to a communication channel. This means that the SMGW must be able to send data to, and receive data from, external entities. By law, all iMSys must have a reachability of at least 95 %. Although internet and several mobile frequencies are readily available, the system provides a communication infrastructure that is independent of the customer. After all, iMSys are often installed in cellars or other places without mobile coverage. Even in Berlin, which has nearly 100 % mobile coverage, LTE could only be expected to function reliably in two out of three cellars.

'To maintain a high level of quality, we cannot simply swap metering equipment when integrating new technologies into existing systems. It is much more important to identify and demonstrate the synergies and new possibilities of the systems so as to foster acceptance and add real value for our customers.'

Clemens Czternasty
Senior Expert in Intelligent Metering Systems, Stromnetz Berlin GmbH

150

successful installation and configuration procedures were carried out with intelligent metering systems

▲ Installation of an intelligent metering system with PLC communication in the Ullstein district.

'Modern broadband powerline technology makes it possible to connect even hard-to-reach sites to the smart grid. It simply uses the existing power system without resorting to the usual mobile phone solutions.'

Dr Christoph July
Research Projects Coordinator,
devolo AG

In order to ensure the 95 % reachability of iMSys mandated by law, metering points without direct mobile phone coverage must also be made accessible. For this purpose, the transfer of data over existing power lines using new transmission technologies like Powerline is being tested to provide connections to software systems for administration (GWA) and meter data management (MDM).

The new communication technologies must meet the highest standards of data security and stability to protect energy infrastructure and ultimately build customer acceptance. This requires that the hardware (i. e. the meter and the SMGW) and the software for meter data administration and processing work together reliably on the relevant communication pathways, so that the iMSys roll-out can take place efficiently and with high-quality data transmission.

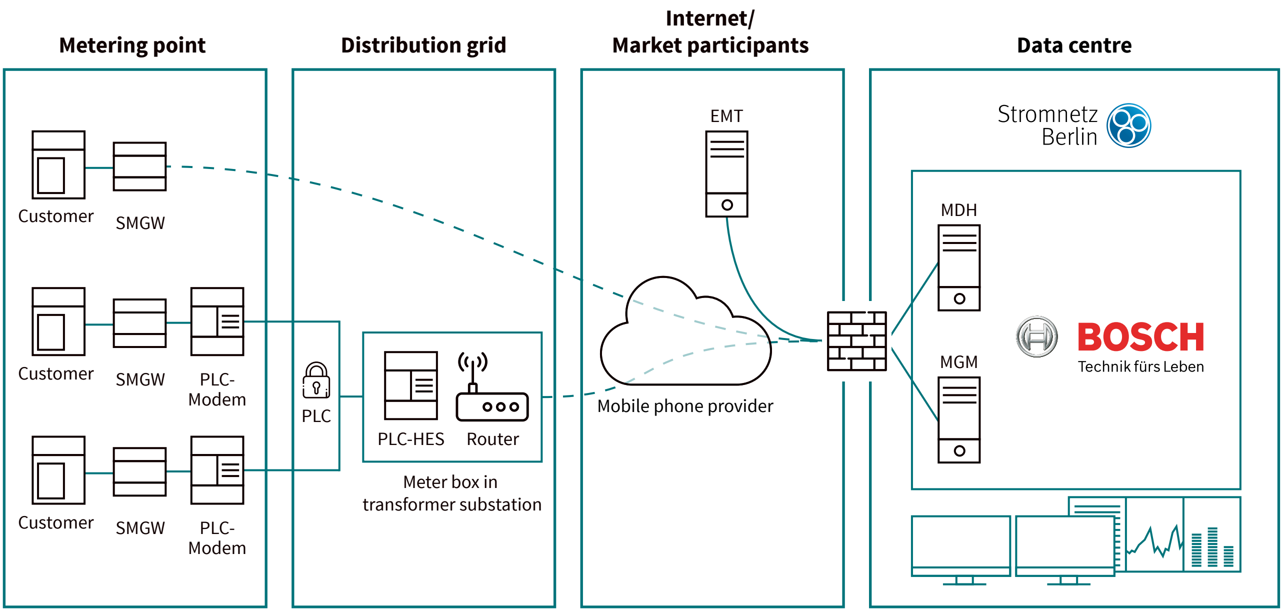
▷ RESULTS // **Modular connection concepts enable high reachability and diverse applications**

Due to the BSI's functional specifications and the demand for intelligent metering systems that allow for cross-manufacturer interoperability, the meter and SMGW technology has already been standardised by the relevant industry associations. At the same time, the heterogeneous electrical systems used by customers must be harmonised through standardised installation configurations in order to ensure an efficient roll-out with a large number of iMSys installed. A standard hardware kit was developed for simple iMSys installation, as well as for communication between iMSys and the distribution transformer substations at Stromnetz Berlin.

Roughly 75 iMSys – initially SMGW prototypes – were fitted at real metering points to test the installation processes, the interaction between the hardware kit and the software system solution for iMSys, and the data transmission over existing electrical lines using powerline communication. Later in the project, the devices were replaced by certified SMGWs at all metering points and a total of 150 installations were completed.

In addition to this testing of the installation processes and the hardware kit, another important step in implementing the various application scenarios was to ensure the scalability, availability and adaptability of the software solution. Software solutions developed by Bosch.IO have made important advances in the provision of meter data to external systems as well as in multimedia capability. Thanks to the deployment of an interface for querying meter readings and consumption values and for exporting meter data, external systems such as the one developed by Fraunhofer IEE can access meter data from the associated data management system as a basis for value-added services, energy forecasts or system optimisation driven by meter data. Targeted adaptations of the software architecture allow for the transmission of one-second-interval measurement data

▼ Schematic overview of the information and communication technology (ICT) to connect the measurement and communication equipment to the software solution and market participants.



HES: Head-end system
PLC: Power-line communication
EMT: External market participant
MGM and MDH: Bosch software solutions

(>10 s) and have been validated in laboratory trials. The configuration of controllable local system (CLS) profiles on SMGWs allows for controlling and switching applications, which can be run on control boxes or other CLS devices, for example using the StromPager (see page 114).

The star-shaped provision of meter data foreseen by BSI makes it necessary to allow more market participants to communicate with the grid. The already existing IPv4 networks necessitate a great deal of coordination efforts between the relevant companies. To reduce the need for these efforts, the existing IPv6 addressing mechanisms have already been tested in an IPv6 test environment and stable operation with iMSys hardware and software has been validated.

▷ CONCLUSION AND OUTLOOK // **Making the most of the potential of intelligent metering systems**

The testing of the new iMSys and a corresponding software system solution have shown the way to new applications and fields of action. The field test with SMGW prototypes in particular has shown the importance of long-term tests to ensure a strong grasp of the requirements of a stable metering point operation and thus an efficient roll-out.

The recording of grid-related readings in low-voltage systems has opened up new possibilities and can, in the final stage of the roll-out, provide a more detailed view of both the low-voltage grids and the control of flexibility and value-added services.

There is a real recognition of the need for full support from IPv6 communication systems for metering and value-added services on the hardware and software side. This support must be further optimised in the context of various partnerships.

‘The reality lab lets us learn in a practical way and together with our partners, helping us develop our software solutions for intelligent metering systems with a focus on customers and users as well as the application scenarios.’

Philipp Mahr
Senior Project Manager,
Bosch.IO GmbH

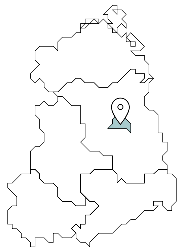
▷ WHAT IS HOLDING BACK THE ENERGY TRANSITION?

To push ahead with the standardisation of the intelligent metering infrastructure, the regulatory framework and specifications for consumption metering (RLM meters) should be adapted so that iMSys can also be fitted in facilities with an annual consumption exceeding 100,000 kWh. This would further increase transparency in the distribution grid and standardise different data sources and solutions.

Market processes have not yet been conclusively clarified: examples include priority switching or the consideration of the role of GWA in market processes. The lack of standards in CLS channel requests, the lack of interoperability among control boxes or the inadequate communications infrastructure and its attendant costs in Germany are all massively hampering the expansion of value-added services. For example, by causing issues such as low data rates due to low-bandwidth mobile standards such as GPRS and competing objectives when allocating CDMA 450 MHz for energy infrastructure applications. Moreover, the lack of internationalisation and the high certification costs of intelligent metering systems are hampering the innovation and willingness to invest of many companies. This holds true for the interaction between smart mobility and smart grid applications on the one hand, and intelligent metering technology on the other.

SP 4.3

FOCUS AREA
Identifying Flexibility



▸ Title of the subproject
Scenarios for the Deployment of Intelligent Metering Systems (iMSys) at SLP Customers

▸ Funding code
Stromnetz Berlin: 03SIN530
Bosch.IO: 03SIN505
Devolo: 03SIN510

▸ Subproject partners

▷ PROJECT PARTNERS
Bosch.IO GmbH

devolo AG

Fraunhofer-Institut für Energiewirtschaft und Energiesystemtechnik IEE

Stromnetz Berlin GmbH

▸ Contact
Stromnetz Berlin GmbH
Wilhelm-von-Siemens-Str. 2–10
12277 Berlin

Clemens Czternasty
T +49 30 492025965
clemens.czternasty@stromnetz-berlin.de

Bosch.IO GmbH
Ullsteinstraße 128
12109 Berlin

Philipp Mahr
T +49 30 726112337
philipp.mahr@bosch.io

devolo AG
Charlottenburger Allee 67
52068 Aachen

Dr Christoph July
T +49 241 18279163
christoph.july@devolo.de

For more information
www.stromnetz-berlin.de
www.bosch.io
www.devolo.de

▲ Wind and solar plants in Feldheim.

Precisely Predicted: Renewable Energy

We have all been there: you drive past a wind farm on a windy day. Some turbines are rotating, others are standing still. But why? On particularly windy days, wind turbines produce extremely large amounts of green electricity – until the turbines are switched off to avoid overloading the power grid. At that point, valuable green electricity is wasted. Flexible industrial processes and storage systems can change that. However, it is necessary to plan their use carefully. This is only possible with forecasts of the green electricity production that are precisely tailored for every generating unit. In WindNODE, the Berlin start-up Solandeo is developing artificial intelligence (AI) to solve this problem and move the energy transition forward – first in Germany, then worldwide.

‘In the future, artificial intelligence will play an increasingly important role in the success of the energy transition. WindNODE offers us a unique opportunity to develop the necessary solutions in cooperation with key stakeholders in the energy industry – for a successful energy transition in Germany and around the world.’

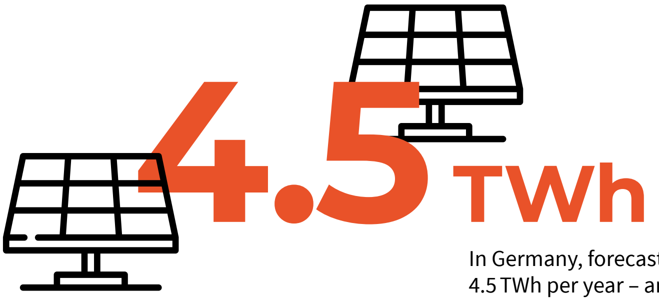
Friedrich Rojahn
CEO,
Solandeo GmbH

▷ CHALLENGES AND SOLUTIONS // **And now ... the power forecast for tomorrow**

The production of renewable energy changes with the weather. And that can change suddenly. Moreover, weather conditions are very local phenomena: one moment you are driving through dense fog, the next you have to shield your eyes from the intense sunlight.

This has consequences for the energy transition: the greater the amount of green electricity supplied by decentralised solar plants and wind farms, the greater the variation in electricity generation from place to place. This makes it increasingly difficult and expensive to maintain grid stability. It also makes it more complicated to keep costs down while maintaining a balance between supply and demand on the electricity market. If there is no electricity, it must be bought at a higher price. If there is excess green electricity, systems must be switched off. In other words: we are not using the available supply of green electricity to its fullest potential.

Flexible consumers and storage facilities can solve the problem, provided that there is a way to determine the optimal time for them to use energy. The energy transition requires localised, precise and cost-effective forecasts of the amount of green electricity that can be produced at specific locations. Previous forecasting



In Germany, forecasting errors can be reduced by up to 4.5 TWh per year – an amount equal to 11 % of Germany's electricity generation from photovoltaics in 2018.

methods – and the subsequent conversion into production forecasts – have relied on expensive supercomputers. This costs time and money. Still, local weather models do not offer sufficiently fine-grained projections. That is why weather forecasts predict the weather for a city, not for individual districts or streets. For the generation of electricity from the wind and sun, however, relatively small-scale variations can make a big difference.

As part of WindNODE, Solandeo is researching forecasting methods using real-time data from smart meters and self-learning algorithms (artificial intelligence) to meet the requirements of the energy transition so that more and more green electricity can be integrated reliably and cost-effectively into our energy system.

▷ RESULTS // **Lower costs for the energy transition**

In cooperation with the project partners, Solandeo has successfully shown that AI can play a crucial role in managing the energy transition. The accuracy of existing generation forecasts based on weather models can be significantly improved, especially in the case of short-term forecasts (up to three hours in advance). This is where the limits of conventional forecasting methods become clear: if the weather changes at short notice, forecasts cannot be issued in time because it can take several hours to calculate a new forecast.

Solandeo's forecasts can be updated continuously and in real time because the underlying AI processes current information at lightning speed. The predictions are based on real-time data collected from individual plants (e. g. from smart meters) as well as from the plants themselves (e. g. turbine data and data from photovoltaic inverters). Each individual plant is assigned with its own AI that specialises in forecasting generation from the plant and continuously learns and improves.

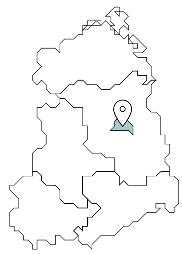
If the processes developed by Solandeo are combined with existing forecasts based on weather models, the accuracy of the forecast can be increased significantly. This increases the efficiency of green power trading and reduces the costs of the energy transition.

▷ CONCLUSION AND OUTLOOK // **Artificial grid intelligence for redispatch 2.0**

Solandeo and other partners have also researched the use of innovative forecasting methods for the efficient operation of energy grids. In collaboration with the transmission system operator (TSO) 50Hertz and Energiequelle, a leading project developer and operator of renewable energy systems, Solandeo investigated a broad spectrum of applications at varying scales, from the entire control area to the energy self-sufficient village of Feldheim in Brandenburg. These applications facilitate the efficient prediction of load flows, especially for redispatch 2.0.

The study considered how data protection can be guaranteed when high-resolution, real-time data are used in bulk, as well as what measures can be taken to ensure that the particularly high IT security requirements of power grid operators are taken into account. In this way, Solandeo is making a major contribution to the advancement of efficient, forward-looking congestion management in the smart grid.

SP 4.4 | FOCUS AREA
Digitalising the Energy System



▸ Title of the subproject
Production Forecasts for Solar and Wind Systems with Real-Time Smart Meter Data

▸ Funding code
03SIN551

▸ Subproject partner

▷ PROJECT PARTNER
Solandeo GmbH

▸ Contact
Friedrich Rojahn
rojahn@solandeo.com

For more information
www.solandeo.com
www.erneuerbare-energie-prognosen.de

▲ devolo, which started with a 25-person team in Aachen, has grown into an international company with around 300 employees.

The Intelligent Home Meets the Smart Grid

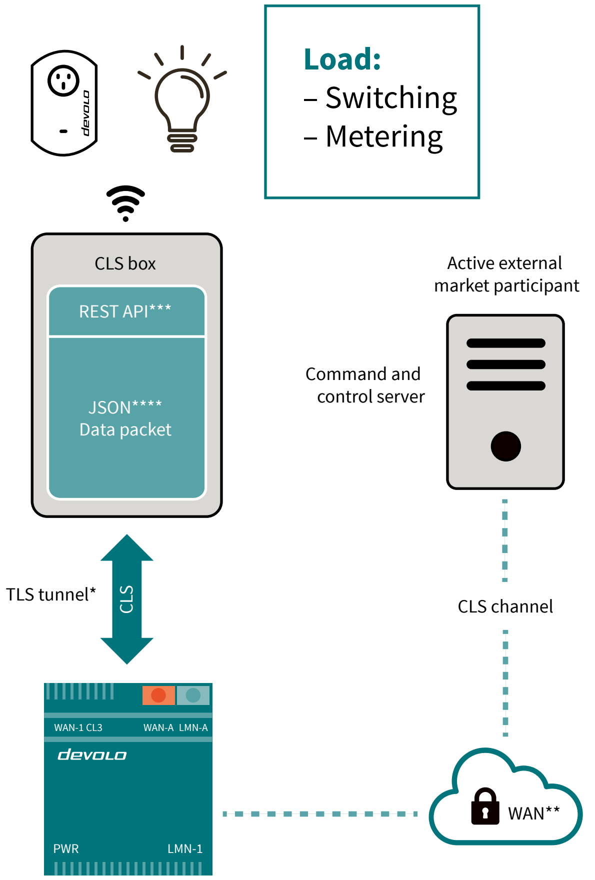
Until now, smart power grids and smart homes have not been combined in a way that benefits end consumers. For instance, it is rarely possible to access value-added services such as consumption history or statistics. The WindNODE partners Bosch.IO and devolo are trying to change this by working on solutions that allow for smart home solutions, heat pumps and photovoltaic inverters to be integrated into the existing smart grid concept in a way that would make them easy to use. Their approach enables energy utilities to be active in the field of home automation in accordance with regulatory requirements. This makes it possible to offer different types of private flexibility, such as controllable loads and energy storage, to interested market players.

‘The close alliance between smart home and smart grid technology fills the gap that is left by the currently used smart grid hardware: added value for customers. In addition to allowing for the retrieval of current consumption data, smart homes provide flexibility that can be easily integrated through the established connection via the SMGW.’

Dr Christoph July
Research Projects Coordinator,
devolo AG

▷ CHALLENGES AND SOLUTIONS // **Regulation versus evolution**

Communication via a German smart meter gateway (SMGW) is limited by strict regulations. To overcome this, it is necessary to expand on the solutions established in the Internet of Things (IoT) environment. An SMGW is currently able to access the home network of an end consumer only via a controllable local systems (CLS) interface. In the current stage of its evolution, the German smart grid can essentially only communicate with customer hardware in two ways that satisfy regulations: protocol conversion/encapsulation of non-smart grid protocols by means of a virtual or physical control box, or a natively supported protocol such as HTTP as communication medium. In this subproject, both approaches were rigorously pursued and tested at visitor sites as well as in laboratory settings. Using existing smart grid technology, the CLS channel of the SMGW proved to be the most accessible type of communication for the partners involved.



◂ Access to smart home facilities within the regulatory framework using SMGW and a CLS tunnel: small-scale flexibility and load management via the control server of an active external market participant.

*Transport Layer Security tunnel
** Wide area network
*** Representational state transfer application programming interface
**** JavaScript Object Notation

10–20 %

Consumption recording accurate to the second:
An expected 10–20 % increase in large, switchable flexibility in private households (electric vehicles, heat pumps)

SP 4.5

FOCUS AREA
Digitalising the Energy System

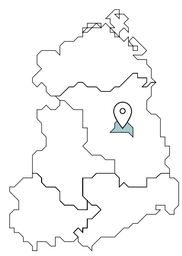
▷ RESULTS // **Submetering and flexibility management**

In the first stage, the gap between smart grids and smart homes was bridged through a direct connection via the 'highly secure communication scenario 4' (HCS4), defined by the BSI for the smart meter gateway. In this scenario, an external market participant initiates a secure channel to a device in the CLS network via an SMGW. In practice, the customer plugs a network-compatible device directly into the CLS network jack of the SMGW. The necessary gateway administrator and energy manager solution for external market participants was developed by Bosch.IO. To control the customer hardware, devolo built a management interface on the smart home control box. In the test, multiple loads were successfully controlled and their consumption measured individually in one-second resolution.

The implementation of the HCS4 in accordance with the requirements was an interesting challenge, as this had not yet been properly tested in the field. However, after successful commissioning, a reliable process could be established.

▷ CONCLUSION AND OUTLOOK // **Added value for the power grid**

Another potential example of added value for customers would be a dedicated IoT-specific interface. The existing framework conditions preclude the implementation of this approach in the current version of the SMGW, however. In the future, it would be desirable to devise a solution that would allow smart home hardware, wall boxes, heat pumps, photovoltaic systems and other customer hardware to be connected to the SMGW directly and without any configuration or other hardware. Direct support for existing IoT protocols on the SMGW would result in ready-made and easily available solutions in this field. This would not only enable customers to find out about their consumption in one central place, as envisioned by 'Transparency and Display Software' (TRuDI), but would also provide a user interface for their meter data and the status of their hardware.



▸ **Title of the subproject**
Controllable Loads in Households and Smart Home Integration

▸ **Funding code**
03SIN510

▸ **Subproject partners**

▷ PROJECT PARTNERS
BOSCH.IO GMBH

devolo AG

▸ **Contact**
Dr Christoph July
T +49 241 18279163
christoph.july@devolo.de

For more information
www.devolo.de

▲ Strompager DX

Secure Control of Flexibility in the Low-voltage Grid

Today, grid congestion is mainly caused by changes in the structure of power generation. At the low-voltage level, consumers are also becoming more relevant because of developments in electromobility, heat pumps and storage heating. As part of the WindNODE project, researchers refined existing control technology for low-voltage applications – an electricity pager called the 'Strompager DX' – and tested the modified device in the reality lab.

'The energy transition is taking place on both a small and large scale. Acceptance will go hand in hand with added value for our customers in Berlin. The Strompager DX is the latest development in our control systems for installations at the low-voltage level and provides a solid technical foundation for new products and services.'

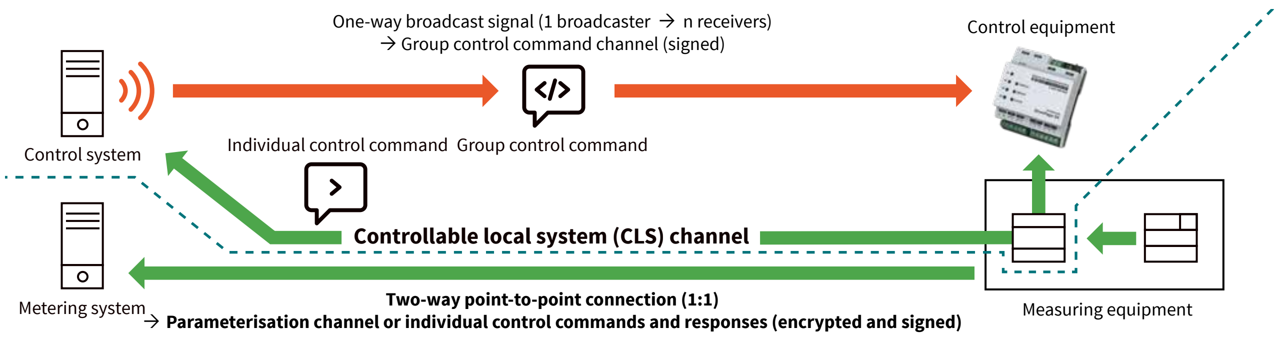
Dr Sandra Maeding
Senior Energy Industry Expert,
Stromnetz Berlin GmbH

▷ CHALLENGES AND SOLUTIONS // Special challenges for on-site flexibility

A large number of flexible applications operate at low voltage levels. Addressing many of the systems that could provide small-scale flexibility requires technologies that are highly scalable and suitable for the mass market. In this part of the power grid, the grid operators do not maintain private data networks. Moreover, the wide variety of locally deployed systems makes it very difficult to develop systems using a single communication technology. Use of broadband technologies to transmit data reduces the accessibility of individual systems, since such technologies often do not have ideal properties for building penetration. Mobile standards like 4G cannot reach every cellar. From the perspective of the grid, another issue is that systems can only be addressed in groups. While switching individual systems does not lead to problems, a whole group of systems connected to a single power line switching synchronously can overload the grid. It is therefore essential to consider the behaviour of groups of systems when thinking about the low-voltage grid.

▷ RESULTS // Combining advantages with the Strompager DX

Since 2014, switching in Berlin's low-voltage grid has taken place via Strompager. In physical terms, this is a one-way narrowband technology with very low bandwidth. However, a broadband point-to-point connection would be more efficient for addressing individual systems (in contrast to groups). The smart meter gateway can provide such a connection over a secure infrastructure. Connecting the Strompager via this channel would allow the advantages of both technologies to be utilised.



▲ Simplified view of the control system.

In addition to enabling higher technical efficiency, this control system also allows authorised market partners to participate in the control mechanisms. During the WindNODE project, Bosch.IO modified the back-end system of the pager-based ripple control (PFR) so that external market participants could securely access approved control units and organise them according to their own criteria. The parameterisation takes place after approval by the grid operator to ensure that there are no grid-critical concentrations of grouped systems.

This process is a first step in coordination at the operating level. It enables every authorised market partner to send control commands without operating a certified control system, as would be mandated for every 'active external market participant' by the technical guideline BSI TR-03109. In this way, the market partners share one field device. This hybrid solution, which consists of an intelligent measuring system and a secure broadcasting mechanism, thus also fulfils the gateway function for value-added services via the future smart meter gateway infrastructure.

Several project partners are jointly testing the Strompager DX in the WindNODE reality lab. The new devices are to be deployed in different neighbourhoods as needed for the partners' respective applications. The pagers can be used, for example, to indicate a switching direction via relay, which can serve as a signal for on-site energy management. This enables orchestrating systems in accordance with events at higher voltage levels, such as deviations in renewable energy forecasts at the TSO level.

1.9 million systems are controlled by existing technology at the low-voltage level today

▷ CONCLUSION AND OUTLOOK // **A technological contribution to grid security and participation**

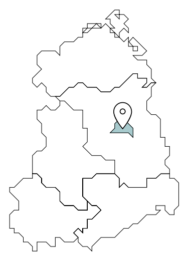
Flexible consumers, such as charging infrastructure for electromobility applications, should be integrated into the power grids quickly. This will require the existing grid capacity to be used to the fullest and the grid to be expanded as necessary. To guarantee the security of the power supply, there must be reliable control. Electricity paging technology can help make the use of flexibility at the low-voltage level more secure and more efficient.

'As the energy transition progresses, control procedures will become more and more important in keeping the overall system in balance. The different types of control must be harmonised to ensure consistency and coordination with the grid. This is the only way that "plannable" measures can reduce the effects of "unplannable" events.'

Oliver Schaloske
Asset Strategy and Innovations,
Stromnetz Berlin GmbH

SP 4.6

FOCUS AREA
Activating Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
EE-Stalker – Low-Voltage Swarm Control for Improved Grid Operations

▸ **Funding code**
03SIN530

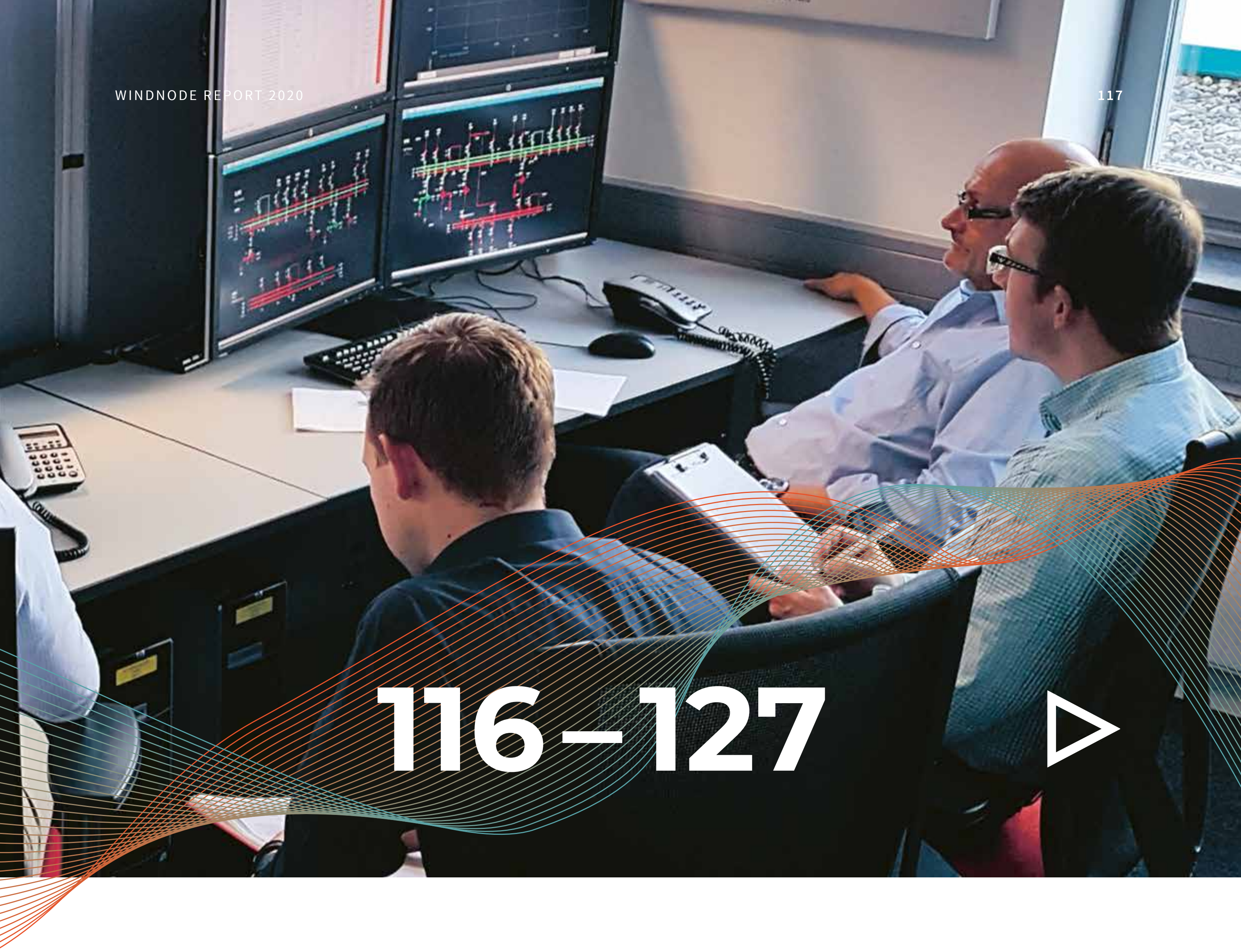
▸ **Subproject partners**

▷ PROJECT PARTNERS
Bosch.IO GmbH

Stromnetz Berlin GmbH

▸ **Contact**
Stromnetz Berlin GmbH
Oliver Schaloske
oliver.schaloske@stromnetz-berlin.de

Participating partners



Market Design and Regulation

How can the efficiency of an intelligent energy system be measured? Which market mechanisms influence its design and what might the appropriate regulatory framework look like?

In this workstream, WindNODE adopts a broader economic perspective. The research starts from systematic investigations and scientifically supported assumptions to address legal and regulatory issues and outline development paths for the overall system.

Workstream 5 is coordinated by Prof. Dr Thomas Bruckner and Dr Hendrik Kondziella (Institute for Infrastructure and Resources Management of Leipzig University) and Hannes Doderer (Institute for Climate Protection, Energy and Mobility) on a voluntary basis.

▲ Siemens **ZUKUNFTSRAUM***ENERGIE* showroom in Berlin.

A Holistic Approach to the Energy Transition

Siemens and the Department of Energy Systems at TU Berlin are demonstrating how possible courses of action in the energy sector can be evaluated in a differentiated manner. This involves linking energy system models with methods from lifecycle assessment (LCA). The results are analysed in terms of economic efficiency, security of supply and environmental and social compatibility, and presented in the Siemens **ZUKUNFTSRAUM***ENERGIE* showroom (Energy of the Future space).

‘Working within the WindNODE project, we have managed to make scientific models and results tangible. We use digital images to bring transparency to the energy transition and communicate interactively. Visitors to the **ZUKUNFTSRAUM***ENERGIE* showroom gain a comprehensive understanding of the issues and possible courses of action.’

Dr Katrin Müller
Principal Key Expert for Sustainability Engineering, Siemens AG

▷ CHALLENGES AND SOLUTIONS **// The energy policy target triangle as a basis for balanced decisions**

How can possible courses of action in the energy industry be comprehensively evaluated to facilitate the best possible business and political decisions? Siemens and TU Berlin are working to answer this question. Energy system assessments typically only consider cost minimisation; at most, they specify a maximum carbon budget. But in order to ensure public acceptance of the energy transition – and the success of the transition itself – it is essential to consider objectives besides cost efficiency, including security of supply and environmental and social compatibility. WindNODE, too, needs to adopt this type of comprehensive analysis in order to create prototypes for new business models and technologies for the energy transition in northeastern Germany.

▷ RESULTS **// Transformation pathways bring new challenges**

For the multi-criteria assessment, Siemens combines two approaches: an energy system model that covers the electricity, heating and transportation sectors, and an LCA model for the environmental evaluation of the energy system. The results are analysed using indicators developed at TU Berlin. The total economic costs of a future energy system are maintained at an even level between all scenarios that were studied. The analysis of ecological effects sheds light on the ongoing transition from a fuel-based to a material-intensive energy system. This is also reflected in the level of air pollutants, which has been declining for years, and in the assessment of resource security.

▲ Presentation of the energy system assessment in Siemens **ZUKUNFTSRAUM***ENERGIE* showroom, with an energy flow chart for the model of the German energy system in 2030.

The results of the analyses will be presented to WindNODE partners, political decision-makers and the broader public in the Siemens **ZUKUNFTSRAUM***ENERGIE* showroom. Here, visitors can interactively explore Germany's energy system from the past to the future through a visualisation that allows them to recognise and discuss (un)expected interconnections. The analyses are presented in even more detail in TU Berlin's study 'Multi-criteria assessment of possible courses of action in the energy sector'.

A holistic evaluation approach was also taken in a second study, which focused on the three energy system challenges of identifying and activating flexibility, grid congestion management and grid planning. This study found that the deployment of information and communications technology in all three domains could make the underlying processes more efficient or tap into existing potentials. As a result, it is possible to improve individual dimensions of the energy policy triangle without putting other areas at a disadvantage.

▷ CONCLUSION AND OUTLOOK // **A guideline for the multi-criteria assessment of possible courses of action**

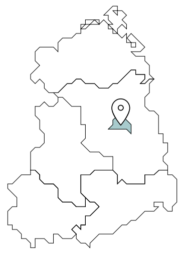
The sophisticated methodological approach chosen in this WindNODE subproject linked energy system models and LCA to carry out an extensive assessment of the effects of possible energy transition scenarios. High priority must be given to both the refinement of the methodology and a joint update of LCA datasets relevant to the energy system; this is the only way to ensure that the model results reflect current technical developments. It is important that raw data and inherent assumptions be disclosed. The DIN SPEC 91432 'Multi-criteria assessment of energy systems' developed in WindNODE will provide an important guideline for future projects in this field at the national, regional or local level.

Environmental effects of the German energy system*:	1990		2030
Material bound within the energy system: copper equivalents according to ReCiPe Midpoint (E) per inhabitant	114 kg	↗	205 kg
Yearly CO_2 equivalents per inhabitant including upstream (Scope 3)	12.8 t	↘	6.4 t

* Based on ecoinvent 3.4

SP 5.1

FOCUS AREA
Identifying Flexibility
Activating Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
Evaluation of the Overall System Efficiency

▸ **Funding code**
03SIN529, 03SIN537

▸ **Subproject partners**

▷ PROJECT PARTNERS
Siemens AG, Corporate Technology

Technische Universität Berlin, Department of Energy Systems

▷ SUBCONTRACTOR
Federation of German Scientists, Initiative 'Meine Energie für meine Stadt'

▸ **Contact**
Jörn Hartung
T +49 30 585923342
joern.hartung@siemens.com

▸ **Visitor site**
ZUKUNFTSRAUM*ENERGIE*
showroom (Energy of the Future space)
Rohrdamm 85
13629 Berlin

Registration required

https://new.siemens.com/de/de/unternehmen/themenfelder/nachhaltige-energie/zukunftsraumenergie.html

▷ INQUIRIES TO
windnode.em.de@siemens.com

For more information
www.siemens.com/dekarbonisierung

Modern Energy Law as a Challenge and an Opportunity

The energy transition is having a profound impact on the entire energy system. Thus far, the legislative framework has been unable to keep pace with this development, causing flexibility and sector coupling to fall by the wayside. Bold revolutionary approaches, such as effective CO_2 pricing or reform of the grid fee system, offer opportunities to modernise energy law.

'The energy transition is embedded in climate action policy and must be implemented across the economy. In addition to the infinite number of small tweaks that could be made to energy legislation, it is also necessary to keep an eye on the big picture.'

Hannes Doderer
Project Manager, Energy Law Team Leader,
IKEM e. V.

'The energy law of the future should not only focus on the material issues of renewable power, flexibility and sector coupling; it must also provide an accessible and participatory legal framework. In regulatory terms, too, the energy transition must once again become a citizen-driven project that stakeholders can understand and help shape.'

Jonathan Metz
Research Associate,
IKEM e. V.

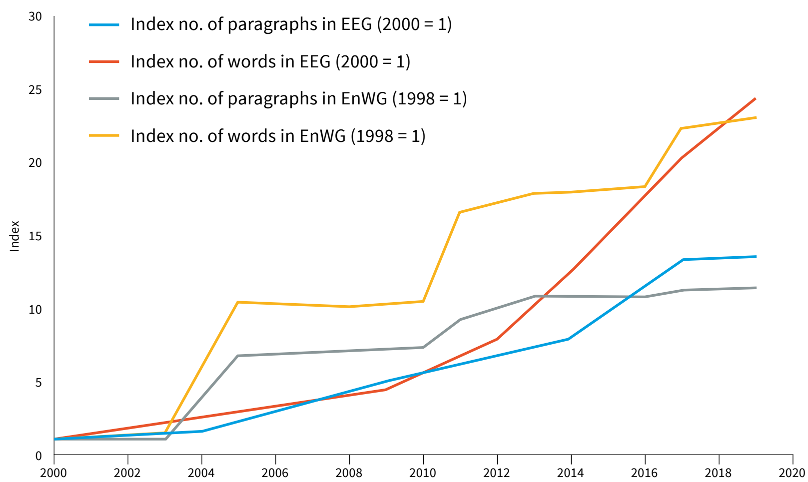
▷ CHALLENGES AND SOLUTIONS // **Flexibility requires a better legislative framework**

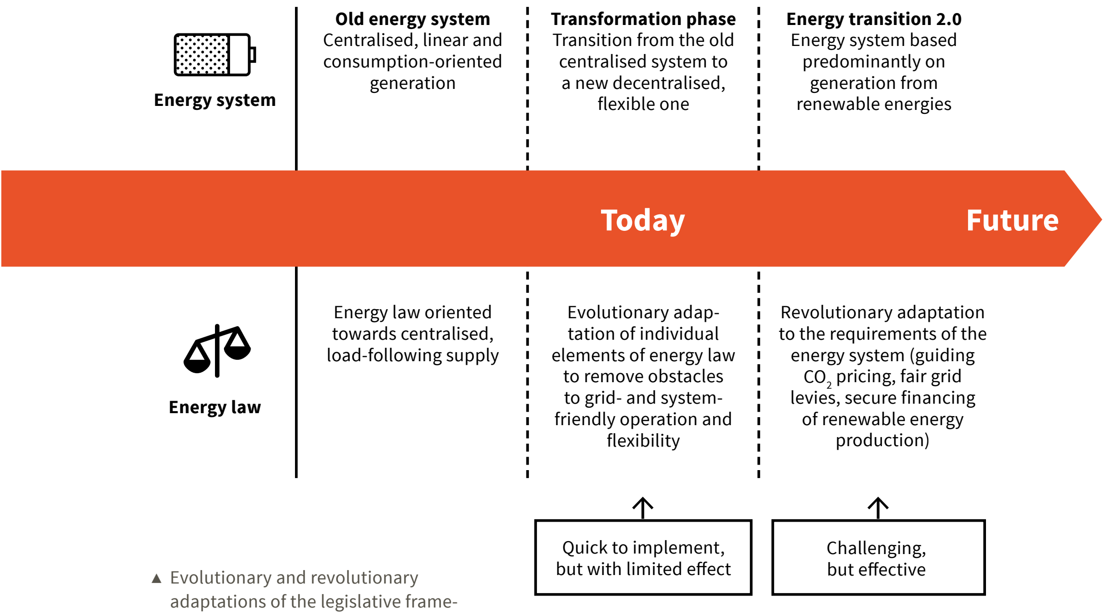
The increase in renewable generating capacity calls for more flexibility in the energy system. Flexibility options are needed to align electricity consumption with intermittent production from renewable sources, especially wind power and photovoltaics. Traditionally, storage systems have been used for this purpose. But industrial loads and sector coupling systems can also help ensure that green electricity is utilised at the time it is produced. Combined with renewable energy, sector coupling technologies can accelerate the decarbonisation of the transport, manufacturing, gas production and heating sectors.

Despite the need for flexibility options, the regulatory environment has thus far not been conducive to their implementation. For example, the existing system of levies and charges means that adopting flexible consumption patterns may even be financially disadvantageous for operators.

Over the years, energy law has given rise to an ever-growing morass of regulations governing grid fees, electricity tax, the EEG levy and other matters. This complexity is further increased by sector- and technology-specific privileges. The number of words in the German Energy Industry Act (EnWG), for instance, increased more than 23-fold between 1998 and 2019.

▼ Increase in the number of paragraphs and words in the German Renewable Energy Sources Act (EEG) and Law on the Energy Industry (EnWG).
Source: Kalis/Dittmar: Quo vadis Energiewenderecht? TaTuP 28/3(2019) with additional references.





▲ Evolutionary and revolutionary adaptations of the legislative framework for an energy transition 2.0

▷ RESULTS // **Solutions are within reach**

As part of the WindNODE project, IKEM reviewed the regulatory framework for energy and analysed barriers to the use of flexibility and sector coupling. Based on this assessment, it then developed proposals for a future legal framework that could meet the growing need for flexibility and decarbonisation. There are two basic approaches to changing the legal framework:

1. The evolutionary approach

The existing legal framework can be adapted gradually through changes to individual laws and paragraphs within the body of energy legislation, thus addressing the flexibility needs of the whole energy system more effectively. The advantage of this evolutionary approach is that it is relatively easy to implement, as existing standards are only modified. The disadvantage is that it does not permit all systemic obstacles and hurdles to flexibility and sector coupling to be removed.

2. The revolutionary approach

The energy transition is affecting every aspect of the energy system. In the past, large and medium-sized power plants produced energy centrally and in line with demand. In the future, the power plants responsible for energy production will be smaller, more decentralised, and primarily based on renewables, which will largely prevent output from being adjusted at will. As a result, consumers will increasingly need to adapt to the supply. This transformation of the energy system offers an opportunity to 'revolutionise' energy law – and, in the process, to streamline and simplify it as much as possible. Measures considered in the context of the WindNODE project include CO_2 pricing and systemic reform proposals for the grid fee system.

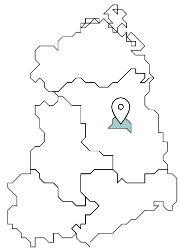
A renewed legislative framework based on legal certainty and effectiveness can incentivise flexibility, strengthen sector coupling and contribute to the decarbonisation of the entire energy system. The challenges associated with these revolutionary approaches include their complexity and the time needed to implement them, as well as the social consensus required. Experimentation clauses can be helpful by providing an opportunity to try out different approaches in limited areas.

▷ CONCLUSION AND OUTLOOK // **Prompt action and long-term vision**

The two approaches are not mutually exclusive, but can complement each other. The first step is to adjust the legal framework bit by bit and modify standards that have a particularly adverse effect on flexibility. Such measures would be relatively easy to implement, and they could be accompanied by a more revolutionary approach in order to create future-oriented energy legislation.

SP **5.2a**

FOCUS AREA
Activating Flexibility



▶ **Title of the subproject**
New Market Design and Efficient Congestion Management

▶ **Funding code**
03SIN519

▶ **Subproject partners**

▷ PROJECT PARTNERS
Institute for Climate Protection, Energy and Mobility (IKEM)

University of Leipzig, Institute for Infrastructure and Resource Management (IIRM)

▷ ASSOCIATED PARTNER
Vattenfall Wasserkraft GmbH

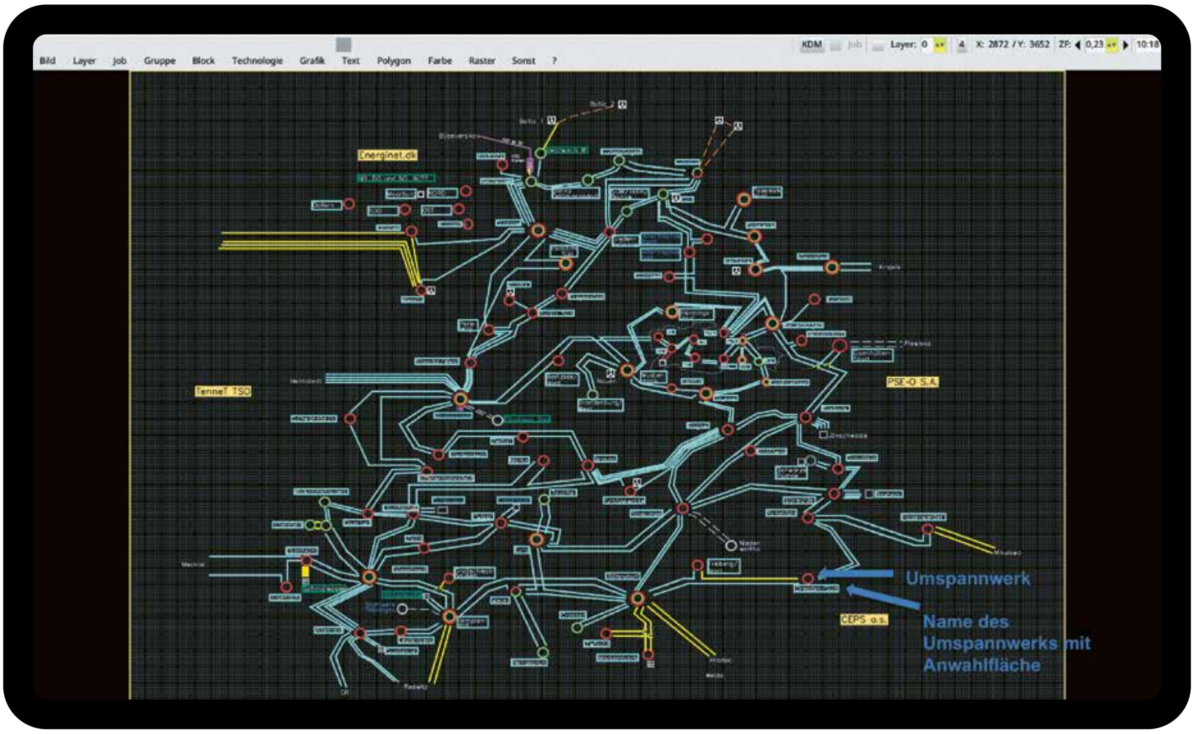
▶ **Contact**
IKEM
Magazinstraße 15–16
10179 Berlin

Hannes Doderer
T +49 157 56153151
hannes.doderer@ikem.de

▶ **Visitor site**
IKEM, Open Office for Legal Matters
Magazinstraße 15–16
10179 Berlin

▷ INQUIRIES TO
Hannes Doderer
T +49 30 408187010
info@ikem.de

For more information
www.ikem.de



▲ The topology of the high-voltage grid in the 50Hertz control area for the year 2030 (geo-referenced) serves as the visual basis for our analyses of flexibility deployment in ways that serve the market and the grid.

Flexibility: Success Factor of the Energy Transition – But a Business Case?

We collaborated with GridLab to adapt our market and grid models to reflect the system in the year 2030. This enabled us to examine plausible scenarios and draw conclusions about future needs for flexibility. The amendment to the Grid Expansion Acceleration Act (NABEG) and the planned grid expansion do not offer any medium-term incentives for more regionalised markets. However, in the short term, flexibility could be incentivised through peer-to-peer electricity trading.

▷ CHALLENGES AND SOLUTIONS // **Where in the energy system is flexibility most needed?**

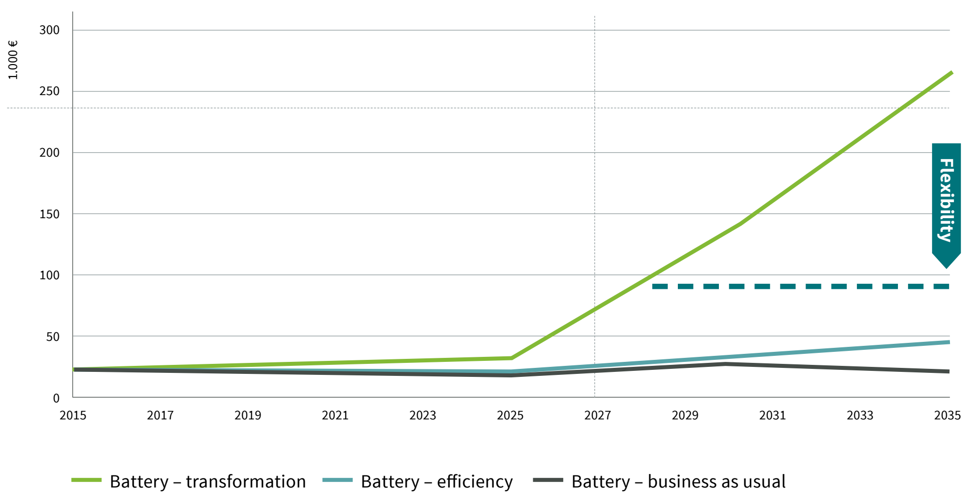
The Energy Industry Act (EnWG) strictly separates grid operation and market activity. It specifies that the price of electricity on the wholesale markets should reflect supply and demand without restrictions from regulators. As a result, the price does not encourage system operators and electricity consumers to behave in a manner that is beneficial to the grid or to comply with physical restrictions of the grid infrastructure. If the technical restrictions of the grid are likely to be violated, grid operators ensure continued operation through the use of ancillary services, including dispatch of conventional power plants when managing congestion. In extreme cases, individual systems, such as wind turbines, must be switched off. Since the market share and local availability of controllable power plants will gradually decrease in the coming years, renewable energy sources and 'non-conventional flexibility options' – such as battery storage, load management and Power-to-X systems – will need to provide ancillary services in the future. The interventions of grid operators in the market-oriented dispatch schedules of power plants and the associated economic costs have increased significantly over the past 10 years.

In addition to rising costs, the fact that green energy in the order of several terawatt-hours (TWh) cannot be integrated into the grid is another reason to consider suitable countermeasures. One answer to the question of how the interaction between the grid and the market should be structured is the 'traffic light concept' and the introduction of smart markets, which has been a prominent proposal for several years. The idea is to activate flexibility in a way that serves the grid and to remunerate it in line with its market value. In the best-case scenario, this will create new business models for technologies that are necessary to ensure a secure and cost-efficient supply of electricity, heat and mobility based on renewable energy sources. This is where the topic of market design touches the technical workstreams of WindNODE: today, grid-friendly operation of virtual power plants, flexible industrial loads and smart neighbourhoods is only economical if supported by legal exceptions like the SINTEG experimentation clause. As the mandatory end of the regulatory test approaches, the requirements for a future market design become an important issue. This is why we have modelled the electricity market and the grid for the year 2030 in a European context.

'Despite the broad spatial distribution of the project partners, a common WindNODE spirit was present from the start. The resulting personal network provides a reliable basis for further collaboration on solutions to implement the energy transition, even after the official end of the project. I am especially heartened by the realisation that demonstration projects could be shown to be technically feasible in WindNODE.'

Dr Hendrik Kondziella
WindNODE Project Manager,
University of Leipzig

Marketing flexibility on the spot market
Battery (1 MW / 4 MWh)



◂ Evaluation of the economic potential of flexibility options marketed on the spot market using the example of batteries (1 MW/4 MWh) in three scenarios. In situations of scarcity (green scenario), the value of flexibility increases sharply.

Thanks to our partnership with GridLab, we were able to go far beyond previous research efforts in terms of technical details and data availability, and could derive a number of valid statements. We built another bridge to the hot topic of digitalisation of the energy industry with an analysis of peer-to-peer (P2P) markets and the development of a software-based research infrastructure.

12 GW

of flexibility options in the WindNODE region

▷ RESULTS // **Flexibility through technical diversity**

Flexibility atlas: The researchers first set out to learn how much flexiblity is available in the WindNODE region today. The database includes public data bases as well as our own research and is divided into four flexibility types: classic end consumers (demand-side management), generating units, energy storage systems and Power-to-X systems. The conventional and renewable generation plants make the greatest contribution to the technical flexibility potential. Given the need for negative flexibility (energy sinks) – especially for grid congestion management – it is clear that curtailing wind and solar is undesirable from a climate policy perspective. Instead, a mix of flexibility options like CHP systems, pumped storage, Power-to-Heat, biomass and load management could be used. These options have a technical potential of around 12 GW in the WindNODE region.

Flexibility needs: Demand for flexibility can result from price differences on the wholesale markets (day ahead, intraday) or from the need for ancillary services. The coupling of the German market area with other European price zones has led to a smoothing of price peaks in recent years, despite the expansion of renewable energy sources. As a result, the value of the short-term deployment of flexibility has also decreased. Based on the power plant availability projections in the grid development plan and the assumption of an ambitious timetable for the coal phase-out, shortages (extended periods of low wind and solar power generation) of several weeks may become a reality, especially in the winter months. This increases mainly the need for positive flexibility (increased generation or load shedding). Higher price differences can also be expected during other periods of the year and will lead to higher costs relative to the status quo. If all expansion measures in the grid development plan are implemented, the grid area will practically be free of congestion by 2030/35. Flexibility options would only need to be activated, for instance via a local market platform, in case of major grid equipment failure or when the renewable feed-in caps defined by the EnWG are reached. However, considerable potential for flexibility use is expected if there are delays in the implementation of the grid development plan.

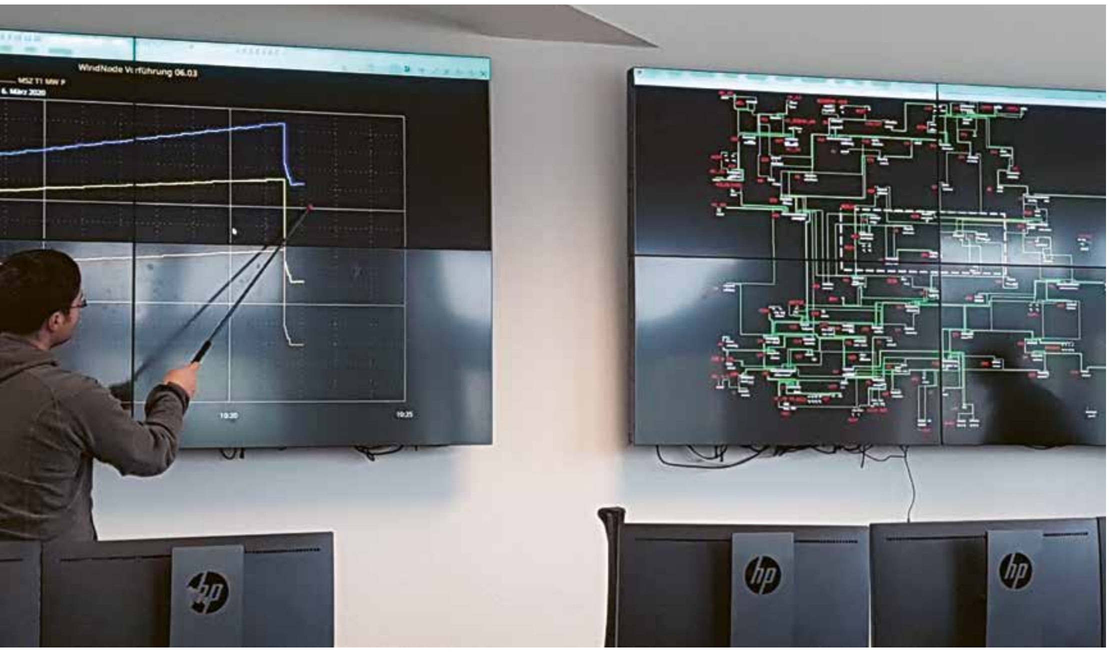
Due to the amendment to NABEG, which was passed during the WindNODE project period, plants with an output of 100 kW or more can be required to provide flexibility in the context of congestion management. This reduces the number of systems that, via a market platform, could potentially generate additional income from the provision of grid-friendly flexibility.

Lab chain: Existing solutions in P2P markets are often characterised by individual, specific market and system designs; there is no comprehensive research infrastructure for experimental research on the energy industry. For this reason, a virtual test laboratory was developed that combines user interaction with an open data layer and a blockchain solution by Fraunhofer FOKUS for securitising bids and liabilities. This enables the participants in the experiment to operate simulated systems and to trade on flexibly designed simulated markets. Diverse system and market constellations can thus be examined, providing insights into the design of future P2P markets.

1,000,000 t

CO_2

of potential CO_2 savings per year in the WindNODE region if curtailed wind power amounting to 5 TWh is used in the heating sector through Power-to-Heat (displacement of heat generation in gas boilers).



▲ In the training simulator of a grid control room, researchers observe whether and how the deployment of flexibility from the distribution grids in the control area affects the thermal load of selected lines in the high-voltage grid.

▷ CONCLUSION AND OUTLOOK // Potential for market-based procurement of flexibility

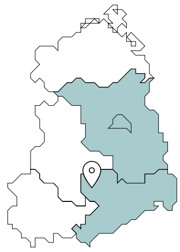
The need for transmission system operators (TSOs) to use a regionalised market platform is significantly reduced due to the planned grid expansion and the extension of the types of systems included in the regulated redispatch as mandated by the NABEG amendment. So far, regulation of congestion management has largely neglected the integration of flexible loads such as classic industrial end consumers, as well as Power-to-X systems. Early identification of this demand-side potential on a market platform could represent added value for grid planning and increase the general security of supply – especially if there are delays in the grid expansion. The possibility of determining local price signals could also trigger an investment dynamic and the associated cost-cutting effects for technologies that are required by the system as part of a comprehensive energy transition. In addition, flexible loads would be able to alleviate the problem of strategic bidding behaviour in consecutive markets, since they usually have structurally different opportunity costs than conventional power plants. If the opportunity costs are considered in a high temporal resolution, it becomes apparent that there is no static merit order of different types of flexibility: instead, a certain range of costs would be expected depending on the intended use, e. g. neighbourhood heat supply. In addition, flexible loads would be able to guarantee CO_2-neutral balancing services in the context of congestion management.

▷ WHAT ARE THE BARRIERS TO THE ENERGY TRANSITION? // Regulatory work must set the right framework

New policies facilitating the rapid expansion of renewable energy sources are urgently required in all sectors! The expansion of wind and solar power systems are currently slowing down, which jeopardises the climate targets for 2030. Only once a high proportion of renewable energy in the system is achieved will price signals indicate the need for flexibility and new business models. There is currently no clear commitment from politicians to a comprehensive energy transition that would be supported by simplified tendering and approval procedures. A sufficiently high CO_2 price could support electricity-based supply concepts in the heating and mobility sectors. Without a strategic preference for green electricity in the form of reduced taxes and surcharges or quotas, gas will remain the benchmark primary energy source in the heating sector for a long time.

SP
5.2b

FOCUS AREA
Activating Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
New Market Design and Efficient Congestion Management

▸ **Funding code**
03SIN540

▸ **Subproject partners**

▷ PROJECT PARTNERS
Institute for Climate Protection, Energy and Mobility e. V. (IKEM)

Institute for Infrastructure and Resources Management of Leipzig University (IIRM)

▷ ASSOCIATED PARTNER
Vattenfall Wasserkraft GmbH

▸ **Contact**
Dr Hendrik Kondziella
T +49 341 9733525
kondziella@wifa.uni-leipzig.de

▸ **Visitor site**
Grid Simulator for Visualisation of Critical Grid States
Mittelstrasse 7
12529 Schönefeld

Registration required

▷ INQUIRIES TO
T +49 30 60086660
info@gridlab.de

For more information
www.gridlab.de
www.uni-leipzig.de

▲ Overview of current blockchain applications in the energy industry from the TU Berlin discussion paper.

The Need for Digital Change

WindNODE subproject 5.3 addressed aspects of digitalisation in the German energy industry. It focused on two major topics: blockchain applications and digital fields of activity for energy companies. It is fair to say that the energy industry is already grappling vigorously with digitalisation issues: from process optimisation to completely digital business models, practices are evolving at high speed.

▷ CHALLENGES AND SOLUTIONS **// Most applications of blockchain technology are in the peer-to-peer domain**

In a discussion paper on blockchain technology in the energy industry, the first step was to develop a methodology for reviewing business models and their compatibility with regard to the applicability of blockchain technology, and the selection of an appropriate blockchain solution. A modular structure based on the technical design of blockchains makes it possible to categorise each building block of the technology and gain a deeper understanding. The second part of the paper presents a holistic market overview (see the above figure) of the current blockchain

‘Similar to the digital evolution of the energy industry value chain into a value network, the WindNODE network is also coming together as a cross-sectoral joint project to create a space in which diverse solutions for the challenges of the energy transition can be developed in a collaborative way.’

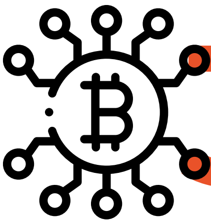
Andreas Corusa
Research Associate
Energy Systems Department,
TU Berlin

applications in the context of the energy industry. There is a notably large number of applications in Europe, especially in Germany, which alone accounts for 32 of the 131 cases observed. Most blockchain applications (37 %) are in the peer-to-peer domain – mainly in digital marketplaces for local trading in renewable electricity.

▷ RESULTS // **From value chain to value network**

An analysis shows that the decarbonisation, decentralisation and digitalisation of the energy system influences traditional business models in all branches of the energy economy. Technologies are deployed in increasingly decentralised ways, leading to a greater need for coordination between individual stakeholders and customers. This means not only that almost all sectors are influenced by the energy transition process, but also that the digital transformation has become an integral part of the energy transition. Solutions based on information and communications technology (ICT) are increasingly finding their way into almost all company activities, giving the ICT sector itself more and more importance.

The merging of the sectors not only makes it more difficult for companies to cope with all of the new kinds of tasks within the value chain; it also creates new and more complex interrelationships. This is particularly evident in newer business models such as virtual power plants. If the business model of a virtual power plant is considered in isolation, it becomes clear that it operates within its own value-added network: it does not merely coordinate the energy flows, but also collects and evaluates large amounts of data. In addition, it offers a number of services and products for different types of customers in different areas of the value chain.



37 %

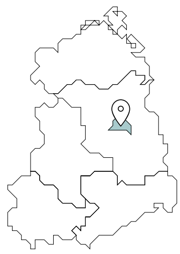
of blockchain applications are in the peer-to-peer domain

▷ CONCLUSION AND OUTLOOK // **Adaptation to change remains a constant**

The implementation of new digital business models against the background of the upcoming smart meter roll-out and the large-scale implementation of intelligent metering systems will show how much success companies in the German energy industry will have in dealing with the transformation. It is a fact that the German energy sector is in a state of great change. Digitalisation and the associated processes are accompanied by a need to change existing business models.

SP 5.3

FOCUS AREA
Digitalising the Energy System



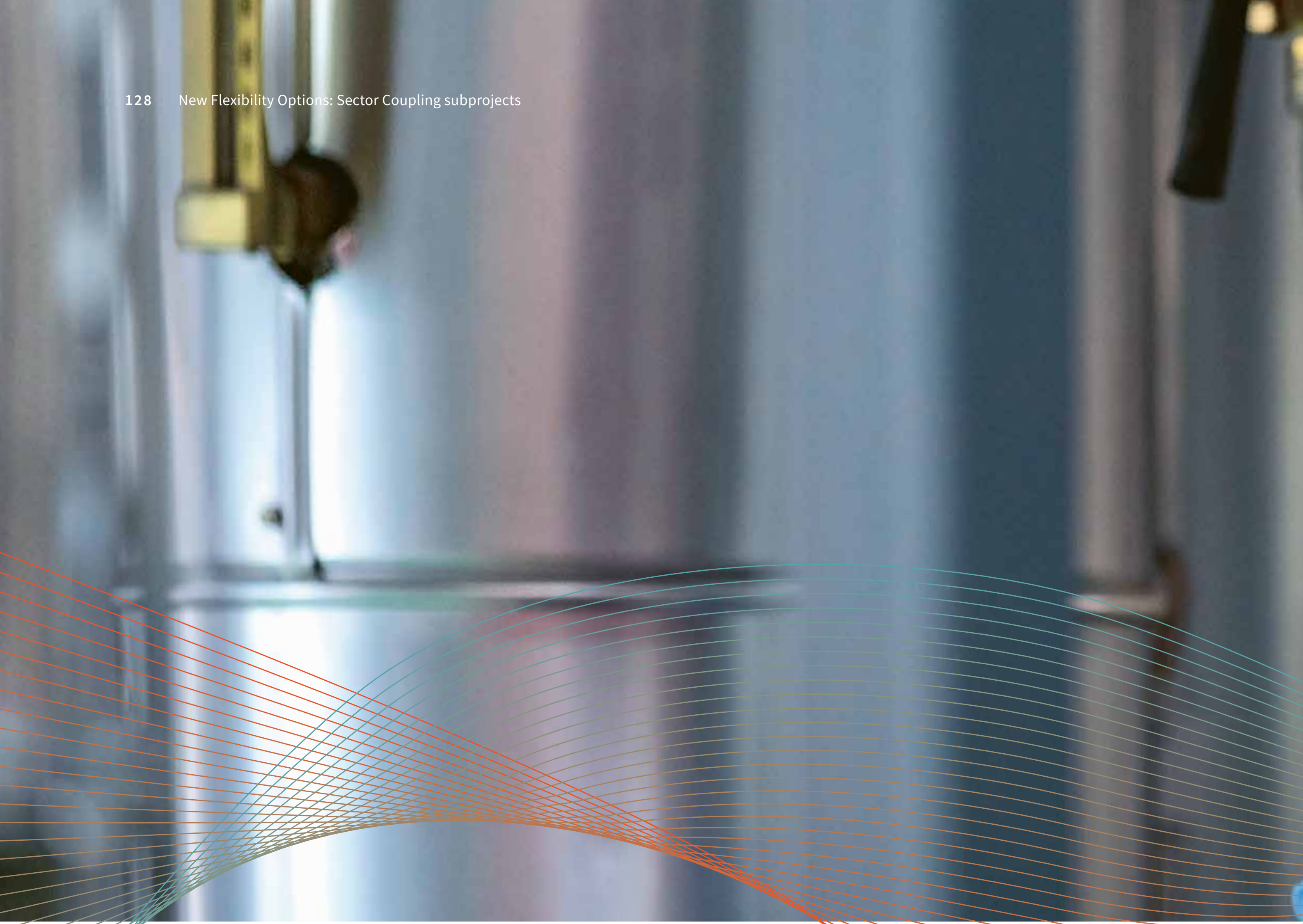
▸ **Title of the subproject**
Business Models in Digital Space

▸ **Funding code**
03SIN537

▸ **Project Partner**
Department of Energy Systems, TU Berlin

▸ **Contact**
Andreas Corusa
andreas.corusa@tu-berlin.de

For more information
www.ensys.tu-berlin.de



Participating partners

Berliner Wasserbetriebe
BMW GROUP
BSR
BVG
eMO
Fernheizwerk Neukölln AG FHW
GASAG SOLUTION+
ILK Dresden
Radeberger Gruppe
SIEMENS
Stadtwerke Hennigsdorf
Stromnetz Berlin
SW FORST
VATTENFALL
WEMAG NETZ GmbH

128 – 153

New Flexibility Options: Sector Coupling

(Functional) storage systems will be important flexibility options in the energy system of the future. They allow for a temporal decoupling of generation and consumption, which benefits the grid and the system as a whole.

In addition to battery storage systems for electromobility, this WindNODE workstream investigates thermal applications such as Power-to-Heat and Power-to-Cold (sector coupling), which demonstrate considerable storage and usage potential, and examines their performance in practical tests. Especially in the area of Power-to-Heat, WindNODE activities range widely in scale – from decentralised small-scale facilities to Europe's largest PtH system with over 100 MW.

Workstream 6 is coordinated by Dr Mathias Safarik (Institute of Air Handling and Refrigeration Dresden) on a voluntary basis.

▲ Berliner Stadtreinigung's fleet of battery-operated utility vehicles.

E-mobility as a Flexible Load on the Electricity Market

Can the controlled charging of a battery-operated vehicle fleet play a role in the energy system as a new flexibility option? Grid operator Stromnetz Berlin has installed 26 controllable e-mobility charging points for Berlin's municipal waste management company, Berliner Stadtreinigung (BSR). In collaboration with ÖKOTEC, BSR developed a prototype solution for controlled charging that allows vehicle batteries to serve as flexible loads. A transferable solution will follow as part of a complementary project.

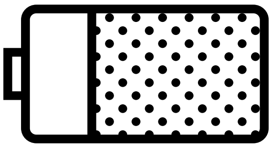
'WindNODE simplified BSR's introduction to electromobility. The results of the reality lab will make it easier for other companies to get started or make the transition as well.'

Christian Heyken
WindNODE Project Manager,
Berliner Stadtreinigung (BSR)

▷ CHALLENGES AND SOLUTIONS **// To what extent can municipal e-vehicle fleets serve as a flexible load?**

In order to keep the power grid stable, flexibility in energy generation and use must be made available – both technically and economically – and brought into alignment. Rather than exploring flexibility options in Power-to-Value systems (subprojects 6.2 and 6.3) or in households (WindNODE workstream 4), BSR examined the potential role of e-mobility as a growing storage technology – especially in municipal and commercial fleets. Thus far, there has been no practical integration of electric vehicles into the energy market as flexible loads.

At the beginning of the project, fused, non-controllable power sockets were the only technology available for charging electric vehicles at BSR. In addition, BSR collected its energy data in 15-minute intervals from the main meter at each property and from each submeter in the charging infrastructure.

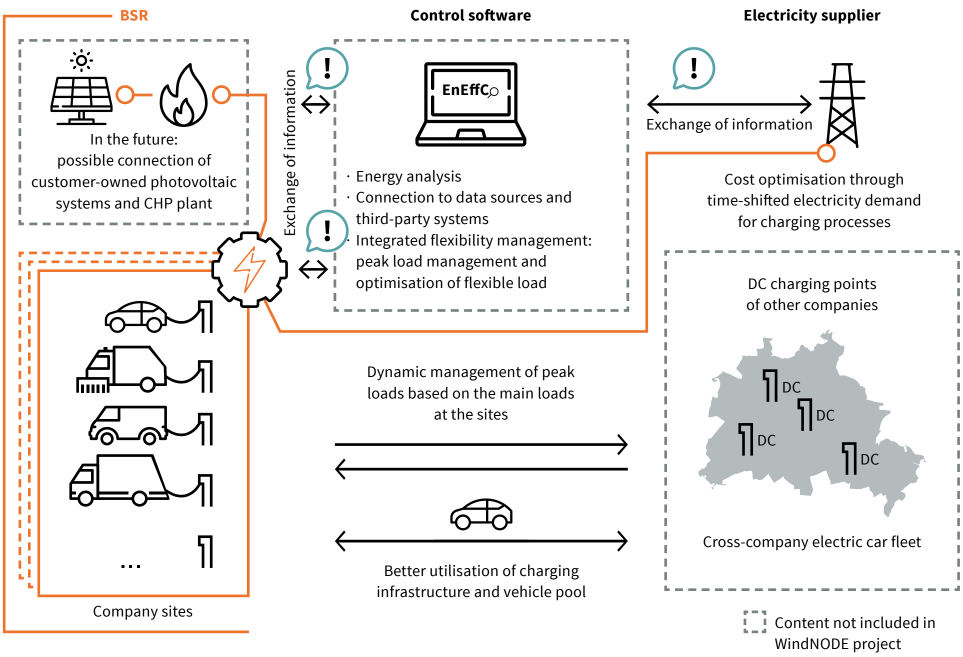


Up to
70%
cheaper charging.

Scenario calculations show a theoretical savings potential of 70 % of the electricity market price.

▷ RESULTS **// BSR is testing energy management optimisation, and the corresponding charging infrastructure, in day-ahead and intraday trading**

First as part of WindNODE, and then as part of other funding projects, BSR installed a total of 85 controllable charging points on the company's properties and continues to push ahead with plans for further expansion. In cooperation with the WindNODE partner ÖKOTEC, BSR developed a prototype that links the e-fleet to the energy market and charges when a high share of renewable energy is available. Based on the results of the project, the best solution to utilise the flexible load and demonstrate intelligent load management proved to be the optimisation of procurement based on market signals in day-ahead and intraday trading. As part of a complementary project, ÖKOTEC tailored the EnEffCo® software to the specific application so that it could serve as a back end for optimisation. In order to manage peak loads while minimising grid fees at the site, it was necessary to install meter technology that could collect data at a higher temporal resolution than before, when the main medium-voltage meter recorded data at 15-minute intervals. The Energiewirtschaftsstelle (an agency for energy-related issues such as procurement in the federal state of Berlin) created a more favourable legal environment by adding a clause to the tender for electricity in Berlin, which allows electricity customers to have separately designated submeters supplied by third parties. Before the end of the project, BSR will also develop a roadmap for further expansion of the charging infrastructure, install a visitor site and evaluate the prototype.



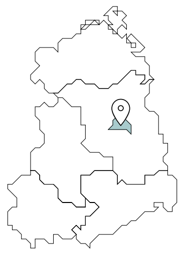
▲ Optimisation of charging costs through time-controlled charging and, in the future, through self-generated electricity. Increasing efficiency through cross-company use of charging stations and vehicle fleet.

▷ CONCLUSION AND OUTLOOK **// Electromobility has potential – if energy suppliers cooperate**

The project has shown that the optimisation of electric vehicle charging on the electricity market is a promising development that could provide not only economic, but also ecological and systemic advantages. Whether this promise is realised, however, will depend on whether electricity suppliers recognise this potential and offer flexible energy supply contracts that acknowledge the flexibility provided by electric vehicle fleets. In addition, it is important to bring the topic of flexible charging to the attention of fleet operators and their suppliers, and potentially even mandate its use.

SP
6.1a
(BSR)

FOCUS AREA
Identifying Flexibility
Activating Flexibility
Digitalising the Energy System



▶ **Title of the subproject**
Electromobility and Battery Storage … Controlled Charging of a Battery-Operated Utility Vehicle Fleet

▶ **Funding code**
03SIN506

▶ **Subproject partners**

▷ PROJECT PARTNERS
Berliner Stadtreinigung AöR

Berliner Wasserbetriebe AöR

▶ **Contact**
Christian Heyken
T +49 307592 2431
Christian.Heyken@bsr.de

▶ **Visitor site**
E-Mobility as a Flexible Load
Ringbahnstraße 96
12103 Berlin-Tempelhof

Open daily

▷ INQUIRIES TO
Christian Heyken
T +49 307592 2431
service@bsr.de

▲ Electric car in the process of charging in one of the BWB's underground car parks.

More Intelligent Charging: Designing More Effective Charging Processes for Electric Vehicles

In the future, Berliner Wasserbetriebe (BWB) will have more grid-connected electric vehicles in its commercial fleet. Growing use of charging infrastructure may increase the utilisation of grid infrastructure at individual company locations, introducing an additional load. Load shifting potentials can help to remedy this situation and relieve some of the burden.

'Berliner Wasserbetriebe electrifies 80 % of its vehicle fleet, accelerating the mobility transition in the public sector. Controlled charging makes charging processes more flexible and adapts them to the generation of renewable energy.'

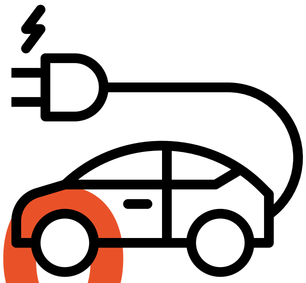
Regina Gnirß
Head of Research and Development,
Berliner Wasserbetriebe AöR

▷ CHALLENGES AND SOLUTIONS // **The problem of uncontrolled charging processes**

The federal state of Berlin aims to reduce the proportion of conventionally powered vehicles in road traffic. As a state-owned enterprise, the Berliner Wasserbetriebe is setting a good example and ushering in the transition in public transport: BWB will gradually convert 80 % of its vehicle fleet to electric vehicles. This will inevitably place an additional strain on the distribution grid. Increased load peaks and phase imbalance can destablise the equilibrium in the distribution grid, and electro-technical control systems must be implemented to manage local loads from the use of charging infrastructure. This makes controlled charging even more important: most electric vehicles are connected to the grid after work, and controlled charging can prevent overburdening the grid.

▷ RESULTS // **Identifying flexibility**

Identifying load shifting potentials requires comprehensive data collection. The charging infrastructure is fully networked at all locations, which allows for a central display that reflects the current status. This is made possible by bidirectional communication between all charging points and a back-end system. The bidirectional connection enables information to be transmitted from charging stations to the back end and consolidated there, while at the same time permitting the charging infrastructure to be controlled by the back end.



>170 electric vehicles by the end of 2020

SP 6.1b (BWB)

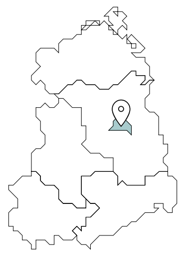
FOCUS AREA
Identifying Flexibility
Digitalising the Energy System

A concept for intelligent shifting of load demand due to the use of charging infrastructure has already been developed for one location as a prototype; in this case, however, data were collected manually. Now, with fully networked components and automated data collection, it is possible to analyse load shifting potentials at all sites that service electric vehicles. Using the now-completed across-the-board shifting of load demand to periods in which loads are typically at a minimum (e. g. at night) can already help to relieve the strain on the grid. In order to utilise the full potential of load management, however, intelligent and dynamic load shifting must be tested. This will require the current demand from the charging infrastructure to be communicated at all times and accommodated in ways that benefit the grid.

▷ CONCLUSION AND OUTLOOK // **Future-proofing mobility**

An analysis conducted during the WindNODE project identified a flexibility potential of over 700 kW in the existing charging infrastructure for the BWB vehicle fleet. This potential can be tapped by adjusting charging processes to facilitate smooth operation of the grid. The expansion of charging infrastructure and the acquisition of heavy-duty utility vehicles will further increase this potential. Cooperation with other municipal companies at the InfraLab site has already led to new developments, including a joint project that tests concepts for a shared vehicle pool.

▼ In order to analyse and control the BWB's charging processes, the flow of information from the charging infrastructure must be digitalised.



▶ **Title of the subproject**
Electromobility and Battery Storage … Controlled Charging of a Battery-Operated Utility Vehicle Fleet

▶ **Funding code**
03SIN550

▶ **Subproject partners**

▷ PROJECT PARTNERS
Berliner Stadtreinigung AöR

Berliner Wasserbetriebe AöR

▶ **Contact**
Berliner Wasserbetriebe
Neue Jüdenstraße 1
10179 Berlin

Regina Gnirß
T +49 3086441628
regina.gnirss@bwb.de

▶ **Visitor site**
InfraLab on the EUREF Campus
Torgauer Straße 15 B
10829 Berlin

By appointment

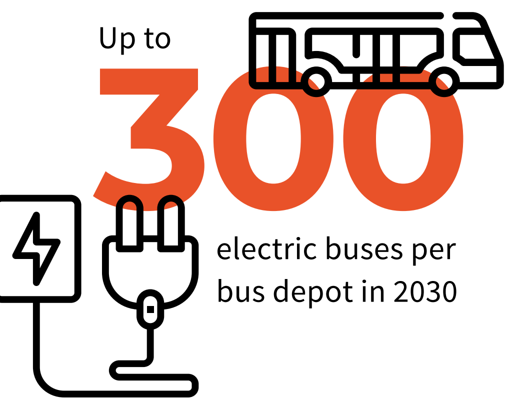
▷ INQUIRIES TO
info@infralab.berlin

For more information
www.bwb.de

▲ Electric bus at a BVG bus depot in Berlin.

Meeting the Challenges of the Mobility and Energy Transition

A variety of charging management systems for electric vehicle fleets are being developed and tested in real-world conditions. This calls for forward-looking concepts that faciliate grid-friendly provision of green electricity for a fully electrified public transport system. Temporary energy storage systems will enable fleet operators to shave critical load peaks. For Berlin's main public transport company, Berliner Verkehrsbetriebe (BVG), this will affect between 100 and 300 electric buses per depot.



▷ CHALLENGES AND SOLUTIONS // **Electromobility has significant potential to optimise energy management**

The use of 'second-life batteries' for temporary storage reduces cost-intensive peak loads in the energy supply. Storage systems and electric vehicles can be deployed in response to market incentives for load shifting, for example to enable the effective use of excess power from renewable energy sources. In contrast, there are few options to shift loads for buildings, workshops and bus washes.

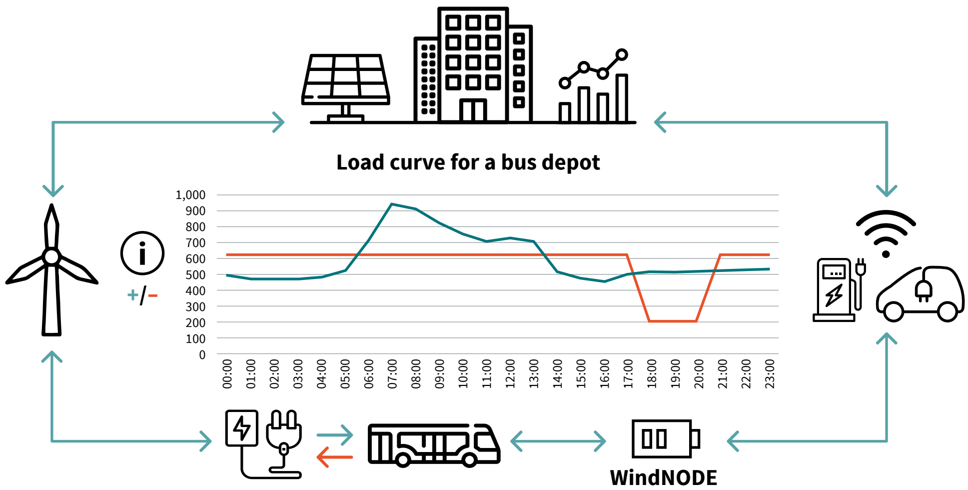
Because electric vehicles are idle for long periods, charging management has particularly high load-shifting potential. The increased range of electric vehicles used in the internal fleet provides additional opportunities. Second-life storage systems remain in limited supply today, which made it a challenge to procure and integrate them as part of this project.

> 'In the shift to electric mobility, the energy transition and mobility transition go hand in hand. We just have to learn how to utilise the flexibility potential of electric mobility. There has not yet been a market ramp-up of e-mobility – but that will take care of itself when fleet operators realise that electric mobility has not only ecological, but also significant economic benefits.'

Heinrich Coenen
Fleet Manager,
BVG

▷ RESULTS // **Complex interplay of individual systems**

The initial construction of the charging infrastructure, including the required grid connection, was completed in 2019. To avoid the need for expanding the upstream power grid, no power is delivered to the charging infrastructure between 6 pm and 8 pm. This is the period in which household electricity consumption in Berlin reaches its highest levels and power grids already experience a peak load. The battery storage system is used to compensate for this, so that urgent charging needs can be met during this time. This allows previously static limits on loads to become more dynamic. To achieve this result, secure data from the power grid operator must be made available to provide information on the current grid load and any over- or undersupply of green electricity. The calculated scenarios show that it is possible to integrate electric vehicle fleets into the system in a way that decreases the need for power grid expansion. Temporary storage systems can be used to reduce peak loads relative to the status quo and therefore partially compensate for variations already.

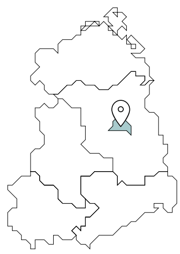


▲ Interrelationships between bus depot management, intelligent charging infrastructure, temporary storage, vehicles with bidirectional charging capabilities, and information from the upstream power grid.

▷ CONCLUSION AND OUTLOOK // **Looking ahead to depot planning 2030**

In the future, a reliable supply of spare parts in the form of traction batteries will be crucial, especially in areas that are critical to the system. This means that not only second-life, but also new batteries will become important as resources for stationary temporary energy storage: manufacturers will have to guarantee sufficient stock and immediate delivery of new batteries. Thus, new opportunities for cooperation between manufacturers and customers should be developed. New batteries can be stored under optimal conditions at consumers with high energy demands while serving a temporary purpose in a stationary energy storage. This mixed use of both new and second-life batteries as temporary energy storage has to be taken into account when envisioning the 'bus depot 2030' with up to 300 electric buses.

SP **6.1b** | FOCUS AREA Identifying Flexibility



▸ **Title of the subproject**
Electromobility and Battery Storage … Grid and System-Friendly Charging Strategies for Battery-Powered Business in Public Transportation

▸ **Funding code**
03SIN549

▸ **Subproject partner**

▷ PROJECT PARTNER
Berliner Verkehrsbetriebe AöR

▸ **Contact**
Berliner Verkehrsbetriebe AöR
Holzmarktstraße 15–17
10179 Berlin

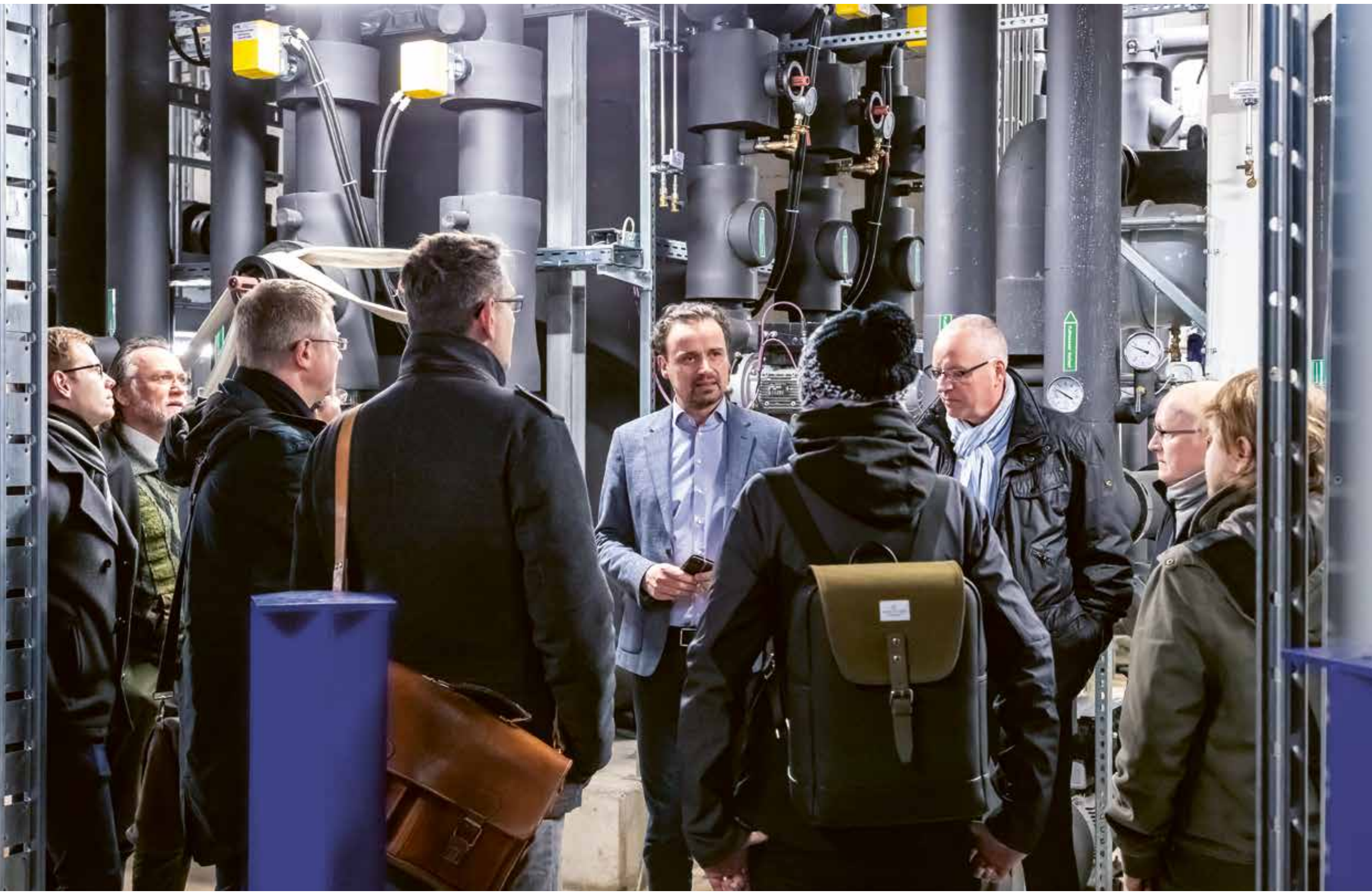
Heinrich Cohen
T +49 30 25627021
heinrich.coenen@bvg.de

▸ **Visitor site**
Indira-Gandhi-Straße Bus Depot
Indira-Gandhi-Straße 98
13053 Berlin

Registration required

▷ INQUIRIES TO
info@bvg.de

For more information
www.bvg.de



▲ Visit to the vacuum ice cold storage unit in Göttingen.

Pumpable Ice – Efficient, Powerful and Flexible

Refrigeration is not only used for air conditioning, but also to produce and store food as well as for cooling in the context of industrial processes. This cooling is often required in large quantities and all year round and is generated with electricity. The ILK Dresden (Institute of Air Handling and Refrigeration) is developing and demonstrating a new type of cold storage for industrial refrigeration systems, enabling this to take place efficiently on a large scale. This makes it possible to store even large cold quantities efficiently. In this way the cold can be generated when the sun and wind provide enough electricity.

‘For a stable energy supply with a high proportion of renewable energy, intelligent storage concepts are necessary to compensate for their volatility. The WindNODE project has developed solutions for this. The vacuum ice slurry technology makes its contribution to more renewable energy in the grid and high security of supply for the industrial cooling and air-conditioning sectors.’

Christine Tillmann
Research Associate,
ILK Dresden

▷ CHALLENGES AND SOLUTIONS **// A new form of cold storage**

Up to now, the possibilities for cold storage in industrial cooling facilities such as cold storage depots, breweries or dairies have been limited. Conventional cold storage solutions such as ice banks or cold water storage units cannot be used for temperature reasons or are difficult to integrate into the relevant systems. Furthermore, temporarily cooling goods below the temperature nominally required is only possible with some products. Moreover, very little energy can be stored in this way.

Therefore, WindNODE is adopting a new approach: a pumpable water-ice mixture for cold storage. Here, ice slurry is produced using the highly efficient and powerful vacuum ice process, and water is evaporated at a very low pressure of around 6 mbar near its triple point. At the triple point, water can evaporate (boil) and freeze at the same time. The evaporation process is continuously maintained by drawing off the water vapour (refrigerant), so that ice crystals form on the water's surface. The freezing water molecules provide the energy required to evaporate other water molecules. This creates a water-ice mixture in the evaporator, which is then transported to a storage container.

This concept means that any amount of cold can be stored with a high energy density at an affordable price and used flexibly for cooling if required. In addition, the ice slurry can be used as a coolant, i. e. to transport energy. Here, too, it excels as it has a significantly higher energy density than cold water or water-glycol mixtures.

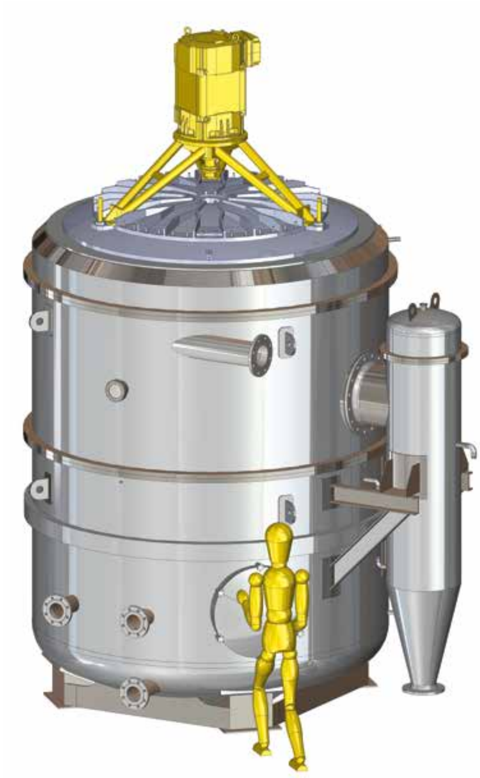
When used in industrial cooling applications, vacuum ice slurry technology, which has now been tested in some initial applications in the air-conditioning segment, must be adjusted in line with the lower temperatures in such applications. This requires shifting the freezing point down to –5 °C. This is achieved with additives such as salt. However, the lower the freezing temperature, the lower the evaporation pressure and the vapour density, which at 0 °C is already down to almost one 300th of the density of air.

▲ Figure 1:
Overview of the 90-m^3 ice slurry storage unit.

The loaded ice slurry storage unit is enough to air-condition

25,000 m^2

of typical office space for a week.



▲ Figure 2: Computer-aided design (CAD) model of the ice slurry generator for freezing temperatures down to – 5 °C.

◂ Figure 3: Vacuum ice cold storage unit for supplying cold to a laboratory building.

For the steam turbo compressor, which drives the process of ice formation, the lower pressure and vapour density pose a major challenge. In addition, however, other sub-components, such as the direct evaporator, had to be adjusted in line with the new operating conditions and the significantly increased power requirement.

▷ RESULTS // **Analyse, develop and demonstrate**

As a first step, to adjust the melting temperature of the ice in line with the relevant requirements, various additives were investigated in a test facility.

750 %

Ice slurry can be used to store seven to eight times as much cold as the same volume of cold water.

The technological requirements for flexible cold storage in large and often extensive refrigeration systems were analysed in collaboration with the Radeberger Gruppe (Radeberger Group), an associated partner of the WindNODE project. Based on this, a number of integration variants of the ice slurry storage unit as well as different options for the provision of cold for ice generation were designed. Much importance was attached to minimising the impact on the existing technology to avoid compromising security of supply.

Figure 4 shows a variant which is suitable for typical refrigeration systems (mostly based on the refrigerant ammonia) in breweries and which has the lowest investment costs. As an alternative to connecting to the existing separator, the total cooling output can be increased with an additional cold water generator. This variant is suitable, among other things, for making use of (storing) electricity from PV generators, as it is often especially abundant at times when the existing cooling system is already under great strain due to high ambient temperatures.

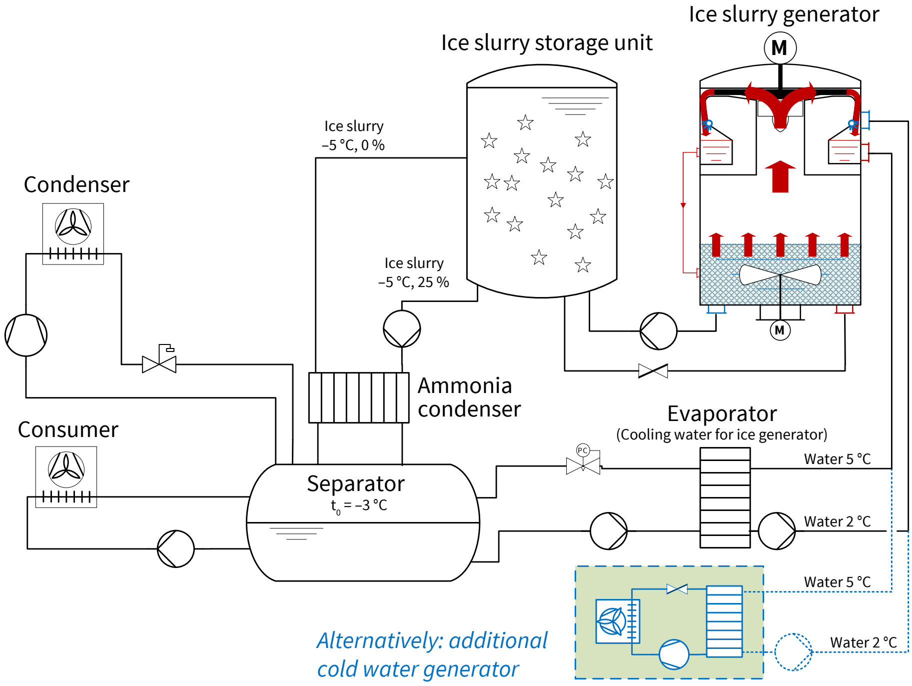
Instead of the electricity-driven cold water generator in Figure 4, an absorption cooling unit driven by waste heat can also provide the cold water required for ice generation. This means that combined heat and power (CHP) stations can be made more flexible and at the same time a high level of energy efficiency can be ensured.

The core component of the vacuum ice generator is the steam turbo compressor. It was adjusted in line with the changed operating conditions in extensive fluid dynamic design and simulation calculations.

In addition, other components were dimensioned and designed, and a vibration analysis of the whole system was carried out. These findings fed directly into the construction of a 400-kW vacuum ice system, which is used to optimise the cooling supply system of a modern large-scale data centre. The simulation calculations were validated with this intermediate step. The results of the tests were taken into account when designing the WindNODE sub-zero ice slurry generator with a maximum ice generation capacity of 500 kW (Figure 2). This demonstrator and the assembly with a 90-m³ ice slurry storage unit (see Figure 1) will be erected in the last year of the project.

▷ CONCLUSION AND OUTLOOK **// Dare to innovate**

The objectives of the subproject were achieved. The next step is to integrate demonstrators into actual industrial cooling systems to gather vital practical experience and to win over prospective users. Besides an appropriate (research funding) policy framework, courageous sponsors and decision-makers in the industry are needed that are ready to try new technologies and pave the way for innovations.



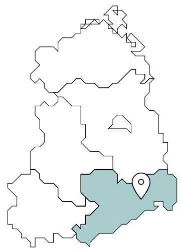
▲ Figure 4: Integration of an ice slurry cold storage unit into an industrial cooling system with direct evaporation without additional cooling generator or alternatively with an additional cold water generator.

▷ WHAT IS HOLDING BACK THE ENERGY TRANSITION?

Discussions with colleagues and potential users show that cold storage as a technology has a future. However, the appropriate conditions are not in place in Germany to achieve the short depreciation periods for cold storage units that companies expect. Pricing structures in other countries and the need for cooling in warm regions provide more favourable conditions. However, to make the move abroad, (more) references in Germany, venture capital and implementation partners are required. A hardware-intensive technology, developed at an independent research institute, unfortunately seems to fall through the cracks of existing public funding opportunities in Germany.

SP 6.2

FOCUS AREA
Identifying Flexibility
Activating Flexibility



▶ **Title of the subproject**
Power-to-Cold (PtC) Applications on an Industrial Scale

▶ **Funding code**
03SIN520

▶ **Subproject partners**

▷ PROJECT PARTNER
Institut für Luft- und Kältetechnik gGmbH (Institute of Air Handling and Refrigeration) (ILK Dresden)

▷ ASSOCIATED PARTNER
Radeberger Gruppe KG

▶ **Contact**
Dr Mathias Safarik
T +49 351 4081-701
mathias.safarik@ilkdresden.de

▶ **Visitor site**
Ice Slurry Storage at ILK Dresden
Bertolt-Brecht-Allee 20
01309 Dresden

Registration required

▷ INQUIRIES TO
Dr Mathias Safarik
T +49 351 4081-701
mathias.safarik@ilkdresden.de

More information at
www.ilkdresden.de/en/

▲ Technical approval and first testing of the circuits of the first intelligent metering system with control box, which is switching the operating mode of a heat pump.

Consumer-oriented, Flexible Heat Generation as a Grid-friendly Measure

The WindNODE project ‘Wind Heating Instead of Night Storage Heaters’ is making consumer loads in the grid more flexible using individual Power-to-Heat demonstrators. Besides analysing the technical and economic requirements for making these systems more flexible, the installation and testing of ‘smart’ equipment in a specific use case is part of the work. The project results serve as blueprints for using flexible electrical heating systems as local loads in the grid: this can increase the local consumption of renewable energy, reduce transmission costs and alleviate grid congestion.

▷ CHALLENGES AND SOLUTIONS // **Use of Power-to-Heat systems for flexible consumption control**

Grid bottlenecks and feed-in management are increasingly common in situations where high local renewable power generation is combined with low local consumption. Solving this problem and enabling a high level of renewable feed-in usually involves grid expansion measures. A possible second approach could be to increase consumer loads at times of high feed-in, also called demand-side management (DSM). Achieving demand-side flexibility is possible, for example, by appropriate sector coupling measures.

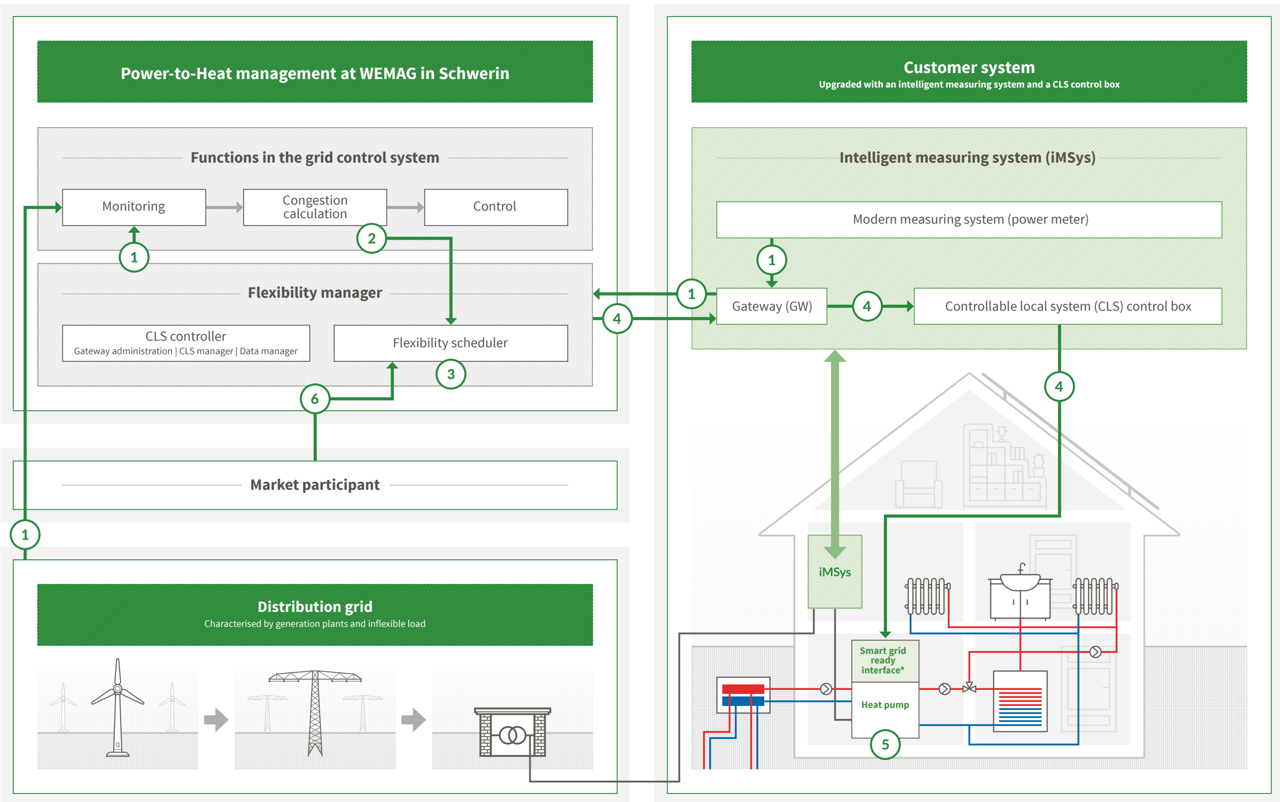
There are existing concepts for coupling the electricity and heat sectors involving night storage heaters (NSHs) and heat pumps. These concepts use time switches to control the point in time used for storing heat, based on lower electricity rates that are offered during fixed time windows, often between 10 pm and 6 am.

The problem with this mechanism is the rigid nature of the time window which cannot be adapted to volatile electricity generation from renewable sources. Using appropriate modern technology in the form of intelligent measuring systems (iMSys) with remote control capabilities (Controllable Local System, or CLS), it is now possible to increase the flexibility of night storage heaters and heat pumps. By implementing an interface into the grid operator`s control system, these assets can even be used in ways that benefit the grid (see Figure 1).

2.2 GW

of generation capacity were curtailed in 2019 to eliminate bottlenecks in the transmission and distribution grids in the WEMAG Netz GmbH area.

▼ Figure 1: Schematic representation of the management of a Power-to-Heat system at the customer's premises by the grid operator.



1 Network control centre monitors the network
→ Receives real measurement data
→ Receives available flexibility potential from the flexible load

2 Network control centre calculates possible grid congestion in advance (forecasting)

3 Development of dispatch schedule for flexible loads to manage grid congestion

4 Activation of the flexibility via iMSys

5 Grid congestion is alleviated with the help of flexibility

6 Potential market participants have access to flexibility options

* Interface to control heat pump

In addition to overcoming the technical challenges, these new mechanisms for demand-side flexibility have to conform to the regulatory framework while also meeting requirements arising from grid operations. Large-scale mobilisation of the existing potential in the form of heat pumps and night storage heaters requires better economic and regulatory incentives. These incentives must target not only the investment costs into new heating systems not based on fossil fuels, but also the annual operating costs.

‘The grid is barely growing fast enough to keep pace with the expansion of renewable energy sources. Grid operators therefore continue to struggle with the management of temporary peaks in power generation. Energy storage should be more strongly considered as a way to optimise grid utilisation and this should be reflected in innovative and economically attractive solutions for grid customers.’

Andreas Haak
Managing Director,
WEMAG Netz GmbH

35 MW

of flexible technical Power-to-Heat potential is forecast in the grid area by 2035

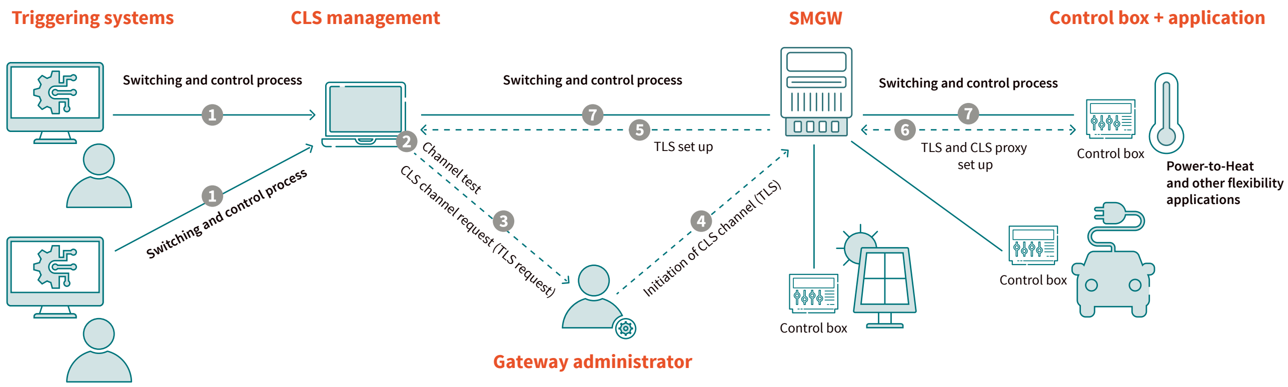
▷ RESULTS // **Deployment of intelligent measuring systems and control boxes**

Technical implementation of the demonstrators

Once the various control systems are successfully tested, WEMAG Netz GmbH relies on the use of a standardised intelligent measuring system in conjunction with a CLS control box. For this purpose, the gateway and the control box are mounted on the three-point meter as a ‘piggyback solution’ (see Figure 3). Communication with the gateway takes place via radio. The control box is linked to the charge control system of a night storage heater or to the control system of a heat pump.

The schedules are currently being created manually in the grid operator's control centre based on weather forecasts and expected renewable power feed-in quantities. Each schedule is loaded onto the corresponding CLS control box via the provided CLS management system. This takes place according to the communication scheme in Figure 2. The CLS box thus controls the operating parameters of the connected flexible heating system depending on the amount of electricity available in the grid.

A first demonstrator has been built. This required an almost 25-year-old oil heating system to be replaced with a modern brine-water heat pump and buffer storage tank of suitable size, as well as the installation of an intelligent measuring system including a CLS control box. The system was then used to test and evaluate different operating schedules as well as their effect on the grid.



▲ Figure 2: Sequence of the switching and control process.

SMGW – Smart meter gateway
TLS – Transport layer system
CLS – Controllable local system

7,000

intelligent measuring systems with control boxes must be installed by 2035 in order to control the 35 MW of flexibility potential

◂ Figure 3: Integrated intelligent measuring system with control box for a heat pump at the customer's premises.

SP 6.3a

FOCUS AREA
Identifying Flexibility
Digitalising the Energy System

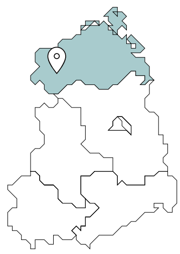
Economic and regulatory assessment of the demonstrator
An analysis of the economic framework shows that there are currently few incentives to invest in a brine-water heat pump due to the high installation and acquisition costs: the alternatives, fossil heating systems and especially condensing boilers, are still cheaper. The subsidies that are currently available do not provide sufficient incentives to invest. However, other heat pump systems (especially air-source heat pumps) have lower acquisition costs and, in combination with the existing subsidy options, already represent a feasible alternative to fossil heating systems.

Compared to fossil fuels, electricity is currently too expensive to incentivise switching to heat pumps and night storage heaters. This is mainly due to the large regulated part of the electricity price (EEG surcharge, taxes, grid fees, etc.). In addition, the current electricity pricing models are too rigid and do not offer economic incentives for flexible behaviour to the end customer.

▷ CONCLUSION AND OUTLOOK **// Interaction between market and grid in a regulated environment**
The next focus is on automating the creation of flexible schedules, on their integration into the grid control system and on the standardised communication with the new intelligent measuring systems. New demonstrators and pilot systems are planned in order to further examine the effects on the WEMAG grid. New market designs and electricity rate models are being developed so that end customers have an incentive to move from fossil fuel-based heating systems to electric heat pumps. This helps mobilising the existing Power-to-Heat potential in the WEMAG grid area.

These studies are accompanied by an analysis of the current regulatory framework and the definition of political and regulatory recommendations for action (including touching § 14a of the German Energy Industry Act, EnWG). This will allow the future relationship between balancing group responsible party and energy suppliers to be redefined and recreated.

Besides the construction of new demonstrators, WEMAG is planning a visitor site. Here, prospective customers can learn about flexible energy consumption by way of a meter cabinet with modern control equipment and an accompanying information panel.



▸ **Title of the subproject**
PtH (Power-to-Heat) Applications for … Distributed Small-Scale Systems – Wind Storage Instead of Night Storage Heaters

▸ **Funding code**
03SIN544

▸ **Subproject partner**

▷ PROJECT PARTNER
WEMAG Netz GmbH

▸ **Contact**
Tim Stieger
Obotritenring 40
19053 Schwerin
tim.stieger@wemag-netz.de

▸ **Visitor site**
Demonstrator for Remote-Controlled Operation of Flexible Power-to-Heat Consumer Appliances
Schaalsee Biosphere Reserve Information Centre
Wittenburger Chaussee 13
19246 Zarrentin am Schaalsee

▷ INQUIRIES TO
kontakt@wemag-netz.de

For more information
www.wemag-netz.de

▲ A visitor site for the energy transition – Germany's first PtH/PtC plant is located in the EUREF Energy Workshop by GASAG Solution Plus.

Carbon-neutral District Supply in the 21st Century

Without a change in the way we deal with heat, there will be no energy transition. This is why we have integrated the first combined Power-to-Heat / Power-to-Cold (PtH / PtC) plant in Germany into an existing supply system, converting excess electricity from wind and solar power into heat and cold. The highly flexible EUREF Energy Workshop by GASAG Solution Plus provides an intelligent, carbon-neutral, fully automated and economical district supply.

▷ CHALLENGES AND SOLUTIONS // **Efficient district supply combined with carbon neutrality**

Renewable power has undergone a rapid expansion in recent years. Experts agree that the energy transition will also have to involve heat and cold applications, however. The power consumed to heat and cool buildings plays a decisive role in the use and expansion of renewable wind and solar power. The keyword is sector coupling: electricity is converted into thermal energy, which can in turn be stored in dedicated storage facilities, heat networks and, in principle, decentralised within buildings. These ideas are tested in the framework of WindNODE at the EUREF Campus in Berlin-Schöneberg. In addition to being an office district with many well-known companies and up-and-coming start-ups, this is a place where the power grid intersects with the local district heating and cooling grid. Today, in the EUREF Energy Workshop by GASAG Solution Plus, we are showing that the efficient interaction of various energy converters and forecast-based operating modes makes it possible to have a climate-neutral energy supply at the same price as conventional energy concepts.

In the framework of this project, heat generation takes place with a large combined heat and power (CHP) plant that runs on biomethane, as well as two other CHP units, two low-temperature gas boilers for peak loads and one electric boiler. This diversity of energy converters enables us to choose between different operating modes between power generation and consumption while generating heat. The biomethane CHP plant is supplied by biomethane from GASAG Bio-Erdgas Schwedt, allowing a fixed remuneration under the German Renewable Energy Act (EEG): this is an important part of what makes the efficient and climate-friendly energy supply possible in the EUREF Campus. Cooling is provided by two vapour-compression refrigeration machines powered by green electricity with the option of free cooling, i.e. the use of cold outside air for more efficient refrigeration.

A unique feature of the plant is Germany's first PtH/PtC storage system, which comprises two storage tanks with a capacity of 22 m^3 that are hydraulically designed in a way that makes it possible to determine individually for each tank whether it should be used to store heat or cold.

This flexibility and the number of energy converters gives us the opportunity to determine the optimal sequence for their use every 15 minutes, based on market and weather forecasts. The quantities of electricity needed to operate the refrigeration compression machines can be procured in advance on the day-ahead market, and there is further potential for optimisation on the intraday market. The extent to which known uncertainties can be incorporated into forecasts for the management of storage facilities was also tested here in partnership with the Leibniz University Hannover.

0 g CO_2

is the certified net amount of CO_2 emissions produced by the EUREF Energy Workshop by GASAG Solution Plus.

5

different machine learning techniques are used for the forecasting.

▶ More than 1,700 guests have attended presentations at the eight multimedia stations of the energy centre in 2019 to learn more about our technology.

‘A decentralised energy transition will only be possible if we deploy sector coupling and digitalisation. Smart, forecast-steered energy systems such as this flagship project and visitor site of the energy transition, which increase flexibility potential and contribute to decarbonisation, will be instrumental in shaping the future of the energy industry.’

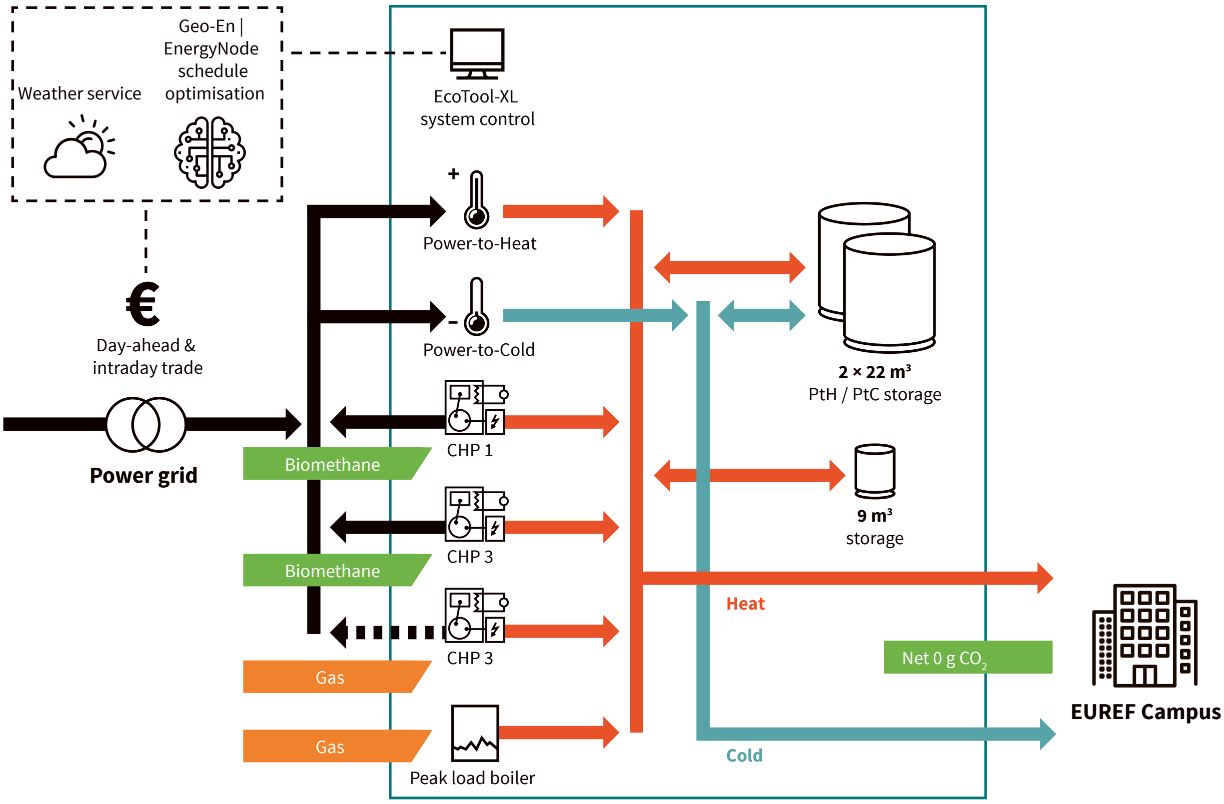
Gunnar Wilhelm
Managing Director,
GASAG Solution Plus GmbH

▷ RESULTS // **The keys of the project**

There are two challenges that come to the fore among those encountered in this WindNODE subproject. First, there is the aim to design and build a plant that could supply the office district EUREF Campus with power in a carbon-neutral way and at the same cost as conventional energy. Second, there is the goal to design a smart control system for the aggregates with a trading connection while achieving full automation and guaranteeing security of supply during operation. The large number of energy converters used means there are many types of prioritisation to explore, offering solid economic and climate-related optimisation potential. Contrary to original assumptions, the project showed that it was optimal to store cold in both storage facilities with vapour-compression refrigeration capacity throughout most of the year, as there is a data centre on the EUREF Campus that requires almost constant cooling. Like other WindNODE partners with PtH plants, we had originally expected more from the electricity balancing market when we submitted our application a few years ago, and are now instead focusing on the intraday market.

A key component of the project was staying on top of the automation technology throughout the process chain – from data generation at the sensor to the automation of forecast generation and schedule optimisation. The higher-level smart control of the energy system, with all the relevant interface coordination, was developed within another research project (funding code 1137-B5-O) by Geo-En Energy Technologies GmbH, which is also a subsidiary of the GASAG Group. The Geo-En | EnergyNode IT solution creates a digital fingerprint of all consumers through a self-learning process based on historical measurement and weather data, which then enables a demand forecast to be made using current weather forecasts. To meet demand, a stochastic optimisation algorithm is used to calculate and transfer to the control system the best possible schedule, while taking into account current market data.

▼ Schematic diagram of the EUREF Energy Workshop by GASAG Solution Plus – all essential components and their heat, cold, electricity and data links



▲ The energy supply of the 5.5-hectare EUREF Campus is already meeting the German government's climate action goals for 2050.

▷ CONCLUSION AND OUTLOOK // **Transferring the results**

The idea behind these research projects is, of course, also to test products for the energy supply of the future. The EUREF Energy Workshop by GASAG Solution Plus will continue to be a visitor site where the energy transition can be experienced up close, even after the end of the project, and will continue to supply the EUREF Campus with carbon-neutral energy. Its most exciting components are the in-depth insights into the use of machine learning and the efficient operation of thermal converters in sector coupling under volatile market conditions. The transfer of the knowledge gained to other projects and fields of application has already begun. We assume that electricity market prices as well as price volatility will continue to increase due to the increases in renewable power being fed into the energy grid, and that this will in turn lead to a further rise in the profitability of flexible plants of this type. Decreasing the high taxes and levies that end consumers have to pay when buying electricity, would give a further much-needed boost to the economic efficiency of projects such as the EUREF Energy Workshop by GASAG Solution Plus and thus also indirectly contribute to a reduction in CO_2 emissions.

▷ WHAT IS HOLDING BACK THE ENERGY TRANSITION?

Ensuring more flexibility and a comprehensive integration of more renewable power requires more economic incentives. To increase the flexibility of consumers in the energy system, there needs to be an orientation towards electricity market prices.

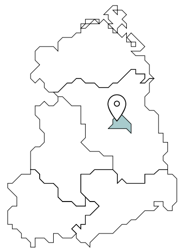
Unfortunately, the price signals in the electricity market have not yet reached regular, non-energy-intensive consumers. Furthermore, they are overshadowed by state-induced rigid and regulated electricity price components, which account for about three quarters of the total electricity price. A reduction in, and, if necessary, increased flexibility of, these components could encourage flexible use of more renewable energy.

‘A key component of the project was staying on top of the automation technology throughout the process chain – from data generation at the sensor and the control signal to the automated combination of various machine learning technologies for the forecasting of heat and cooling loads and the associated schedule optimisation.’

Dr Michael Rath
WindNODE Project Manager,
GASAG Solution Plus GmbH

SP **6.3c**

FOCUS AREA
Activating Flexibility



▸ **Title of the subproject**
PtH (Power-to-Heat) Applications for … Supplying the EUREF-Campus with Combined PtH/PtC

▸ **Funding code**
03SIN515

▸ **Contact**
GASAG Solution Plus GmbH
T +49 30 78727872
solution@gasag.de

▸ **Visitor site**
Energy Workshop on the EUREF Campus by GASAG Solution Plus
EUREF-Campus 1 – 25
10829 Berlin

Registration required

▷ INQUIRIES TO
T +49 30 78727872
solution@gasag.de

For more information
www.energiewende-erleben.de
www.gasag-solution.de

▲ Level 1 of the Power-to-District-Heating plant; view of the heads of the electrodes and a draining group.

Using Power instead of Curtailing It – Wind and Solar Power in the Berlin District Heating Supply

As part of WindNODE, Vattenfall has conducted research and practical tests to investigate how a 120 MW Power-to-District-Heating plant at the site of the Reuter West combined heat and power (CHP) plant can use surplus wind and solar energy from the surrounding area to supply up to 30,000 Berlin households in the winter months and up to 300,000 households in the summer months from 2019 onwards. The project thus contributes to the reduction of fossil fuels in heat generation. The focus is on integrating surplus renewable energy into the district heating supply through innovative strategies for demand-side management and a coordinated response to grid congestion management.

Power-to-District-Heating is a key technology for the integration of renewable energy into Berlin's district heating system. Vattenfall constructed the largest Power-to-District-Heating plant in Europe as part of its strategy to phase out the use of hard coal in Germany's capital completely by 2030. By decommissioning the Reuter C hard coal unit in 2019, the company has already reached an important milestone in its climate agreement with the federal state of Berlin.

With a thermal output of 120 MW, the Power-to-District-Heating plant at the Reuter West site will be the largest of its kind in Europe. During the heating period, it will be able to generate district heating from electricity for over 30,000 Berlin households.

The Power-to-District-Heating plant will provide Berlin with a valuable tool for renewable energy integration. If a large amount of renewable electricity is available, the plant will use it to generate environmentally friendly district heating, eliminating up to 5,000 tonnes of carbon dioxide emissions per year. The renewable energy used for this purpose is equivalent to approximately 10 % of Berlin's total electricity requirements in summer – or the energy demand of 750,000 refrigerators.

This newly commissioned Power-to-District-Heating plant is a hybrid facility that is not only capable of converting renewable electricity into 'green district heating'. It also has a grid-friendly effect: by displacing conventionally generated heat, it allows the CHP plant to produce less heat and less power. This, in turn, means less additional electricity fed into the grid during times of high renewable feed-in.

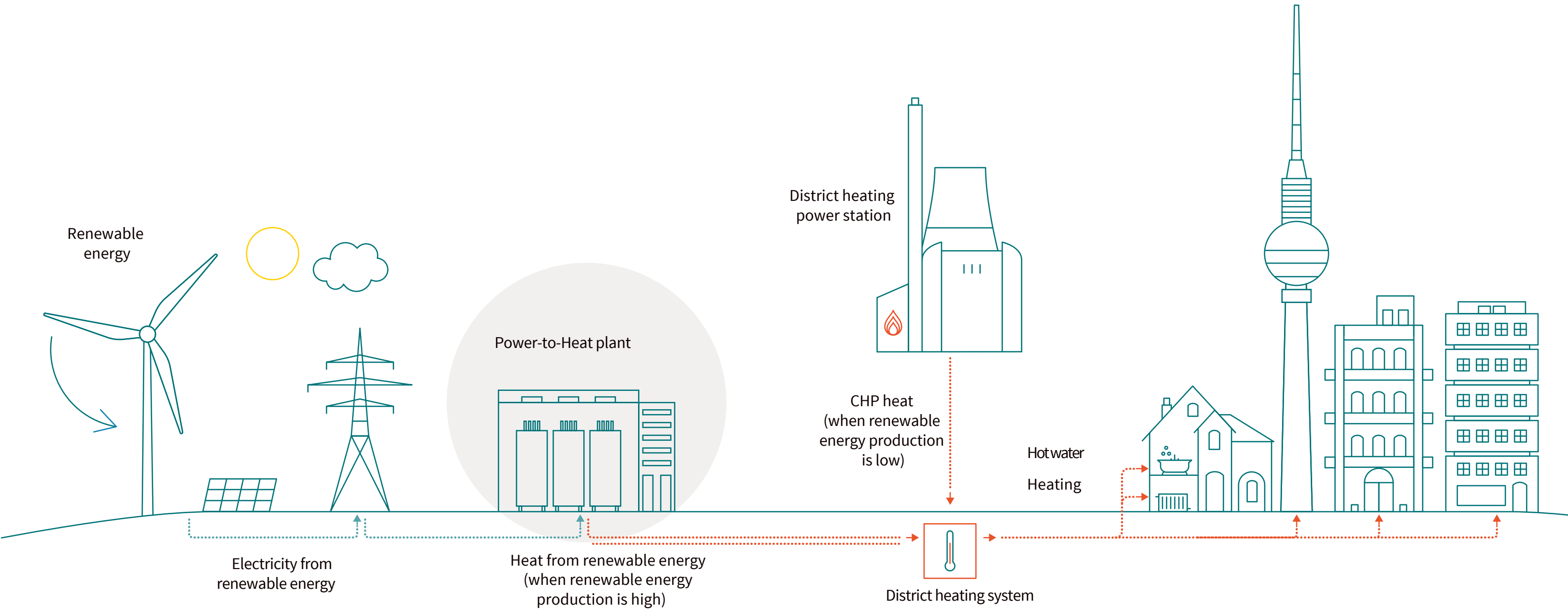
▷ CHALLENGES AND SOLUTIONS **// We must work together to reduce our carbon footprint**

The sparsely populated federal states of northeastern Germany offer excellent conditions for the production of renewable energy but are less and less able to consume the growing amount of electricity produced. The Berlin region, on the other hand, has one of the largest district heating networks in the European Union. As a result, the area has great potential for a fast and cost-efficient coupling of electricity and heating sectors that could increase the use of renewable energy in its building stock.

The current Power-to-District-Heating project opens up an opportunity for the Berlin-Brandenburg metropolitan region to become an important location for flexibility and shiftable loads in the context of the energy transition. Berlin is connected to 50Hertz's extra-high-voltage grid and has favourable hydraulic conditions for district heating thanks to the historical development of a meshed grid instead of a radial system. These factors make Berlin an ideal place to cultivate political, media and public acceptance of Power-to-District-Heating technology.

'WindNODE is a joint project to master the energy transition. This is already the first success factor – a task of this size can only be achieved together! The people involved in designing the future are taking a holistic approach: with the help of digitalisation, they are intelligently linking the sectors of heating, power generation and mobility. We, too, have learned a great deal from WindNODE. This is essential for us, because we want to ensure that our district heating system is entirely carbon-neutral by the time our children's children turn on the heating or take a hot shower.'

Dr Tanja Wielgoß
Chair of the Board,
Vattenfall Wärme Berlin AG



▸ Schematic diagram of a Power-to-District-Heating system.

'The 'biggest kettle in Europe' converts surplus green electricity into heat and is therefore an important part of the heating sector in Berlin. Vattenfall Wärme Berlin AG provides innovative heating solutions that will help the capital city achieve climate neutrality by 2050 – and it's advancing the heating transition in Berlin.'

Thomas Jänicke-Klingenberg
Senior Manager,
Vattenfall Wärme Berlin AG

This flexibility measure explored in this project is intended to convert surpluses from renewable power plants in northeastern Germany into district heating for Berlin's building stock, providing benefits for both grid and market. System integration through Power-to-District-Heating is attractive to consumers because it eliminates the need to install additional building services or make behavioural changes to obtain district heating generated from renewable energy. The necessary smart demand-side management takes place at the interface between the district heating supplier and the electricity grid operator.

Coordinated operation at the interface of the heat and electricity sectors must take into account both restrictions related to the grid and to the district heating system hydraulics. For this reason, the contribution of Vattenfall Wärme AG to the WindNODE project focuses on the technical analysis of the interaction between CHP and Power-to-District-Heating plants at the same site, as well as on the derivation of the resulting energy marketing and balancing options.

▷ RESULTS **// Great potential for 'green' district heating**

The first test results show that small Power-to-District-Heating plants such as the one in Berlin-Buch can reach full capacity within 10 seconds and thus provide grid-related system services extremely quickly – before wind turbines must be curtailed.

The large electrode boilers could conceivably be online within 15 minutes. The limiting factors in this context are the maximum starting current and the hydraulic feed-in of heat into the district heating system, as conventional generation plants must be shut down in turn. Vattenfall Wärme Berlin AG plans to construct a 50,000 m^3 hot water storage tank (max. 95 °C) at the Reuter West site to facilitate the feed-in process.

During tests with the WindNODE flexibility platform, it became apparent that flexibility bids based on the maximum power of the electrode boilers would have caused an increase in the grid fees paid by the district heating power stations. Because the facility is connected to the distribution grid, it does not fully benefit from the compensation for disadvantages in grid fees under the SINTEG Ordinance (SINTEG-V), unlike comparable plants connected to the transmission grid. The bids on the WindNODE flexibility platform were therefore always selected in such a way that the maximum amount of electricity agreed in the plant's existing contract could not be exceeded. Easing the burden on the power grid as much as possible while 'using power instead of curtailing it' would require a change to the regulatory framework, and an effective experimentation clause would have to contain broader provisions.

▼ Exterior view of the Power-to-District-Heating site.

▲ The Power-to-District-Heating plant was officially commissioned on 18 September 2019.

▷ CONCLUSION AND OUTLOOK // **The findings from the WindNODE project will contribute significantly to the decarbonisation of district heating**

Power-to-District-Heating is a key technology for the decarbonisation of the heating sector and can provide rapid support for the electricity grid. Preventing the curtailment of renewable energy producers will require action that is effective across all grid levels, including the transmission as well as distribution grids. This means that in case of congestion in the transmission system, excessive energy can be passed through a nearby junction with the distribution grid to a consumer connected at the lower level. Grid capacity and the regulatory framework are limiting factors for sector coupling.

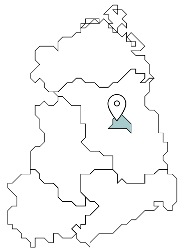
Nevertheless, it will be necessary to electrify part of the heating sector – with fast electric or electrode boilers that provide advantages for the grid, as well as with heat pumps capable of baseload operation, which are harder to control but significantly more energy-efficient.

In the course of the phase-out of hard coal from CHP generation, which is scheduled for completion by 2030, Vattenfall Wärme Berlin AG will design and build additional Power-to-District-Heating plants and deploy large heat pumps, for example using wastewater.

The WindNODE project has provided an opportunity to gain essential insight and to identify limitations. In the future, this insight must be applied – and these limitations overcome.

SP
6.3d

FOCUS AREA
Identifying Flexibility
Activating Flexibility



▸ **Title of the subproject**
PtH (Power-to-Heat) Applications for … Large-Scale System Integration of Power-to-District-Heating in Berlin

▸ **Funding code**
03SIN542

▸ **Project partner**
Vattenfall Wärme Berlin AG

▸ **Contact**
Thomas Jänicke-Klingenberg
T 030 26710314
waerme-kommunikation-berlin@vattenfall.de

▸ **Visitor sites**

CHP Plant Mitte (20 kW)
Here, visitors can see how app control is used in the grid-friendly operation of the future
Köpenicker Straße 59 –73
10179 Berlin

CHP Plant Buch (5 MW)
E-boiler plus storage as a tool to decarbonise an isolated grid
Schwanebecker Chaussee 11 – 15
13125 Berlin

CHP Plant Reuter West (120 MW) – Germany's largest Power-to-Heat plant
Großer Spreering 5
13599 Berlin

▷ INQUIRIES TO
waerme-kommunikation-berlin@vattenfall.de

All power plant sites are closed to the general public. At the three sites listed above, prior registration is required for visits or guided tours, and personal protective equipment (PPE) is mandatory.

For more information
www.vattenfall.de

Surplus Electricity from Renewable Sources for Climate-neutral District Heating

The construction of the grid buffer storage unit is one element of the 'Hennigsdorf heating hub', a long-term strategy developed by Stadtwerke Hennigsdorf with scientific support in order to make 80 % of local district heating climate-neutral. Surplus electricity from northeastern Germany will be used to generate heat and ensure that the grid remains stable.

'The grid buffer storage unit is a model solution for the flexible use of surplus electricity from renewable energy sources. The goal is to integrate as much renewable energy as possible into the energy system while maintaining the stability of the grid.'

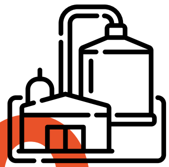
Thomas Bethke
Managing Director,
Stadtwerke Hennigsdorf GmbH

Heat storage and surplus electricity

In February 2020, after six months of construction, the technical approval process was completed for the new grid buffer storage unit at CHP Zentrum, and the unit began trial operation. The heat storage system, which has a capacity of 1,000 m^3, began regular operations in the second quarter of 2020. The system is made of steel, weighs roughly 100 tonnes and measures 18 metres tall and 10 metres in diameter. Since August 2019, the public has been able to observe construction in real time on the Stadtwerke Hennigsdorf website. Over the past several months, those interested in sustainable heating have used the construction web camera to obtain information about the process of building the storage unit, as well as the role of the unit in the broader 'heating hub' concept and the use of surplus electricity for district heating.

▷ CHALLENGES AND SOLUTIONS // **Energy law and basic economic conditions**

Hennigsdorf aims to increase the share of renewable energy in local district heating not only by using surplus electricity from volatile energy sources like wind and sun, but also by recovering industrial waste heat, shifting heat load through storage expansion, and collecting solar heat – all orchestrated using a comprehensive control system. However, the construction of a Power-to-Heat



80%

climate-neutral district heating

◂ Left: Beginning of construction of the grid buffer storage unit and launch of the construction web camera. From left to right: S. Saule (Managing Director Economic Development Agency Brandenburg), Mayor T. Günther, Stadtwerke Managing Director T. Bethke, J. Hangweirer (Kremsmüller Industrieanlagenbau).

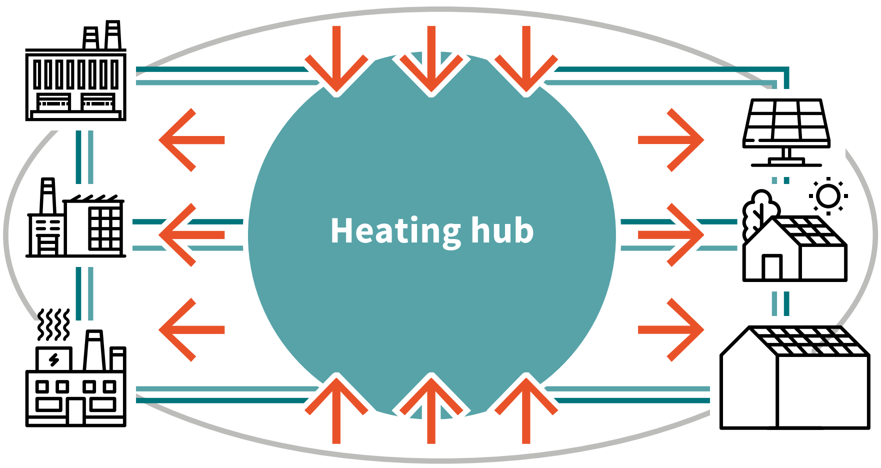
Right: The grid buffer storage unit in March 2020.

plant has been postponed due to the current economic environment and the existing regulatory framework. Instead, a combined heat and power (CHP) plant provided the flexibility potential of around 1 MW that was tested as part of WindNODE. In the future, the commissioning of the grid buffer storage unit, in conjunction with combined heat and power (CHP) and corresponding market signals, will provide the desired flexibility.

▷ RESULTS // **Flexibility potential in the power grid**
The project created the technical conditions to mobilise flexibility potential – by expanding heat storage and optimising load shifting in the heating network. In addition, it also helped increase the share of renewable energy sources used in the district heating network.

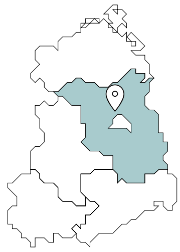
▷ CONCLUSION AND OUTLOOK // **Sector coupling**
Flexibility in the heating sector creates the potential for greater flexibility in the electricity sector.

▾ The multifunctional district heating network as a heating hub.



SP **6.3e**

FOCUS AREA
Identifying Flexibility
Activating Flexibility



▸ **Title of the subproject**
PtH (Power-to-Heat) Applications for … Industrial Waste Heat and PtH in District Heating for Load Flexibility in the Power Grid

▸ **Funding code**
03SIN534

▸ **Subproject partner**

▷ PROJECT PARTNER
Stadtwerke Hennigsdorf GmbH

▸ **Contact**
Stadtwerke Hennigsdorf GmbH
T +49 3302 5440-0
info@swh-online.de

Gerd Bartsch
gerd.bartsch@ruppin-consult.de

▸ **Visitor site**
Grid Buffer Storage Unit
Rathenaustraße 4
16761 Hennigsdorf

Registration required

▷ INQUIRIES TO
T +49 3302 5440-0
info@swh-online.de

For more information
www.swh-online.de

Participating partners

- Berliner Wasserbetriebe
- BMW GROUP
- b-tu Brandenburgische Technische Universität Cottbus - Senftenberg
- DECKEL MAHO Seebach GmbH
- Fraunhofer IFF
- Fraunhofer IWU
- htw. Hochschule für Technik und Wirtschaft Berlin University of Applied Sciences
- India
- INFRALEUNA
- KWD AUTOMOTIVE
- LEAG
- E
- ÖKOTEC ENERGIEMANAGEMENT GMBH
- OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG
- SIEMENS
- Zere

154 – 173

Industrial Load Shifting Potential subprojects

By shifting their loads over time, industrial enterprises can not only support the power grid but also save costs by bringing the resulting flexibility to market.

In this workstream, WindNODE is systematically identifying the technical, procedural and business requirements for industrial load shifting. The partners take the necessary steps to find different flexibility options in a selection of processes and industries, and bring them to market. Their findings are used to inform guidelines that can be applied outside the project.

Workstream 7 is coordinated by Andreas Hüttner (Siemens AG) on a voluntary basis.

◂ Building the demonstrator at the E^3 Research Factory for Resource-Efficient Production.

The Factory of the Future Will be Flexible – Including in Terms of Energy

What does it take to design and operate a future-proof factory? Many different elements are required, but one essential component is a sustainable energy supply. Specifically, this addresses the use of renewable energy generated on site as well as energy flexibility. How is this achieved? It requires an active energy management system that keeps track of all energy-related systems in the factory and is incorporated into all levels of planning and control.

‘What does the energy transition signify for industrial production? How can factories participate? These are some of the challenges for which our WindNODE subproject has developed solutions. We have identified opportunities and elaborated technical solutions for use in the “factory of the future”.’

Mark Richter
Head of ‘Future Factory’ Department, Fraunhofer Institute for Machine Tools and Forming Technology (IWU)

▷ CHALLENGES AND SOLUTIONS // **Factories must be rethought – not least in terms of energy**

How can factories – in which transparency was, until ten years ago, limited to energy billing – participate successfully in restructuring the energy system in the future? To accomplish this, it is important to identify flexibility potential and make the most of it via appropriate solutions. The first step is to analyse the energy use of the existing process chains in order to derive more precise forecasts of the energy demand. This subproject conceptualised and developed an active overarching energy management concept based on a range of parameters (e. g. integration of locally generated renewable energy and of local energy storage, as well as energy-sensitive production planning). The resulting system orchestrated all energetically relevant components in the factory: energy sources, converters, storage and sinks. With its focus on discrete manufacturing processes, the Fraunhofer Institute for Machine Tools and Forming Technology (IWU) is thus now tackling a key priority for future-proof production in Germany.

▷ RESULTS // **The factory is a smart grid with active energy management**

The first step was to examine the demonstrator scenarios with regard to their usage and availabiliy of electrical energy resources as well as distinctive process-dependent features. For this purpose, a process chain for the massive forming of drive components for cars in the E^3 Research Factory for Resource-Efficient Production was analysed at the Fraunhofer IWU. The project

1.3 GW

of flexible load from metal-cutting machine tools in Germany*

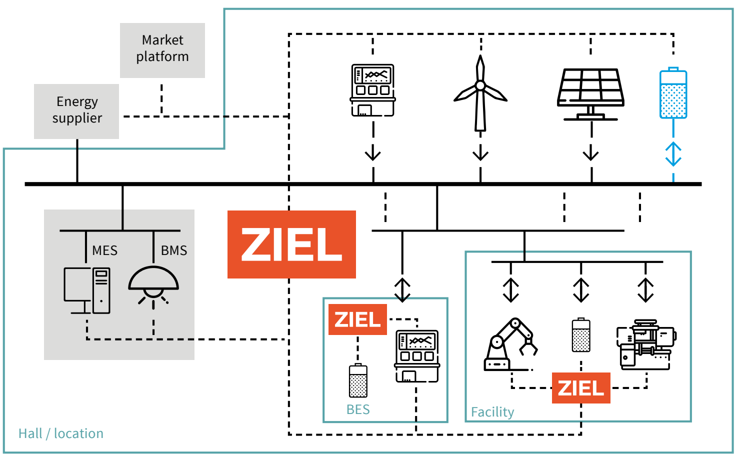
* Assuming that 50 % of those tools in Germany's manufacturing industry can be made more flexible.

partner Karosseriewerke Dresden GmbH carried out investigations in its pressing plant; and another project partner, DECKEL MAHO Seebach GmbH, studied its mechanical production department, which includes 22 cutting machine tools.

At DECKEL MAHO Seebach and in the E³ Research Factory, simulation models were developed for machines, systems and in some cases the energy supply technology, such as combined heat and power units, photovoltaic systems and energy storage systems, as well as their connections in terms of control and energy flows. The simulation models were used to conceptualise an energy price-oriented production planning/control system and, especially at DECKEL MAHO Seebach, could be successfully verified by informing real-life production planning.

In addition, newly developed strategies and algorithms enable the active control of energy flows between energy sources, sinks and storage facilities in factories. A generic interface was developed for this purpose. It allows the energy-related components to communicate with components linked to production technology, production infrastructure and building infrastructure. The overall system of energy price-oriented production planning/control and active energy management is the new future-proof intelligent energy and load management for factories, which was named "ZIEL", or Smart Energy and Load Management (see figure below).

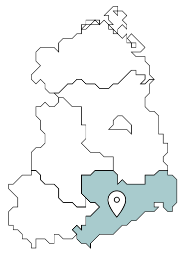
▷ CONCLUSION AND OUTLOOK // **A tried and tested active energy management for factories is ready**
The focus is now on completing the demonstrator. The final implementation and roll-out phase is already underway, with all relevant components connected to the ZIEL system. Next, control, planning and forecasting strategies will be implemented, validated and subsequently integrated into the modular, flexible and expandable software framework. At the same time, the new factory dashboard 'FactoryView' is being deployed to enable internal visualisation and control of the factory; this also allows for external communication (e.g. with energy market platforms). The result is a demonstration of a completely new and active energy management system for factories.



▲ 'ZIEL': The Smart Energy and Load Management System for factories.

SP 7.1

FOCUS AREA
Identifying Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
'ZIEL' – Algorithms and Methods for the Intelligent Energy and Load Management of the Future

▸ **Funding code**
03SIN514

▸ **Subproject partners**

▷ PROJECT PARTNER
DECKEL MAHO Seebach GmbH

Fraunhofer Institute for Machine Tools and Forming Technology IWU

Karosseriewerke Dresden GmbH

▷ SUBCONTRACTOR
Federation of German Scientists 'Meine Energie für meine Stadt' (My Energy for My City)

▸ **Contact**
Mark Richter
T +49 371 5397-1103
mark.richter@iwu.fraunhofer.de

▸ **Visitor site**
E³ Research Factory for Resource-Efficient Production
Reichenhainer Straße 88
09126 Chemnitz

Registration required

▷ INQUIRIES TO
info@iwu.fraunhofer.de

For more information
www.iwu.fraunhofer.de

▲ **ZUKUNFTSRAUM***ENERGIE* visitor site in Siemensstadt Berlin.

Flexible Processes in Industrial Production as Functional Energy Storage

Thanks to automation and digitalisation, industrial loads can provide flexibility for several hours without causing significant losses in energy or exergy or additional demand for valuable resources. In order for the idea to catch on, it is important that the value put on demand flexibility increases, above all through a higher proportion of intermittent renewable energy in the electricity system and a tax and levy system that promotes flexibility.

1 %

By making only 1 % of the electricity used in industrial activities in Germany more flexible, we can achieve the same effect as 53 million charging processes for electric vehicles.

10

The flexibility periods determined for the start times of production processes range from 10 minutes to 10 hours.

200

More than 200 metering points have been installed and activated at the Siemens factories in Berlin.

▷ CHALLENGES AND SOLUTIONS // **Creating transparency**

In 2018, industrial processes consumed roughly 226 TWh – some 44 % of the electricity used in Germany. Siemens aims to utilise this potential to increase the integration of intermittent renewable electricity. Its goal for subproject 7.2 was to develop an industrial load management system and set it up as a showcase at its Berlin site. At the beginning of the project, topics related to the electricity market or the grid played little role in the production planning process. In addition, the energy consumption of individual production plants was not yet transparent.

▷ RESULTS // **Combining energy management, optimisation and web applications**

In WindNODE, a cloud-based energy management system based on the Spectrum Power 5 grid control system was implemented as the basic system for managing flexibility with over 200 metering points in a Siemens plant in Berlin that produces dynamos, gas turbines, switchgear and metering devices. The newly discovered load profiles, coupled with the experience of production employees, made it possible to find theoretically flexible electrical loads in

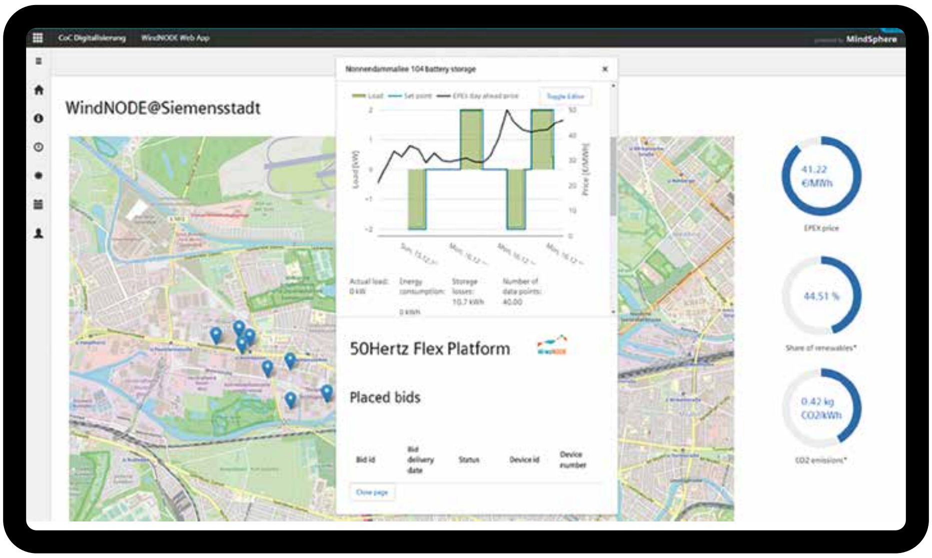
‘In WindNODE, we showed that industrial load management can play a significant role in facilitating better integration of wind power and photovoltaic electricity. Automation and digitalisation provide the technical foundation for this development. What is needed now is a system of taxes and levies that promotes flexibility for electricity and a rapid expansion of renewable energy in order to improve Germany’s CO_2 balance.’

Ute Redecker
Business Unit Manager for Digital Grid Germany,
Siemens AG

the order of some 20 MW. Due to the limitations of the production processes, however, it is not possible to fully leverage the 20 MW. During implementation, flexibility concepts were developed and implemented for several production processes (e. g. kilns and test stands) and production-related systems (e. g. electric conveyor vehicles and ventilation systems) with a total demand of more than two megawatts. The subdivision into different ‘flexibility levels’, from a fixed time delay to fully automated optimisation, makes it possible to increase flexibility in line with the possibilities of the production process. A delay in start time, for example, is suitable for increasing the flexibility of sintering furnaces in the production of heat-resistant ceramic tiles for gas turbines.

The MindSphere app ‘WindNODE Web’ (pictured below) was developed as a convenient, user-friendly way to record flexibility and schedule its activation. A connection to the WindNODE flexibility platform developed in subproject 1.2 (see p. 66) to manage grid congestion was successfully established and tested in closed-loop operation.

With **ZUKUNFTSRAUM***ENERGIE* (Energy of the Future space), Siemens has opened an interactive showroom in which interested parties can familiarise themselves with industrial load management, for example in the ‘Energy Tetris’ scenario (pictured on opposite page).



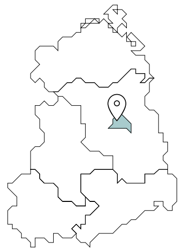
▲ Entering the flexibility of planned production processes in WindNODE Web.

▷ CONCLUSION AND OUTLOOK // **A holistic view of energy in a company**

Flexible loads should be deployed for a range of energy market and grid-related applications. In order to improve economic efficiency, the necessary infrastructure (e. g. metering devices and energy management systems) should also be used in other applications, such as system monitoring or the analysis of consumption data required for ISO 50001 certification. To ensure that the intermittent generation of photovoltaic and wind power takes place with as little loss and as few resources consumed as possible, the tax and levy system for electricity must create targeted incentives to achieve flexibility in the demand for electricity.

SP 7.2

FOCUS AREA
Identifying Flexibility
Activating Flexibility



▶ **Title of the subproject**
Intelligent Industrial Load Management in Berlin

▶ **Funding code**
03SIN529

▶ **Subproject partners**

▷ PROJECT PARTNER
Siemens AG

▷ SUBCONTRACTOR
Federation of German Scientists, ‘Meine Energie für meine Stadt’ (My Energy for My City)

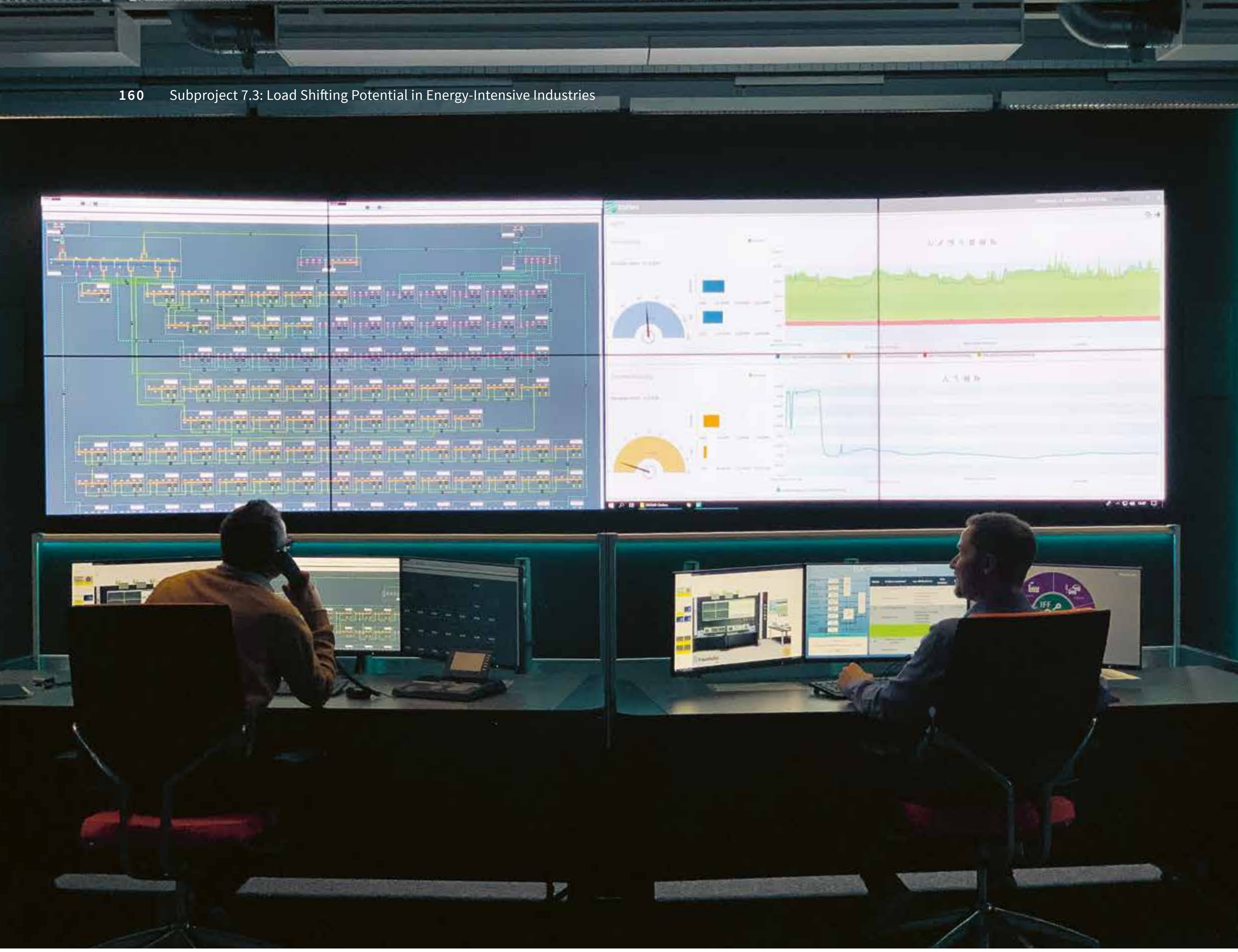
▶ **Contact**
Siemens AG
Andreas Hüttner
T +49 174 1550832
huettner.andreas@siemens.com

▶ **Visitor site**
ZUKUNFTSRAUM*ENERGIE* showroom (Energy of the Future space)
Rohrdamm 85
13629 Berlin

Registration required

▷ INQUIRIES TO
windnode.em.de@siemens.com

For more information
https://new.siemens.com/de/de/unternehmen/themenfelder/nachhaltige-energie/zukunftsraumenergie.html



▶ Cross-sector monitoring, optimisation and control in the Industry Energy Hub VDTC.

Toolbox and Sales Display for Industrial Flexibility

How is the value of flexibility quantified? By comparing the available supply with demand. As part of the WindNODE project, Fraunhofer IFF in Magdeburg identified the flexibility properties of industrial technologies with regard to the requirements of the wider energy system. This required it to analyse, optimise and demonstrate the current and prospective marketing and savings potential of this flexibility in the context of the energy transition.

‘The growing awareness of customers is increasingly spreading to the suppliers and is thus finding its way into industrial processes. The call for “green” products and services is becoming louder. Individual companies in the automotive industry are already obliged to comply with upper bounds on CO_2 for the parts they produce. Against this background, load flexibility is an important factor in optimally integrating renewable power sources and establishing the “net-zero-energy factory” concept in the medium to long term.’

Dr Pio Lombardi
Convergent Infrastructures,
Fraunhofer IFF

▷ CHALLENGES AND SOLUTIONS // **Bringing together flexibility supply and demand**

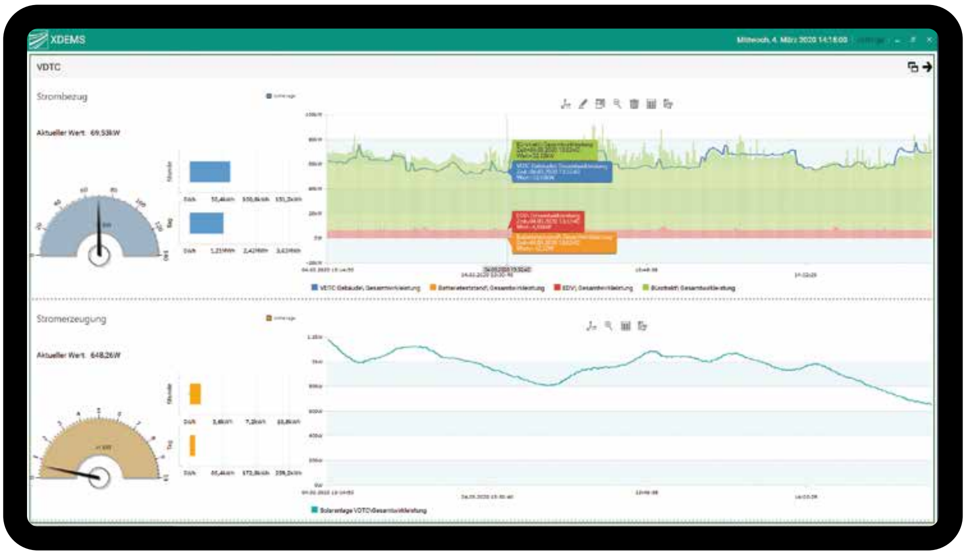
‘Flexibility is not a criterion in purchasing decisions’: under the current paradigm, most companies buy energy in accordance with this general principle. At present, grid congestion management processes are what determines which products can feasibly be traded on the markets. Due to a lack of monetary incentives, it is today largely irrelevant whether a particular behaviour would benefit the grid and facilitate the integration of renewable energy from wind and photovoltaics. Although elements like the balancing power market or interruptible loads represent powerful tools that grid operators can use to stabilise the energy system, the sometimes high barriers to access hinder the broad participation of potential suppliers.

As a result, in order for demand-side flexibility to gain traction, it is important to find a balance between an appropriate level of integration at the flexibility provider, and the requirements and price ranges determined by the grid and markets. In other words: how deeply does a company have to change its internal processes in order to meet the challenges of a sustainable integration of renewable energy?

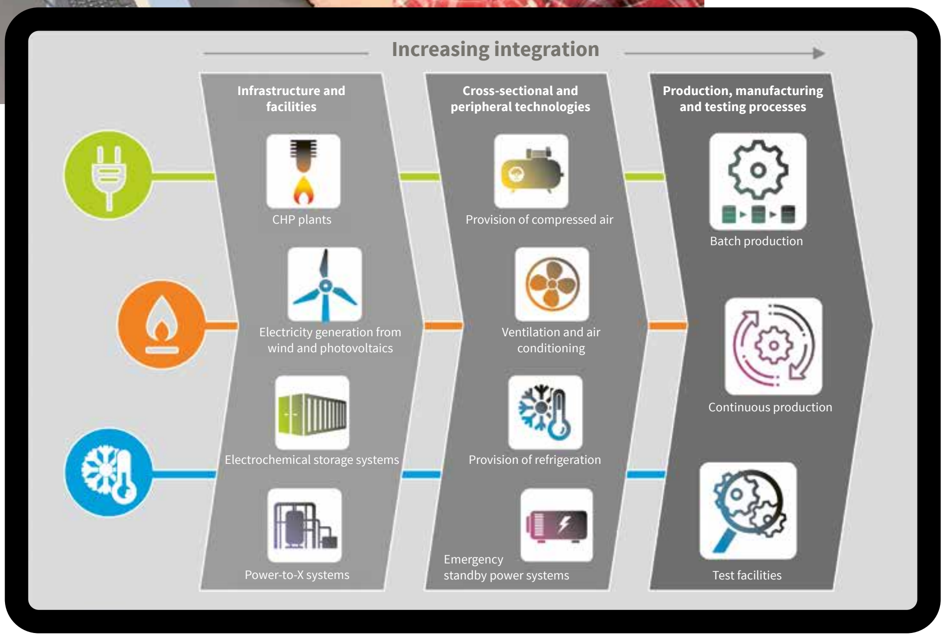
More than

8

business models and applications that lead to cost savings by using demand flexibility are possible under current legislation.



▸ Visualisation and processing of consumption data by the Cross-Dynamic Energy Management System (XDEMS).



▸ Training and knowledge transfer at Fraunhofer IFF. Complexity in identifying, modelling and utilising industrial flexibility increases at higher levels of integration.

3

levels of integration for the identification, modelling and utilisation of flexibility options

1 Infrastructures and facilities

2 Cross-sectional and peripheral technologies

3 Production, manufacturing and testing processes

▷ RESULTS // **Encyclopaedia, broker and toolbox for industrial flexibility**

An industrial flexibility study developed as part of the WindNODE project addresses three main issues. Part 1 analyses the general technology portfolio with regard to the capacity for load and generation flexibility, including combined heat and power (CHP) plants, emergency standby power systems, ventilation systems and different process types. By comparing advantages and disadvantages, it shows the kinds of organisational, financial and technical investment required to increase the flexibility of existing systems.

Part 2 identifies available methods to describe, provide information on, and communicate technical properties between the supply and demand sides. Various mathematical models provide insight into how certain technical properties relate to (financial) value. Part 3 focuses on the transition to different savings applications and business models. First, a description of the German electricity market design and the relevant actors provides an overview of the effects of a decoupled, liberal electricity market. Existing mechanisms are then reviewed in detail, including not only the balancing energy market and electricity exchange, but also the existing options for savings through 'atypical grid usage'. The Business Model Canvas is used to illustrate the value proposition, cost structure, activities and resources of each use case. In the final step, proposals are presented for prospective flexibility marketing options under modified regulations.

The operational concepts studied in the project were implemented in practice in the Industry Energy Lab. In this context, the Virtual Development and Training Centre (VDTC) represents an industrial infrastructure, including, among others: controllable and non-controllable loads, a renewable generation system, a lithium-based storage system, a hydrogen electrolysis system and various electric vehicles as a small-scale counterpart to real energy systems. With the help of adapted XDEMS monitoring and control software, the system could be monitored, optimised and controlled as a whole. This included, above all, the forecasting of consumption and generation. The operating strategies developed in this process meet the requirements of a 'net-zero energy factory'.

▷ CONCLUSION AND OUTLOOK **// There is potential, but incentives are lacking**

The industrial flexibility portfolio contains many different technologies and measures with individual advantages and disadvantages. However, the identification, modelling and utilisation of site-specific flexibility can only be carried out on a case-by-case basis and involves a large number of stakeholders. If, for example, only 1 % of the electricity used for mechanical energy in industry is deployed flexibly and in a coordinated manner by the technologies demonstrated here, up to 10 % of the curtailed redispatch energy can be saved (approximately 10 TWh in 2018). Flexibility is thus essential to ensure the success of the energy transition and the sustainable integration of renewable energy. This will require further investigation into interactions with other paths of development.

'In the energy industry, the traditional commodity business is increasingly fading into the background. Flexibility, reliability and sustainability: these are the new values that companies consider when purchasing energy. This shows the impact Fridays for Future has had on the industry landscape. If you take this route as an entrepreneur, you will not be able to avoid the realisation that sustainability and responsibility also have a cost.'

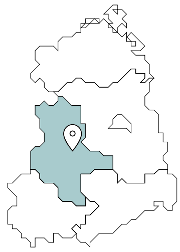
Prof. Dr Przemyslaw Komarnicki
Director, Convergent Infrastructures,
Fraunhofer IFF

▷ WHAT ARE THE BARRIERS TO THE ENERGY TRANSITION?

Entrenched market positions and high barriers to entry for new and smaller players are the main obstacles to economically optimal solutions in an energy market that promotes the best possible integration and utilisation of renewable energy. Distributed ledger technologies (e.g. blockchain) and cloud-based services, among others, can be used to meet the technical requirements for a transparent and non-discriminatory system of supply and demand. However, well-established mechanisms often prevent innovative developments.

SP 7.3

FOCUS AREA
Identifying Flexibility
Digitalising the Energy System



▶ **Title of the subproject**
Load Shifting Potential in Energy-Intensive Industries

▶ **Funding code**
03SIN514

▶ **Subproject partners**

▷ PROJECT PARTNER
Fraunhofer Institute for Factory Operation and Automation IFF

▷ ASSOCIATED PARTNERS
InfraLeuna GmbH

Zentrum für Regenerative Energien Sachsen-Anhalt e. V.

▷ SUBCONTRACTOR
Otto-von-Guericke-Universität Magdeburg

▶ **Contact**
Dr Marc Richter
T +49 391 4090374
marc.richter@iff.fraunhofer.de

▶ **Visitor site**
Industry Energy Hub VDTC
Joseph-von-Fraunhofer-Straße 1
39106 Magedeburg

Registration required
Business days 9 am to 4 pm

▷ INQUIRIES TO
ideen@iff.fraunhofer.de

For more information
www.iff.fraunhofer.de

▲ Flexibility as a business model.

Market Integration of Demand-side Flexibility

The aim of our subproject was to develop cost-effective solutions for the market integration of industrial and commercial flexibility. We focused on expanding the established systems for energy controlling to avoid expensive duplicate development and to facilitate market launch as effectively as possible.

‘To us, a reality lab means bringing together innovative partners to jointly create something new.’

Arne Grein
Head of Energy Markets,
ÖKOTEC Energiemanagement GmbH

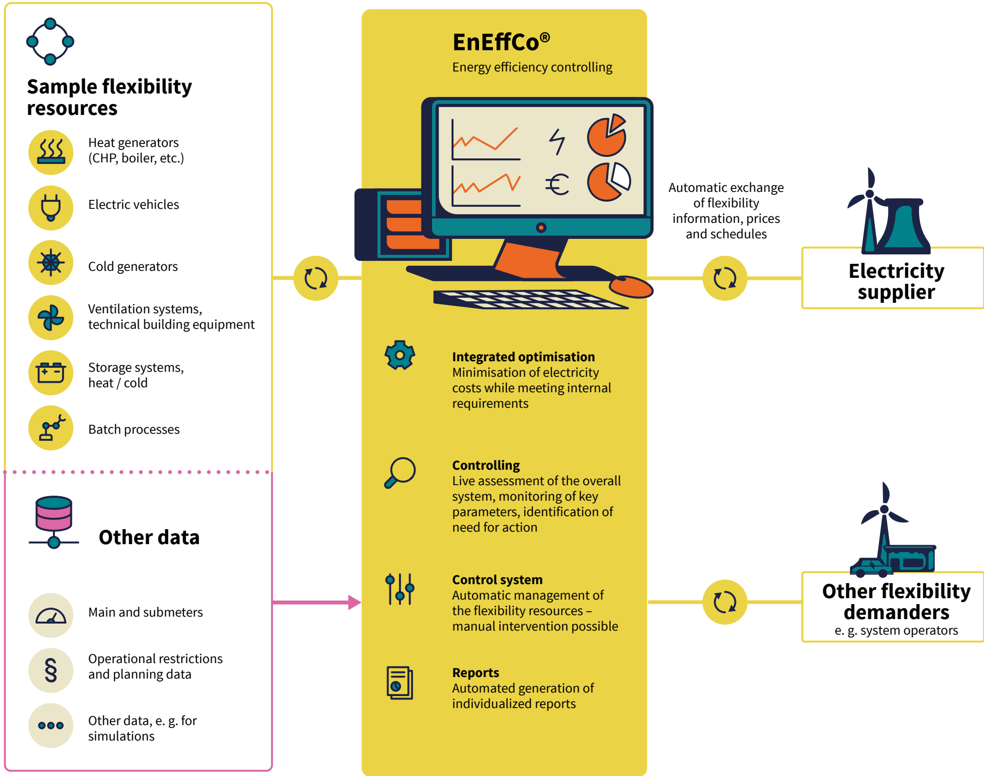
▷ CHALLENGES AND SOLUTIONS **// Cost-effectiveness is key**

Due to operational and often legal requirements, industrial companies have established energy controlling and an existing data acquisition infrastructure. The aim was to supplement the existing control and monitoring system in a cost-efficient manner so that a systemic interface is created which can be used both at the measurement and control levels of the industrial site. In addition, the system should include the necessary algorithms and processes to evaluate flexibility in view of the markets, and use marketing platforms to integrate it into the relevant markets.

ÖKOTEC has developed the concept of a technical interface for automated flexibility assessment and control and has demonstrated the processes in a pilot project at industrial sites. Innovative methods for the forecast and dynamic analysis of the availability of flexible plants were developed, which serve as a basis for market, grid and system-optimised dynamic operation enabling an efficient energy system.

The system enables operators at industrial sites to automatically determine the available flexibility potential, locally and incorporating all relevant data. The relevant offers can be transmitted to market partners or grid operators. If the use of flexibility is contracted, efficient and optimised schedules can be translated into control signals that are sent to the respective flexible systems.

EnEffCo® for the integrated optimisation of flexibility resources



▲ A powerful interface is crucial for the market integration of industrial flexibilities between the facilities on site and the marketing service provider.

SP **7.4**

FOCUS AREA
Identifying Flexibility
Activating Flexibility
Digitalising the Energy System

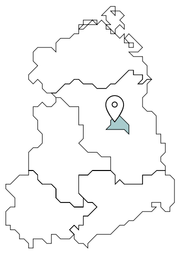
▷ RESULTS // **Success through cooperation**

In addition to the development of program modules of our successful and widely used energy efficiency controlling system EnEffCo®, we have analysed and prepared concrete use cases within the framework of WindNODE so that implementation can take place. Detailed investigations of use cases were carried out in the areas of water supply and waste water disposal, food retail, beverage industry, waste disposal, municipal heating networks and public transport. In many cases, commercially interesting perspectives have emerged. Together with BSR, the municipal waste disposal company in Berlin, a pilot implementation of intelligent charging of electrical vehicles was realised. In a joint follow-up project, this solution is now being extended to other locations. Furthermore, it has been possible to design and implement flexible electricity supply contracts with several energy suppliers.

▷ CONCLUSION AND OUTLOOK // **Further standardisation in specific applications**

For the time after WindNODE we are planning the further development of the methodology. Here, the focus will be on greater modularisation and standardisation of the software components, so that the costs of tapping into flexibility potential continue to fall, and on testing concrete business and billing models with energy suppliers. In addition, our work continues on analysing, and engaging with, further industrial and commercial sectors.

Simulations have shown a savings potential of up to **70 %** – based on the wholesale electricity price.



▸ **Title of the subproject**
Market Integration of Industrial Flexibility via an Interface Between Energy Controlling and Marketing Platforms

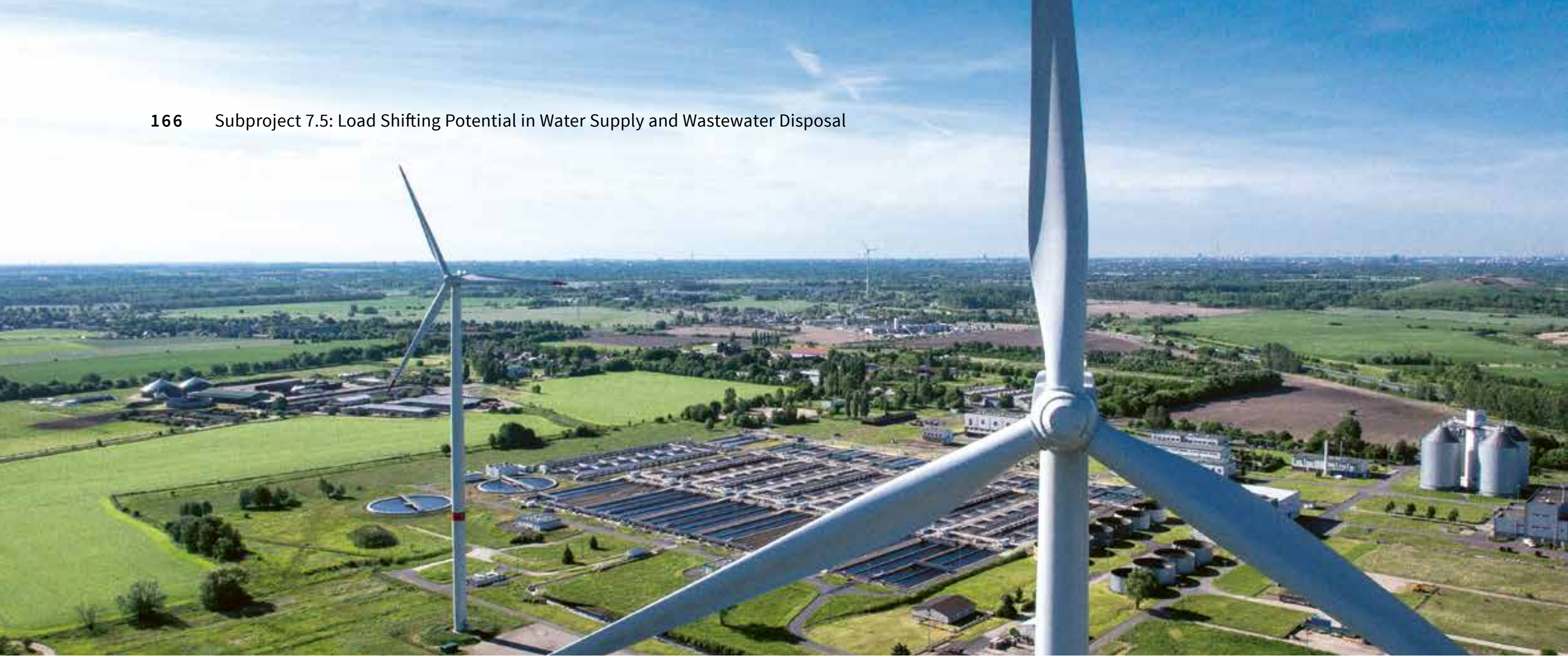
▸ **Funding code**
03SIN522

▸ **Subproject partner**

▷ PROJECT PARTNER
ÖKOTEC Energiemanagement GmbH

▸ **Contact**
Arne Grein
T +49 (30) 536397 – 49
a.grein@oekotec.de

For more information
www.oekotec.de/de/flexibilitaetsmanagement



▲ Aerial view of the Schönerlinde wastewater treatment plant which is operated by Berliner Wasserbetriebe.

Innovative Load Management for Climate-friendly Wastewater Treatment Plants and Waterworks

Depending on the realities on a given site, the combination of renewable energy sources with innovative load management systems and available storage capacity can provide greater flexibility. It was first necessary to perform in-depth analyses of energy consumption to determine the load shifting potential; results were verified using simulations. As a side benefit, the study identified new opportunities to save and utilise electricity and heat. These findings will allow the company to make plant operations even more efficient and climate friendly.

‘Modifying plant processes and introducing measures to control energy consumption, generation and storage have allowed Berliner Wasserbetriebe to increase the flexibility of its operations. This enables BWB to respond appropriately to the integration of volatile renewable energy in the context of the energy transition.’

Regina Gnirß
Head of Research and Development,
Berliner Wasserbetriebe AöR

▷ CHALLENGES AND SOLUTIONS // **Large-scale consumers as an opportunity**

A transformation process is required in order to phase out coal and nuclear power and expand renewable energy. Flexible energy consumption in all industrial sectors and in wastewater management is therefore essential.

Wastewater treatment facilities are major consumers of electricity: the nearly 10,000 municipal wastewater treatment plants in Germany consume roughly 3,200 gigawatt hours (GWh) of electricity each year.

Berlin’s wastewater treatment plants already produce enough fuel from the renewable energy carriers sewage sludge and sewage gas to meet 70 % of their energy requirements. Fuel from these sources, in combination with wind and solar energy, has made facilities like the Schönerlinde wastewater treatment plant 84 % self-sufficient. Because water consumption and wastewater inflow can be predicted reliably, available flexibility can be estimated in advance.

The wastewater treatment plants operated by Berliner Wasserbetriebe have high levels of automation but lack a system for optimising energy behaviour. Following a series of tests performed using the SIMBA# simulation model, a multi-stage system for automation was integrated into the Münchehofe wastewater treatment plant in order to reduce annual peak load. Automatic load shedding begins

70 % of energy requirements from renewable energy carriers

Berlin's wastewater treatment plants already produce enough fuel from the renewable energy carriers sewage sludge and sewage gas to meet 70 % of their energy requirements.

as soon as the grid load reaches a predetermined threshold value. The load management system uses an energy consumption forecast for this purpose. Process engineering technologies like grit chambers, centrifuges and blowers used in the various stages of biological purification are then ramped down or switched off.

▷ RESULTS // Flexibility thanks to load management

First, an in-depth energy efficiency study was conducted: electrically important structural components were prioritised on the basis of the operational data and performance measurements collected in accordance with Worksheet DWA-A-216; simulations were then used to validate the findings. After implementing the load management into the plant process control system, a successful one-year test was completed at the Münchehofe wastewater treatment plant. The assessment included an analysis of process-related effects on the quality of water outflow and system optimisation. Transferability to other systems was evaluated using simulation models, based on data sets from load management tests carried out at the Münchehofe plant.

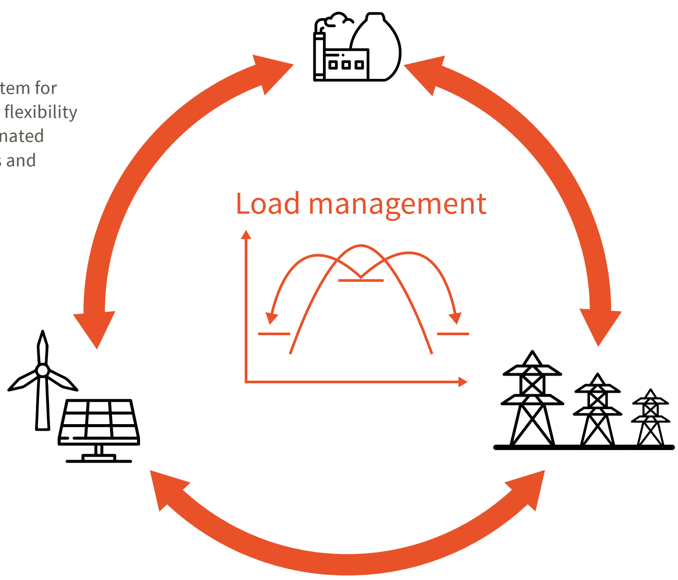
As a side benefit, the study made it possible to identify new opportunities to save and utilise electricity and heat, which will allow the company to make plant operations even more efficient and climate-friendly. Implementing load management at all Berliner Wasserbetriebe wastewater treatment plants could yield a positive flexibility potential of 5.9 megawatts (MW).

▷ CONCLUSION AND OUTLOOK // Wastewater treatment plants support the energy transition

Beyond the current WindNODE project, Berliner Wasserbetriebe will adapt its approach to other environments in order to implement load management at additional wastewater treatment plants; it will also increase the use of external data like wind forecasts in order to boost system efficiency in accordance with the terms of the Critical Infrastructures Ordinance (KRITIS).

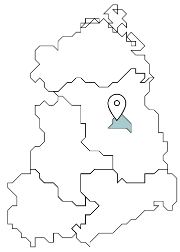
A follow-up study to the WindNODE project will integrate an electrolyser into a Berliner-Wasserbetriebe wastewater treatment plant. There is significant potential for hydrogen technology to be deployed at such facilities. Local production of hydrogen from wind energy and the subsequent methanation stage yields energy-related benefits and can reduce climate impact. Hydrogen electrolysis, in particular, produces synergistic effects: oxygen generated during the process can be converted into ozone and then used for further wastewater purification. This allows for the expansion of existing load management to provide negative flexibility (increased consumption).

▸ Intelligent load management system for electricity demand optimisation: flexibility potential utilised through coordinated control of generators, consumers and storage systems.



SP 7.5

FOCUS AREA
Identifying Flexibility
Digitalising the Energy System



▸ Title of the subproject
Load Shifting Potential in Water Supply and Wastewater Disposal

▸ Funding code
03SIN550

▸ Subproject partner

▷ PROJECT PARTNER
Berliner Wasserbetriebe AöR

▸ Contact
Regina Gnirß
T +49 30 86441628
regina.gnirss@bwb.de

▸ Visitor site
InfraLab on the EUREF Campus
Torgauer Straße 15 B
10829 Berlin

Registration required

▷ INQUIRIES TO
info@infralab.berlin

For more information
www.bwb.de

▲ Interior view of the BMW battery storage farm in Leipzig.

BMW Battery Storage Farm Leipzig – Energy Optimisation in the Manufacturing Plant

The BMW Group has a holistic view on electromobility. The electrification of mobility is increasingly blurring the lines between the energy and mobility sectors. This development allows traction batteries, such as those used in electric vehicles, to remain useful even at the end of the vehicle life cycle, when they generally have reduced capacity. ‘Second-life applications’ of this kind can make significant contributions to sustainability, environmental protection and the energy transition.

▲ Ideal conditions for a holistic approach to the energy transition at the BMW Group's plant in Leipzig.

‘The Leipzig battery storage farm is a milestone for us on the way to the sustainable mobility of tomorrow. WindNODE has given us an opportunity to get new energy management concepts off the ground and try them out so that we can think through the necessary conditions for flexible use by producers and consumers in advance. WindNODE has provided an excellent framework for identifying problems and collaborating with project partners to develop alternatives.’

Alexander Funke
Project Manager,
BMW Group

▷ CHALLENGES AND SOLUTIONS **// A holistic perspective on electromobility**

Renewable energy leads to high volatility in the power grid. This poses challenges for transmission system operators (TSOs), who are responsible for ensuring the stability of the grid. Flexible storage capacity can help by compensating for short-term fluctuations within seconds. Although traction batteries installed in electric vehicles typically have reduced capacity and power at the end of the vehicle life cycle, they can still have practical uses. In a second-life application at the Leipzig plant, used electric vehicle batteries are integrated into a battery storage farm that serves as a large storage system, increasing sustainability. This approach recycles vehicle batteries while providing economic benefits. Over the long term, reusing batteries can contribute significantly to the energy transition at the level of large-scale industrial consumers, as well as to sustainability and environmental protection goals.

Challenging aspects of this project included not only the technical integration of the BMW i3 batteries, but also enabling the battery storage farm to provide grid stability services. As a result, the storage can help compensate for the volatility in transmission and distribution grids caused by fluctuating feed-in from wind or solar farms. For this purpose, it was necessary to create a suitable infrastructure, including an IT system, for the scalable integration of used storage systems, and to develop basic capabilities for additional storage business models. As part of this process, integration into the local energy system and site-specific properties had to be taken into account. In light of the existing regulations, an important consideration was whether it would be possible to integrate the battery storage farm into the plant infrastructure as a flexibility option (for example, to cover short-term peak loads at the plant) and use the installed storage to further benefit the grid.

Up to

13.6

MW

of power

The battery storage farm at the BMW Group's Leipzig plant is designed for a total power output of up to 13.6 MW.

▷ RESULTS **// The world's largest stationary battery storage farm**

With up to 700 BMW i3 batteries, the battery storage farm at the BMW Group's Leipzig plant is currently the world's largest stationary storage system consisting of new and used vehicle batteries. The solution is unique in that the BMW i3 batteries can be transferred directly from the vehicle to the battery storage farm, without any need for pre-installation modifications. Future vehicle battery storage system models can also be integrated into the BMW battery storage farm in Leipzig. The facility currently uses 60 Ah and 94 Ah batteries from the first BMW i3 generations. Thanks to the fully scalable setup, it is already capable of integrating next-generation batteries. The technical design of the plant consists of four partitions, each of which has one transformer. Five inverters are connected to each of the four transformers, with up to 36 high-voltage batteries (HVB) integrated per inverter. The system's total power output is approximately 13.60 megavolt ampères (MVA).

Each of the four partitions can be controlled separately and thus be deployed in different use cases. The quantities of energy involved can be separated cleanly between the partitions since each subunit has its own calibrated metering point for this purpose.

Since 1 January 2018, the BMW battery storage farm in Leipzig has helped optimise the integration of renewable energy into the public power grid and therefore contributed to grid stability beyond the plant's borders. The facility is currently used to provide primary balancing power. Deployment of high-voltage batteries in a stationary secondary application makes it possible to use resources carefully and sustainably.

The battery storage farm was enabled for use in local optimisation in order to react flexibly to future requirements. Among other benefits, this allows for better integration of locally generated electricity from the four wind turbines at the BMW Group's Leipzig location into the facility's energy consumption, further reducing the plant's CO_2 footprint. Alternatively, the battery storage farm can be used as part of the facility's energy demand management system to reduce plant energy costs.

▼ The battery storage farm plays a role in the success of the energy transition by providing primary balancing power.

▲ Project sketch of the battery storage farm at the BMW Group's plant in Leipzig. The electrification of mobility is increasingly blurring the lines between the energy and mobility sectors.

▷ CONCLUSION AND OUTLOOK // **Dare to increase flexibility**

The battery storage farm's location – as part of the plant infrastructure – would allow the system to be used in a variety of applications. All three alternatives for its use (i.e. in the electricity market, local optimisation or grid services) involve behaviour that is beneficial to the market or grid. Price fluctuations are a product of supply and demand; as a result, use of the battery storage farm in price-driven optimisation, for example on the intraday market, can balance supply and demand. As a second alternative, use in local optimisation can help reduce the load in the upstream grid by avoiding peak loads. The third application, participating in the balancing power market, is by definition serving the grid. However, due to various regulatory hurdles, the flexible deployment of behind-the-meter storage systems is, if at all, only possible under extensive restrictions and associated with a significant administrative burden.

It may be helpful to establish a separate legal definition for battery storage systems. This could facilitate the adaptation of regulatory provisions for battery storage systems. The current approach – which treats battery storage systems as consumers or producers on a case-by-case basis – hinders, rather than helps, the integration of such systems into complex energy management regulations.

▷ WHAT ARE THE BARRIERS TO THE ENERGY TRANSITION?

The existing regulatory framework proved to be a major obstacle in project implementation, particularly with regard to the dynamic integration of battery storage systems. Battery storage systems can only serve as an essential building block in the energy transition if the flexibility they provide is combined effectively with other factors, namely usage, profitability and timing.

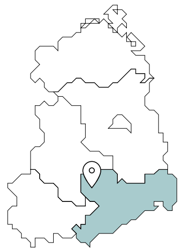
700

BMW i3 batteries

The BMW Group's plant in Leipzig can accommodate up to 700 BMW i3 batteries. This makes the large-scale battery storage farm the world's largest stationary storage facility consisting of new and used vehicle storage systems.

SP 7.6

FOCUS AREA
Identifying Flexibility
Activating Flexibility



▶ **Title of the subproject**
Combined Use of a Battery Storage Farm for Grid Services and Intelligent Energy Management at a Large Industrial Manufacturing Site

▶ **Funding code**
03SIN552

▶ **Subproject partner**

▷ PROJECT PARTNER
BMW AG

▶ **Contact**
Alexander Funke
T +49 89 38258085
Alexander.AF.Funke@bmwgroup.com

▶ **Visitor site**
BMW Battery Storage Farm
BMW-Allee 1
04349 Leipzig

Tours for individuals and private groups

▷ INQUIRIES TO
info@bmw-besuchen.com

For more information
press.bmwgroup.com/h3Yn0

▲ Large battery at the Schwarze Pumpe power station.

Flexibility in an Intelligently Organised Network

Virtual power plants are a key element in making the supply of electricity more flexible. As part of these networks, individual technical units can make optimal use of their capabilities. This can be learned with the help of digital twins at the system level, under realistic conditions and with real control algorithms. Such simulations allow economic and technical effects to be assessed and optimised for daily use.

‘Through our involvement in WindNODE, we have produced concrete project results and developed exciting possibilities for the future of energy supply as part of a committed network. This is a further building block for the future of Lusatia as an energy region and a modern technological hub.’

Dr Christian Fünfgeld
WindNODE Project Manager,
LEAG

▷ CHALLENGES AND SOLUTIONS // **Increasing flexibility potential**

Today, a ‘virtual power plant’ generally refers to a cross-regional bundling of individual facilities to form large-area power plants. The Schwarze Pumpe site combines a number of flexible base load units with a large battery. It can also flexibly integrate large industrial consumers and fluctuating generation from wind and solar systems. The variable combination of these individually addressable systems into virtual power plants makes it possible to react efficiently to new needs and opportunities in the markets. An example is the introduction of new conditions regarding the provision of balancing power, which reduce the time periods for service provision from 24 to 6 × 4 hours. This enables a plant to participate in the individual bids in a given day in a range of different ways. Such a system was not possible in the past, but makes it possible to boost the efficiency of the plants today. Virtual power plants like the *LEAG energy cubes* make it possible to substantially increase the potential for flexibility.

Change in plant load

Individual plants can only ever respond to high flexibility requirements with varying degrees of efficiency. A virtual power plant, however, combines and deploys its constituent plants optimally in accordance with their characteristics. It is especially important in this context to ensure that a) the planned output is fully achieved and b) the plants are run within their operational limits.

Initial simulations show that the joint provision of primary balancing power through a combination of a flexible base-load power plant and a large battery can place a greater or lesser burden on the component plants, depending on the deployment strategy. For these assessments, a digital twin was developed to map two power plant units and the large-scale battery BigBattery Lausitz at the Schwarze Pumpe site with high accuracy. This made it possible to simulate specific plant behaviour under external and internal operating conditions that realistically reflect elements like the grid situation or the feed-in of renewable energy. The operating results of the digital twin allowed realistic conclusions to be drawn about the load on the individual plants and the efficiency of the overall process.

data points connect the battery and the power plant.

▷ RESULTS // **Virtual power plants – real performance**

LEAG energy cubes

The application scenarios developed will be implemented in LEAG's virtual power plants in the future. This will make it possible to combine and plan while taking into account fluctuating generating units and the flexibility of industrial loads. The networking of controllable power plants will increase efficiency in the entire generation pool.

Close links between large-scale battery and power plant

The large-scale battery was directly connected to the power plant control system through around 2,500 data points by the project partner Siemens. This direct link between battery and power plant enables optimal deployment strategies for the first time.

Other combinations under consideration

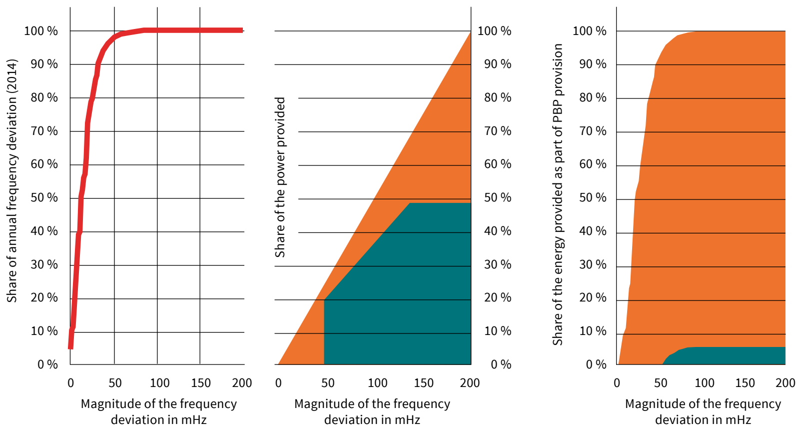
The project partner BTU Cottbus-Senftenberg is conducting cell tests to demonstrate the influence of the loads on real battery cells and enable conclusions to be drawn about different economic deployment strategies for batteries. Simulations for a hybrid combination of large-scale battery, wind power plant and hydrogen electrolysis point the way to new structures for virtual power plants.

▷ CONCLUSION AND OUTLOOK // **Requirements for virtual power plants**

Energy supply as an infrastructure task requires stable solutions with clear specifications. To achieve this, virtual power plants must:

- be able to be configured flexibly,
- link the boundary conditions of supply with the possibilities offered by the markets, and
- observe and make the most of the operating limits of the technical equipment.

All sectors of supply and consumption must contribute to maintaining the security of energy supply at the high level on which Germany, as an industrial country, builds its added value.

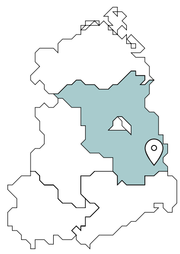


◂ **Cause, reaction and effect:**
98 % of the requested primary balancing power (PBP) is in the range +/– 50 mHz (left). Deploying the battery in tandem with a power plant causes it to supply most of the energy needed (right).

— Battery
— Power plant

SP 7.7

FOCUS AREA
Identifying Flexibility
Activating Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
Innovative Lusatia Energy Hub

▸ **Subproject partners**

▷ PROJECT PARTNERS
Brandenburgische Technische Universität Cottbus-Senftenberg (Brandenburg University of Technology Cottbus-Senftenberg), Chair of Power Plant Engineering

Siemens AG

▷ ASSOCIATED PARTNER
Lausitz Energie Kraftwerke AG (LEAG)

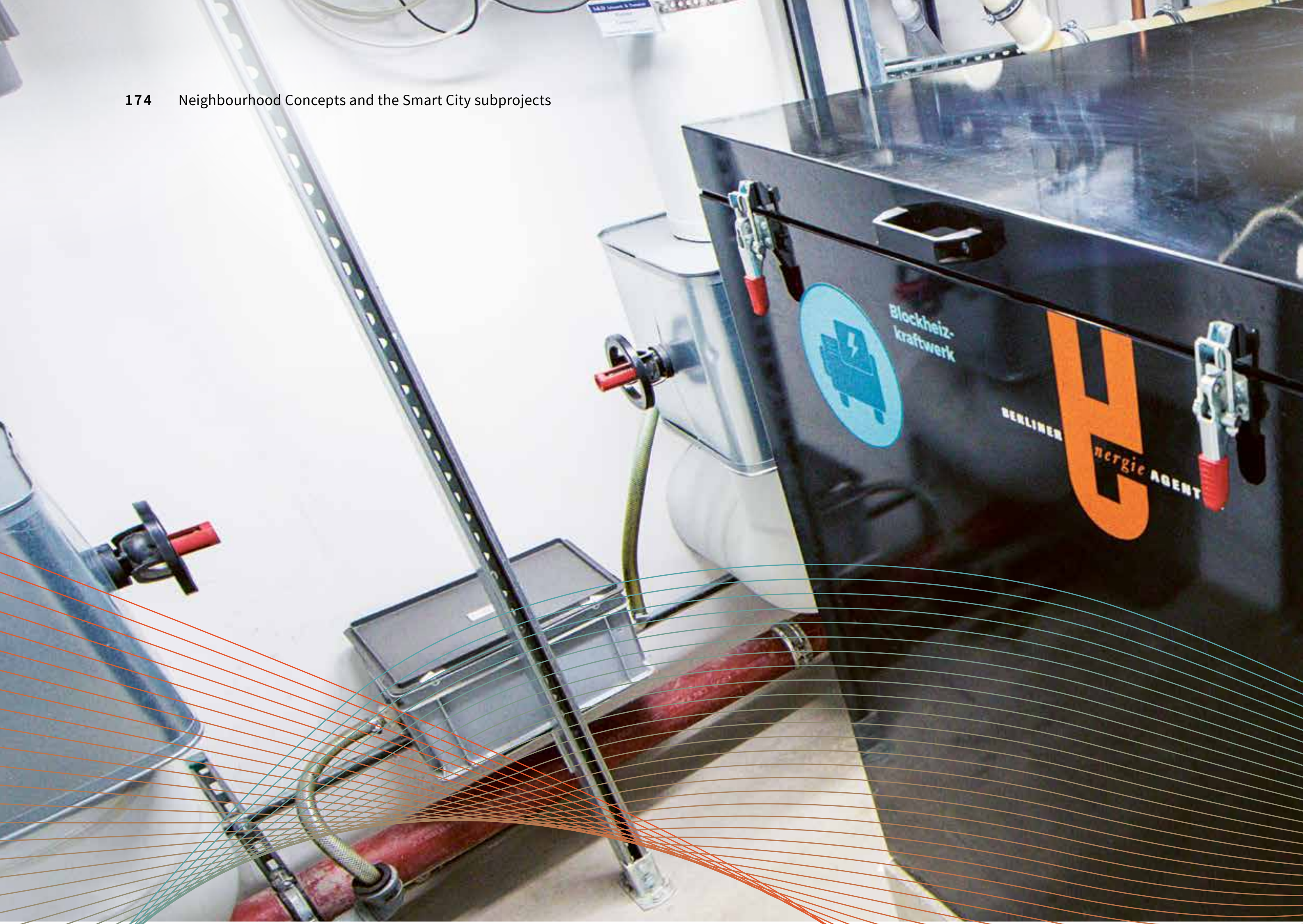
▸ **Contact**
Dr Christian Fünfgeld
T +49 355 2887-2635
christian.fuenfgeld@leag.de

▸ **Visitor site**
Schwarze Pumpe Power Station, Visitor Centre
An der Alten Ziegelei
03130 Spremberg
OT Schwarze Pumpe

The Schwarze Pumpe power plant visitor centre is open Monday to Friday from 9 am to 4 pm and Saturday from 10 am to 4 pm. Visitors interested in a tour of the power plant should register early.

▷ INQUIRIES TO
Visitor services
T +49 355 2887 3561
besucherservice@leag.de

For more information
www.leag.de/energycubes



Participating partners

BERLINER nergie AGENTUR

Borderstep Institut für Innovation und Nachhaltigkeit

degewo Mehr Stadt. Mehr Leben.

RIEDEL

Dresden.

enersis UNDERSTANDING DATA

e+Zeit Ingenieure® ganzheitlich · energieoptimiert · nachhaltig

Gewobag Die ganze Vielfalt Berlins.

LUMENION

nymoen | strategieberatung con|energy gruppe

SENERTEC

SPIE

TU berlin

Westsächsische Hochschule Zwickau University of Applied Sciences

WEWOBAU Bei uns wohnt die Zukunft.

Zentrum eG Wohnungsbaugenossenschaft

zev strom erdgas wärme

174–189

Neighbourhood Concepts and the Smart City

In the model regions Berlin, Dresden and Zwickau, WindNODE is implementing smart city designs with a focus on the flexibilisation and regionalisation of loads and decentralised generation by consumers.

The goal of this workstream is to test different designs, understand the potential of neighbourhood concepts in the context of the energy transition – for example, with regard their effect on the grid and the system – and identify options for transferring results to other regions.

Workstream 8 is coordinated by Dr Severin Beucker (Borderstep Institute for Innovation and Sustainability) on a voluntary basis.

Energy Transition in the Low-voltage Grid – Model Region Zwickau

Energy storage experts at the Westsächsische Hochschule Zwickau (West Saxon University of Applied Sciences Zwickau) and SenerTec Sachsen are collaborating with Zwickauer Energieversorgung (ZEV), the local utility, to demonstrate the energy transition in an intelligent low-voltage grid. The concept uses energy storage, smart meters, smart buildings, electromobility and intelligent consumption to increase levels of flexibility of producers and consumers in a model region of 1,109 residential units, and to ensure that renewable feed-in reaches 211 kW_p.

‘We have achieved the goal of generating as much knowledge as possible – even if not all of the findings were positive. Many issues come to the surface only after in-depth thinking and deployment. Know-how for an all-electric society can only be developed in real-world projects.’

André Hentschel
Technical Managing Director,
Zwickauer Energieversorgung GmbH

▷ RESULTS **// The systems are running!**

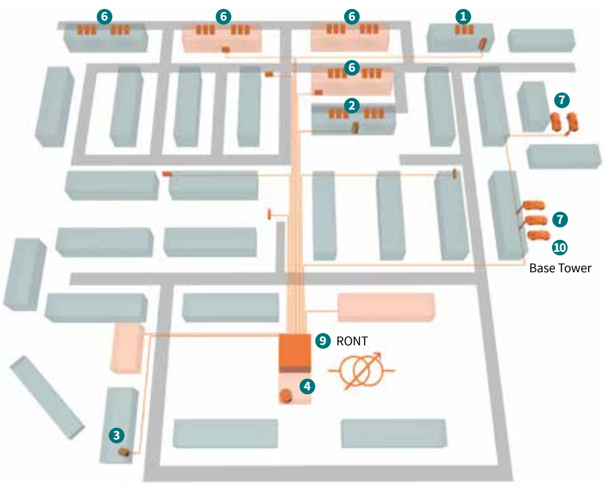
The heart of the electrical supply network is the ❾ controllable distribution transformer (RONT) with an output of 400 kV or 10/0.4 kV. It is supported by four storage systems which store and consume locally generated energy on site. Four scenarios are being tested and validated: energy self-sufficiency, a concept for landlord-to-tenant electricity supply with a similar control scheme, grid stabilisation to increase the voltage at the connection point, and ❶ a central energy storage facility to relieve the transformer and test different modes of operation. In addition, a ❿ Base Tower was built to make it possible to charge electric vehicles. The ❼ electric vehicles are thus integrated as intelligent loads. In addition, the relevant parameters of the entire grid area are measured in one-second intervals, visualized and evaluated. The data and control commands travel through the intelligent grid to the ubineum control centre, a site that can be visited as part of WindNODE. ❺ Load and feed-in forecasts are used to inform the control of all assets.

▼ Figure 1: Basic diagram of the model region Marienthal in Zwickau.

❶ Energy storage
Flexibility option featuring four planned energy storage units with the aim of **storing and using locally generated energy on site**

❷ Smart Home
Incorporating flats as **intelligent consumers** (via appliances such as freezers), measuring consumption behaviour all the way to the end consumer

❸ ICT
Intelligent networking of all components all the way to the control centre at the visitor site **ubineum**



❼ Electromobility
Integration of electromobility solutions as **intelligent consumers** via a control app for end users

❽ Blockchain
Local energy market with **automated contract processing** for various stakeholders (energy storage, end consumers, generators with grid feed-in, utilities)

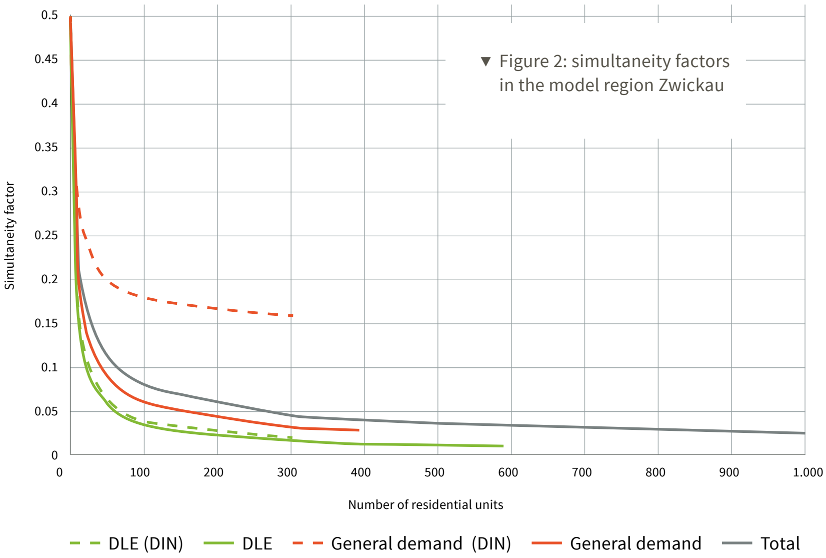
❾ Controllable distribution transformer
(RONT)

❹ Metering system
Acquisition of all meter data needed to **calculate control algorithms** for the flexibility options

❺ Forecasting
Development of more precise **load and feed-in profiles** to allow for the creation of forecasts featuring different types of flexibility

❻ Renewables
Feed-in from photovoltaic systems to provide generation flexibility and useful local energy

❿ Base Tower
Multifunctional streetlight with two charging points providing a total output of up to 22 kW



▼ Figure 2: simultaneity factors in the model region Zwickau

The energy storage systems are controlled based on the scenarios. The energy storage system for grid stabilisation can adjust the voltage at the connection point by up to 2.3 V, as can be seen in the example of simultaneity factors depicted in Figure 2. Here, the capacity of the inverter is the decisive factor with a quantitative influence on grid voltage. The energy storage systems 'energy self-sufficiency' and 'landlord-to-tenant electricity supply' are controlled via a program evaluating the live metering data, the forecast data for the solar power system and the load. In this case, the economic viability depends on the appropriate balance of power output and energy capacity.

The scenarios and complex network enable ❽ blockchain-based billing in energy trading. The model region therefore contains providers, end users and the district balance responsible party (BRP). The contracts are processed and drafted via an online platform. An example of a participant is the owner of an electric vehicle, who can obtain inexpensive ❻ renewable energy from local solar power production on the roofs of the adjacent district near the Base Tower.

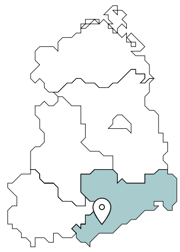
▷ CONCLUSION AND OUTLOOK // **Identifying optimisation potential and developing solutions**

The project has shown that the local energy system with participating assets down to the level of the end customer is able to work in a grid-friendly manner. The challenges identified so far lay, on the one hand, in the use of off-the-shelf components for intelligent deployment in the low-voltage grid and, on the other hand, in the expansion of ICT for the purpose of recording and evaluating metered data every second. After the end of the project, the solutions found here can be transferred to other, similar districts. For example, when implementing these concepts elsewhere, it is important to correctly size the components. This has become easier as the methods and tools developed can be used to simulate other energy grids and configurations as well.

1,109 connected residential units

SP **8.1a**

FOCUS AREA
Identifying Flexibility
Digitalising the Energy System



▸ **Title of the subproject**
Model Region Zwickau/ Marienthal Neighbourhood

▸ **Funding codes**
03SIN546, 03SIN547, 03SIN528

▸ **Subproject partners**

▷ PROJECT PARTNERS
Westsächsische Hochschule Zwickau – University of Applied Science

SenerTec Center Sachsen e. K.

Zwickauer Energieversorgung GmbH

▷ ASSOCIATED PARTNER
SPIE SAG GmbH Region Ost

Westsächsische Wohn- und Baugenossenschaft eG Zwickau

▷ SUBCONTRACTORS
enersis Europe GmbH

nymoen strategieberatung GmbH

▸ **Contact**
Prof. Dr Mirko Bodach
T +49 375 5361454
mirko.bodach@fh-zwickau.de

▸ **Visitor sites**
ubineum
Uhdestraße 25
08056 Zwickau

▷ INQUIRIES TO
info@ubineum.de

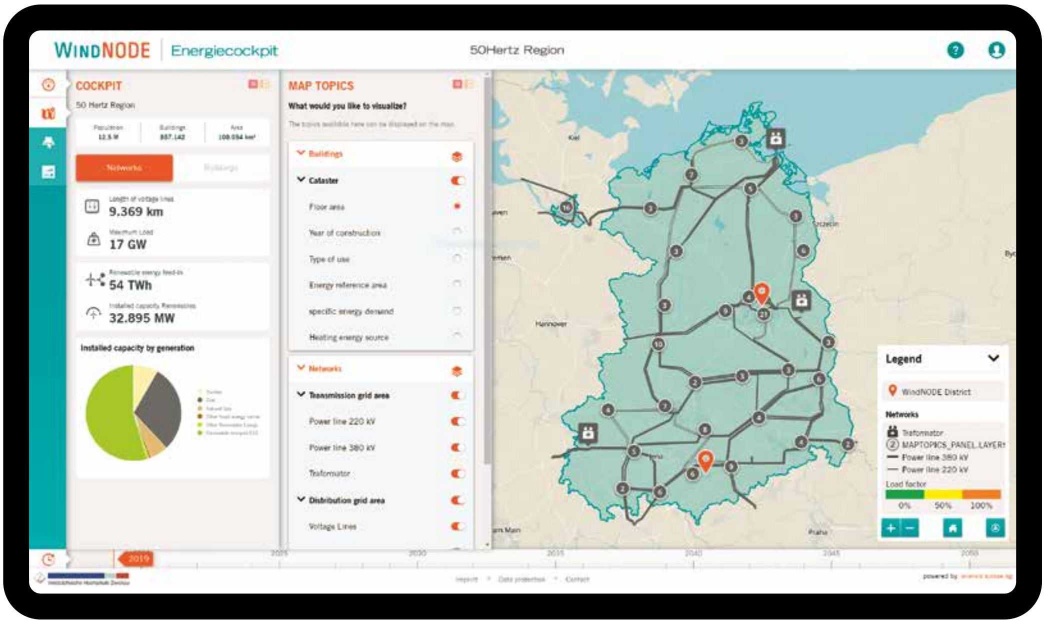
Energy Storage 5
Berthold-Brecht-Str.
08060 Zwickau

▷ INQUIRIES TO
bjoern.veit@fh-zwickau.de

Base Tower
Richard-Holz-Str. 1e
08060 Zwickau

▷ INQUIRIES TO
thomas.hempel@fh-zwickau.de

For more information
www.fh-zwickau.de



◂ WindNODE Energiecockpit: overview of the 50Hertz control area.

WindNODE Energiecockpit – Making the Energy Transition Visible

The energy transition is a necessary step towards mitigating climate change. In order to create visibility for the scenarios and measures associated with this transition, the University of Applied Sciences Zwickau (Westsächsische Hochschule Zwickau) and enersis europe launched a digital platform, the WindNODE Energiecockpit. The platform supplements information on aspects of neighbourhood renovation with grid-related data. It also simulates certain effects of the energy transition and makes it tangible to users of the platform.

‘WindNODE is a successful practice-oriented and interdisciplinary research project. What sets WindNODE apart are not only the innovative project results that hold their own against international standards, but also the unique culture fostered among the participants. WindNODE serves as a blueprint for upcoming reality laboratories, structural change and the European energy transition.’

Thomas Koller
CEO & Founder,
enersis europe GmbH

▷ CHALLENGES AND SOLUTIONS // **Transparency and scenario building**

There is evidence of climate change everywhere. Fridays for Future aims to significantly limit its effect. In response, more and more cities and municipalities have declared a climate emergency. Their goal is to increase transparency about their emissions and learn about the specific actions they can take – not only to pursue climate goals, but also to develop a more proactive approach.

To meet this need, the University of Applied Sciences Zwickau and enersis europe launched the WindNODE Energiecockpit. The platform visualises development and renovation potentials at the neighbourhood level as well as simulating the limits of the low- and high-voltage (LV/HV) grid infrastructure, thereby indicating a future demand in flexibility services.

The data for the WindNODE Energiecockpit are provided by GRIDS energyCity, a digital platform that supplies information and guidelines for the efficient implementation of an urban energy transition. Key figures are presented in a geographical context, which allows energy efficiency measures to be planned easily and monitored over longer periods of time.

The Energiecockpit features

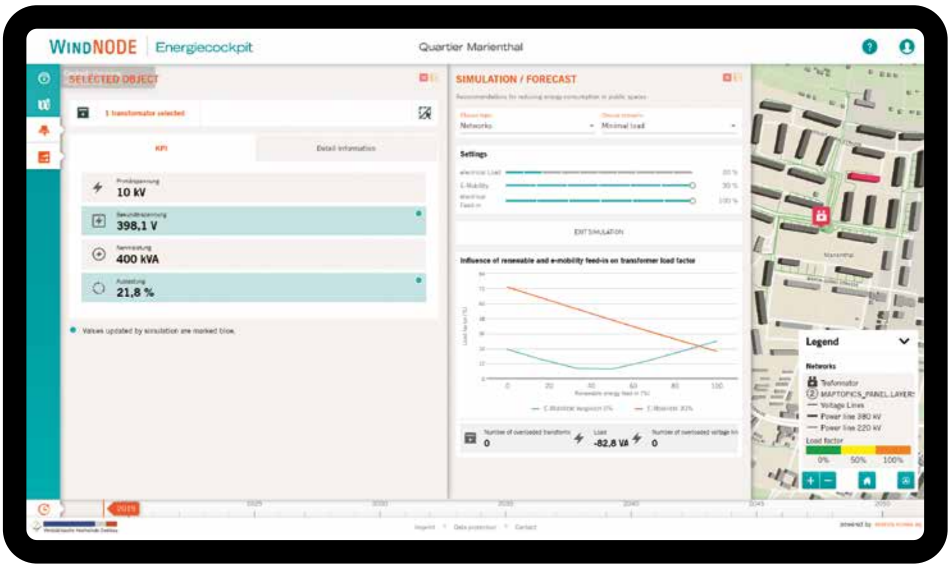
9,374 km

of simulated power lines.

▷ RESULTS // **Digital 'energy cockpit'**

In order to deliver added value from the data, WindNODE partners selected the key figures (e. g. CO_2 emissions and primary energy demand) that would be the primary target of visualisation and evaluation. For better usability, the platform was developed with the help of user-experience and user-interface designers (UX/UI designers).

The WindNODE Energiecockpit presents load scenarios in LV and HV grids and provides renovation roadmaps for the districts of Marienthal (Zwickau) and Prenzlauer Berg (Berlin). It also displays simulation options for evaluating the effects of renewable energy and an increase in electromobility. The Energiecockpit is available to WindNODE partners and can be used for communication and education, for example at the University of Applied Sciences Zwickau.



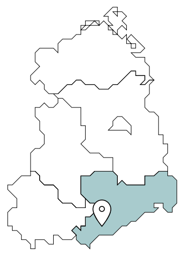
▲ WindNODE Energiecockpit: simulation of low-voltage grid utilisation.

▷ CONCLUSION AND OUTLOOK // **Monitoring the energy transition**

The responsibility for taking decisive action against climate change falls increasingly to cities and municipalities. The WindNODE Energiecockpit outlines the measures needed to reach climate targets and makes critical aspects of the energy transition visible at an early stage. A holistic approach will require the involvement of a wide range of stakeholders, as in the WindNODE joint project itself. Municipal utilities possess an extensive treasure trove of data from various sectors that is ideal for use in digital decarbonisation and the Energiecockpit.

SP 8.1b

FOCUS AREA
Digitalising the Energy System



▸ **Title of the subproject**
WindNODE Energiecockpit – Making the Energy Transition Visible

▸ **Funding code**
03SIN546

▸ **Subproject partner**
enersis europe GmbH
as subcontractor to Westsächsische Hochschule Zwickau (University of Applied Sciences Zwickau)

▸ **Contact**
enersis europe GmbH
Johannes Sigulla
T +49 33 203849424

▸ **Visitor site**
WindNODE Energiecockpit
https://windnode.grids-energycity.com

Login data available under:
support@enersis.freshdesk.com

▷ INQUIRIES TO
johannes.sigulla@enersis.de

For more information
www.enersis.ch

▲ Diagram explaining the ‘how’ of the model neighbourhood in Berlin-Prenzlauer Berg.

Efficiency and Flexibility in the Building Stock: Results from a Model Neighbourhood in Berlin

An innovative approach developed in a 1960s residential neighbourhood in Berlin can facilitate the energy transition. Building automation increases renewable energy use and boosts energy efficiency in buildings. Project results show that flexible behaviour can make an important contribution to reducing CO_2 emissions in the building sector without affecting living comfort.

▷ CHALLENGES AND SOLUTIONS // **Building automation is necessary to mobilise flexibility**

The building sector is responsible for as much as 36 % of total final energy consumption in Germany and therefore plays an important role in the energy transition. Most of the energy used in buildings is derived from fossil fuels, such as natural gas and oil. The largest share is used for room and water heating. The existing building stock is especially important, as this is where most of the energy is consumed. This presents the building sector with a dual challenge: it must significantly reduce its energy consumption and increase the proportion of its energy that comes from renewable sources.

Building automation has a key role in both tasks. It allows buildings and flats to be linked intelligently with the energy system, which in turn enables energy production and storage to be controlled and optimised throughout a building. The creation of this network is also a prerequisite for the use of buildings for sector coupling, i. e. the flexible provision or consumption of energy. Heat production units (e. g. heat pumps, combined heat and power (CHP) units, heating rods in hot water storage tanks), as well as electrical generators and storage units (e. g. PV systems, batteries in buildings or electric vehicles), can be used for this purpose. In general, however, such systems have thus far been operated and controlled in isolation from one other – rarely as part of a network.

An innovative approach to address this issue was developed in the WindNODE model neighbourhood of Berlin-Prenzlauer Berg. Building automation in the neighbourhood allows heating systems to operate in accordance with current demand, decreasing the consumption of heating energy by roughly 25 % relative to similar buildings. In addition, options to store renewable energy or convert it into heat (heating rods in hot water storage tanks with a capacity of 48 kW_{el}) were installed and the new and existing systems (CHP plant with a capacity of 34 kW_{el}, boiler, etc.) were networked via building automation and pooled through the energy management system. The resulting pool can be operated in accordance with criteria of self-optimisation and with energy market objectives (e. g. balancing electricity or prices on the electricity exchange). The neighbourhood can thus function in a flexible manner or in a way that benefits the grid, for example by absorbing surplus electricity from wind turbines and converting it into heat. It can also feed self-generated electricity into the grid at times when relatively little renewable energy is available. All of this presupposes that the living comfort of the tenants in the buildings is not impaired and that flexible control creates an economic benefit.

'In the Berlin model neighbourhood, we were able to show that buildings react to market incentive signals flexibly and in a way that benefits the grid. This makes it possible to save and move large amounts of energy. If we wish to tap this potential, we need a higher CO_2 price and variable electricity prices.'

Dr Severin Beucker
Founder and Partner,
Borderstep Institute for Innovation und Sustainability gGmbH

25%

savings on heating energy through demand-oriented control of heat generation in buildings with building automation

▸ Networked energy generator: a modulating combined heat and power plant in the model neighbourhood.

‘With this flagship project, we showed that automating existing buildings makes a significant contribution to CO_2 reduction and prepares residential areas for sector coupling between electricity and heat.’

Dr Manfred Riedel
Consultant on behalf of Dr Riedel Automatisierungstechnik GmbH

▹ RESULTS **// Model solution for the energy transition in the building stock**

The energy management system developed in the WindNODE model neighbourhood provides a template for energy transition solutions in existing buildings. This was achieved through the following steps:

- ▹ In addition to the existing modulating CHP plant (34 kW_{el}), which supplies the neighbourhood with heat and electricity, heating rods were installed in existing hot water storage tanks with a capacity of 48 kW_{el}. This increased the capability of the neighbourhood to function in a flexible manner, with little technical effort.

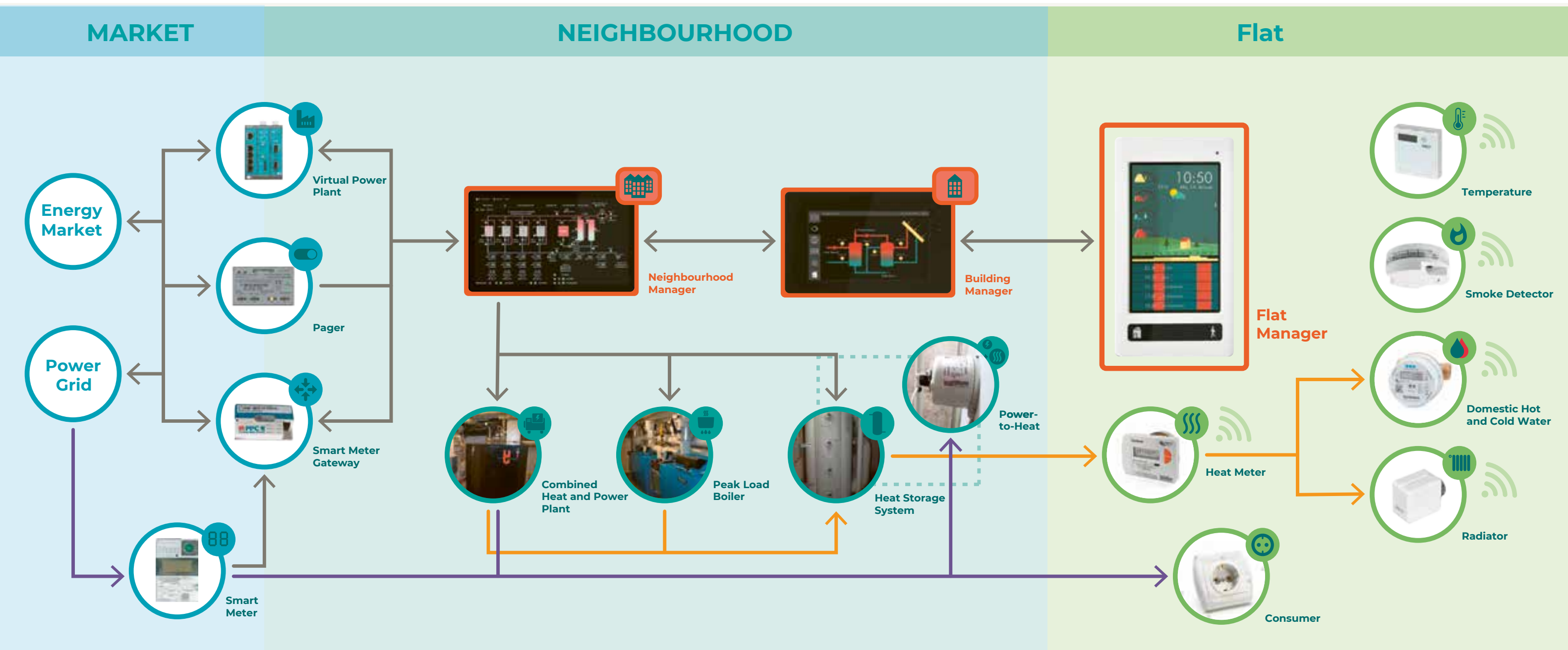
- ▹ The CHP plant and heating rods in the hot water storage tanks were integrated into the neighbourhood’s energy management system via the existing building automation system. This makes it possible to use and control them in an integrated manner for a range of optimisation objectives such as a heat- or electricity-oriented operating modes. Adapting the operating modes of the systems and increasing the use of renewable energy can reduce CO_2 emissions by 10 %.

- ▹ A gateway was used to create an interface to the operator of a virtual power plant. This operator can offer the units – in this case CHP plants and heating rods – or their flexible operation on the energy market, e.g. on the balancing power or spot markets. The operator also determines the profits that can be achieved from bringing these products to market.

- ▹ The load profiles of individual households, buildings or other consumers with a low degree of aggregation in neighbourhoods and in the low-voltage grid are characterised by clearly recognisable load peaks. Algorithms were therefore developed through machine learning to take these characteristics into account. This allows for even more efficient energy management adapted to the optimisation goals.

- ▹ In addition, business models for flexible or grid-friendly neighbourhood operating modes were developed with the relevant stakeholders. It was shown that the models could be implemented quite well in technical terms, but that there are currently very few incentives for flexible operation in neighbourhoods. However, the possible contributions of the models to energy efficiency and CO_2 reduction as well as a good cost-benefit ratio argue in favour of mobilising flexibility from the building sector.

▾ Schematic diagram of the energy management in the model neighbourhood of Berlin-Prenzlauer Berg



▲ Outside view of the model neighbourhood in Berlin-Prenzlauer Berg.

Finally, a visitor site open to both professional visitors and interested residents was set up in the model neighbourhood of Prenzlauer Berg. This will show that it is possible to digitalise a building complex with existing building services and that this results in major advantages to tenants, such as energy and CO_2 savings and increased living comfort. A similar but simplified concept was implemented in a partner neighbourhood in Berlin-Schöneberg, which can also function in a flexible way.

▷ CONCLUSION AND OUTLOOK // Utilising flexibility

Test results from the model neighbourhood in Berlin – Prenzlauer Berg show that it is possible to make various flexibility options in existing neighbourhoods usable through the use of currently available building services. Building automation can integrate both existing systems (CHP plants, heat pumps, etc.) and new units (PtH elements) into a site-related energy management system.

In the future, the energy transition will require flexibility and possibilities for sector coupling in neighbourhoods. Reasons for this include the expansion of renewable energy and the development of electromobility, which will require a charging infrastructure and lead to increased use of stationary batteries and mobile storage units from electric vehicles in neighbourhoods. This will create a need to efficiently control new energy sources and energy sink technologies in the context of energy management in neighbourhoods and use these to reduce CO_2 emissions.

At present, flexibility originating in neighbourhoods can only be traded on the energy market to a limited extent, as the associated legal and organisational expenses are too high compared to the achievable revenues. However, this is set to change as the share of renewable energy in the energy mix rises, because the considerable flexibility potential of neighbourhoods can be used to respond to these changing circumstances.

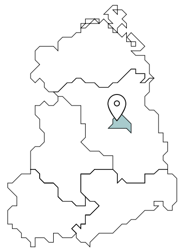
▷ WHAT ARE THE BARRIERS TO THE ENERGY TRANSITION? // The building sector has great potential to reduce CO_2 emissions

The example of existing neighbourhoods shows that the building sector, with its major CO_2 reduction potential, can make a substantial contribution to the energy transition and climate action. Thus far, this potential has been underused, in part because of market failures related to fossil energy sources, which are too cheap relative to renewable energy sources. It is also the result of the investor-user dilemma, which prevents landlords from investing in building automation, which benefits tenants disproportionately and is difficult to refinance due to low operating and ancillary expenses.

Politicians and legislators should take action on both of these points and correct mistakes. This would give energy savings and flexibility a market value, enabling them to be traded sensibly. The building sector would then be able to contribute much more than before to the energy transition and the integration of renewable energy.

SP 8.2

FOCUS AREA
Identifying Flexibility
Digitalising the Energy System



▶ Title of the subproject
Model Region Berlin/
Prenzlauer Berg Neighbourhood

▶ Funding code
03SIN504

▶ Subproject partners

▷ PROJECT PARTNERS
Borderstep Institute for Innovation und Sustainability gGmbH

Dr Riedel Automatisierungstechnik GmbH

Technische Universität Berlin, Distributed Artificial Intelligence-Laboratory

▷ SUBCONTRACTORS
Berliner Energieagentur GmbH

Wohnungsbaugenossenschaft Zentrum eG

▶ Contact
Dr Severin Beucker
T +49 30306451000

▶ Visitor site
Model Neighbourhood Prenzlauer Berg
Wohnungsbaugenossenschaft
Zentrum eG
Hosemannstraße 43
10409 Berlin

Registration required

▷ INQUIRIES TO
Thomas Dittmann
T.Dittmann@wbg-zentrum.de

Smart Energy Testbed and Smart Home Showroom
Ernst-Reuter-Platz 7
10587 Berlin

Registration required

▷ INQUIRIES TO
Marcus Voß
marcus.voss@dai-labor.de

For more information
www.borderstep.de

▲ Water treatment plant in Dresden.

Model Region Dresden: Municipal Load Shifting Potential

Thanks to the diverse nature of their electricity consumption, there is great potential for load management in municipalities. An efficient use of resources requires that the different types of load shifting potential be arranged in order of priority. TU Dresden has developed a tool for this purpose. In addition, load shifting potential within a municipal environment was examined in Dresden Kaditz – eastern Germany's largest wastewater treatment plant outside of Berlin, with an annual energy demand of 23.5 GWh.

▷ CHALLENGES AND SOLUTIONS // **Criteria for load shifting**

To assign a priority to the different types of load shifting potential, TU Dresden has developed a Microsoft Excel-based tool together with the City of Dresden, DREWAG and ENSO. This tool evaluates each load shifting potential against technological and location-specific criteria. The technological criteria include the level of technological maturity and the regulatory framework. The evaluations are stored in the tool so that a user can simply assign a technology to a given load shifting potential. The location-specific criteria (e. g. technical potential and willingness of local parties to support the project), on the other hand, must be recorded and entered into the tool manually by users. The tool then evaluates the different types of load shifting potential and orders them by priority. Users have the option to individually weigh the criteria, allowing for a special focus on factors like profitability or acceptance during implementation.

In the specific application example of municipal urban drainage, the main goal was to identify flexibility in energy consumption so as to create a capacity to react to the volatility of renewable energy sources. There was an assessment of the energy consumption of wastewater treatment at the water treatment plant, wastewater transport in the sewer network, and wastewater transfer. Different possibilities were discussed, from short-term increases in energy consumption to counteract load peaks to temporary reductions in energy consumption. For the purposes of wastewater treatment in Dresden, it is important to take into account that wastewater is transported within a mixed system: in rainy weather, rainwater will flow alongside the domestic and commercial wastewater. From the point of view of energy consumption, this leads to different load conditions and must be considered differently from the baseline.

‘Dresden’s urban drainage sets new standards with its ecologically and economically optimised wastewater management at the municipal level. In order to be able to operate the wastewater treatment plant in a climate-neutral way even as a large-scale consumer, the city is investigating sustainable ideas – such as the activation of reservoirs in innovative projects for drainage control in cases of extreme rainfall – as part of the WindNODE project.’

Gunda Röstel
Commercial Managing Director at Stadtentwässerung Dresden GmbH
Member of the German government’s national hydrogen council

1,850 km

of sewer canals serve some 700,000 customers in the Dresden region as well as in the districts of Meissen and Saxon Switzerland-Eastern Ore Mountains.

▷ RESULTS // **Sports facilities and ice rinks as flexible loads**

Ordering the existing types of load shifting potential by priority has shown that, in addition to the typical flexibility achieved in ventilation and air conditioning, there are also considerable possibilities for load shifting in places like urban drainage and sports facilities. Much can be gained by prioritising this potential, since the actors involved show a particularly high willingness to provide support and the potential itself is comparatively large. The further course of the project therefore focused on these two topics.

In sports facilities, the greatest potential for flexibility comes from the cold processes used to cool ice rinks. A rough energy concept shows how existing flexibility can be increased and how energy efficiency and sector coupling can make an economic contribution to the operation of these facilities. This concept comprises five core components (energy management, solar power system, battery storage, e-mobility and CHP plant), which can be combined to great economic advantage. The energy management system ensures that the prerequisites are in place to implement load shifting. However, given the lack of regulatory incentives (including a lack of price signals and rigid grid fees), it cannot currently be put into practice.

Energy consumption for wastewater treatment:

23,5 GWh

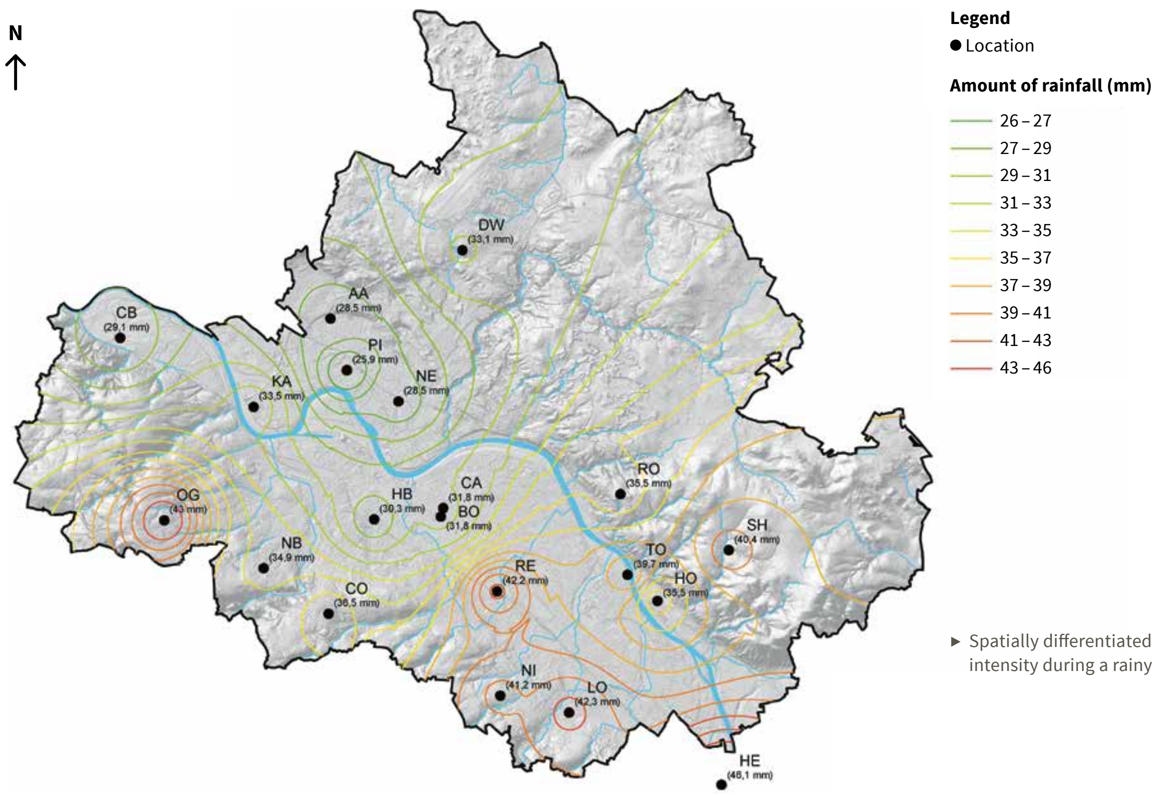
per year

Most of the devices used for the transport of wastewater within the sewer network of the urban drainage system, which has an annual energy demand of 420 MWh, are small and deployed in temporary fashion: as a result, it is only possible to evaluate total energy consumption for devices with an operating-hours counter. Of the 87 installed pumping stations, 66 are wastewater pumping stations equipped with hour counters, and their nominal output is 462 kW. Their average consumption of 50 kW (1,150 kWh/day) is essentially dependent on the volume of wastewater. Since the systems are necessary for the safe discharge of wastewater and the existing pumping facilities were not dimensioned with storage management in mind, the wastewater pumps cannot be used for load balancing. This also applies to the mixed-water storage tank in the sewer network. In addition, the need for permits under German water law and operational issues – such as the risk of structural damage, pre-acidification of sewage or odour nuisance – mean that it is not possible to make full use of the 91,200 m³ network volume.

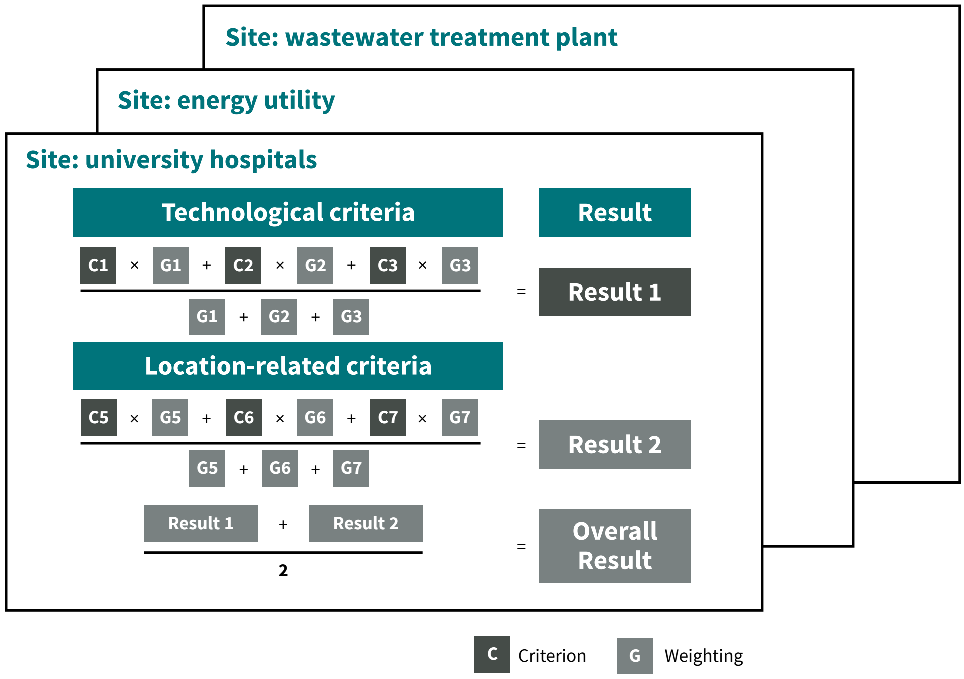
▷ CONCLUSION AND OUTLOOK **// Lack of regulatory framework**

The regulatory framework required to make the most of load shifting potential is currently lacking, and this uncertainty is hampering the implementation of projects – the lack of suitable markets is a particular problem. It is therefore important to think about the topic and address it in political terms so that the different types of potential can be realised if and when the prerequisites are met. When it comes to sports facilities, it could be possible to demonstrate economic fields of application, for instance.

There is no possibility for flexible energy load management in the domain of wastewater transport, as the sewer network and the retention volumes available in the mixed water network play a critical role in flood and water protection. In the process of wastewater or downstream sludge treatment, there is a time-limited potential to reduce energy consumption or to increase it via additional ventilation. The fact that the power required by the waste-



▸ Spatially differentiated precipitation intensity during a rainy weather event.



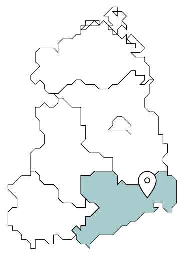
▲ Methodology for the assessment of flexibility options.

water treatment plant is dependent on the amount of wastewater and the occurrence of rainy weather means that these kinds of potential are not readily available in the framework of flexible load management. The importance of decentralised wastewater treatment plants and the effects of wastewater transfer on the daily energy demand in a catchment area must be examined more closely when implementing any concepts. In particular, due to the transport routes, it is currently only possible to imperfectly quantify the energy involved in shifting the material load peak (involving nitrogen) from a transfer area to the central treatment plant.

▼ Flood pumping station and overflow basin Dresden-Johannstadt.

SP 8.3

FOCUS AREA
Identifying Flexibility



▸ **Title of the subproject**
Model Region Dresden/Municipal Load Shifting Potential

▸ **Funding code**
03SIN521

▸ **Subproject partner**

▹ PROJECT PARTNER
Landeshauptstadt Dresden

▸ **Contact**
Gerold Fritsche
T +49 351 822-1119
gerold.fritsche@se-dresden.de

▸ **Visitor site**
Dresden-Kaditz Sewage Treatment Plant
Scharfenberger Straße 152
01139 Dresden

Online registration required

▹ INQUIRIES TO
Sebastian Perkams
T +49 351 822-2020

For more information
www.stadtentwaesserung-dresden.de

▲ The Lumenion high-temperature steel storage facility in Berlin-Reinickendorf.

Using Steel to Store Wind and Solar Power as Electricity and Heat

A new type of high-temperature storage system in a residential neighbourhood owned by Gewobag in Berlin's Reinickendorf district makes it possible to provide a secure and grid-compatible electricity and heat supply based on regional renewable energy. In the course of one year, the storage start-up Lumenion has built a 2.4 MWh storage block made of steel and integrated it into the district electricity and local heating supply operated by Vattenfall Energy Solutions.

‘This pilot project with Gewobag and Vattenfall Energy Solutions is an important milestone for our technology, as well as for the quick and cost-efficient decarbonisation of our energy system. Our steel storage tanks make it possible to choose the time when clean energy is actually used – whether as heat or as electricity. We are already planning further systems with 40 MWh and even 600 MWh.’

Hanno Balzer
Managing Director,
Lumenion GmbH

▷ CHALLENGES AND SOLUTIONS // **Sector-coupling storage in commercial use**

The pilot project in Reinickendorf tests the new type of steel storage in commercial use and deploys it in regular operation as part of WindNODE. In practice, the storage facility will be integrated into the district electricity and local heating supply of the Gewobag residential neighbourhood with an existing gas-powered combined heat and power unit (CHP) from Vattenfall Energy Solutions GmbH. The storage system will temporarily absorb any excess electricity and feed it into the heat supply when required. At a later date, the system can also be expanded to include a power generator. For the time being, however, the current regulatory framework prevents cost-effective electricity reconversion.

▷ RESULTS // **Important milestone for successful scaling**

For Lumenion, this project was an important milestone in the successful scaling of the new technology. Further systems of 40 MWh and 600 MWh are currently in the planning stages. The innovative steel storage facilities make it possible to shift the time when clean energy is used – whether as heat or as electricity. Lumenion technology stores the excess production of regional wind and solar energy plants in a grid-friendly and space-efficient manner at temperatures of up to 650 °C. To do this, it deploys a steel storage core heated using an electrical heater. Steel is especially well-suited to high-temperature storage because its thermal properties allow it to be heated easily and very cheaply while storing very large amounts of energy in a small space.

650 °C

Lumenion stores excess wind and solar energy at 650 °C in steel elements for the price of just a few cents. This energy can then be reconverted into electricity with a time delay and/or used as process, district or local heating.

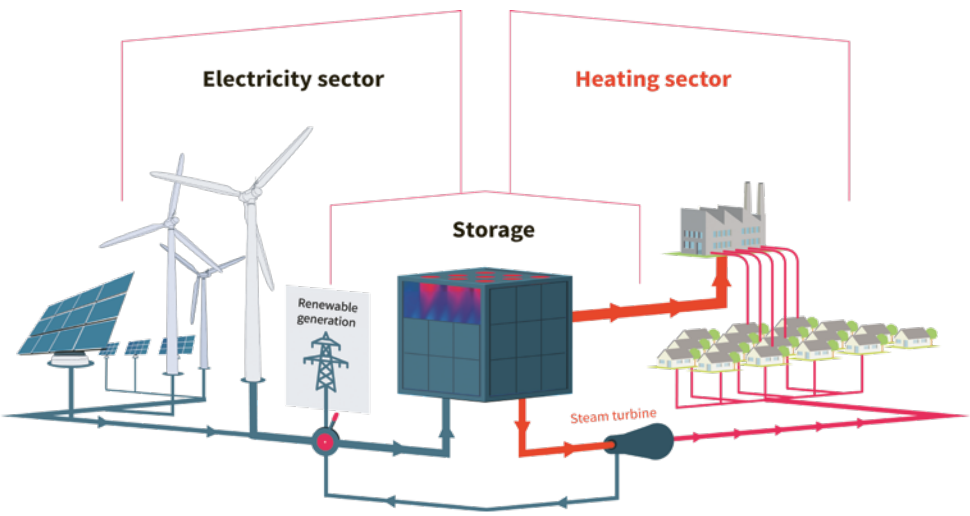
Thanks to the high temperatures, the stored energy can, in principle, be reconverted into electricity via a turbine unit, used entirely for heating or to provide hot water for households, as needed. Roughly half of the energy used in Germany is used as heat – for hot water in homes, heating and industrial processing. In the future, sector coupling will allow excess power generation from wind and solar energy systems to be converted into heat. This technology will allow the heating sector to be decarbonised step by step.

Lumenion had already successfully tested the control and operation of the innovative storage system with a 450-kWh prototype on the Oberschöneweide campus of the Hochschule für Technik und Wirtschaft (HTW Berlin, University of Applied Science).

Within Gewobag's urban neighbourhood, the decentralised storage of electricity as heat enabled by the high-temperature storage system improves the CO_2 balance for 700 residential units. The input power is 360 kVA, which is used in stages of four times 90 kVA to test and demonstrate different power consumption scenarios.

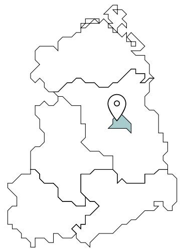
▷ CONCLUSION AND OUTLOOK **// Efficient integration of wind and solar power through sector coupling**

Decentralised sector coupling systems are often regarded as an important component of an emission-free energy supply. As part of our contribution to the WindNODE project, we are working with our partners at Gewobag and Vattenfall Energy Solutions GmbH to demonstrate methods to combine the heating and electricity sectors in a cost-effective way while reducing CO_2. WindNODE provides an important platform for this innovative approach: it offers the technical framework for a new type of systemic sector-coupling solution and an opportunity to test the technology for a large-scale rollout.



▲ Lumenion high-temperature storage model.

SP 8.4 | FOCUS AREA Identifying Flexibility



▶ **Title of the subproject**
Comparison and Transfer of Neighbourhood Concepts

▶ **Funding code**
03SIN504

▶ **Subproject partners**

▷ PROJECT PARTNER
Borderstep Institute for Innovation and Sustainability gGmbH

▷ ASSOCIATED PARTNERS
degewo netzWerk GmbH

eZeit-Ingenieure GmbH

GEWOBAG ED Energie- und Dienstleistungsgesellschaft mbH

Lumenion GmbH

▶ **Contact**
Dr Constanze Adolf
T +49 30 55570510
constanze.adolf@lumenion.com

▶ **Visitor site**
High-Temperature Steel Storage System Pilot Plant
Bottroper Weg 6
13507 Berlin

Registration required

▷ INQUIRIES TO
constanze.adolf@lumenion.com

For more information
www.lumenion.com
www.gewobag.de

Participating partners

- 50hertz | Elia Group
- ASEW Das Effizienz-Netzwerk für Stadtwerke
- B.A.U.M.
- Berlin Partner für Wirtschaft und Technologie | Berlin
- Berlin Brandenburg Energy Network e.V.
- Borderstep Institut für Innovation und Nachhaltigkeit
- DIN
- DKE VDE DIN
- energy saxony
- enviaM
- Iberdrola
- eit InnoEnergy Knowledge Innovation Community
- Stromnetz Berlin
- TU berlin
- ThEGA Thüringer Energie- und GreenTech-Agentur

Participation and Dissemination

WindNODE is a showcase project and an invitation to participate: it invites the public to get excited about the energy transition, discover their own role in it and contribute fresh ideas for an intelligent energy system.

At the same time, this workstream aims to establish national and international contacts, elaborate norms and standards, and open up new markets for partners and their technologies. After all, WindNODE is a joint project that develops transferable solutions, or blueprints, that can advance the energy transition everywhere – in Germany and abroad.

Workstream 9 is coordinated by Wolfgang Korek and Benjamin Horn (Berlin Partner für Wirtschaft und Technologie GmbH) on a voluntary basis.

▲ WindNODE showroom in the foyer of 50Hertz near Berlin Central Station.

WindNODE Energy Transition Showroom

It is extremely important to make the energy transition transparent and comprehensible in order to increase public acceptance of the ongoing transformation process. With the WindNODE Energy Transition Showroom, 50Hertz fosters understanding of the interaction between energy transition, grid and market in the intelligent energy system of the WindNODE region.

‘By setting up the WindNODE Showroom as a visitor site within the showcase for intelligent energy, 50Hertz ensures that the exciting and complex interrelationships of the energy transition can be understood by everyone interested in visiting our headquarter. After all, acceptance and participation begin with information. WindNODE has made an important contribution in this context.’

Dr Dirk Biermann
Managing Director for Markets and System Operation, 50Hertz Transmission GmbH

▷ CHALLENGES AND SOLUTIONS // Energy transition made tangible

The WindNODE Energy Transition Showroom aims to make the research and results of WindNODE as clear and understandable as possible for all interested parties so that it will be effective as a showcase project. It is important to involve the stakeholders in this process, because building a sustainable and safe energy system for the future can succeed only when met with widespread public acceptance.

Stakeholders are highly aware of the energy transition. This includes the expansion of renewable electricity generation on land and at sea, the associated extension of the electricity grid, and the evolution of electricity prices as well as taxes and levies. These developments cannot be viewed in isolation, however, but must be viewed holistically. The legal, regulatory, technical, business-related and economic contexts are therefore highly complex and require thorough explanation.

▷ RESULTS// Explaining the why

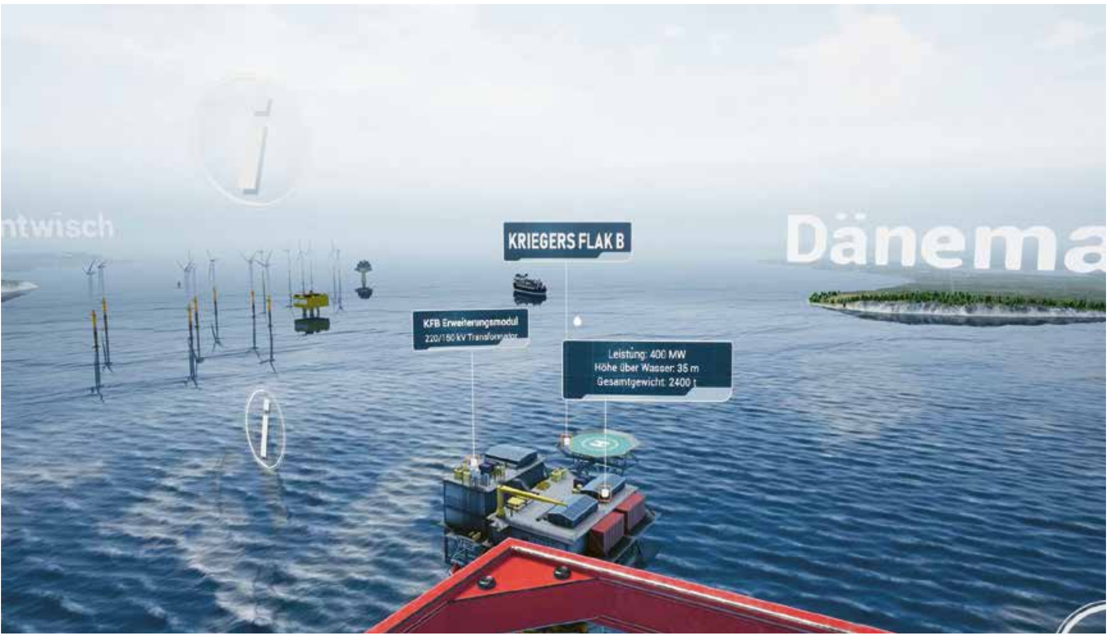
The WindNODE Energy Transition Showroom was designed to explain the reasons and details of the energy transition. 50Hertz set up a visitor site in its central headquarters in Berlin-Mitte that provided information for a public audience on a range of topics. The showroom remained open until spring 2020.

163 m²

of exhibition space was used for the visitor site, featuring numerous topics and solutions related to the energy transition.

Visitors can currently find out more about the following topics:

- What challenges does the energy transition pose for the market, grid and system?
- How do WindNODE projects help to overcome these challenges?
- What is the current grid utilisation in the 50Hertz grid area?
- How do the employees of a transmission system operator experience the challenges linked to the energy transition?
- How can smart meter data be used to operate the electrical system securely and efficiently in the future?
- How can the WindNODE flexibility platform help reduce the expensive curtailment of wind turbines?
- What role will sector coupling play in the future energy system?



▶ Experiencing the work of 50Hertz in virtual reality.

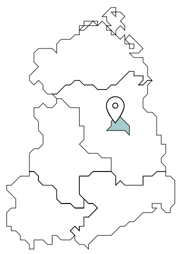
▷ CONCLUSION AND OUTLOOK // **Experiencing the results**

A special highlight of the exhibition is the opportunity to interactively experience everyday life in the 50Hertz control room and the tasks of the system operators in virtual reality. For example, users can use balancing power to stabilise the grid frequency or react to grid congestion by dispatching generating units. Each scenario is accompanied by background information that covers related topics as well.

Using new kinds of multimedia formats like VR, the showroom enables visitors to gain deeper insights into the complexity as well as the importance of the energy transition. This forms part of an effort to foster stakeholder dialogue and increase public participation.

SP 9.1

FOCUS AREA
Developing a Reality Lab



▶ Title of the subproject
WindNODE Energy Transition Showroom

▶ Funding code
03SIN500

▶ Subproject partners

▷ PROJECT PARTNER
50Hertz Transmission GmbH

▷ ASSOCIATED PARTNER
Iberdrola Renovables Offshore Deutschland GmbH

▶ Contact
Dr Georg Meyer-Braune
T +49 30 51502133
georg.meyer-braune@50hertz.com

▶ Visitor site
WindNODE Energy Transition Showroom
Heidestraße 2
10557 Berlin

Registration required

▷ INQUIRIES TO
georg.meyer-braune@50hertz.com

For more information
www.50hertz.com

WindNODE Live! – a Showcase for Participation and Replication

To boost participation and disseminate project results, Berlin Partner organised a range of specialist events and created a mobile exhibition that presents an overview of WindNODE activities to the public. Creative contributions from the 'Energy meets Art' initiative of Technische Universität Berlin were another key focus area.

▼ Christian Rickerts, State Secretary in the Senate Department for Economics, Energy and Public Enterprises, learns about project activities at the WindNODE Live! tabletop diorama.

▸ Animating the energy transition: development and production of an artistic explanatory video by TU Berlin in cooperation with the animation studio Monströös.

Over the past three years, the travelling exhibition WindNODE Live! has presented the WindNODE partners and their work to visitors at more than 20 locations. At each stop, it displayed project highlights, presented visitor sites and used image and sound in animated graphics to showcase the core elements of the workstreams on a table-sized map of northeastern Germany. Visitors were treated to a bird's-eye view of the workstreams and could explore their contents in greater depth. The exhibit also provided the setting for many attractive photographs, which have been especially valuable in external communication and were well received on social media.

In some cases, local press reported on the exhibition opening in their area. The different locations provided opportunities to reach a range of target groups, from simple consumers to curious laypeople to professional audiences. Interactive elements made it possible for visitors to become active participants, which allowed them to absorb the information in a playful way. As a result, the exhibition format played an important role in facilitating the knowledge transfer that was a key aspect of the WindNODE project.

As part of the subproject, a number of expert dialogue events were held on the topics of sector coupling and flexibility in the intelligent energy system. These events targeted a more specialist audience; each addressed issues from a range of perspectives, but all were conducted at an expert level. At the Berlin Energy Days 2017 and 2018, for example, discussions were organised on digitalisation as a driver of sector coupling and the system-stabilising effect of sector coupling at the municipal level. Workshops were organised to dive deeper into issues such as the visitor sites of the energy transition, or the different types of flexibility in the intelligent energy system. At re:publica19, a focus session was devoted to the question: ‘Digitalisation, energy transition, big data – what's all that to me?’

In addition, the subproject tested event formats that established links to other industries. These annual cross-industry forums focused on the challenges associated with the energy transition, on connecting the energy and healthcare industries (Tag der Energiewirtschaft 2017), on the mobility sector (Crossing Industries, Coupling Sectors 2018, hosted by Siemens) and on information and communication technology (DIGITAL.CLEAN.ENERGY Barcamp 2019). Between 2017 and 2019, a total of approximately 1,100 experts participated in eleven different events.

Finally, participants in the ‘Energy meets Art’ initiative developed inter- and transdisciplinary objects and works of art to visualise the energy transition and approach it from an emotional perspective, incorporating content from the fields of energy, art, architecture and ecology (see page 220 for a special feature on this initiative.)

‘The challenge of presenting the potential and opportunities of an energy transition in a “tangible” way using the tools of Enlightenment 2.0 can trigger something in people – and not just on a purely intellectual level. This impulse is valuable, because the energy transition is a community project.’

Roland Strehlke
Communications Manager
Department of Power Engineering,
Berlin Partner für Wirtschaft und Technologie GmbH

▲ Energy drop: collecting energy in a hub storage system integrated into a wind turbine for use at a later time. Student design work. TU Berlin in cooperation with FB Modell + Design.

This part of the subproject focused on three main topics: first, cooperation with artists who created works of art on the energy transition; second, a collaboration with Prof. Dr Ingo Uhlig from the Department of Energy Systems at Technische Universität Berlin on the subject of artwork from around the world related to climate, ecology, energy and resources; and third, the implementation of study projects in the fields of ecology and environmental planning, architecture, and art and design.

▷ CHALLENGES AND SOLUTIONS // Acceptance and 'aha!' moments

A successful energy transition will require acceptance from the population at large, and this has to be based on knowledge and information. This is why visitors to WindNODE Live! were educated and informed about the contents of the showcase project, the participating WindNODE partners and the key topics in a mobile 'table of contents you can walk through' – an installation intended to provide an 'aha!' moment or two.

By comparison, the goal of 'Energy meets Art' was to analyse the technical progress brought about by the energy transition and make these advancements visible. The initiative aimed to present the national and global opportunities of the 'German energy approach' in an appealing and innovative way. As part of the programme, a joint networking platform was created for artists, students and energy experts so that participants could provide mutual inspiration. This platform facilitated the production of content that was featured in the exhibit to promote knowledge transfer. The individual pieces were compiled into a catalogue to showcase the exchange of ideas that took place within 'Energy meets Art'.

▷ RESULTS // Comics, films and art exhibition

By the end of 2019, the exhibition had been presented at 20 locations, and five more stops are planned for 2020. In total, an estimated 20,000 visitors have toured the exhibit. The press in Dresden and Rostock reported on its respective openings.

More than 40 contributions in the form of posters, films and comics as well as objects and works of art were created as part of the 'Energy meets Art' project. The contributions will be made available for exhibitions of all kinds and will be presented in a printed catalogue. Some of the contributions, as well as the films, are already available online on the WindNODE internet platform and on YouTube, while others can be accessed via QR codes in the printed catalogue.

▲ Wind of change: illustrated short story about the restructuring of our energy supply and the technical advancements made by humans as part of this transition – TU Berlin in collaboration with illustrator, children's book writer, and comic creator Thilo Krapp.

▲ Central element of the travelling exhibition: the tabletop diorama with movable 3D elements on a map of the WindNODE region.

▷ CONCLUSION AND OUTLOOK **// Strong arguments vs. simple explanatory models**

The WindNODE Live! exhibition demonstrated how difficult it is to educate different groups about the goals of the digital energy transition – and the challenges of sector coupling and flexibility – in order to increase public acceptance. Even in-depth discussions on this topic by experts in the field often remained relatively superficial. A key observation from this project was that the simple question of how sector coupling could be successfully implemented always met with the same response ('it's the duty of regulators'). This was an important lesson. Adapting the questions and designing new discussion formats made it possible to anticipate and prevent this kind of response. At the same time, it became clear just how high the symbolic value of specialist events – especially in a format like WindNODE Live! – was to the external impact of the showcase as physical points of contact and forums for discussion. The 'analogue' aspect of these events seems to be important, too: while social media and other online activities can support the work to increase acceptance and public participation, they cannot fully substitute coming together.

▷ WHAT ARE THE BARRIERS TO THE ENERGY TRANSITION?

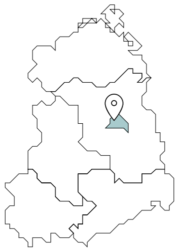
Although the energy transition is supported by a broad social consensus, only a small segment of society recognises and fully understands the details of this transition. Complexity, particularly where legislation is concerned, is one of the main obstacles to the energy transition: it acts as a deterrent and limits the potential for new, digital business models that could represent a significant step forward in the integration of renewable energy into the energy system.

25

The WindNODE Live! travelling exhibition made 25 stops between 2018 and 2020. It visited all six federal states in the WindNODE region, introducing an estimated 20,000 people to the showcase and the topics that it addressed.

SP 9.2

FOCUS AREA
Developing a Reality Lab



▸ **Title of the subproject**
WindNODE Live! – A Table of Contents You Can Walk Through

▸ **Funding code**
03SIN05

▸ **Subproject partners**

▷ PROJECT PARTNERS
Berlin Partner für Wirtschaft und Technologie GmbH

Technische Universität Berlin, Former Department of Site Science/Soil Protection Ecology

▸ **Contact**
Berlin Partner für Wirtschaft und Technologie GmbH
T +49 30 463020
windnode@berlin-partner.de

▸ **Visitor site**
Travelling exhibition WindNODE Live!
windnode@berlin-partner.de

Exhibition schedule:
www.windnode.de/en/results/energy-and-society/windnode-live

Energy meets Art:
www.windnode.de/en/results/energy-and-society/energy-meets-art

▷ INQUIRIES TO
windnode@berlin-partner.de

For more information
www.windnode.de/ueber/schaufenster

WindNODE Challenge – Shaping the Energy Transition Together

In order to increase acceptance for the energy transition, Berlin Partner used creative competition formats and cooperative educational games to involve external stakeholders in the showcase. The company also cooperated with the Borderstep Institute to conduct a study on incubator programmes in the energy industry.

‘The energy transition affects all of us. Unorthodox approaches can contribute significantly to its success. One of the main messages from the WindNODE Challenge is that we must live this, not use it as an empty phrase.’

Benjamin Horn
Project Manager Energy Technologies,
Berlin Partner für Wirtschaft und Technologie GmbH

▷ CHALLENGES AND SOLUTIONS // **Access to the showcase facilitates acceptance**

One of the challenges of a showcase project the size of WindNODE is opening up and disseminating the content and results of the activities to people outside the project. At the same time, various studies have shown that, over the past few years, increasing levies and local burdens resulting from infrastructure expansion have often put public acceptance of the energy transition to the test. The two core objectives of the WindNODE Challenge were thus to make WindNODE accessible to external stakeholders while helping to build support for the energy transition. The main target groups for the contest were students and start-ups. For this reason, a study conducted in parallel with the annual WindNODE Challenges dealt explicitly – and for the first time – with the emergence of incubator and acceleration programmes in the energy industry. The study focused mainly, though not exclusively, on the WindNODE region.

▷ RESULTS // **Experimental formats yield new insights**

The first Challenge, held in 2018, sought innovative approaches to develop the municipal utilities of the future, integrate electromobility, envision the future of smart meters and build enthusiasm for the energy transition. In the contest,

▼ Active in the energy transition: as part of WindNODE Challenge 2019, the Energy Transition Game allowed players to assume the roles of ministers, start-up founders and energy suppliers and make far-reaching decisions about the energy transition.

▲ WindNODE Challenge 2018 finalists at the award ceremony on 5 December 2018 in Berlin.

Solmove was awarded first prize for its 'smart solar road', an intelligent solar roadway that generates 100 kWh of clean electricity per square metre. Ellery Studio won second place for its Solar Punk Festival 2018 (SPF18). Starting in August 2018, SPF18 brought together 30 people – NGOs, scientists, artists and students – to create a walk-in installation (the 'Solar Capsule') that was inspired by the scientific presentations and methods of design thinking and futurology. Fresh Energy came in third place with an app that uses complex algorithms to analyse individual electricity consumption data from smart meters. WindNODE Challenge 2019 tested the Energy Transition Game, a role-playing simulation about the energy transition. The simulation is an example of 'serious gaming': players assume new roles, take on the responsibility of a minister, NGO or power plant or grid operator – and experience entirely unexpected effects of climate change. A computer running in the background uses algorithms to analyse scores and determine the game state. The game was developed by the Centre for Systems Solutions (www.systemssolutions.org) and the 'think-and-do-tank' Thema1. The WindNODE Challenge 2020 calls on participants to present the energy transition in a one-minute video. There is no limit on creativity; all ideas are welcome, as are all genre categories – including fictional, animated, documentary and science fiction films. A prize of €4,000 will be split between the winners.

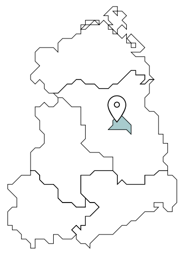
▷ CONCLUSION AND OUTLOOK // **Qualitative vs quantitative approach to increasing acceptance**

A key lesson learned was that activities were often limited to regional 'bubbles' of subject matter experts and others with a special interest. One way forward might be to offer a wider range of creative formats that might spark interest in other groups as well. Insights from the WindNODE Challenge can guide the design of participatory measures used in future research projects. They can help in determining the appropriate allocation of resources and inform discussions about the most effective measures for reaching large audiences. In addition, these insights also indicate which measures are suitable to target select groups in a more in-depth way.

80% of the participants in WindNODE Challenge 2019 (Energy Transition Game) agreed with the statement that 'serious games' can help increase knowledge and understanding of the energy transition among non-experts.

SP 9.3

FOCUS AREA
Developing a Reality Lab



▸ Title of the subproject
WindNODE Challenge – The Energy Transition as a Community Project

▸ Funding code
03SIN05

▸ Subproject partners

▷ PROJECT PARTNERS
Berlin Partner für Wirtschaft und Technologie GmbH

Borderstep Institute for Innovation and Sustainability gGmbH

▷ ASSOCIATED PARTNERS
Berlin-Brandenburg Energy Network e. V.

KIC InnoEnergy Germany GmbH

▷ SUBCONTRACTOR
B.A.U.M. Consult GmbH

▸ Contact
Berlin Partner für Wirtschaft und Technologie GmbH
T +49 30 46302-0
windnode@berlin-partner.de

For more information
www.berlin-partner.de

▲ International delegation visit to the booth of Berlin Partner at the E-Word 2020 in Essen.

International Networking and Benchmarking

The appeal of a showcase project on the scale of WindNODE is not limited to northeastern Germany, but extends even beyond the country's borders. To maximise the project's reach, Berlin Partner organised a series of international trade events and hosted several international delegations. Energy Saxony prepared a benchmarking study that conducted an expert comparison of the WindNODE results on an international level.

'WindNODE has shown workable solutions for the energy transition beyond regional and national borders. This has enabled new forms of cooperation, networks and partnerships between energy regions.'

Wolfgang Korek
Head of Energy Technologies Unit and
Manager of the Energy Technology Cluster,
Berlin Partner für Wirtschaft und Technologie GmbH

▷ CHALLENGES AND SOLUTIONS // **International export of ideas**

International networking has two components: export of the energy transition 'made in Germany' and international exchange of experience. In order to raise international awareness of WindNODE and share project results abroad, it was essential to build relationships with international partners. These connections were cultivated in a number of ways; for example, Berlin Partner helped organise several professional events, such as a networking get-together in Brussels with other European energy regions and the Urban Energy Forum in the years 2018 – 2020.

Energy Saxony developed a benchmarking system that could be used to evaluate the central challenges and proposed solutions of the WindNODE project and compare them with other European projects. The resulting study shows how flexibility is integrated into the power grid in other parts of Europe, thus providing an overview of different instruments and their applicability to local conditions.

30

delegation receptions, roadshows, lectures in international contexts, and presentations at trade exhibitions and conferences took place in subproject 9.4 alone. There were countless more throughout the WindNODE project.

▷ RESULTS // **Qualitative comparison in a European context**

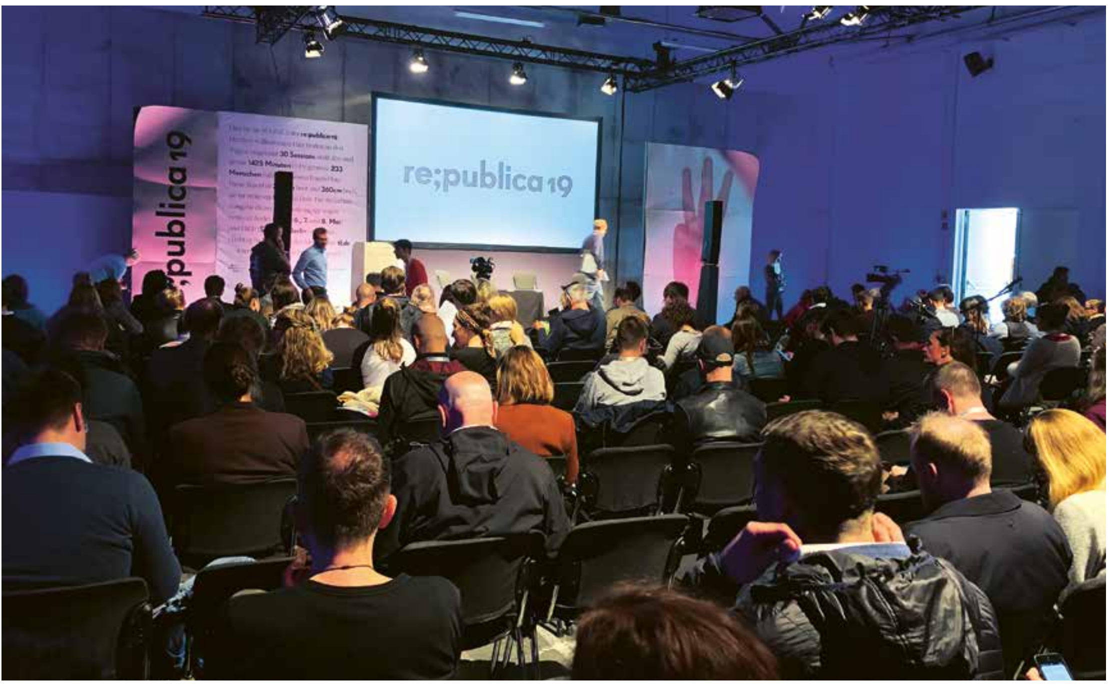
Cooperations and partnerships made international networking events even more successful. The Urban Energy Forum, for example, was organised in close collaboration with the Berlin-Brandenburg Energy Network in the years 2018–2020. Thanks to this cooperation, the Forum was featured as an international B2B event at the Berlin Energy Week and as an official side event at the Berlin Energy Transition Dialogue, which was hosted by the Federal Ministry of Economic Affairs and Energy at the Federal Foreign Office.

The benchmarking study contains recommendations for technical and regulatory measures based on a qualitative comparison with other European initiatives. The underlying system can be applied as a tool for similar topics in the field of smart grids.

▷ CONCLUSION AND OUTLOOK // **Energy transition at different speeds**

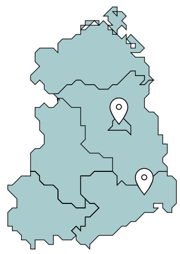
The networking activities with international partners revealed the different levels of energy transition progress within Europe. In particular, the challenge of integrating large amounts of renewable electricity into the energy system and the associated grid congestion were difficult for some international partners to understand, as many other countries are still at the very beginning of their own energy transition process. Nevertheless, they can provide helpful impulses, such as when it comes to the development of digital services designed to solve energy-related problems.

▼ International exchange of experience, which was a key part of the Urban Energy Forum, was also integrated into other WindNODE events, such as at re:publica19.



SP 9.4

FOCUS AREA
Developing a Reality Lab



▶ Title of the subproject
WindNODE: International Networking and Benchmarking

▶ Funding code
03SIN05

▶ Subproject partners

▷ PROJECT PARTNERS
Berlin Partner für Wirtschaft und Technologie GmbH

Energy Saxony e. V.

▷ ASSOCIATED PARTNERS
Berlin-Brandenburg Energy Network e. V.

KIC InnoEnergy Germany GmbH

Thüringer Energie- und GreenTech-Agentur GmbH

▶ Contact
Berlin Partner für Wirtschaft und Technologie GmbH
T +49 30 46302-0
info@berlin-partner.de

Energy Saxony e. V.
Kramergasse 2
01067 Dresden
info@energy-saxony.net

For more information
www.berlin-partner.de
www.energy-saxony.net

▲ Your choice of cards will decide: controllable feed-in and consumption are flexibility options that help to restore balance.

Hertzschlag / Heartbeat: a Game is Worth a Thousand Words

Hertzschlag, meaning heartbeat in English and referring to the unit hertz, is a participatory tool that engages interested members of the public in a playful way while meeting the need for education and transparency during the energy transition. The board game was created in collaboration with a professional game developer and is primarily intended for a young audience aged 12 years and over. Players have fun as they learn about the interconnections between individual components of the energy system and about the power grid, renewable energy and energy efficiency. This approach educates players on climate change and cultivates an understanding of technical and systemic challenges. The game will be used mainly in Berlin schools. Supplementary educational material is included to help teachers incorporate the game into their lesson plan.

▷ CHALLENGES AND SOLUTIONS // **The inspiration for the game**

Studies show that the public does not feel adequately informed about the energy transition. Power grids play an essential role in the energy transition and are instrumental in integrating renewable energy into the grid and accommodating new consumption behaviour, as in the context of electromobility. Because our work as urban distribution system operators is mostly ‘underground’, however, it goes largely unnoticed by the general public. It was important to us to create a participatory workstream as part of WindNODE so that we could make the often incomprehensible world of the energy system more accessible. That is how the idea for a game was born: we wanted to create an activity that would focus on the themes of the WindNODE project and allow players to directly experience all of the interconnections between individual elements of the power system.

▷ RESULTS // **The finished game**

Thus far, 3,000 games have been produced, and the first school classes have successfully tested the finished game. The following elements played an especially large role in the game’s success:

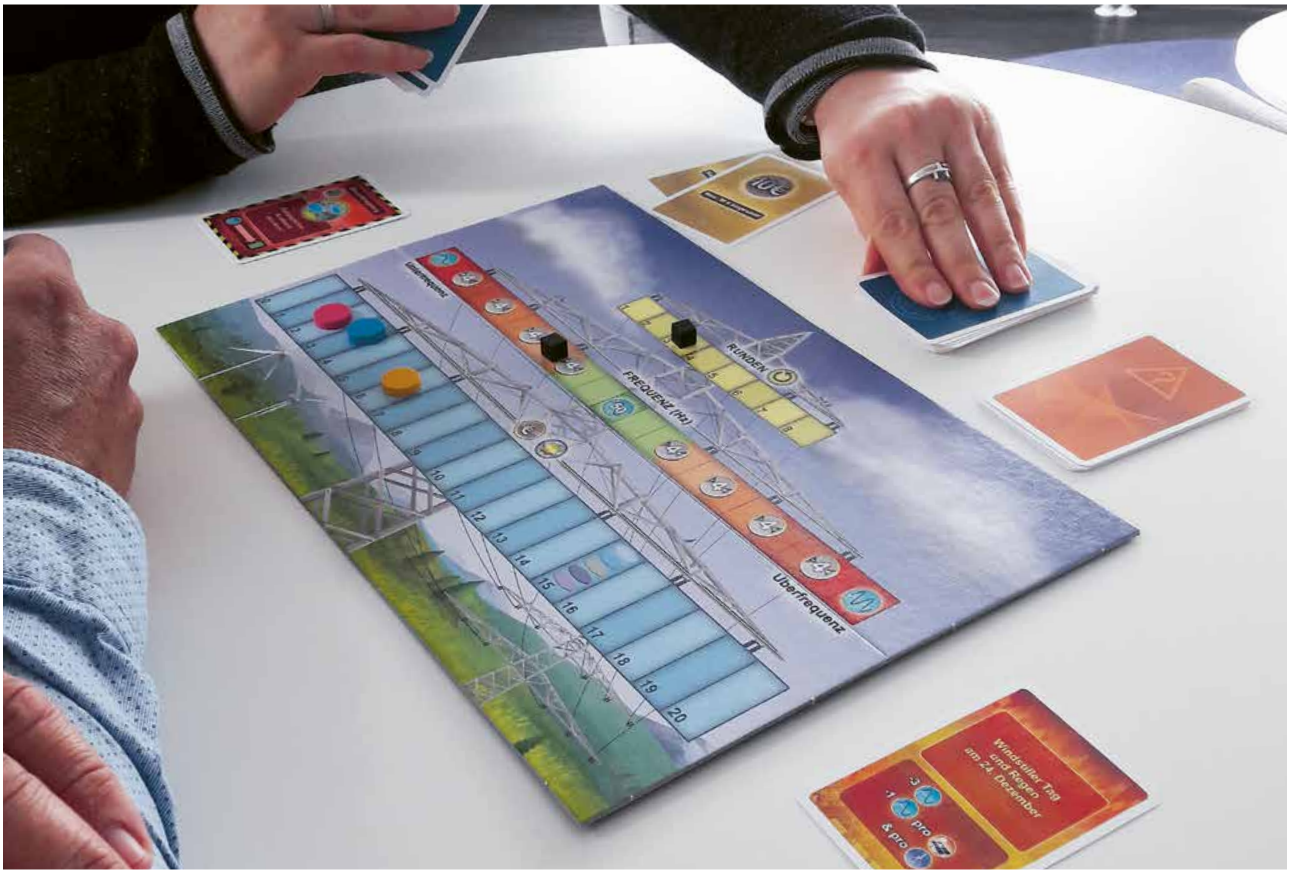
Game developer: In order to create the game's mechanics, it was important to lay the groundwork by finding the right partner: a professional game developer. Internal coaching allowed us to familiarise him with ‘our world’ and design a board game that conveyed energy system interconnections in a playful way.

Target group segmentation and design thinking: We identified the target audience on the basis of the ‘persona’ technique, which was supplemented by our impressions from personal interviews. In determining the appropriate target group, we considered which audience would best respond to a board game, how we could best accomplish this and what minimum age we should set to ensure that players would understand the educational material.

‘It’s great to see the kinds of creative participatory methods that can reach a young target group. By offering supplementary educational material, we’ve put together a climate education package that will be of interest to schools. I look forward to getting feedback and refining our approach to provide additional learning opportunities.’

Anja Lehmann
WindNODE subproject leader
Stakeholder Management &
Communication,
Stromnetz Berlin GmbH

▼ Weather conditions, system disruptions and everyday occurrences featured in the ‘event cards’ could throw the energy system out of balance.



‘The energy transition is an extremely relevant topic for our society. Climate change education in schools is important in order to build understanding – and therefore acceptance – from an early age. It can even lay the groundwork for new problem-solving strategies. We also see it as our responsibility to make this complex material accessible to young people. Hertzschlag is both educational and fun. We look forward to bringing the game into Berlin's schools.’

Dr Erik Landeck
Managing Director,
Stromnetz Berlin GmbH

Because the topic of energy is already part of the curriculum in German schools for 15- and 16-year-olds, we selected pupils from this age group as our target audience and organised a design-thinking workshop with them. This allowed us to incorporate the prior knowledge and expectations of the pupils into the game development and develop the basic concept of the game, which we used to design a prototype.

Game methodology: We collaborated with the game developer to create playing cards, as well as ‘event cards’ that can significantly alter the course of the game. We then tested the game by playing several rounds with different focus groups, including pupils and members of the Stromnetz Customer Advisory Board. Input from both insiders and outsiders of the energy industry allowed us to create a broad range of energy-related event cards.

Design and branding: What should the game be called? The name ‘Hertzschlag’ won the naming contest at the 2019 WindNODE hackathon (Subproject 1.3 Open Data Portal, see p. 68). The winning subtitle, ‘Haltet das Stromnetz unter Spannung’ [‘Keep the grid energised’], is a direct reference to the power grid. Thematic references to this topic are included in the artwork for the box and playing cards, which was developed by a graphic designer. It was important to make the game visually interesting so that even those outside the energy industry would be curious about the contents.

Supplementary teaching materials: Professional teaching materials accompany the game in order to facilitate its use in schools and help educators get started. Supplementary resources include an informational brochure, worksheets and online exercises.

Use: Classroom sets of board games, along with supplementary teaching materials, will be offered to all Berlin secondary schools.

▷ CONCLUSION AND OUTLOOK // **Participatory approach**

The game allows pupils to learn from personal experience and understand how the power grid is affected not only by the use of renewable energy, but also by their own decisions, the political environment, and much more.

▸ Box, gameboard, event cards and sample pages from the rulebook.

3,000

games were produced in the first print run.

Game features:
- The game is semi-cooperative. Individual players can win points while striving towards a common goal.
- The objective of the game is to keep the energy system balanced at all times, i. e. the frequency at 50 hertz.
- If the system gets too far out of balance, everyone loses.
- The individual actions of every player affect the frequency and thus the balance. Events (weather, system disruptions, etc.) can also throw the system out of balance.
- The more weather-dependent renewable energy is in play, the greater the impact of weather-related events. Flexibility options also become more important. Controllable generators and consumers help to restore balance.
- In addition, all players have an individual goal to optimise their energy mix and energy efficiency; each player also has a secret goal. This allows players to win individually.
- Interactions between neighbouring players add even more fun to the game. Players can choose to respect their mutual deals – or not.

The game has already been tested successfully at a Berlin school. A detailed plan for further distribution will be developed and initiated in 2020.

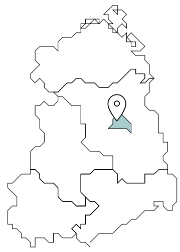
▲ Charging process at one of the 30 charging stations at the Stromnetz Berlin facility.

Visitor site

Stromnetz Berlin is also offering the public an opportunity to explore charging infrastructure at a visitor site. More than 30 parking spaces with modern charging points can be seen at Eichenstraße 3a in Berlin-Treptow. During a tour of the underground car park, visitors learn about technical capabilities of common charging processes, connection variants for at-home charging, and payment options. The site features conventional 11 kW charging boxes as well as AC/DC 'fast chargers', which deliver up to 50 kW of power.

SP 9.5

FOCUS AREA
Developing a Reality Lab



▸ Title of the subproject
Gamifying Electricity

▸ Funding code
03SIN530

▸ Subproject partner

▹ PROJECT PARTNER
Stromnetz Berlin GmbH

▸ Contact
Stromnetz Berlin
Eichenstraße 3a
12435 Berlin

Anja Lehmann
kommunikation@stromnetz-berlin.de

▸ Visitor site
Experience Electromobility – the 'World' of Charging Infrastructure
Eichenstraße 3a
12435 Berlin

Registration required

▹ ACCESS INFORMATION
www.stromnetz.berlin/fur-berlin/windnode-besuchbarer-ort-elektromobilitat

For more information
www.stromnetz.berlin/fur-berlin/energiewende/verstehen-und-teilhaben

Municipal Utilities as Multiplies in the Intelligent Energy System

Public utilities, of which more than one thousand exist in Germany, are key players in the energy transition and have the capacity to use intelligent energy systems to disseminate and implement innovations throughout their region. In this subproject, ASEW looks at the transfer and implementation of innovative business models and participation experiences in the WindNODE context.

‘For us, being part of the WindNODE project means identifying new and innovative business models for the municipal utility landscape. The goal is to use public energy suppliers – that is, municipal utilities – as innovation multipliers. Their participation is crucial to the success of the energy transition.’

Stefan Schulze-Sturm
Project Manager WindNODE,
Arbeitsgemeinschaft für sparsame Energie- und Wasserverwendung (ASEW) in the Verband kommunaler Unternehmen (VKU)

▷ CHALLENGES AND SOLUTIONS // **Municipal utilities are increasingly positioning themselves in new business fields**

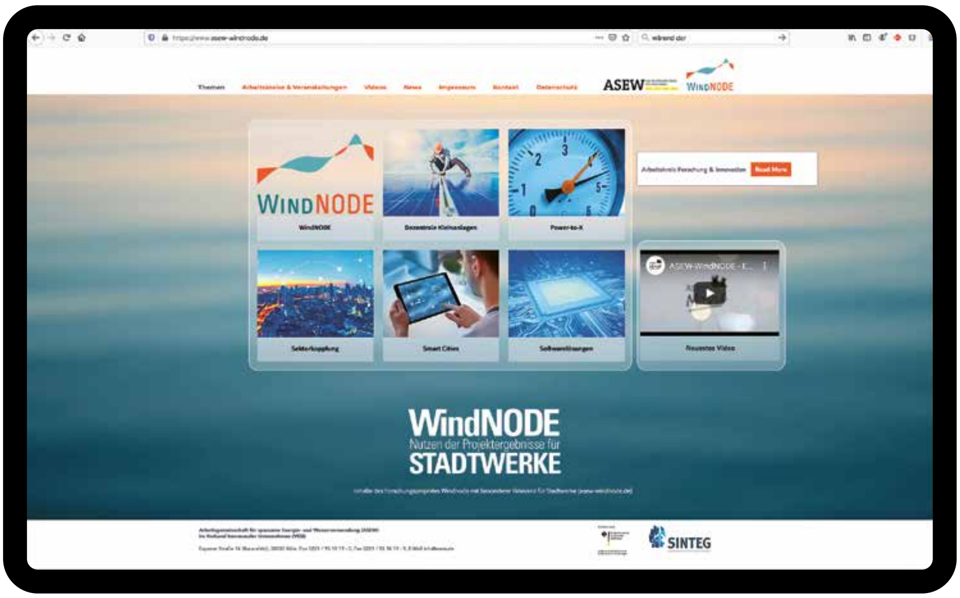
As a WindNODE project partner, ASEW strives to disseminate its results through a range of channels and to reach as many people and companies as possible. ASEW provides municipal energy suppliers throughout Germany with innovative approaches linked to numerous domains within the energy industry, and the results of WindNODE are imparted to the same municipal utility landscape through a variety of channels. The aim is to provide municipal utilities with food for thought and implementation examples for future applications based on the results of other WindNODE subprojects. In some cases, German municipal utilities have not yet reached the point of being strongly engaged in technologies with a distinct research character. However, as many energy suppliers are increasingly positioning themselves in fields other than classic commodity trade for electricity, gas, water and heating, the WindNODE project results can be expected to become more and more interesting for municipal utilities in the coming years.

For over

30

years, ASEW has been supporting its members in a range of energy industry domains.

▸ The website **www.asew-windnode.de** presents subprojects that are of particular relevance to municipal energy suppliers and could set examples to follow.



▸ ASEW travelled to the trade fair E-World to conduct interviews with experts.
The resulting video clips can be found at www.asew-windnode.de

Within WindNODE,
ASEW created

20

films

in close cooperation with other affiliated and associated partners.

▷ RESULTS // **Working group meetings, film recordings and a dedicated website**

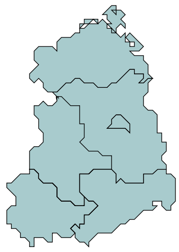
Under the auspices of WindNODE, ASEW created a dedicated website – www.asew-windnode.de – to present subprojects of particular interest to municipal utilities. In addition, ASEW has, at regular intervals, organised meetings of the working group 'Research & Innovation', in which WindNODE partners were able to exchange information on the technical and economic feasibility of projects with municipal utilities from all over Germany. In recent years, the working group has been held as part of the annual event 'ASEW in Dialogue', where individual WindNODE partners were also given the opportunity to present their projects through an information booth in addition to taking part in the working group. Moreover, ASEW produced around 20 film clips – which are publicly available on its YouTube channel and the website www.asew-windnode.de – within the framework of WindNODE. Impressions from trade exhibitions and from the Research & Innovation working group were documented and recordings of facilities and project approaches made on site at the respective partners' premises. Supplemented by expert interviews, these videos provide a striking impression of the relevant background and special features.

▷ CONCLUSION AND OUTLOOK // **Municipal utilities as innovation boosters**

Municipal utilities in Germany are well placed to make the most of WindNODE results by implementing them in a modified form so as to increase their share of renewable energy or develop new business models. To make sure that WindNODE's findings are deployed in practice, it is essential that project results be preserved in the long term and that associated partners be able to show even years from now the elements that are crucial to their implementation. Only by sharing experience can we make sure that follow-up projects can be put in place even more cost-efficiently and smoothly, thereby making a decisive contribution to achieving the climate action goals of the coming years and decades.

SP **9.6**

FOCUS AREA
Developing a Reality Lab



▸ **Title of the subproject**
Municipal Utilities as Innovation Multipliers in the Intelligent Energy System

▸ **Funding code**
03SIN501

▸ **Subproject partners**

▷ PROJECT PARTNER
Arbeitsgemeinschaft für sparsame Energie- und Wasserverwendung GbR im VKU

▷ ASSOCIATED PARTNER
envia Mitteldeutsche Energie AG

▸ **Contact**
ASEW
Eupener Straße 74
50933 Cologne

Stefan Schulze-Sturm
T +49 221 93181932
schulzesturm@asew.de

For more information
www.asew-windnode.de

Setting Standards to Shape Markets

The Deutsches Institut für Normung (German Institute for Standardisation, DIN) and the Deutsche Kommission Elektrotechnik (German Commission for Electrical Engineering, DKE) are working to develop standards for a successful energy transition. Together with other WindNODE partners, they are laying the foundation for an energy system based entirely on renewable energy. This process begins with the establishment of technical rules that can be used by the entire energy industry. The partners are creating the first parts of a holistic framework in the WindNODE project.

‘As part of the WindNODE project, DIN contributes to the energy transition and develops the standards necessary to achieve energy and climate action targets.’

Friederike Nabrdalik
Junior Project Manager,
German Institute for Standardisation (DIN)

▷ CHALLENGES AND SOLUTIONS // **Making results useful**

Standards are consensus-based measures that reflect the current state of the art and provide the foundations for broad and efficient economic applications. The creation of standards requires cooperation within the industry in order to promote further development and achieve market penetration.

As part of the WindNODE project, DIN and DKE aim to integrate showcase results and developments into the various standardisation processes at an early stage. This should facilitate a quick and uncomplicated introduction of the standards to the market.

Standards are the results of processes. DIN’s work will begin in earnest towards the end of WindNODE, when most of the projects begin to bear fruit; this is when results will have to be turned into standards and norms.

3+1

3 DIN SPECs
1 standardisation project that will be developed further by standardisation committees after the project ends

▷ RESULTS // **From taking inventory, to developing standards**

The first step in laying the foundation was to take stock of existing norms and standards. Relevant norms and standards were identified in five key focus areas: energy production, information and communication technology, market, infrastructure and flexibilisation. Project-related activities were sorted into these categories.

Based on this foundation, approaches for standardisation were discussed and evaluated with WindNODE partners over the course of the project. Some of these initiatives led to concrete work plans. The resulting specifications (DIN SPECs) fit seamlessly into existing technical regulations.

Project work was divided across several specifications. **DIN SPEC 91410-1**, for example, relates to the flexibility platform: it specifies the requirements for supplier participation in a flexibility platform and is intended to significantly facilitate the trading of flexibility. This DIN SPEC was developed within a partnership involving all SINTEG flexibility platforms and can therefore be widely applied.

Another standard, **DIN SPEC 91432**, describes the multi-criteria evaluation of energy systems and contains an evaluation method for comparing energy systems across a comprehensive set of indicators related to climate and resource protection. The evaluation can provide observations on the security of supply as well as economic efficiency and can thus be used as a basis for public funding decisions and transparency.

A third area involved the creation of **DIN SPEC 91410-2**, which applies to the observation and evaluation of flexibility in buildings and neighbourhoods. This guideline aims to assess and describe technical and economic criteria in neighbourhoods, enabling a qualitative and quantitative identification of flexibilities in urban space.

‘WindNODE is all about flexibility – and that means rolling up our sleeves and setting the standards!'

Sönke Nissen
Project Manager,
German Institute for Standardisation (DIN)

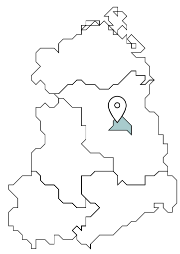
▷ CONCLUSION AND OUTLOOK // **Using standards to shape the energy system of tomorrow**

These standards are breaking new ground in their fields and they can provide the impetus for the development of a comprehensive framework for the energy system of tomorrow. Early exchanges with other partners, both internal and external to the project, have already contributed to bringing relevant stakeholders together and ensuring that the DIN SPECs are applied. In order to weave these activities even more closely together, DIN and DKE are actively involved in a continuous exchange with standardisation committees. This covers topics like the data modelling of flexibility, which was discussed in a SINTEG-wide workshop; the results will be passed on to the relevant standardisation committees.

This process helps to combine activities in the project with various aspects of standardisation. In the long run, WindNODE standards could become international standards, thus actively contributing to the transformation of the energy system and increasing public acceptance.

SP 9.7

FOCUS AREA
Identifying Flexibility
Activating Flexibility



▶ Title of the subproject
Standardisation in the Intelligent Energy System

▶ Funding code
03SIN548

▶ Subproject partners

▷ PROJECT PARTNER
DIN Deutsches Institut für Normung e. V.

▷ SUBCONTRACTOR
DKE Deutsche Kommission Elektrotechnik in DIN und VDE

▶ Contact
Sönke Nissen
T +49 30 26012438
Johann-Soenke.Nissen@din.de

▶ Visitor site
NormenWerk
Budapester Straße 31
10787 Berlin

Registration required

▷ INQUIRIES TO
presse@din.de

or more information
www.din.de/de/forschung-und-innovation

▲ 'Energy in Motion' exhibition at the TU Berlin.

Changes in Culture and Communication in the Energy Field

The energy transition affects all parts of society. Participation means not only accepting the content communicated, but also finding new solutions together through dialogue. The result is an important step in the learning process that both changes our behaviour and leads to an understanding of new solutions and rules. A transformation like the energy transition also means a change in society – and in each and every one of us.

'The transformation of the energy system touches the very heart of society. It is therefore important to involve everyone affected. This makes it a key priority to research and test different formats that can accomplish this goal.'

Jan Suchanek
Research Associate,
Department of Energy Systems,
TU Berlin

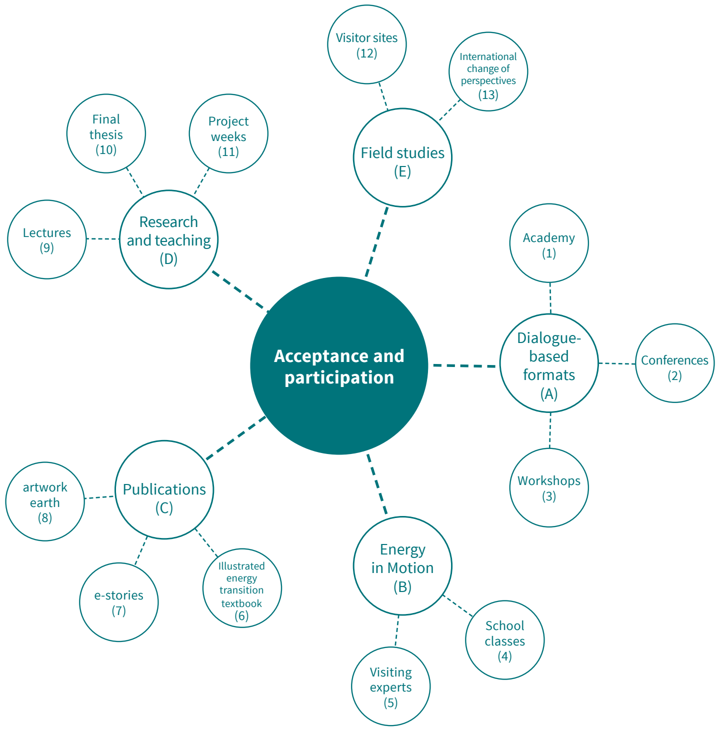
▷ CHALLENGES AND SOLUTIONS // **Building trust through knowledge transfer**

Participation and acceptance are key prerequisites for a successful energy transition. In order to build public understanding, it is essential to actively address and engage members of the public.

In this subproject, the goal was to use participatory concepts to reach out to different target groups and to provide explanations and direct experience that would clarify even hard-to-understand technical approaches. Various formats were selected for this purpose. The chapter 'Energy and Society' includes detailed descriptions of these formats, including the projects artwork.earth (p. 244), e-stories (p. 240), Energy and Art (p. 234) and an exchange of perspectives between two schools in Nepal and Germany (p. 236).

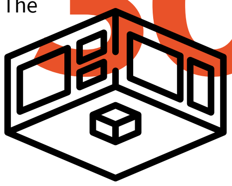
▷ RESULTS // **Energy transition and society**

The **(1) WindNODE Academy** serves as a central hub for the WindNODE network. Academy participants explore the energy system of the future, which can only function through sector coupling. A one-hour lecture is followed by an hour-long discussion among the partners. At these events, project partici-



▲ The Department of Energy Systems takes a holistic approach and successfully employs a variety of formats.

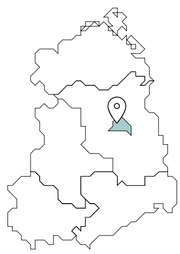
Energy in Motion@TU Berlin:



The **300 m²** exhibition, which opened in June 2019, was visited by almost 650 interested visitors so far

SP 9.8

FOCUS AREA
Developing a Reality Lab



▸ **Title of the subproject**
The User Perspective: Acceptance and Participation

▸ **Funding code**
03SIN537

▸ **Subproject partners**

▹ PROJECT PARTNER
Department of Energy Systems of the TU Berlin

▹ SUBCONTRACTOR
Maria Reinisch Marketing Kommunikation

▸ **Contact**
Andreas Corusa
andreas.corusa@tu-berlin.de

Jan Suchanek
suchanek@tu-berlin.de

▸ **Visitor site**
Energy in Motion@TU Berlin
Straße des 17. Juni 135
10623 Berlin

Opening hours vary.
Individual registration possible at www.energy-in-motion.tu-berlin.de

▹ INQUIRIES TO
suchanek@tu-berlin.de

For more information
www.ensys.tu-berlin.de
www.artwork-earth.com

pants receive input from their academic peers on approaches tested in the reality lab. Sessions with a sharp focus on current technical solutions and partners' new business models, such as the enersis Energiecockpit (p. 178), alternate with others that address entire sectors or even the energy transition in a social context. Developments in the heating market or energy transition narrative, for example, were considered from the perspective of cultural studies. The Academy has also been described as the 'beating heart of WindNODE' because of the regular events and exchanges that take place there.

Experiences from the dialogues were incorporated into **(2) conferences** and **(3) workshops.** The exhibition **(B) Energy in Motion@TUBerlin** provides visual explanations of fundamental energy concepts in a vivid presentation intended for a broad **(5) audience**, primarily **(4) school-children.** What is energy? What forms does it take? How is it produced, converted, distributed? And finally: what future energy system is compatible with a liveable future? The exhibition aims to spark interest in the topic and thus encourage students to enter these fields.

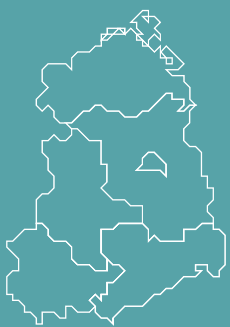
We are also preparing a series of **(C) publications.** One of these is **(6) an illustrated energy transition textbook** on the intelligent energy system of the future. This presents the complex issues involved in the energy transition in a generally understandable way, making key concepts accessible to a broad readership. **(7)** Another popular format, **e-stories** (p. 240), is an essay series that discusses various literary and historical aspects of energy to explore how forms of energy affect, and have affected, our lives. The online platform **(8) artwork.earth** (p. 244) presents a collection and catalogue of works of fine art related to energy and the climate.

▹ CONCLUSION AND OUTLOOK // Participatory and opportunity-oriented formats have an inspirational effect

It is clear that there is enthusiasm about the topics of energy transition and climate change in all segments of society and among everyone from schoolchildren to experts. In order to build this enthusiasm, the format and method used to communicate knowledge must actually reach specific target groups.

Holistic approaches that transform society, not only through technological developments but also – and above all – through social change, will become increasingly important in the future and offer plenty of space to establish scientific connections. Society has a chance to play an active role in shaping the coming changes that will affect all areas of life.

The Visitor Sites



WindNODE is a showcase for intelligent energy: we develop model solutions and make them visible to specialists in the field, as well as to politicians and interested members of the public. We also encourage dialogue, build networks and promote a positive view of the German energy transition. Our visitor sites bring the concept of a 'showcase' to life.

The term 'visitor site' is meant literally – a real, physical place that is open to the public. Each site introduces visitors to some facet of WindNODE and makes project results tangible and easy to understand.

For more information:
www.windnode.de/en/about/showcase

WindNODE Live!

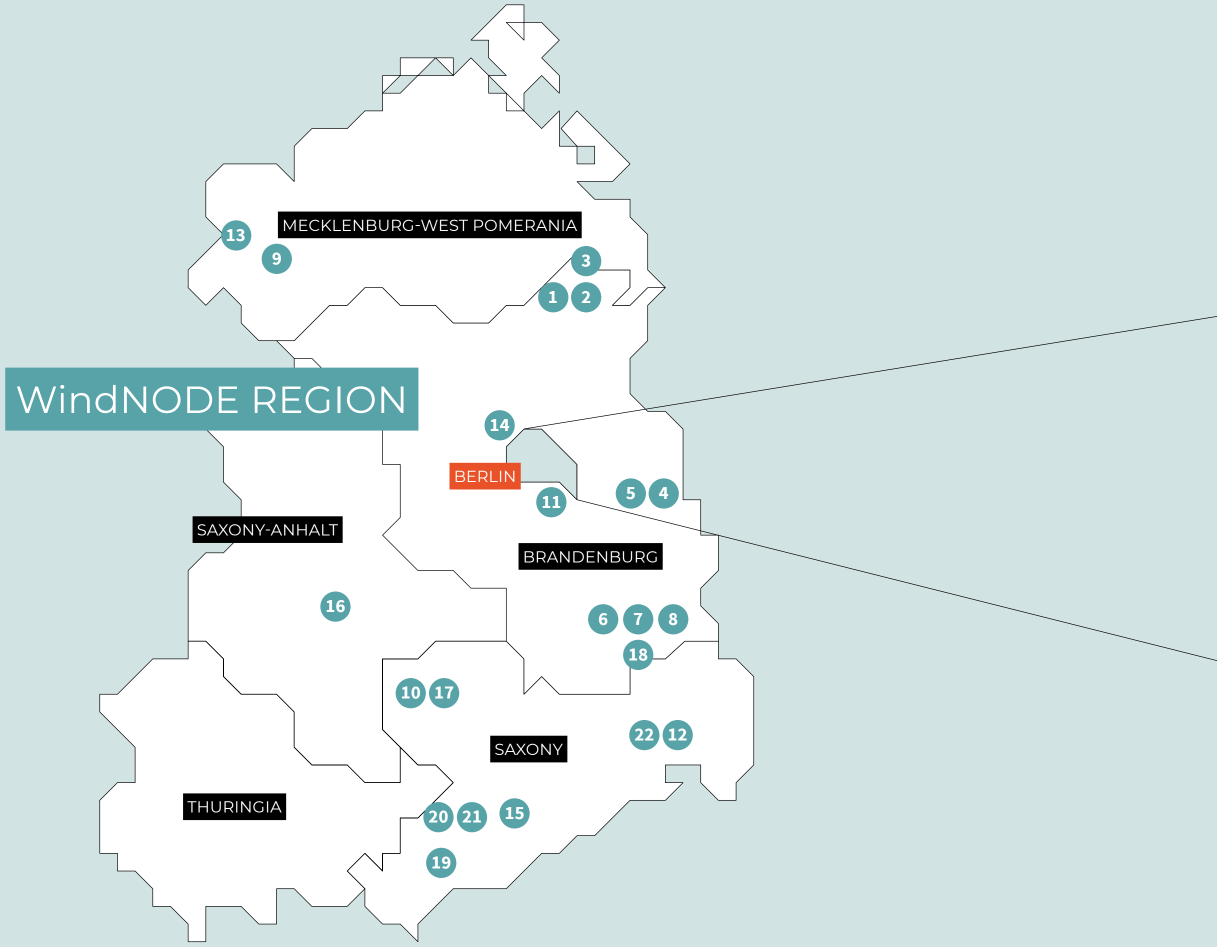
The travelling exhibition provides an opportunity for audiences to learn about the WindNODE project and participating partners in an interactive multimedia format. It toured the WindNODE region during the project period. Information in the exhibition is presented in German and English.

FOR MORE INFORMATION ON WINDNODE LIVE!, SEE P. 194 OR VISIT
www.windnode.de/en/results/energy-and-society/windnode-live

→ WindNODE online

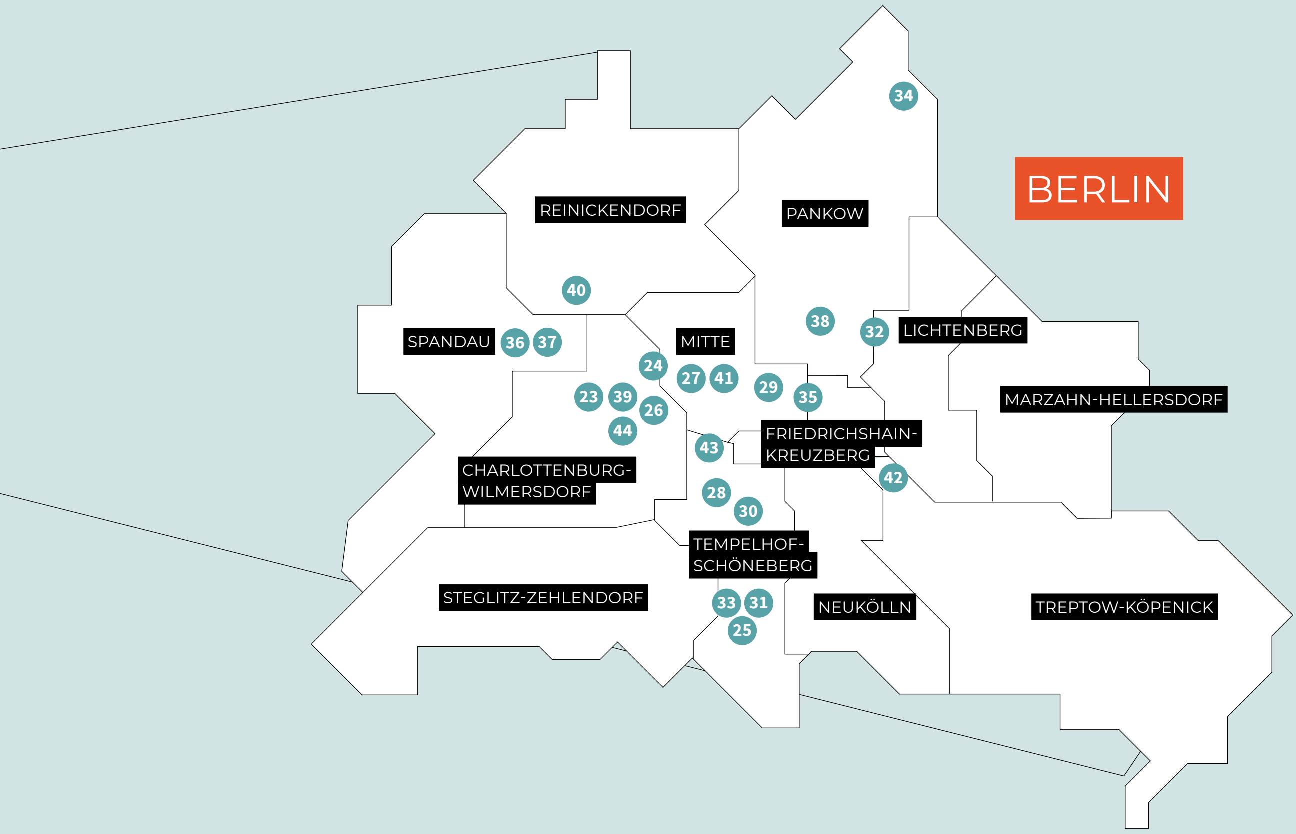
NAME	WEBSITE	PAGE
WindNODE Energy Data Marketplace Fraunhofer FOKUS	https://datenmarkt.windnode.de (German only)	62
WindNODE Flexibility Platform 50Hertz, Stromnetz Berlin, WEMAG Netz, ENSO Netz, e.dis	www.flexplattform.de (German only)	66
WindNODE Open Data Portal Stromnetz Berlin, Fraunhofer FOKUS	https://daten.windnode.de (German only)	68
Energyhack Stromnetz Berlin, OKFN	www.energyhack.de (German only)	68
Renewable energy to the point Solandeo	www.erneuerbare-energie-prognosen.de (German only)	110
WindNODE Energiecockpit enersis	https://windnode.grids-energycity.com/ Login data available under: support@enersis.freshdesk.com	178
Benefits of WindNODE Results for Municipal Utilities ASEW	www.asew-windnode.de (German only)	206
artwork.earth TU Berlin EnSys	www.artwork-earth.com	244
Energy in Motion@TU Berlin TU Berlin EnSys	www.energy-in-motion.tu-berlin.de (German only)	210
Energy and Art Maria Reinisch Marketing Communication, TU Berlin EnSys	www.energie-und-kunst.de	234

WWW.WINDNODE.DE/EN
Our website provides a full list of visitor sites, including site locations, contact information and opening hours.



→ Visitor sites in the WindNODE region

	NAME	PARTNER	SP	PAGE
1	**Hybrid Power Plant with Power-to-Gas Plant**	ENERTRAG	2.2	76
2	**Control Centre of the Uckermark Integrated Power Plant**	ENERTRAG	2.2	76
3	**Wind Heat Storage / Power-to-Heat Plant**	ENERTRAG	2.2	76
4	**Frankfurt (Oder) District Heating Power Station**	Stadtwerke Frankfurt (Oder)	2.3	80
5	**Heat Exchanger Station (WÜST) 8.0**	Stadtwerke Frankfurt (Oder)	2.3	80
6	**Municipal Energy Control Centre & Municipal Energy Management System (KEMS) Demonstrator**	IBAR Systemtechnik	2.4	82
7	**Visitor Centre for Smart Energy Grids (BIENe)**	BTU Cottbus-Senftenberg	3.2	88
8	**Power System Simulator (PSS)**	BTU Cottbus-Senftenberg	3.2	88
9	**Lankow Battery Storage**	WEMAG	3.3b	90
10	**Trading Room and Virtual Power Station Control Centre**	Energy2market	4.1	102
11	**Grid Simulator for Visualisation of Critical Grid States**	Uni Leipzig, GridLab	5.2b	122
12	**Ice Slurry Storage at ILK Dresden**	ILK Dresden	6.2	136
13	**Demonstrator for Remote-Controlled Operation of Flexible Power-to-Heat Consumer Appliances**	WEMAG	6.3a	140
14	**Grid Buffer Storage Unit**	Stadtwerke Hennigsdorf	6.3e	152
15	**E^3 Research Factory for Resource- Efficient Production**	Fraunhofer IWU	7.1	156
16	**Industry Energy Hub VDTC**	Fraunhofer IFF	7.3	160
17	**BMW Battery Storage Farm**	BMW	7.6	168
18	**Schwarze Pumpe Power Station, Visitor Centre**	LEAG	7.7	172
19	**ubineum**	SenerTec, WHZ, ZEV	8.1a	176
20	**Energy Storage 5**	WHZ	8.1a	176
21	**Base Tower**	WHZ	8.1a	176
22	**Dresden-Kaditz Sewage Treatment Plant**	Dresden Landeshauptstadt	8.3	184



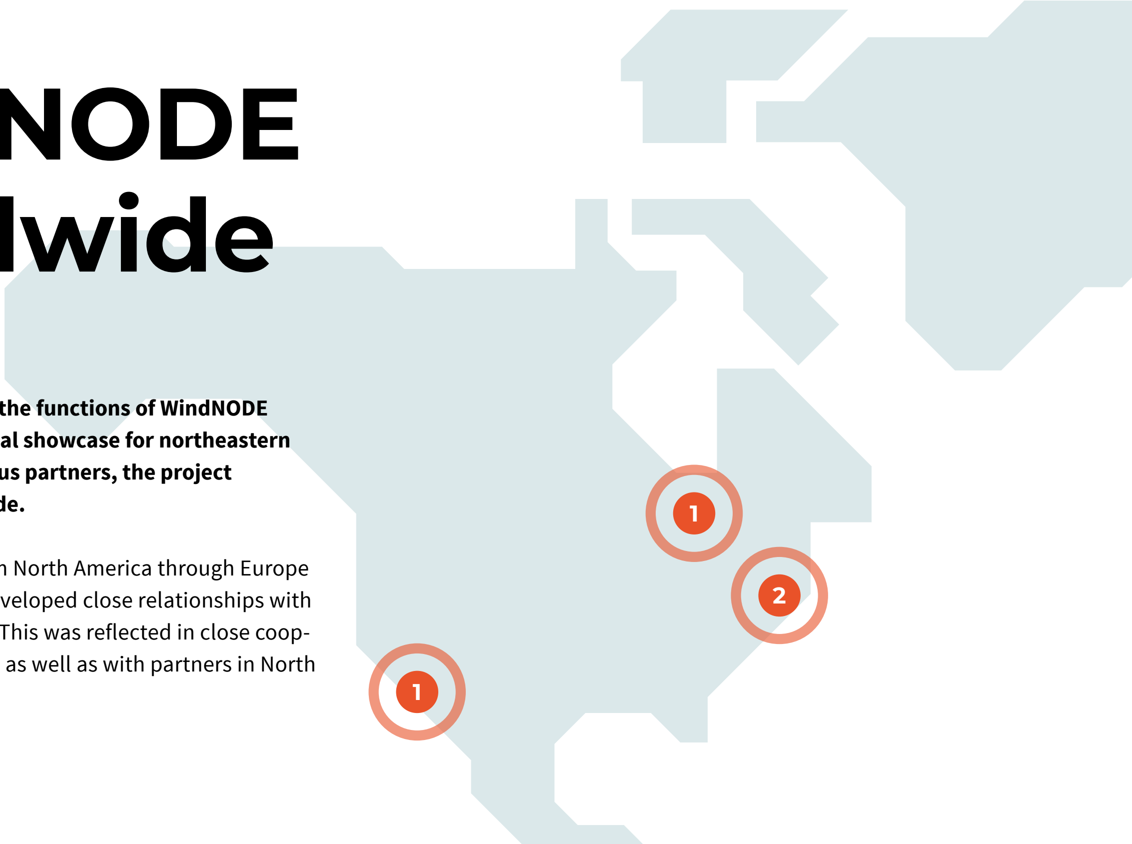
→ Visitor sites in Berlin

	NAME	PARTNER	SP	PAGE
23	**eGovernment Laboratory and IT4Energy Centre**	Fraunhofer FOKUS	1.1/1.3	62/68
24	**Pumacy Technologies Solution Center**	Pumacy	1.4	70
25	**Audi Power Storage**	Belectric	2.1	74
26	**Real-Time Lab for the Energy Transition**	TU SENSE	3.1	86
27	**Kaufland Showcase Store**	Green Cycle	4.2	104
28	**Lidl Showcase Store & Battery Storage System**	Green Cycle	4.2	104
29	**Open Office for Legal Matters**	IKEM	5.2a	120
30	**E-Mobility as a Flexible Load**	BSR	6.1a (BSR)	130
31	**InfraLab on the EUREF Campus**	Berliner Wasserbetriebe	6.1a (BWB)/7.5	132/166
32	**Indira-Gandhi-Straße Bus Depot**	BVG	6.1b	134
33	**Energy Workshop on the EUREF Campus**	GASAG	6.3c	144
34	**CHP Plant Buch (5 MW) with E-Boiler**	Vattenfall Wärme	6.3d	148
35	**CHP Plant Mitte (20 kW)**	Vattenfall Wärme	6.3d	148
36	**CHP Plant Reuter West (120 MW) – Germany's largest Power-to-Heat plant**	Vattenfall Wärme	6.3d	148
37	**ZUKUNFTSRAUM***ENERGIE* showroom (Energy of the Future space)	Siemens	5.1/7.2	118/158
38	**Model Neighbourhood Prenzlauer Berg**	Wohnungsbaugenossenschaft Zentrum	8.2	180
39	**Smart Energy Testbed and Smart Home Showroom**	TU DAI-Labor	8.2	180
40	**High-Temperature Steel Storage System Pilot Plant**	Lumenion	8.4	188
41	**WindNODE Energy Transition Showroom**	50Hertz	9.1	192
42	**Experience Electromobility – the 'World' of Charging Infrastructure**	Stromnetz Berlin	9.5	202
43	**NormenWerk**	DIN	9.7	208
44	**Energy in Motion@TU Berlin**	TU Berlin	9.8	210

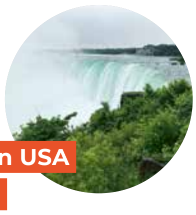
WindNODE Worldwide

For its entire duration, one of the functions of WindNODE was to serve as an international showcase for northeastern Germany. Together with various partners, the project promoted the region worldwide.

WindNODE had a presence from North America through Europe to Central and East Asia and developed close relationships with several international partners. This was reflected in close cooperation with NEDO from Japan, as well as with partners in North America, for instance.



▸ Delegation tour



1 Road show in USA and Canada.

Together with the Parliamentary State Secretary of the Federal Ministry for Economic Affairs Iris Gleicke, and at the invitation of GTAI (Germany Trade and Invest), WindNODE was presented on a roadshow in North America.
12 – 16 June 2017 ▸ Los Angeles, USA and Toronto, Canada

▸ Presentation

2 IKEM Sustainable Energy Academy

At the invitation of the Interamerican Development Bank and IKEM, WindNODE presented its first project results. There was great interest, especially in the SINTEG-V regulatory sandbox experience.
6 – 9 December 2017 ▸ Washington, DC, USA

▸ Workshop

3 Early Adopters, Disruptors and the Energy Transition

Together with the British Embassy, WindNODE organised a workshop at the Clean Energy Ministerial 2018.
22 May 2018 ▸ Malmö, Sweden

▸ Conference

4 Energy Transition World Forum, Keynote: Grid integration of renewable energy.
16 May 2019 ▸ Amsterdam, the Netherlands

▸ Symposium

5 Presentation of WindNODE at an annual sustainable development symposium at the University of Cambridge.
21 July 2017 ▸ Cambridge, United Kingdom

▸ Workshop

6 From Energiewende to Energy Transition: European Perspectives on Smart Energy Systems

Berlin Partner organised a discussion platform in Brussels as part of the WindNODE International Network.
24 – 27 October 2017 ▸ Brussels, Belgium

▸ Delegation tour

7 Together with the Governing Mayor of Berlin Michael Müller, WindNODE took part in the Smart City Expo World Congress.
13 – 14 November 2018 ▸ Barcelona, Spain

▸ Trade exhibition

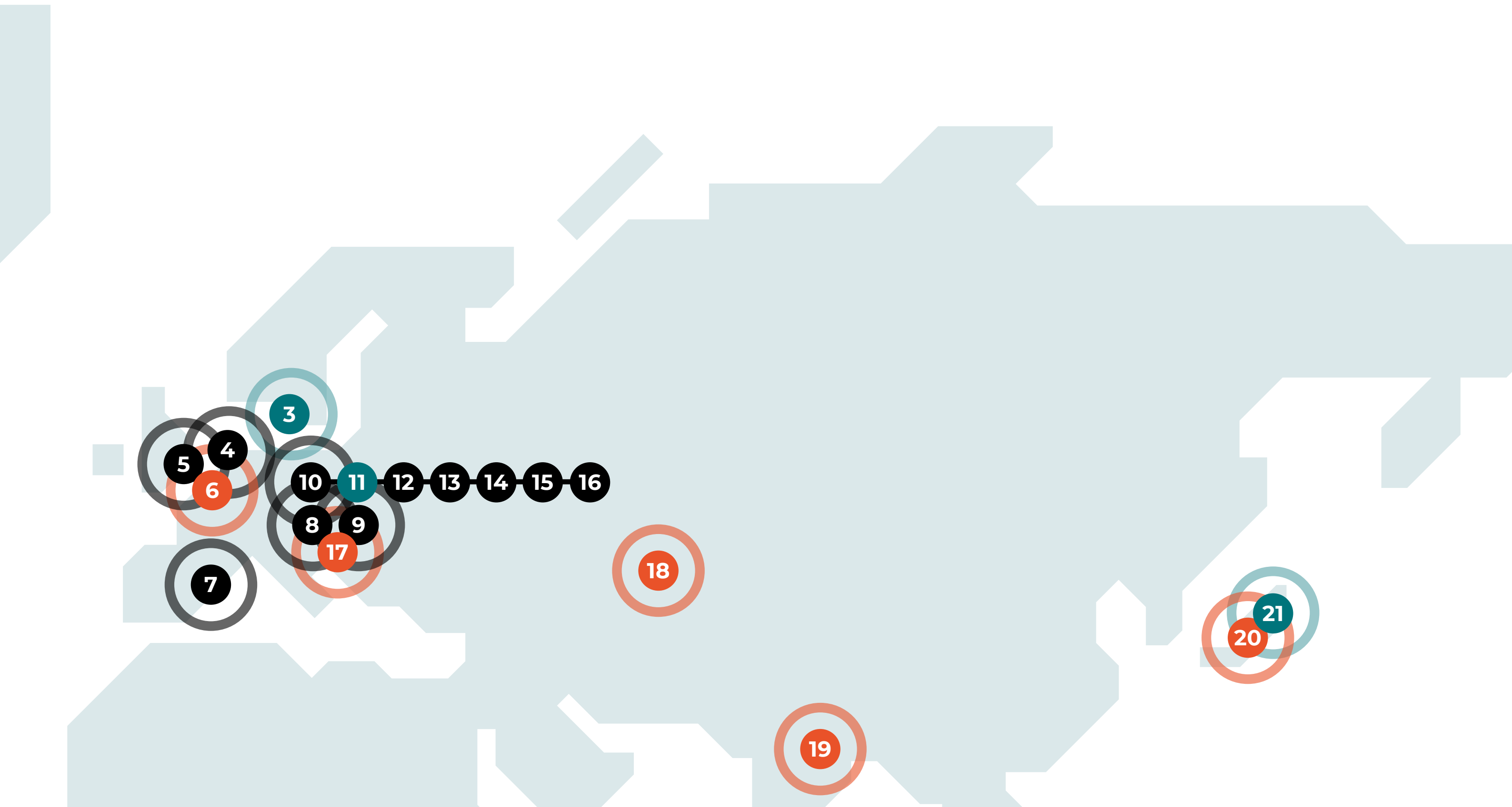
8 Roundtable 'Demonstration projects for a new energy world – first experiences' at the Smart Energy Systems Week Austria 2017.
16 – 17 May 2017 ▸ Graz, Austria

▸ Trade exhibition

9 Presentation at the European Utility Week.
6 – 9 November 2018 ▸ Vienna, Austria

▸ Delegation reception

10 NEDO visit in Lusatia. Discussion on points of contact in system integration and innovative battery systems integration and control.
11 September 2019 ▸ Cottbus, Germany



▸ Delegation reception

11 Reception of high-ranking METI delegation

As part of the German-Japanese energy partnership, WindNODE welcomed a high-ranking delegation from the Japanese Ministry of Economic Affairs (METI).
18 February 2020 ▸ Berlin, Germany

▸ Presentation

12 Keynote presentation at the German-Japanese Cooperation Council (GJETC).
7 March 2019 ▸ Berlin, Germany

▸ Delegation reception

13 Prospects for cooperation in the energy transition and structural change: meeting with NEDO.
1 April 2019 ▸ Berlin, Germany

▸ Delegation reception

14 Presentation at the Pakistani-German Renewable Energy Forum (PGREF).
15 – 21 September 2019 ▸ Berlin, Germany

▸ Delegation reception

15 Presentation for Korean TSO KEPCO.
3 December 2019 ▸ Berlin, Germany

▸ Delegation reception

16 Presentation for the Canadian Smart Grid Delegation.
11 September 2018 ▸ Berlin, Germany

▸ Conference

17 16th IAEE European Conference

Keynote presentation of the WindNODE experiences at a plenary session of IAEE's annual European conference.
25 – 29 August 2019 ▸ Ljubljana, Slovenia

▸ EXPO 2017

18 Future Energy Forum at the Expo 2017

WindNODE keynote presentation at the Future Energy Forum and participation in the German Energy Dialogue, which was opened by the German Federal President Steinmeier.
10 – 11 July 2017 ▸ Astana, Kazakhstan

▸ Delegation tour

19 Road Show in South Korea

At the invitation of Germany Trade and Invest (GTAI), WindNODE was presented at an event in South Korea.
October 2016 ▸ Seoul, South Korea

▸ Conference

20 Japanese-German Industry Forum (JGIF) in Tokyo

WindNODE was presented at the invitation of GTAI in Tokyo and laid the foundation for continued exchange with several Japanese partners.
20 – 24 July 2017 ▸ Tokyo, Japan

▸ Delegation tour

21 Stakeholder dialogue in Japan

Tour together with WFBB and GTAI. Lectures and workshops at the invitation of NEDO, JETRO and several other Japanese partners. Visit to the World Smart Energy Week in Tokyo.
26 February 2019 ▸ Tokyo and Osaka, Japan

Our Drive

More than 70 institutional partners and more than 400 individuals collaborated on a positive vision of the energy vision in WindNODE. The seven institutional members of the steering committee represent the WindNODE partners and are responsible for the strategic orientation of the joint project.

'The WindNODE project period passed at lightning speed. Every day was exciting and brought new connections and insights. I was particularly impressed by the open and constructive exchange between the project partners and the steering committee. I would like to thank everyone involved for this spirit and hope we will all stay connected even after the project ends.'

Olaf Ziemann
Special Representative for the Energy Transition and System Management,
50Hertz Transmission GmbH

'In WindNODE, we worked with our partners to develop future-oriented solutions for the urban distribution grid of the future. With a focus on digitalisation and participation, we are supporting Berlin on the way towards climate neutrality. We will transfer the results and valuable experience from the WindNODE project to our long-term operational practice.'

Claudia Rathfux
Head of Customer and Market Relations,
Stromnetz Berlin GmbH

'The road to meeting 100 % of our energy needs from renewable energy sources is long, and our progress on it depends on interdisciplinary know-how. Only a strong symbiosis of business and science, as exemplified in the day-to-day of WindNODE, can effectively overcome this challenge.'

Dr Armin Wolf
Head of IT4Energy Centre,
Fraunhofer Institute for Open Communication Systems FOKUS

‘With WindNODE, we have succeeded in creating the basic requirements for a 100 % renewable energy supply in the 50Hertz grid area. Many federal states have shown great interest in our solutions, which are an excellent basis for further cooperation and concrete implementation steps.’

Lukas Rohleder
Managing Director,
Energy Saxony e. V.

‘WindNODE shows how the energy transition can succeed. Making consumption more flexible has a particularly important role. Industrial loads can make a significant contribution through automation and digitalisation, as well as through AI-based forecasting processes and associated load shifting.’

Danny Günther
Sales Manager, Digital Grid (Region East),
Siemens AG

‘The energy transition does not take place in a vacuum – it affects cities and rural areas alike; links the electricity, heating and transport sectors across federal states; and requires solutions that are both practical and acceptable to people in rural and urban areas. This is what we are working for, and what WindNODE embodies like no other showcase.’

Wolfgang Korek
Head of Energy Technology Division,
Berlin Partner für Wirtschaft und
Technologie GmbH

Klaus Henschke
Energy Technology Cluster Manager,
Wirtschaftsförderung Land
Brandenburg GmbH (WFBB)

Benjamin Horn
Senior Manager Innovation,
Berlin Partner für Wissenschaft und
Technologie GmbH

We would like to thank the former members of the steering committee, who have contributed significantly to the success of WindNODE.

Dr Peter Eulenhöfer
Wirtschaftsförderung
Land Brandenburg GmbH
(WFBB)

Dr Robert Franke
Formerly of
Energy Saxony e. V.

Gregor Hampel
Formerly of
Stromnetz Berlin GmbH

Dr Dietmar Laß
Formerly of
Wirtschaftsförderung
Land Brandenburg GmbH
(WFBB)

Prof Dr
Ina Schieferdecker
Formerly of
Fraunhofer Institute for
Open Communication
Systems FOKUS

Dr Alexander Willner
Fraunhofer Institute for
Open Communication
Systems FOKUS

Sebastian Witt
Formerly of
Wirtschaftsförderung
Land Brandenburg GmbH
(WFBB)

Special

Energy and Society

Energy and society constantly interact. For example, in the past, the culture of miners in German mining regions had a considerable influence on wider society. Chernobyl and the emerging energy transition also politicised a segment of the population and significantly influenced the energy agenda. The following pages feature literary and artistic contributions created in the context of WindNODE to address the ever-changing relationship between energy and society. We hope you enjoy them.

Feature

220 – 245

Energy is Culture.

Paris, the Atlantic, Bitterfeld and Brandenburg, the Fiji Islands…

Beyond WindNODE, SINTEG and the European Green New Deal, the energy transition and climate change action are international projects that have mobilised our global society. They have inspired a range of activities and events around the world, including: the Paris Climate Agreement (signed by 197 and withdrawn from by the United States) a ‘Skolstrejk för klimatet’ initiated in Stockholm, and the media event surrounding a transatlantic journey in a sailboat; the concept of a ‘hydrogen society’ in Japan; the prospect of a ‘Solar Valley’ near Bitterfeld; and ‘man on the moon’ narratives that signal the emergence of a new realm of energy, which is no less fascinating than the first trip to the moon half a century ago. And there’s more: lignite remaining in the ground in Germany and natural gas remaining in the ground in the Netherlands, a country that has also begun to protect its flat coastline with innovative dyke constructions made of kevlar; off-grid solar energy systems for newly resettled villages in the Fiji Islands, where atolls have been left exposed and unprotected as water levels rise; and innovative wind energy villages in Brandenburg, the federal state surrounding Berlin, which is experiencing increasing desertification. Meanwhile, populist rhetoric is everywhere – not just in Rio de Janeiro or Washington, but also among ‘climate change sceptics’ in German parliaments and verbal aggressors displaying ‘FUCK YOU GRETA’ bumper stickers on their cars.

Icons and resisters

An overview of this kind does not only illustrate the global character of the energy transition and climate protection; it also points directly to their social and cultural dimensions. In other words: if we look closely between the technological and economic processes and ecological developments, we find images charged with meaning and emotion, highly symbolic actions, icons and heroes, with a deep passion for a better future. Regional, national or individual identities are negotiated; history is linked with the future and the visionary; and the coming challenges are giving rise to positive outlooks – buoyed by the sense of emerging opportunities – as well as to resistance. Objective political discourse is beset by populist resentment and language that derails the conversation.

From the socket?

From these developments, it is evident that the discourse on energy has changed. It has become more controversial, more intense and richer in imagery, and framed in terms that are increasingly political, emotional and rhetorically charged. Those in the energy sector often show irritation when confronted with the observation that they have become the focus of cultural debate. Perhaps it is time to underscore the dawning of a new era by challenging an all-too-familiar phrase: electricity no longer simply comes from the socket! Electricity and energy are showing new facets and have become complex social issues that have taken on new, increasingly visible dimensions in culture and communication. Much has changed since the first cautious attempts to bring the invisible commodity 'electricity' to life with colours like green and yellow.

Corona effects: ecological dependency, vulnerability

Here is a hypothesis: the recent mobilisation around energy- and resource-related issues will continue even after the corona pandemic and the associated crisis have subsided. In fact, it will likely increase. Of course, while it is difficult to assess or estimate the effects of corona, it is always easy to speculate. Still, it seems clear that an in-depth and concrete reflection on our lifestyles and our behaviour, our values and the process for determining our values, has long been underway. We recognise our fragility and vulnerability (a term that is now becoming an established part of the colloquial lexicon); we are becoming more sensitive, perceiving ourselves as living beings and as communities that are interwoven with the environment and dependent on it. We understand more clearly than ever that no one can exclude themselves from this reality. From an ecological perspective, there are no islands; everything exists in relation to everything else – across both national and physical borders – which makes feedback effects unavoidable. There is a fundamental similarity between the corona crisis and the climate crisis: both are making us more attentive to our own vulnerability and more aware of the fact that our relationships with our globalised environment involve many different types of exchanges. This greater awareness also carries opportunities. Namely, the possibility that there is growing interest in a "soft" modernisation, that we become more curious about and more receptive to sustainable and ecological models of economic activity and renewable energy. The possibility that the policies and projects of the Green New Deal could be supported by a change in convictions and a cultural movement.

Ecological modernity: WindNODE and art

The energy transition must now be adapted to this new cultural and social reality. How exactly this can be done, especially considering the impact of corona, is a matter that future projects must resolve. It is evident, however, that WindNODE has repeatedly ventured into largely unexplored terrain – the intersection between the energy transition and society – without limiting itself to the now-obligatory, formulaic phrases of 'public acceptance'; it has probed the connections between energy and socio-cultural life and, in doing so, has identified the cultural potential of the energy transition. This may sound abstract, but that is by no means the case. WindNODE takes a concrete approach, and we focus on art: artists and authors have long described the symbiotic relationship between energy (transition) and culture. They reflect and construct the connection between ecological necessities; technical innovations; and the new potential that the transition holds, both for our lived experience of everyday life and for our communities. Art finds and invents forms, narratives, practices and concepts for living in an ecologically complex world, and thus goes far beyond what science and the techno-economic field of the energy sector can offer on their own. It is art that makes the energy transition visible – as part of the 'sustainable modern', indeed as a central element of a specific ecological modernity.

In WindNODE, there are projects that shape and work together on this transition in experimental ways; this gives rise to cooperative partnerships with artists that produce works on the energy transition. These include the cross-genre project **Energy meets Art** by Björn Kluge and Gerd Wessolek, as well as the comparative cultural project **Changing Perspectives on the Energy Transition** by Maria Reinisch and Andreas Corusa, which links Nepal and Germany. Other WindNODE projects approach the topic from a different angle by documenting and analysing the transition. This is visible, for example, in Ingo Uhlig's two projects: **art.work**, a platform for digital documentation, and **e-stories**, a series of essays related to literature and energy.

All of this provides inspiration for rich energy transition narratives that move beyond 'electricity comes from the socket'. The following pages present the projects in greater detail. We hope you enjoy browsing this compilation. Dear reader, prepare to be surprised!

A text by Ingo Uhlig

Energy Meets Art

▸ **Statue of Power**
Hanno Schröder – Johanna Babel – Luisa Pöpsel

Statue of Power is a sculptural model that deals with the spatial, architectural and aesthetic manifestation of energy generation systems in the landscape. The image of 'the landscape' has always been subject to constant change. Energy supply, in particular, has always had a strong influence on landscapes and will continue to do so in the future.

Art is Full of Energy

It is difficult to communicate scientific knowledge and technical developments to the public without venturing outside the discipline – especially when it comes to far-reaching changes in energy policy and society, such as the energy transition.

120

students and artists worked together to develop unconventional ideas and concepts related to the energy transition.

Energy meets Art uses new formats and ideas to address the topic of the energy transition and to communicate particular WindNODE research topics to the public. A network of invited scientists, artists, students and energy experts worked with different methods and techniques over a period of three years to 'emotionalise' the energy transition.

The results included a close collaboration with art professors Myriel Milicevic and Dr Alexandra Regan Toland, as well as art scholar and designer Burkhard Lüdtke.

The focus was not on engineering, but on visionary approaches, and the outcome was a wide range of approaches, ideas, products and models. These were devised not only to be entertaining, but also to embolden and incite people to engage with new forms of energy, as well as to arouse interest, feelings and fascination for the energy transition.

See p. 226 for artistic work, p. 228 for student work and p. 232 for energy diaries by students.

'The always pleasant and inspiring partnership within WindNODE brought us a lot of joy and broadened our horizons. We had a wonderful opportunity to think beyond the conventional limits of an energy technology research project with Energy meets Art.'

Dr Björn Kluge
Project team member,
Department of Soil Science / Soil Protection Ecology,
TU Berlin

Prof. Dr Gerd Wessolek
Project leader,
TU Berlin

Artistic work

Energy Brings Change

Betty Beier archives soil conditions and their changes due to human intervention by creating pieces she calls 'soil clods' – the soil surfaces of landscapes, fixed permanently in acrylic or synthetic resin. The object created in the framework of WindNODE shows a print of earth from a corn field that was subsequently dug up to lay underground cables for a power line.

The soil clod archive (Erdschollenarchiv)
'Since 1997, my soil clod archive has documented processes that change the landscapes in places as far apart as Germany, Iceland, China, Alaska and, most recently, Brazil. Using on-site measures to collect traces, I capture what is lost in sculptures I call soil clods. These soil clods are made permanent in acrylic or synthetic resin and accompanied by a history and photo documentation, as well as drawings.'

▲ The soil surface of a corn stover field before the laying of an underground cable. Dimensions: 1 m².

Betty Beier – 'For me, the focus is on the earth'
My mission is to boost appreciation for nature in general and the earth in particular, and to stand in solidarity with people who are literally losing the ground under their feet. Climate change is destroying indigenous peoples – including us. Our landscape is changing significantly by the hour. Dams are swallowing up the landscape. Hunger for raw materials is destroying the landscape. One-sided use of the soil is making the landscape monotonous. The irreparable consequences are relocation through displacement, homelessness and hunger. The speed of these developments is sweeping us with them. The power to influence these processes will be taken from us if we do not immediately reverse course.

We are not the ones who lose out. We are not being driven out. We are not starving. We use rare soils in our consumer goods. This is exactly where I come in as an artist – to home in on a scarcely acknowledged commodity and storage medium: the ground.

Ephemeral and amorphous

Markus Wirthmann, artist

Markus Wirthmann is an artist who creates artwork from ephemeral and amorphous materials. Water, sand, light and air become part of technical experiments that incorporate scientific processes as aesthetic tools.

While the artist sets the material framework, he generally leaves the creation of the form to mechanical devices. These reproduce phenomena that appear to be natural, such as the creation of sand dunes or a solar eclipse. These devices and the works they produce can be seen side by side in numerous exhibitions. This combination enables the artist to avoid clear metaphysical or poetic attributions. Instead, Wirtmann's sculptural work is in constant flux, with an image congealing again and again to reveal the conditions of its own creation.

Markus Wirtmann was born in Aschaffenburg in 1963 and graduated from the Braunschweig University of Art and the Berlin University of the Arts. He has had teaching assignments and visiting professorships at universities in the US, Germany and China since 2006. He currently lives and works in Berlin.

► The piece *Äolische Prozesse – WindNODE (Aeolian processes – WindNODE)* consists of a range of modules and control elements as well as the WNTable, which resembles a pool table. The modules are: four cross-blow fans, timers, motion sensors, and sand.

With their changing arrangement, number, and amount of energy, the fans continuously generate new WindKNOT sculptures, thus creating spooky, fleeting works of art.

Student work

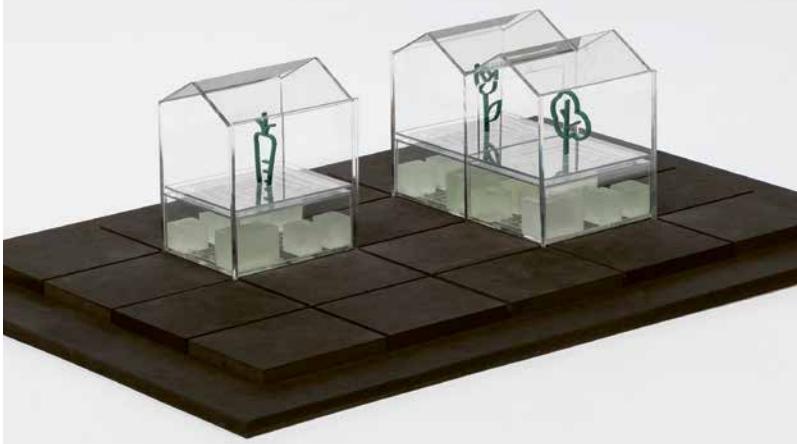
The Next Einstein is Coming!

‘Search, find and present your thoughts on the theme of energy transition. Formulate and develop concepts and ideas, and improve your understanding of topics related to obtaining, storing, transporting and consuming energy. Communicate your thoughts and results in three-dimensional models and objects. Models are spatial reality in their own dimension.’

Burghard Lütdke

Ideas and concepts should be made into concrete objects to view and understand. Some 50 architecture students motivated by this principle met to explore WindNODE project themes from different perspectives and express them concretely through model-building techniques. The focus was on vision rather than engineering. The process resulted in a diverse range of ideas, approaches and models that show how students have dealt with the topics of energy and the energy transition beyond the boundaries of their own disciplines.

The ideas and models are intended not only to entertain, but also to embolden and incite further work on new forms of energy, and arouse interest, feeling and fascination for the energy transition. Only a small selection of the more than 20 models created can be shown here.



Server farming – using waste heat from data servers

Bahar Yildirim – Kathrin Geußer – Lisa-Marie Wesseler

On average, 70 % of the waste generated in Germany is recycled. Physical waste is collected in a sorting system in which it is separated into categories and recycled, incinerated or reused. Data waste is different, however, and increases continuously due to the constant use of internet-connected devices.

So that time does not run out on us

David Eder – Johannes Greubel – Fee Filipzik

The energy clock visualises the generation of energy from different sources, which it divides into nuclear, fossil and renewable energy. The clock's four sides illustrate the respective proportions of the three energy sources in the world, in Europe, in Germany and in Berlin. Blue represents regenerative sources while yellow stands for nuclear energy and red for fossil sources.

Drive-by energy – harvesting airflow while driving

Selin Caki – Paulina Hagen – Arvid Nestler

In this model concept, otherwise unused airflow from cars and trucks driving in the street is captured to power street-lights, emergency call points and other traffic facilities. Guardrails along motorways or country roads are fitted with small rotors that convert the airflow from passing cars and trucks – which would otherwise be wasted – into usable electrical energy. Each installation consists of four rotors attached to a cable-guiding rail, which are inserted and wired in the channel of the guardrail.

WindpalmE – Windcatcher for urban areas

Helene Herrmann – Janel Osmankulova

In the WindpalmE, wind causes the 'palm fronds' to vibrate, which generates electrical energy in the 'fruit clumps' via the piezoelectric effect. This energy is led through the trunk and is stored in the 'root' area. The base is also a seat and charging station. The sculptural character of WindpalmE makes it particularly suitable for urban areas. Each one can produce around 15,000 kWh per year of electricity if the wind power's energy is fully utilised. An average efficiency of around 40 % (Cp = 0.4) would allow some 6,000 kWh to be generated per year, providing roughly enough energy to supply two households for one year.

Urban energy generation

Elphine Elphine – Julia v. Vietinghoff

This model of urban energy generation is based on a concept by the design studio Atelier DNA (www.atelierdna.com/portfolio/windstalk). The poles are roughly 50 m high and stand on bases with a diameter of 10 to 20 m. At the base, the poles measure around 30 cm across, tapering to 5 cm at the tip. They generate energy using piezoelectric ceramic disks, which are arranged inside the poles along their entire length. When the wind causes the poles to sway, the piezoelectric disks are subjected to pressure. This shifts the positive and negative charges, creating an electrical voltage. There is also a generator at the foot of each 'wind stalk' that is operated hydraulically. This generates additional energy through movement.

Underground updrafts

Moritz Ott – Leonardo Schmitz – Sören Wernitz

The advertising column was invented in Berlin as long ago as 1854. Now the concept is being reconsidered and refined. This solution generates energy by using the air stream in underground stations to drive a propeller in the underground tunnel. The rotary motion of the propeller is converted into electric current. The energy obtained can be used for things like lighting the train schedule displays or advertising. There is also an option to integrate smartphone charging stations and heated benches into the column.

Vertiwind – Making the most of facade surfaces

Karolina Gula – Katharina Kocol – Oksana Tyltina

In this solution, small Vertiwind wind power modules are designed as elements and integrated into the facade. They function as ‘resistance rotors’: the whole rotor surface offers resistance to the wind and is made to rotate by wind power. A facade of 5 metres × 15 metres can fit almost 800 Vertiwind modules and generate up to 3,900 kWh per year given an average wind speed of 5 m/s (expected in an inland location). The vertical shape is chosen for facades in urban areas, as it is better suited than horizontal wind turbines for locations with tricky wind conditions such as residential areas and cities. They also cause fewer noise emissions.

Spatz:2050

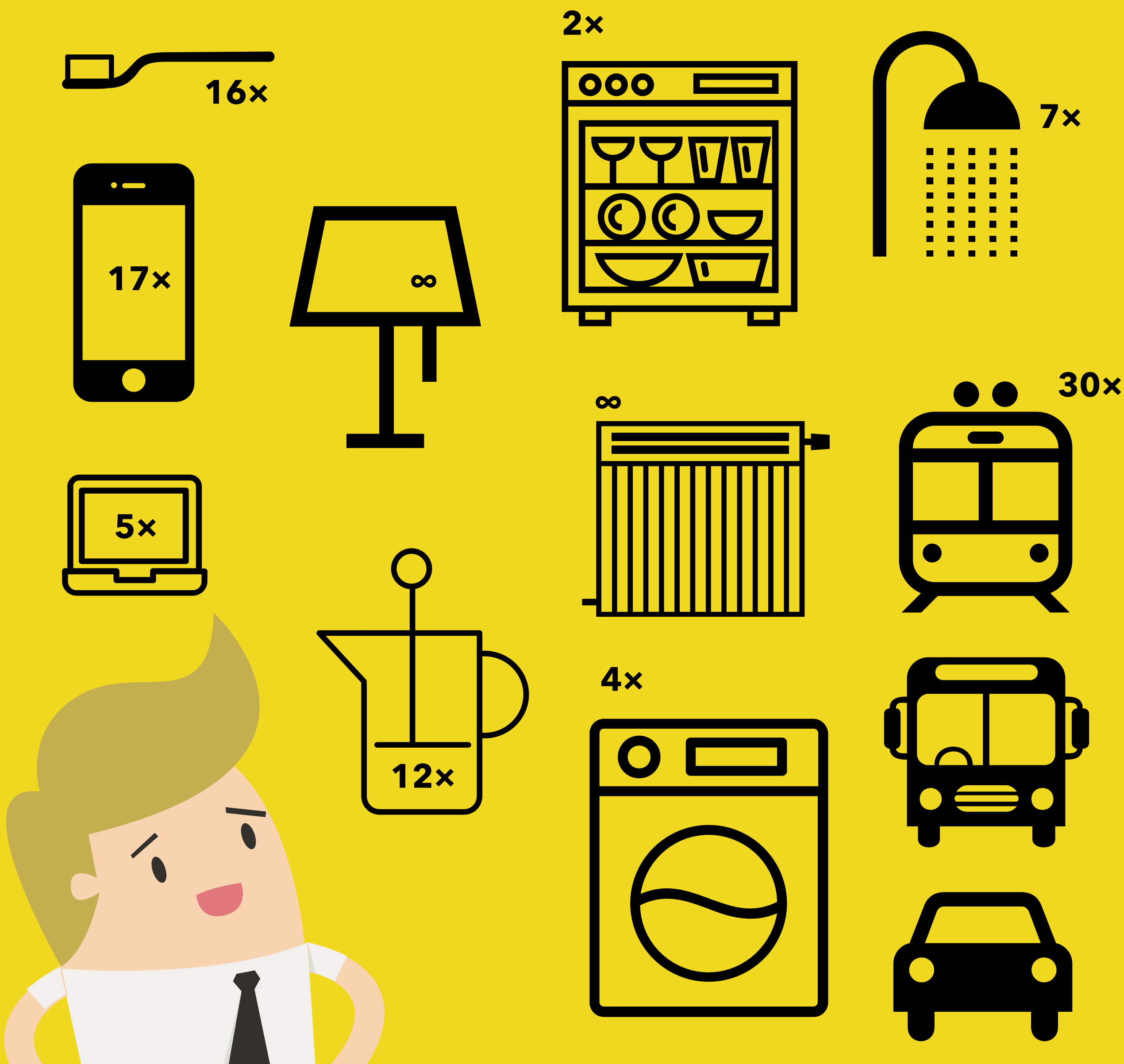
Lisa-Marie Kolbinger – Julian Mönig – Sina Riedlinger

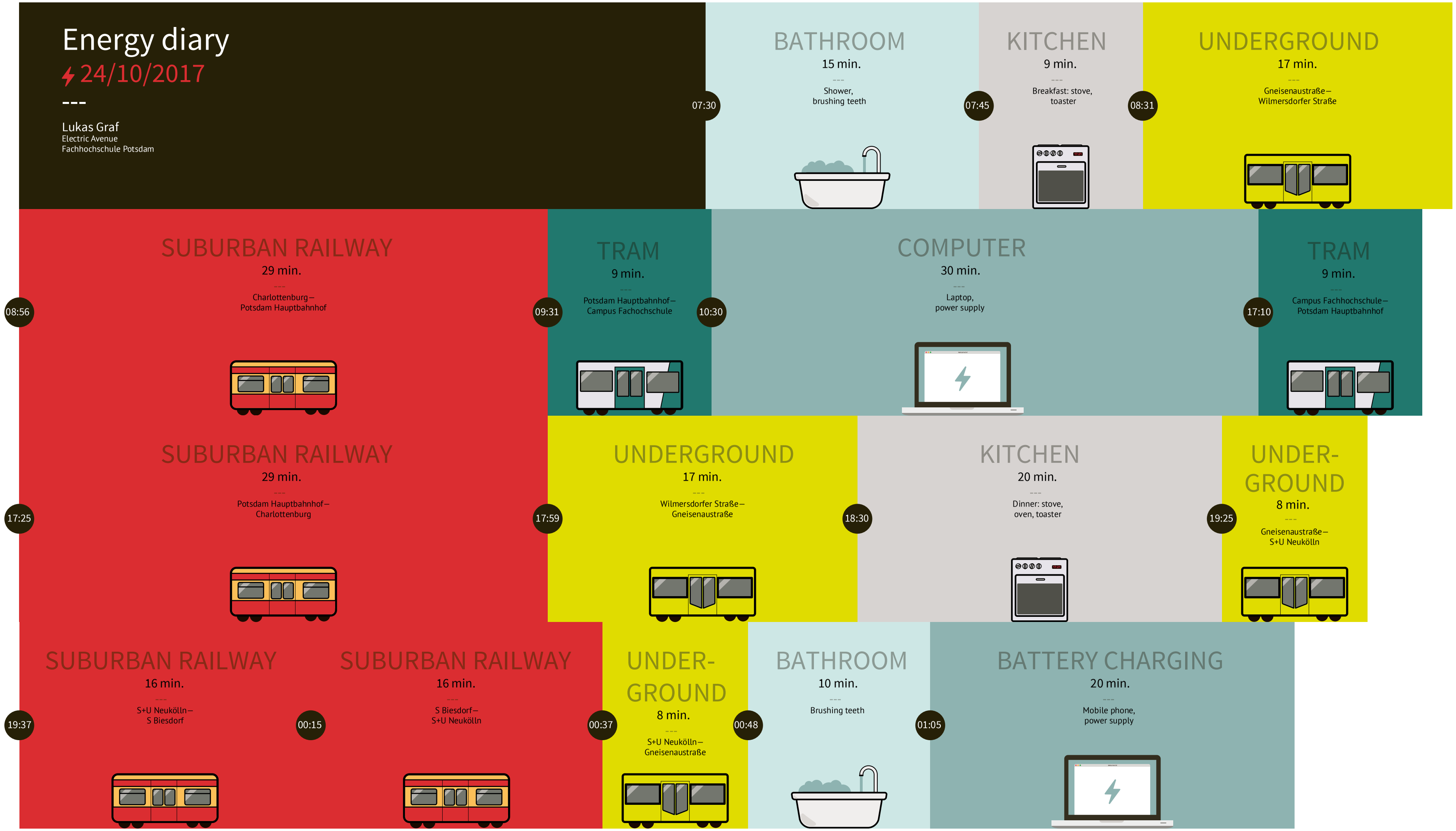
The starting point for the Spatz:2050 flying power plant is the need for future-oriented energy storage methods. Spatz:2050 rises to great heights and uses the wind speeds there to store energy. When its reservoirs are full, the device descends to earth. Additional energy is generated as it descends. In contrast to large-scale photovoltaic or wind power plants, the Spatz:2050 only temporarily affects its surroundings. The students felt that the direct visibility of the object was important because it would raise awareness of the production of energy required on a daily basis.

Diaries

168 Hours of Energy

Energy diaries: how much energy do I use in a week? For a week, students kept diaries to record how much energy they used at what time in everyday life.




Energy diary
24/10/2017

Lukas Graf
Electric Avenue
Fachhochschule Potsdam
07:30
BATHROOM
15 min.

Shower,
brushing teeth
07:45
KITCHEN
9 min.

Breakfast: stove,
toaster
08:31
UNDERGROUND
17 min.

Gneisenaustraße–
Wilmersdorfer Straße
08:56
SUBURBAN RAILWAY
29 min.

Charlottenburg–
Potsdam Hauptbahnhof
09:31
TRAM
9 min.

Potsdam Hauptbahnhof–
Campus Fachochschule
10:30
COMPUTER
30 min.

Laptop,
power supply
17:10
TRAM
9 min.

Campus Fachhochschule–
Potsdam Hauptbahnhof
17:25
SUBURBAN RAILWAY
29 min.

Potsdam Hauptbahnhof–
Charlottenburg
17:59
UNDERGROUND
17 min.

Wilmersdorfer Straße–
Gneisenaustraße
18:30
KITCHEN
20 min.

Dinner: stove,
oven, toaster
19:25
UNDER-
GROUND
8 min.

Gneisenaustraße–
S+U Neukölln
19:37
SUBURBAN RAILWAY
16 min.

S+U Neukölln–
S Biesdorf
00:15
SUBURBAN RAILWAY
16 min.

S Biesdorf–
S+U Neukölln
00:37
UNDER-
GROUND
8 min.

S+U Neukölln–
Gneisenaustraße
00:48
BATHROOM
10 min.

Brushing teeth
01:05
BATTERY CHARGING
20 min.

Mobile phone,
power supply

Energy and Art

Visions of a Successful Energy Transition

Visions are what drive us and lead us to achieve great things. And the energy transition is certainly a massive goal! We have made significant progress in expanding renewable energy. But in addition to building more wind and solar plants and digitalising the energy sector, we need to bring people along with us. How can we change the way companies and citizens think and act with regard to the way we consume electricity? How can every company and every individual contribute to the success of the energy transition?

How can you adapt your energy consumption to the availability of wind and sun – without sacrificing comfort? How can we motivate companies and citizens to participate, think critically and inspire one another so that the greatest project of our generation – the energy transition – can succeed? To meet this challenge, it is vital for people everywhere to take action and join in, read up on the topic and develop a vision for the future.

▸ **Fifty-one very different works of art** were created in the Energy and Art project to capture diverse ideas about a successful energy transition.

▸ **Maria Reinisch**, who manages the project, leads a tour of the exhibition.

▸ **'Energy transition made in Germany – intelligent, secure, clean, affordable'.** This vision was articulated by Peter Altmaier, Federal Minister for Economic Affairs and Energy, and translated into an image by artist Andrei Krioukov as part of Energy and Art.

The key is to win not only minds, but also hearts. In other words, we must tap into emotion in addition to knowledge and information.

What does a successful energy transition look like in our imagination? This is the role of art: it allows us to approach the topic in a meaningful and emotional way and stimulates reflection. In short: art enables us to address people holistically. And it transfers very different ideas and concepts to the canvas. The works of art shown here – each of which incorporates three unique perspectives – show just how varied the results can be. As part of the creative process, participants attended presentations, which were followed by small group discussions that brought together different ideas.

Artists then transformed the results of these discussions into images, which allowed them to add their own personal touch. In the end, 51 pictures were produced – 51 different visions, ideas and perspectives of schoolchildren, entrepreneurs, employees, students, scientists and politicians. These are accessible in German and English in the book *Visionen einer gelungenen Energiewende* (Visions of a Successful Energy Transition) as well as on a website. The images were also exhibited at numerous stops while on tour through the WindNODE region, inspiring a wide audience.

For more information:
www.windnode.de/energie-und-kunst
www.energie-und-kunst.de

Changing Perspectives on the Energy Transition

Learning from Others as a Cornerstone of Sustainable Global Energy Use

How can we make sure the energy transition is successful? How can an energy supply based on renewable sources work? What do questions of energy generation and use mean to young people from places as far apart in social and economic terms as Germany and Nepal – and what can we learn from each other?

In the photo project 'Changing perspectives on the energy transition', we asked young people from Germany and Nepal for their point of view: how do they see and experience energy and the changes in our energy systems? We would like to raise awareness and enthusiasm for this important topic and encourage further reflection based on their authentic outlook and their ideas and associations.

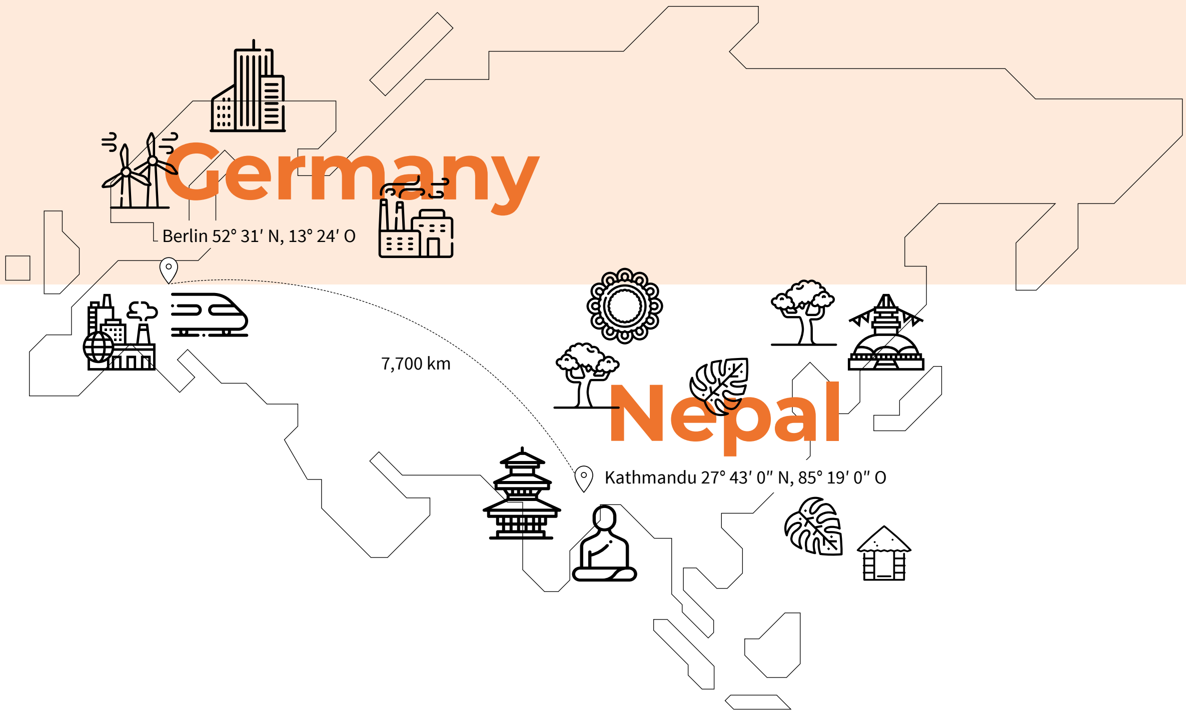
Approximately 100 schoolchildren in Germany and 140 in Nepal participated in the project between October 2019 and February 2020. Each class had a week of lessons on different aspects of climate change and the energy transition, the transformation of the energy system, and their own behaviour in terms of energy use. There was a great deal of discussion and play and the pupils were encouraged to take photos related to these topics and to record their thoughts in short texts and stories. The results are presented on the following pages.

Contact
Maria Reinisch Marketing Kommunikation
Schlehenring 30
85551 Kirchheim
info@kunst-und-energie.de

For more information
www.perspektivwechsel-energiewende.de

240

pupils from Germany and Nepal captured their perspectives on the energy transition in photos as part of the Energy and Art project.



‘A lot of people want to change the world, but not themselves. Instead of cars and ships, use your feet and your voice.’

Efe, Serhat, Dilara, Maurice
Germany

Project week

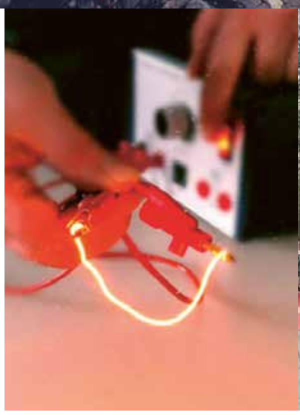
Berlin

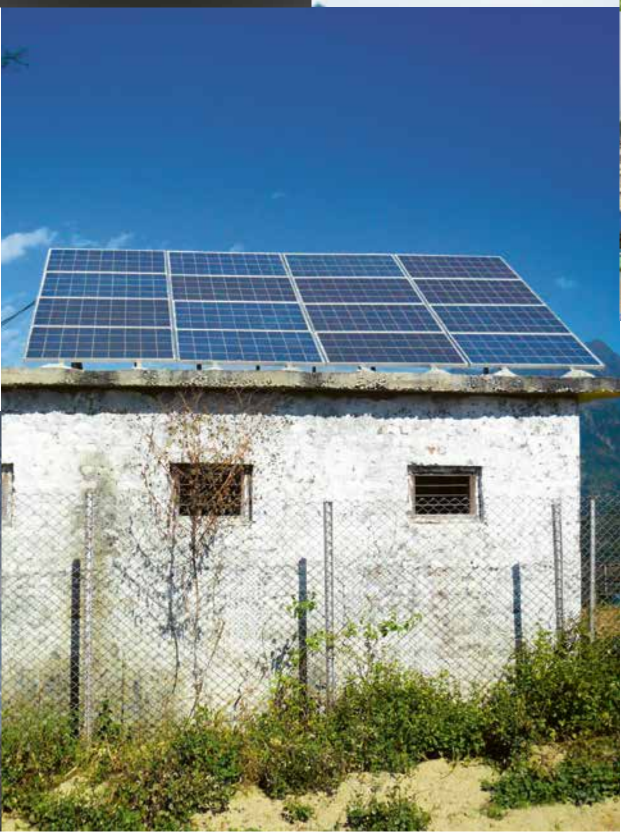
In January 2020, a project week was held in four classes (ages 16 to 17) at a school in Berlin-Neukölln. Each class had its own schedule and visited different WindNODE partners in Berlin during the week. TU Berlin, Siemens, Vattenfall, GASAG and 50Hertz offered the pupils an inside look at the complexity of the energy revolution. At Stromnetz Berlin, they tested the game Hertzschlag, meaning ‘heartbeat’ in English and referring to the unit hertz (see subproject 9.5, p. 202).

The pupils took photos on energy-related topics and wrote short texts about them in small groups. The pictures deal with the energy transition, environmental and nature conservation, and waste avoidance – all subjects shaped by urban life.

‘It’s green! The way is clear for the victory of green energy. Don’t wait for the people behind you to honk their horn.’

Mina Giselle
Germany





‘Energy can be used in ways that do no harm to others. It is one of the most important things in a person’s life.’

Sankash, Bhavana, Darshana
Nepal

Project week

Nepal

In Nepal, two project weeks each were organised in Kankada and in a monastery in Kathmandu in November 2019. During these weeks, children took photographs and wrote texts about energy. They were also given the opportunity to build solar plants. The photos and texts by the children and young people in Kankada focused on energy in nature, the movement of water and the cultivation of plants.

Unlike those of the young people in Germany, almost every picture showed people or animals. In the pictures and texts of the students at the monastery, energy is seen as a triad, a combination of spiritual, human and mechanically useful energy.

‘Hey you! Change your perspective and see the energy in the rain, the light, the trees, the clouds and maybe even in the darkness!’

Kunga, Jinpa, Tsultrim
Nepal

e-stories

Electricity, Energy and Literature

The ‘e-stories’ began with a historical and literary overview of the Romantic era and the age of Goethe, and have now charted the course of these currents through the year 1980. This was the year in which an interdisciplinary trio of authors from the Öko-Institut in Freiburg – Florentin Krause, Hartmut Bossel and Karl-Friedrich Müller-Reissmann – chose the expression *Energie-Wende,* or ‘energy transition’, as the title of their book *Energie-Wende: Growth and Prosperity Without Oil and Uranium.* Since then, the term has been used all over the world.

In the e-stories, we traverse the cultural dimensions of these developments, question how energy transition narratives are told, and show that the technical innovations associated with this new age are part of a blueprint for the future: a transformation in the sense of a ‘sustainable modernity’, with ecologically intelligent lifestyles and communities based on solidarity.

The remaining essays will trace the connection between energy, energy transition, and literature up to the present day and a bit beyond – into ‘solar’ science fiction.

The e-stories will continue to appear on the WindNODE homepage in German and English. We plan to publish them as a printed book in 2021. This means that the first compendium of literary history on the topic of energy transition will have originated in the WindNODE cosmos.

‘We are talking about energy and energy technology here – but also about changes in living and working environments, which have been traced very precisely in literature, as with a kind of magnifying glass. The literary texts are full of knowledge about transformative shifts in energy, in both the past and the present.’

Prof. Dr Ingo Uhlig
Department of Energy Systems, TU Berlin
and the Institute for German Language and Culture,
Martin Luther University Halle-Wittenberg.

This yearbook contains e-story no 9.

e-story 09
‘Energy Transition’

09

It is around the year 1980 in Baden-Württemberg, in the area east of Tübingen – Reutlingen, Metzingen, Eningen, the Swabian Jura. Georg Landerer is a man just past his prime, practising the dying art of typesetting. In a melancholic state of mind, he gives up his trade and leaves his wife and family; his children are already grown. He does not leave the country, although he finds West Germany frustrating. ‘Suddenly, nothing felt right anymore. Work lost its meaning. Every conversation wounded me before it even started. The news on TV confirmed my condition.’

Peter Härtling’s (1933 – 2017) novel *Das Windrad* follows the character’s depression and biographical disorientation, through the bleak towns and rain-swept slopes of the Swabian Jura. The appearance of a second protagonist offers a breath of fresh air: the sculptor Kannabich, a springy, sometimes manic figure, turns the narrative towards the nascent energy transition. The artist plans to erect a wind turbine on the slopes of the mountains – a turbine ‘which, no matter how much electricity it would generate, would be a great work of art’. It is this character of the figurative artist that introduced the subject of renewable energy into the history of German literature thirty-five years ago. To a large extent, it still remains an art project: the energy transition.

The term also hails from southwestern Germany. In 1980, an interdisciplinary trio of authors from the Institute for Applied Ecology in Freiburg (Öko-Institut Freiburg) – Florentin Krause, Hartmut Bossel and Karl-Friedrich Müller-Reissmann – published a report entitled *Energie-Wende: Wachstum und Wohlstand ohne Erdöl und Uran (Energy Transition: Growth and Prosperity Without Oil and Uranium).* This historical document, distributed as a small volume in bright orange, is, like Härtling's novel, a testimony to an ecological and energy-oriented counterculture that emerged from the anti-nuclear demonstrations and the environmental movement. The earliest aesthetic evidence of these new energy sources can probably be found among the protest marches and demonstrations of the time, in the art on protest signs or in songs. Härtling also takes the reader into this sphere: in his novel, the authorities have officially banned the wind energy project, the police have already been deployed, and Kannabich is welding the wind turbine tower at dizzying heights, while a crowd of demonstrators at the foot of the tower fights for the construction to continue. By using the unexpected verb ‘to sway’ *(schunkeln)*, the text succeeds in underlining the great swell of emotion the people are feeling: the ‘chains of people began to move back and forth, to sway, to make movements, as if following some inaudible music … some began to sing, first against each other, then with each other.’

This wind turbine performance intensely tracks the symbolic forces that had to spread with the new energy sources while revealing that energy upheavals are a matter of cultural expression and movement as well.

The zeitgeist of West Germany and the energy protests around 1980 are also the subject of a current novel. Nicol Ljubic (1971*) offers a retrospective on the green resistance in its most radical form in his 2017 work *Ein Mann brennt (Being on Fire),* also set in the southwestern region of the country. The author tells the story of Hartmut Gründler (1930 – 1977), a teacher and environmental activist from Tübingen who self-immolates on 21 November 1977 in protest against the nuclear policy of the SPD government of the time. An ethical paradox is unfolded with precision and patience as Ljubic shows how a thoroughly philanthropic idea hardens and becomes the source of piercing sorrow. He describes a moment of radicalisation and shows how illusory spaces that are largely inaccessible to communication can form around the players, even at the heart of a progressive green movement. Looking back to the late 1970s from our present, he documents the same gloomy determination that emanated from Josepha Nadler, Monika Maron’s heroine from 1981’s *Flight of Ashes.*

Maron's Bitterfelder Bogen: *Ein Bericht (Bitterfeld Arch: A Report)* from 2009 adopts a completely different view of this period. The literary account, which traces the rise of the Q Cells company, finds its sympathetic figure in the company founder, Reiner Lemoine, who was born in 1949 and died prematurely in 2006. On several beautifully penned pages, Maron highlights Lemoine's time as an energy pioneer in the early 1980s. He looked like John Lennon, studied at the Technical University in West Berlin and joined forces with like-minded people to found the engineering collective Wuseltronik, which occupied a commercial complex in Berlin-Kreuzberg and worked on energy-related inventions. Wuseltronik focused on the development of wind- and solar-powered electronics.

'These were the years of major protests, teach-ins, sit-ins, demonstrations and squatters. Lemoine and his friends – which included engineers as well as anti-nuclear activists – felt that it was not enough to always just oppose something: it was also important to act. The name *Wuseltronik ['busytronics']* testifies both to the chaotic and cheerful atmosphere of those years and to the seriousness of the initiative.'

In passages like these, Maron not only portrays the dedicated engineer; she also shines a spotlight on the young energy transition project as a cultural phenomenon that encompasses and touches on different areas of life. The reader observes a progressive energy culture and an emerging, enthusiastic time in which technology, art and new ways of life came together and inspired each other.

Lemoine seems to have always kept in mind the connection and mediation between energy and society. As entrepreneurial success came from the technical innovations, and Wuseltronik became the solar-power company Solon and eventually Q Cells, he created the Reiner Lemoine Foundation. Established shortly before his death in 2006, this part of his legacy focuses on ethical issues, such as a goal of 'reaching 100 % renewable energy'. The foundation's stated mission is one of educational and developmental support, spanning technology and culture. The pages of the foundation website feature these idealistic principles as well as a short video about Lemoine. It is an entertaining document that is well worth watching for a history of the engineer and the culture of engineering, with appearances by Lemoine and his comrades-in-arms and friends from the early Berlin years. The contributions and pictures from a period lasting some three decades are accompanied by a Lemoine quote that may come across as unacademic, but in its unconventionality calls for nothing other than the recognition of technology and renewable power as a cultural good and social value: 'To hell with commerce, let's do the right thing.'

The late 1980s – in the shadow of the Chernobyl disaster of April 1986 – still see the publication of several key texts, such as Christa Wolf's (1929 – 2011) narrative *Störfall (Accident: A Day's News)*, Gabriele Wohmann's (1932 – 2015) book *Der Flötenton (The Sound of the Flute)* and Gudrun Pausewang's (1928 – 2020) youth novel *Die Wolke (Fall-out)*, all three of which are published in 1987. After this period, however, there is a lull in the publication of literary works on energy and environmental issues. The reasons for this certainly include two major transformations: Germany's reunification ties up literary capacities at the same time as innovations from another technical area beckon; literature discovers digital life. As the genre of the German pop novel shows, writing remains technology-oriented and is fully entering the information age. The *Techniktagebuch ('technology diary')*, established in 2014 by Kathrin Passig (*1970), and maintained by her since then can be seen as a kind of culmination of this development. It is a body of texts which was created through a spirit of collective energy and currently spans more than 7,000 pages, with over 5,000 contributions by some 400 authors. In 2019, this artistic community blog received the Grimme Online Award. It takes a while to outline its monumental character, but once it does, it provides an impressive testimony of life with digital artefacts. When asked what kinds of energy and electricity flow through the devices mentioned, the search function of the online chronicle reveals only the smallest amounts of text.

The 2010s are another period of heightened literary preoccupation with energy. But they would not simply follow the 1980s and their energy narrative, the pathos of their movements and the sometimes-heroic gestures of their central figures. Bridging the gap between the artistic and technical avantgarde was easier in the early phase of the energy transition. An obvious explanation for this could be that literature and the technical-ecological counterculture came together easily in the role of system critique. Since then, however, the development of

▲ ‘Energy transition’: 1980 – 2020. Forty years since the publication of *Energie-Wende: Growth and Prosperity Without Oil and Uranium.*

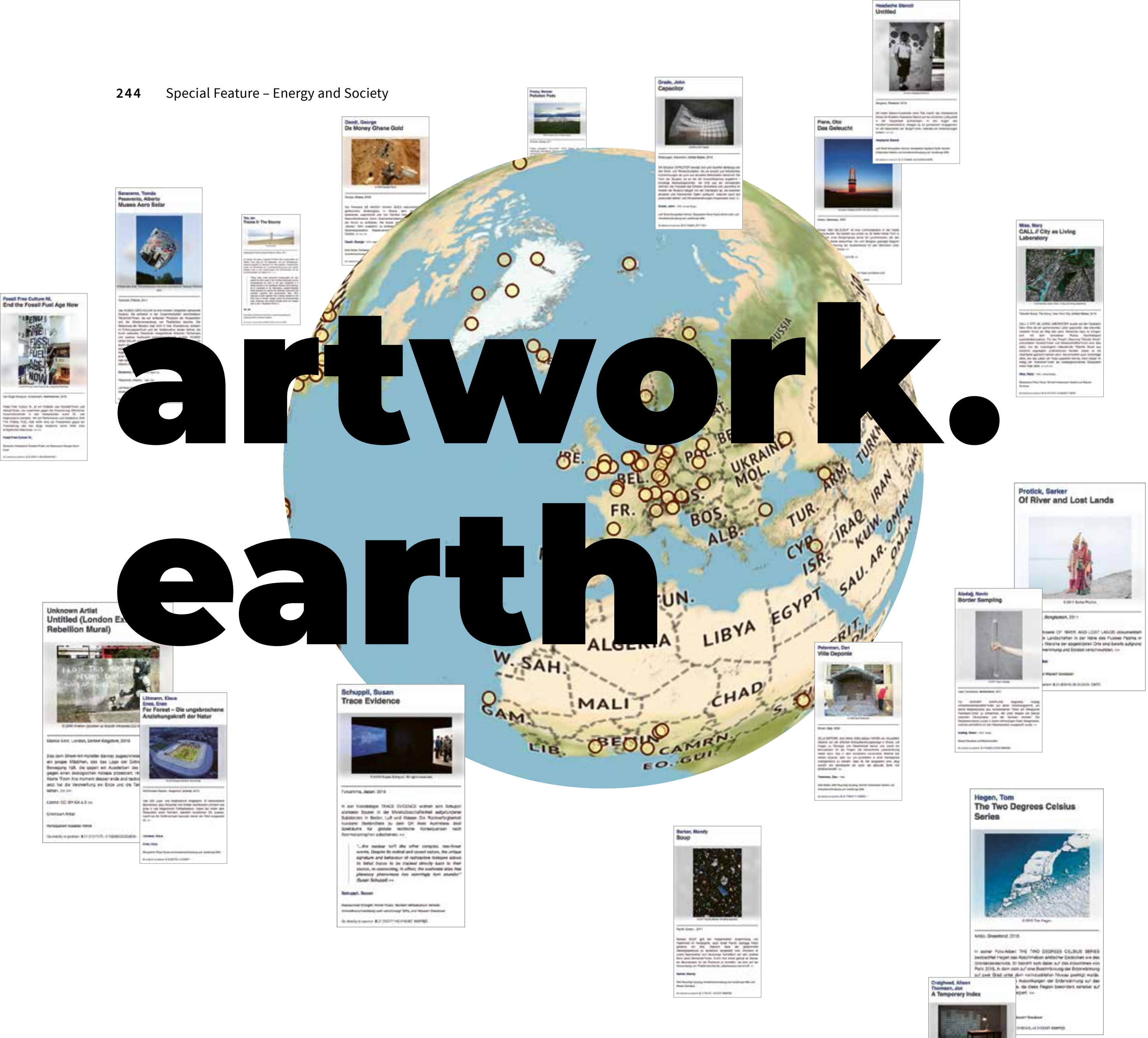
renewable energy sources has long since left such easy-to-survey niches behind. One path led via Wuseltronik to Solon, Q Cells and ultimately Hanwha Q Cells: it connected the fictitious wind turbine experiments in the Swabian Jura to the establishment of reality labs that today test technical, economic and regulatory scenarios; but above all, it moved from a concern for specific eco-systems and places to an examination of a climate crisis that can only be solved through global action.

The fact that things are much more complicated today with regard to renewable energy is ultimately indicative of the success of the ‘energy transition’ that took shape around 1980: no longer a counter and niche culture, but a transformation process with a breadth and diversity of expression that encompasses every aspect of society.

For more information:
https://www.windnode.de/en/results/energy-and-society/essay-series/

▸ Literature, other sources and texts from research

- Peter Härtling, Das Windrad, Luchterhand Verlag, Darmstadt 1983.
- Nicole Lubic, Ein Mensch brennt, Deutscher Taschenbuch Verlag, Munich 2017.
- Florentin Krause, Hartmut Bossel, Karl-Friedrich Müller-Reissmann, Energie-Wende. Wachstum und Wohlstand ohne Erdöl und Uran, S. Fischer Verlag, Frankfurt a. M. 1980.
- Monika Maron, Flugasche, S. Fischer Verlag, Frankfurt a. M. 1981.
- Monika Maron, Bitterfelder Bogen, S. Fischer Verlag, Frankfurt a. M. 2009.
- Christa Wolf, Störfall. Nachrichten eines Tages, Luchterhand Verlag, Darmstadt 1987.
- Gabriele Wohmann, Der Flötenton, Luchterhand Verlag, Darmstadt 1987.
- Gudrun Pausewang, Die Wolke, Maier Verlag, Ravensburg 1987.
- Kathrin Passig und Autorenkollektiv Techniktagebuch, https://techniktagebuch.tumblr.com
- Jonas Torsten Krüger, „Unter sterbenden Bäumen“. Ökologische Texte und Prosa, Lyrik und Theater. Eine grüne Literaturgeschichte von 1945 bis 2000, Tectum Verlag, Marburg 2001.
- Benjamin Bühler, Ökologische Gouvernementalität. Zur Geschichte einer Regierungsform, Transcript Verlag, Bielefeld 2018.



artwork. earth

The Atlas for Art on Ecology and Climate, Energy and Resources

Artists all over the world are working on topics related to climate change and renewable energy, but the art they produce is often known only in their immediate surroundings or specific professional circles. The project 'artwork.earth' therefore aimed to collect these works of art and make them systematically accessible to a broad audience. Its catalogue currently contains around 150 entries and will be continuously updated.

◂ **www.artwork-earth.com**
A web-based interactive atlas that provides information on art, with a focus on topics including energy and the energy transition. Visitors are invited to discover the functions and contents of the atlas for themselves.

Contemporary art illuminates local ecological situations in a global context – examples include resource theft in Lagos, Nigeria (George Osodi), the dwindling ice of Greenland and Iceland (David Buckland, Olafur Eliasson), radiation in Pripyat, Ukraine (Cornelia Hesse-Honegger), or sustainably greened building technology on Dortmund rooftops (Natalie Jeremijenko). The profile of the lived realities and possibilities of life in the Anthropocene is thus sketched based on the most diverse locations and approaches, and recent energy developments are reflected as cultural change and as an opportunity for successful transformation.

In the artwork.earth project, works of art are collected, plotted on a map and marked with pins. Clicking on a pin opens a window containing the main information about the work and the artist in German and English, as well as images and links. This documentation is creating an unprecedented archive with a global reach to accompany climate- and energy-related changes. Ecological and technical developments are visible here as cultural and artistic representations. And information is provided to support and inspire further scientific, educational, participatory and environmental-policy projects.

The project is organised under the direction of Prof. Dr Ingo Uhlig, who works at the Department of Energy Systems at the TU Berlin and at the Institute for German Language and Culture at the Martin Luther University Halle-Wittenberg.

10 Questions and Answers about WindNODE

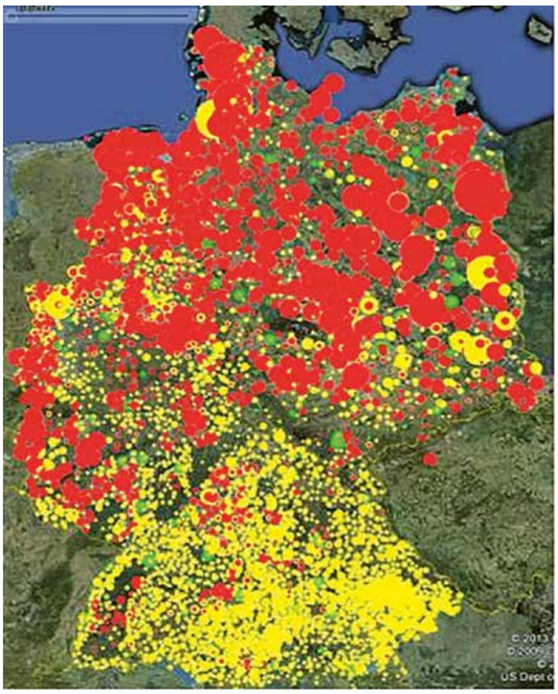
▹ Question 1

What does WindNODE stand for?

The name WindNODE comes from the project's full title, 'Windenergie als Beitrag Nordostdeutschlands zur Energiewende' ('Wind energy as northeastern Germany's contribution to the energy transition').
Northeastern Germany consists of the 'new federal states' of Brandenburg, Mecklenburg-West Pomerania, Saxony, Saxony-Anhalt, Thuringia and Berlin. Together, these six states form a region that, as of 2019, already produces enough renewable energy to cover more than 60 %[1] of its electricity needs. The largest share of renewables in the region comes from wind energy – and the name WindNODE reflects this unique feature (see illustration). The generation of renewables is not a key focus of the WindNODE project (with the exception of workstream 2); it simply provides a broader context for our questions regarding *system integration*, such as: how can very large quantities of renewables – which, in the future, may meet or exceed 100 % of energy needs – be integrated into the energy system safely and efficiently? Because wind power units connected to the grid are generally larger than units for photovoltaics, problem-solving strategies in WindNODE differ in some respects from the more cellular approaches of other SINTEG joint projects. The WindNODE project is based on work carried out by the Cluster Energy Technology Berlin-Brandenburg and other partners from the energy industry in 2013 – 14 for a study with the working title *'Wind in die Städte'* or 'wind into the cities' (named after a study from Stromnetz Berlin and GridLab published in 2012). The basic idea is to enable rural areas that are net exporters of green energy to supply urban load centres. The urban centres act as intelligent, flexible consumers, and the whole system becomes an interplay of regionalisation and transmission of load flows. This concept is not exclusive to Berlin-Brandenburg, of course, and in 2015, as project development continued, it was extended to include all of northeastern Germany, facilitated in large part by a merger with the cluster coordinated by Energy Saxony.

By the way, how do you actually pronounce WindNODE – in German or English? Both pronunciations are common and permissible. The German version retains the original meaning behind the acronym; the English version reflects our international orientation, and 'node' alludes to the networks that are so important in the energy system.

▾ Development of the renewable energy landscape in Germany in 2018.



Photovoltaics
Wind power
Biomass

> 1,600,000 plants
49,628 MW installed wind power
41,687 MW photovoltaics

[1] Source: 50Hertz (2020).

▷ Question 2

What contribution has WindNODE made to the success of the energy transition?

Model solutions for flexibility and reality labs in the second phase of the energy transition

It has been roughly 20 years since the Renewable Energy Sources Act (EEG) was passed, and in that time the German energy transition has achieved two especially notable successes: a near-total abandonment of nuclear power and an increase in the share of renewables in Germany's gross electricity consumption to 42.1 %[1] (currently at over 60 % in the WindNODE region) as of 2019. In its first two decades, the energy transition was first and foremost an electricity transition. Now that the next phase of the energy transition has begun, it is important to integrate very large shares of volatile renewables (the goal is 100 %) into the electrical energy system safely and efficiently. At the same time, to decarbonise the other energy sectors of the final energy consumption, especially mobility and heat. This can succeed only through a series of measures that intertwine and complement one another like pieces of a puzzle, including: energy efficiency (to minimise the primary energy requirement), the expansion of renewables (to make the required primary energy as green as possible), grid expansion (to balance supply and demand on a large scale), short- and long-term storage systems that include hydrogen (to prepare for extended periods of low wind and solar power generation), sector coupling (to decarbonise the heating and mobility sectors in particular) and flexibility (to adapt the use of green electricity as much as possible to the supply). WindNODE focuses on the identification and use of flexibility options.

>200 MW

technical flexibility options identified in WindNODE

Demand-side flexibility will become more important in the future

The 'dual phase-out' of nuclear energy and coal-fired power generation will decrease the flexibility of production in the future. WindNODE therefore focused on developing model solutions to increase demand-side flexibility, sector coupling and the digitalisation of our energy system. We are investigating this topic in a total of 50 subprojects, which can be grouped into four major focus areas:

1. Identifying flexibility by systematically finding, developing and characterising technical potential for load shifting and sector coupling (see the Best Practice Manual: Identifying Flexibility Options). We have found more than 200 MW of technical flexibility options in WindNODE.

2. Activating flexibility, i. e. tapping economic potential through behaviour that benefits the grid, system and market (see question 7). The concept of a flexibility platform for market-based grid congestion management is completely new (subproject 1.2, p. 66).

3. Digitalising the energy system as a driver for digitalisation and business models in the energy industry (see question 6).

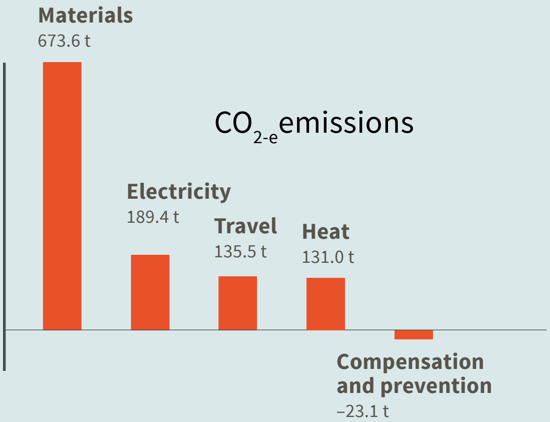
4. Developing a prototype of a reality lab with transferable blueprints, further development of the regulatory framework and opportunity-oriented energy transition narratives (see question 5).

Work in the first three focus areas produced innovative technologies, which are presented in the subproject profiles (see p. 60 – 211). WindNODE thus provides model solutions for the system integration of renewable energy on all levels: technical, economic, regulatory and social.

[1] Source: Federal Ministry for Economic Affairs and Energy (2020).

▹ Question 3

What was the carbon footprint of WindNODE itself?



Approximately 1,106 tonnes of greenhouse gases were emitted in the course of the project

In the service of a good cause, WindNODE itself emitted carbon dioxide (CO_2) and greenhouse gases (GHG). This is because, even as we worked on sample solutions for a 100% renewable energy supply, the heating and electricity used in our offices and laboratories was not yet climate neutral. Our business trips and the equipment needed for our demonstrators also have a carbon footprint. We wanted to determine the sum of all of these emissions. In collaboration with Siemens and the Department of Energy Systems at TU Berlin, we developed a life-cycle assessment (LCA) procedure for WindNODE, which is based on existing standards, in particular ISO 14001. The majority of our partners participated in data collection and recorded total working years, business trips, material costs and more. As with any LCA, a number of assumptions and simplifications were required in order to calculate a carbon footprint from the data. For example, we needed to define the system boundaries (i. e. what is part of WindNODE's project work and what is not) and use our existing figures to extrapolate the numbers for partners who had not participated in the data collection. Even though the result is subject to some degree of uncertainty, we are sure of the magnitude: WindNODE was responsible for 1,106 tonnes of GHG emissions (CO_2 and CO_2 equivalents [$CO_{2\text{-e}}$]). Relative to the project budget, this corresponds to a GHG intensity of roughly 16 tonnes of CO_2 per million euro – a magnitude that, based on the current literature, would be expected for the field of 'science and technology'.[1]

[1] See PCAF Netherlands (2019), p. 82.

Greenhouse gas accounting should become a standard part of future projects

To our knowledge, research and development (R&D) projects in the energy and climate sector seldom reflect critically on their own carbon footprint; in any case, we have found few indications in the literature that there is much precedent for such accounting. We recommend making greenhouse gas accounting a regular part of future R&D projects and climate change activities in general (e. g. climate conferences). Our work can provide a methodological blueprint for this task.

think • go climate conscious
atmosfair

WindNODE is GHG-neutral: we have offset our emissions

The top priority must always be to avoid emissions that have a damaging impact on the climate. Where this is not possible or not yet practicable, measures should be taken to reduce emissions elsewhere by the same amount (a practice called compensation). In this spirit, we at WindNODE decided to offset our emissions by supporting a wind energy project in Nicaragua (certified in accordance with the Clean Development Mechanism Gold Standard). We partnered with Atmosfair – the best in its class, according to German consumer watchdog Stiftung Warentest – which implements climate change measures to offset unavoidable emissions. We would like to thank the following WindNODE partners who participated in this effort voluntarily and without financial assistance:

50hertz | Elia Group
ASEW Das Effizienz-Netzwerk für Stadtwerke
Berliner Wasserbetriebe
BMW GROUP
Borderstep Institut für Innovation und Nachhaltigkeit
BOSCH Technik fürs Leben
BSR
DIN
Fraunhofer IFF
Fraunhofer IWU
GASAG Solution +
IKEM
SIEMENS
Stromnetz Berlin
VATTENFALL

▷ Question 4

What innovations and technologies have emerged from the project?

Germany Land of Ideas
Landmark 2018
National Sponsor Deutsche Bank

We define innovation as doing something new, in a new way

Many of WindNODE's innovations are a combination of new technology and a novel concept for its application – which is why WindNODE was honoured as a 'Landmark' in the 2018 Land of Ideas Competition. Due to space constraints, we can only describe some of these model solutions here as an example, but all such solutions are presented in full in the subproject profiles on pages 60 – 211.

Thanks to the electrically powered i3, the BMW Group in Leipzig owns old batteries from electric cars. What 'software' can be employed to use this hardware efficiently? The solution was to connect the existing components to create a storage farm and thus create a 'second life application' on the factory premises (subproject 7.6, p. 168). Berliner Stadtreinigung (subproject 6.1a (BSR), p. 130), Berlin's municipal waste company, controls the charging of batteries in its vehicle fleet in such a way that the process serves as a flexible load to relieve the power system. Lumenion (subproject 8.4, p. 188), too, has focused on creating innovative storage concepts: a steel storage system is being integrated into one of Vattenfall's existing gas-fired combined heat and power plants (CHPs) to supply local heating and electricity for a residential neighbourhood managed by Gewobag. This allows surplus electricity to be absorbed and later fed into the heat supply. The latest home automation technology, among other innovations, is finding its way into Berlin neighbourhoods. We use this technology as a springboard for developments that will make the building sector better able to accommodate applications ranging from landlord-to-tenant electricity to virtual power plants (subproject 8.2, p. 180).

We give existing, proven technologies a new chance with clever ideas

Innovation in the energy sector often does not even require the latest hardware. Using existing technology in clever, innovative ways can go a long way towards making the energy transition environmentally friendly and affordable. The intelligent reactive power management system developed by WEMAG shows how existing components in the distribution network can be used in the future to compensate for important functions of large power plants (subproject 3.3b, p. 90). In collaboration with Bosch.IO, Stromnetz Berlin demonstrates how the venerable infrastructure of pager-based ripple control can be modernised with little effort and used to benefit the grids (subproject 4.6, p. 114). Even night storage heaters, long dismissed as a relic of a bygone era, are finding their way into the energy system of the future thanks to a clever idea: used with heat pumps, which are growing increasingly popular, these storage heaters can ensure green-electricity-friendly consumption patterns for end customers (subproject 6.3a, p. 140). And Berliner Wasserbetriebe (subproject 7.5, p. 166), the water supply and wastewater disposal company for Germany's capital, is reducing the annual peak load in its Münchehofe wastewater treatment plant by analysing energy consumption in combination with multi-level automation.

Our innovations make complexity manageable

WindNODE has also produced and promoted innovations to address issues that are complicated enough to make the energy system of the future seem almost unmanageable: ENERTRAG shows (subproject 2.2, p. 76) how clever concepts for data collection and transmission make it possible to efficiently control a large number of very different technical components in a regional power plant. The Fraunhofer Institutes IWU and IFF have developed methods that can be used to comprehensively analyse and control the complexity of energy technologies in factories and production chains for the first time. Siemens has implemented similar methods in its Berlin plants (subprojects 7.2, p. 158). There has long been political demand for a cross-sectoral approach to energy; the integrated operation of electricity and heating infrastructure is already possible today at IBAR in Cottbus and at the municipal utilities of Hennigsdorf and Frankfurt (Oder). This is based on highly specialised software solutions (subprojects 2.3 and 2.4, pp. 80 – 83).

We treat buzzwords as side notes, not goals in themselves

And what is WindNODE's position on the buzzwords in the innovation debate? Which innovation report can do without blockchain and artificial intelligence? We see ourselves as pioneers of tangible innovations, with a certain distance from catchphrases that are difficult to back up with substance. But, of course, WindNODE partners have also researched these topics. We have sprung into action wherever there are promising applications – that is, where technology, markets and regulation intersect: Solandeo is using technologies from research on artificial intelligence (AI) to develop localised, high-resolution 'generation forecasts' for use in green electricity trading and grid operation optimisation (subproject 4.4, p. 110). The application of sophisticated online sensor technology for fault investigation in low-voltage systems, sometimes called 'predictive maintenance', is part of the work carried out by Stromnetz Berlin (subproject 3.3e, p. 98). On p. 106 and p. 112 (subprojects 4.3, 4.5), Bosch.IO and develo show how an efficiently networked architecture for smart meter systems can be the starting point for digital service platforms.

▷ Question 5

There have already been a lot of energy research projects. What is special about WindNODE?

WindNODE shows how reality labs work

Funding for research and development (R&D) activities that focus on energy technologies has existed for a long time. R&D funding allowed E-Energy to operate as a 'large-scale laboratory' across Germany from 2008 to 2013[1], which paved the way for later energy research projects on system integration. It did so by demonstrating for the first time that digitalisation would play a key role in enabling a smart energy transition and, in particular, the dynamic integration of fluctuating renewables under the moniker 'Internet of Energy'. In preparation for the imminent introduction of smart meters, important findings were obtained from large-scale field tests, especially with regard to load shifting in households and intelligent distribution networks. The five SINTEG showcases (C/sells, Designetz, enera, NEW 4.0 and WindNODE) were created in its aftermath and are now pioneers in their own right for 'reality labs for the energy transition', which are now supported as part of the federal government's 7th Energy Research Programme – establishing a new, third 'funding pillar' to supplement the two traditional ones: basic and applied research. This one is about finding solutions that are suitable for mass rollout and developing blueprints, about validating market-oriented system solutions and effectively demonstrating our innovation prowess.

Regulation becomes part of the experiment

The SINTEG programme is unique because it extends far beyond the high technology readiness level (TRL) of application- and market-oriented demonstrators. This begins with the SINTEG Ordinance ('SINTEG-V'), which has allowed a regulatory sandbox to become part of an energy research project for the first time. This opens up certain experimental possibilities for project participants that would not otherwise be available under the current regulatory framework for the energy industry (see p. 55) and has proven to be an extremely important catalyst for our reality lab. With over 70 partners involved, WindNODE is also much larger than typical joint projects. We have created a lively network – to our knowledge, the largest of its kind to date – which includes all of eastern Germany and unites a region behind one ambitious vision: an energy system based on 100 % renewables. We present sample solutions for the energy transition embedded into large, operational ecosystems in the real world. Our solutions are interdisciplinary, cooperative and cross-sectoral, incorporating all partners who will be part of a future energy system. This strengthens existing partnerships, such as the close cooperation between TSOs and DSOs, and leads to entirely new, unexpected network effects that go far beyond the actual project work – for example, when WindNODE co-organised the First Lusatia Conference, where it initiated concrete ideas for structural change in the coal region of Lusatia.

Between energy and industrial policy: 'show and tell' for innovations from Germany

Last but not least, a showcase project is also about visibility. WindNODE has engaged in cross-border activities and reached a size that makes it appealing beyond regional boundaries. We are ambassadors for the energy transition made in northeastern Germany, a testimony to the skill of local engineers, and champions of the many opportunities of the transformation.

[1] See BMWi (n.d.), 'E-Energy'.

▹ Question 6

How has WindNODE contributed to 'digitalisation'?

The results of WindNODE make it clear: the digitalisation of the energy transition is occurring at smaller scales than originally assumed. The integration of renewable energy does not require a large, monolithic 'telephone switchboard in the Internet of Energy'. Instead, specialised, often small and agile, technical solutions lead the way to a more efficient energy system of the future. These technologies are on display, for example, in the following subprojects:

- On the consumer side, the 'Smart Meter Gateway Manager' and 'Metering Data Hub' software solutions developed by Bosch.IO as part of subproject 4.3 (Scenarios for the Deployment of Intelligent Metering Systems (iMSys) at SLP Customers, p. 106) communicate with the smart meter gateway to get current data on power consumption. The same communication channel can then be used to issue commands to controllable loads and flexibility reserves on the consumer side. A potential receiver of such commands could be one of devolo's smart home devices, which were extended with the appropriate interfaces (subproject 4.5: Controllable Loads in Households and Smart Home Integration, p. 112). WEMAG's work on controlling night storage heaters (subproject 6.3a, p. 140) using smart meter infrastructure and Stromnetz Berlin's 'StromPager' that can be connected to, among other things, electric vehicle charging points (subproject 4.6: EE-Stalker – Low-Voltage Swarm Control for Improved Grid Operations, p. 114), are further examples of digitalised control solutions on the lower voltage levels.

- Inspired by the platform economy, Fraunhofer FOKUS together with Stromnetz Berlin worked in the subprojects 1.2 and 1.3 (Innovative Process Platform, p. 62 and Open Data Portal, p. 68) on the development of an energy data and energy services platform that enabled WindNODE partners to participate in a secure data exchange with interoperable systems using open standards. For example, feed-in data from Stromnetz Berlin, DWD weather data and load data from a Siemens plant in Berlin could be made available to WindNODE partners for further use.

- In subproject 4.4 (Production Forecasts for Solar and Wind Systems with Real-Time Smart Meter Data, p. 110), Solandeo developed a solution that creates feed-in projections for green power trading and forecasts for grid utilisation in compliance with data protection standards and independent of regulatory requirements. This shows a pathway to more efficient energy trading as well as improved grid utilisation.

- The flexibility platform developed by 50Hertz in cooperation with other WindNODE partners in subproject 1.2 (Innovative Process Platform, p. 66) is another digital solution, this time leveraging a platform to alleviate grid congestion via automated bidding. When congestion is imminent in certain sections of the grid, grid operators can utilise the flexibility offered on this platform – a system that is potentially scalable to large numbers of participants thanks to digital technology.

- To address energy efficiency issues in neighbourhoods, the 'energy cockpit' developed by enersis in subproject 8.1b (WindNODE Energy Cockpit – Making the Energy Transition Visible, p. 178) allows for the creation of individualised, financially viable renovation roadmaps of residential buildings. The software evaluates the technical status quo of the heating systems in the neighbourhood and can be used to develop scenarios for pathways to improved efficiency.

- The installation of smart building technology in traditional residential buildings shows that digitalisation measures can have a direct monetary benefit for private end customers. Through clever use of digital technology, the partners around Borderstep Institute and Riedel Automatisierungstechnik were able to demonstrate savings of around 24 % in heating energy. All this without the use of costly thermal insulation (subproject 8.2: Model Region Berlin/Prenzlauer Berg Neighbourhood, p. 180). One example of such technology is a digital flat manager using self-learning systems to intelligently plan the unit's heating.

- The energy hackathons organized by Stromnetz Berlin and the Open Knowledge Foundation opened up the digital space surrounding our energy system to a broader public (subproject 1.3: Open Data Portal, p. 68).

▷ Question 7

What can we learn from WindNODE about energy market design?

The existing regulatory framework inhibits sector coupling and flexibilities

When people want to test hypotheses in experiments, they head to the laboratory. In the WindNODE project, we investigate hypotheses in a reality lab. However, we do not look at technical problems in isolation, but consider the issues embedded in their economic and legal contexts. These aspects are important because, under the current framework, there is a large gap between what is technically feasible and ecologically sensible on the one hand, and what is economically sound on the other hand. For example, grid-friendly sector coupling and the concept of 'using before curtailing', two guiding principles in the pursuit of flexibility, are both economically desirable and supported politically, but subject to regulatory hurdles that are often prohibitive. While Power-to-Heat, Power-to-Gas and other sector coupling ideas are much discussed, for example, the reality is that even with negative energy prices, taxes and levies make these use cases loss leaders. Our hypothesis was thus that the current tax and levy system hinders flexibility for three reasons. First and most crucially, the Renewable Energy Sources Act (EEG) imposes a surcharge – now nearly € 0.07/kWh – that makes green energy expensive and would need to be replaced with a CO_2 pricing system based on the 'polluter-pays principle', requiring those responsible for pollution to pay for the damage caused. Second, so far, the current system of power grid fees has not only not stimulated flexibility that would benefit the grid and the overall system, it has actually prevented it. And third, the electricity tax, which is a rigid tax on consumption – roughly € 0.02/kWh for private households and commercial customers – encourages 'flat energy-saving behaviour' rather than stimulating or dampening demand for electricity based on the current supply of renewables.

The experimentation clause is a valuable catalyst for energy system innovations

The experiences in the WindNODE project confirmed this hypothesis. Several initiatives to facilitate sector coupling, especially in the heating sector, could not be implemented to the desired extent, some face an unclear future after the project's conclusion. For example, ENERTRAG is delivering nearly CO_2-free heating to the town of Nechlin (Brandenburg) using electricity sourced during peak production of the neighbouring wind farm, which would otherwise be curtailed due to grid congestion. Proper experimentation during WindNODE was only possible thanks to a regulatory experimentation clause, the SINTEG Ordinance, that remains in force roughly for the duration of the project. While the ordinance did not remove all obstacles under the current legal regime, it promised a compensation for potential economic disadvantages. In other words, participants of the SINTEG programme could be reimbursed for some of the economic losses that they potentially incurred if they operated their assets in ways that might be beneficial to the system, but are not currently incentivised by energy law. Due to the way the legal framework works, deviating from an optimal strategy even for a short duration during a research project might inflict massive financial damages on single partners.

The prospect alone of a 'regulatory sandbox', designed to test out new ideas, was enough to make participating in WindNODE and other showcases attractive to many partners. While the implementation of SINTEG-V was not without its problems, the overwhelming interest demonstrates that a regulatory sandbox remains an important building block in energy research and reality labs.

The time has not yet come for the flexibility platform

One of the ideas experimented on in WindNODE is the flexibility platform, a tool designed to apply market-based processes to minimise the economic costs of grid congestion management in keeping with the principle of 'using instead of curtailing'. However, the amendment to the Grid Expansion Acceleration Act for the Transmission Grid (NABEG), by including even small-scale generators in the mandatory redispatch process, dried up the pool of potential flexibility providers even before the project came to an end. While the market-based congestion management system of the flexibility platform is thus off the table for the time being, it nevertheless led to much academic debate around efficiency, potentials for abuse and ways around them.

▷ Question 8

What added value has WindNODE generated for the region of eastern Germany?

WindNODE increased the visibility of the region and provided new ideas for structural change

As a reality lab, WindNODE has several unique features that set it apart from conventional R&D projects: first, WindNODE is a networking platform with over 70 partners – currently the largest such platform for the energy transition and structural change in northeastern Germany. And second, WindNODE is a showcase project that introduces the energy transition skills of an entire region to a national and international audience. The 'new federal states' have a long tradition in energy technology and digitalisation. Today, they continue to play a leading role as an innovative energy region, but they still have some catching up to do when it comes to 'show and tell'. At the Eighth Eastern German Economic Forum in 2017, the assembled eastern German economics ministers confirmed that their region has an image problem. It is not that eastern Germany has a negative image in the eyes of the international community – but that it has no visibility at all. WindNODE has travelled extensively in Europe and around the world, along with partners including GTAI (Germany Trade and Invest) and the economic development agencies of the federal states (Berlin Partner, Energy Saxony, WFBB) to strengthen the image of the region as a major player in the energy industry and lay the groundwork for collaboration (for an overview of our activities, see 'WindNODE worldwide', p. 216). This has noticeably increased the region's international profile, as demonstrated by the reports of new international business from our partners in small and medium-sized enterprises (SMEs). These experiences also help build the self-confidence of a region that has mastered 'energy and change' more than any other, but still faces unique challenges in achieving structural change. WindNODE triggers network effects that go far beyond the focus of the original project: it served and serves as a platform for the 'who's who' of our regional energy industry, enabling many new collaborations on the way. This was evident, for example, at the First Lusatia Conference: Structural Change and Energy Transition, which was organised by WindNODE in cooperation with the Minister President of Brandenburg and the Institute for Climate Protection, Energy and Mobility (IKEM) and held on 9 September 2019 at the Schwarze Pumpe power plant. In the 'Lusatian memorandum for sustainability, innovation and jobs', ten well-known companies presented concrete ideas constructive pathways for the structural change in Lusatia, from wind and solar parks to new production facilities for high-temperature heat storage systems to ideas around hydrogen economy and green data centres. Work on these ideas for the future has only just begun – and WindNODE can rightly be considered a catalyst.

▸ From left to right:
Dr Klaus Freytag
(Representative of the Minister President of Brandenburg for the Lusatia Region),

Markus Graebig
(Project Director WindNODE),

Dr Martina Münch
(Minister for Science, Research and Culture in Brandenburg),

Prof. Dr Jörg Steinbach
(Minister for Economic Affairs, Labour and Energy in Brandenburg),

Simon Schäfer-Stradowsky
(Managing Director IKEM),

Michael Stein
(Managing Director KSC),

Dr Benedikt Ortmann
(Managing Director BayWa r.e. Solar Projects)

at the First Lusatia Conference 2019 in Schwarze Pumpe.

▹ Question 9

How has WindNODE improved acceptance of the energy transition, and created opportunities to participate in it?

As an R&D project, WindNODE is primarily aimed at a specialist audience. Nevertheless, it is important to us to involve the public, increase acceptance of the energy transition and, on top of that, pass on our fascination with this project. The foundation of this effort is our comprehensive WindNODE narrative 'Wir können Energie und Wende' a German play on words that roughly translates to 'we have experience with both energy, and transition.' Our narrative focuses on the special features of our region, it aims to explain the challenges of the energy transition's second phase and to identify the opportunities that the energy transition offers for our project region and for all of Germany as an exporting nation. An overview of WindNODE provides several particularly valuable lessons learned from the project:

- **Create physical points of contact in the region**
  The success of our visitor sites and the WindNODE Live! exhibition serve as a reminder that real-world interaction and physical spaces are still important in today's digital world. It is essential for a showcase project like WindNODE to have strong ties with its model region; this requires the project to have a physical presence, for example by establishing accessible points for information, demonstration and experience.

- **Enable and encourage a change of perspective**
  The discourse around the energy transition has become more complex and more extreme in the past. Formats like the Energy Transition Game help participants change their perspective and start a dialogue with one another. Even within WindNODE, it was sometimes necessary to overcome 'language barriers' between different disciplines. Our WindNODE Academy made significant progress on this front. Last but not least, approaches like Energy and Art – which even featured international collaboration – offer new perspectives and can therefore increase acceptance.

- **Leave the community:**
  As a showcase project, WindNODE, like SINTEG as a whole, should not be a 'closed shop'. Even with relatively modest resources, we were able to achieve surprising successes (especially with the WindNODE Challenge, WindNODE Live! and Energyhacks) and convey at least the core concepts that we examined in the WindNODE project (i. e. sector coupling, flexibilisation, digitalisation of the energy system) to an interested audience.

- **Solving real problems:**
  Both the overarching WindNODE narrative and our specific projects, such as the visitor sites or the Lusatia Conference, achieve one thing above all: they show that the energy transition can help tackle tangible problems successfully, from climate change to structural change to a specific technical challenge. This is our takeaway: with the right approach, the energy transition is not the problem, it is a solution to the problem.

Professionals for the energy transition
Even today, in Germany and around the world, everyone is directly affected by climate change – whether or not they are interested in the issue. The droughts in 2018 and 2019 are just one example. The international Fridays for Future movement has given voice to the concerns of many – especially young people – about their future and the conservation of natural resources. At WindNODE, we fully share these concerns about effective climate protection and want our work to help solve this challenge. To achieve this goal, WindNODE brings together many experts who specialise in topics related to the energy transition and climate change, including engineers, physicists, lawyers, economists, data scientists and social scientists. But we believe that the energy transition is by no means just an issue for "professionals". It is a project of our society as a whole. Fridays for Future has shown how important a public wake-up call can be.

▹ Question 10

What lasting impact has WindNODE had – and what comes next?

WindNODE builds networks and collaboration, systemic approaches and beacons of the energy transition
WindNODE is much more than the sum of its parts. It is a systemic approach to a 100 % renewable energy system. It is a demonstration that flexibility works. It is proof that large showcase projects can unite all of northeastern Germany behind a common cause. It is an excellent network of experts and mutual trust that lays the foundation for future projects – some of which are already in the works. It is a long list of visitor sites that inspire excitement about the energy transition. And it is much more: we asked our nine workstream coordinators what they think the lasting impact of WindNODE will be and what will come next. The answers speak for themselves; we have included some of them below.

What lasting impact has WindNODE had?

‘WindNODE has shown us that meeting 100 % of the energy demand with renewables is possible – not only in terms of technical capacity, but also in economic and regulatory terms.’

‘One lasting effect of WindNODE is the valuable experience that was gained regarding various flexibility options (...) as well as knowledge about which steps will have to come next to broaden the use of these options in the sectors of mobility, heating and cooling.’

‘The certainty that there is actually (...) no alternative to the comprehensive use of renewable energy’.

‘Demonstrators that can increase the visibility and importance of the energy transition (...)’.

‘Greater trust between the various stakeholders in finding common solutions’.

‘An excellent network of experts that has shown that the energy transition works when partners from different disciplines collaborate to find solutions’.

‘A systemic approach to a system based on 100 % renewable energy’.

‘The appeal of a large showcase project that generates a sense of solidarity in our region, and a lively network of partners who will continue to cooperate in innovative contexts in the future’.

What comes next?

‘(With the) ICT networking platform, the common goal was to use data to create added value for the energy industry. (…) The central overarching question (is) how to address the tension between economic interests and the openness of data and services.’

‘What is still missing is a legal framework that will make these ideas for system-friendly sector coupling economically feasible.’

‘WindNODE is just the beginning of a bold strategy for reality labs that can open up technical, economic and regulatory fields of experimentation.’

‘WindNODE (has) shown possibilities for energy flexibility. We will build on this to (...) continue the decarbonisation of industrial sites.’

‘Hopefully many more projects (...) to integrate renewable energy’.

‘WindNODE is the starting point for numerous new project ideas and plans for the energy transition, such as the inclusion of data centres in flexibility concepts or the use of AI-based platforms for energy management and energy supply in residential areas.’

Publications

A large number of publications were produced during WindNODE in the form of discussion papers, studies, reports and in other formats. There were three categories of publications:

▶ **Signature papers**
were drawn up within the WindNODE Coordination Committees and serve to consolidate results in our focus areas. All signature papers are listed and highlighted below.

▷ **Peer review papers**
are documents that were developed unilaterally by individual partners or workstreams and have gone through an internal quality assurance process in the form of a peer review by other WindNODE partners. In other words, partners provided technical feedback on the document, which was subsequently taken into account. All peer review papers are listed and highlighted below.

Partner papers
were written unilaterally by individual partners. The texts were not necessarily coordinated with other WindNODE partners before publication and may also represent individual opinions. Selected partner papers are listed in the non-exhaustive list below.

Note: this list explicitly does not include academic theses (bachelor, master or doctoral dissertations or Diplomarbeiten) created within the framework of WindNODE, the countless lectures and presentations at specialist events, or the numerous guest contributions and reports about WindNODE in press or specialist media.

▶	**11/20**	Beucker, Doderer, Funke, Koch, Kondziella, Hartung, Maeding, Medert, Meyer-Braune, Rath, Rogler **Synthesebericht Flexibilität, Markt und Regulierung** **(Flexibility, Markets and Regulation: Insights from the WindNODE Reality Lab, available in English);** WindNODE findings and recommendations // Berlin, November 2020
▷	**11/20**	Corusa (Publisher), Predel (Publisher) **Digitalisierung und IT-Security in der deutschen Energiewirtschaft** **(Digitalisation and IT security in the German energy industry);** Study, TU Berlin, Institute of Power Engineering // Berlin, August 2020
	10/20	Corusa, Predel, Schöne **Eine Marktübersicht der Blockchain in der Energiewirtschaft – Von der Idee zum Geschäftsmodell, von der Technologie zur aktuellen Anwendung (A market overview of the blockchain in the energy industry – From idea to business model, from technology to current application);** Study, TU Berlin, Institute of Power Engineering // Berlin, October 2020
	10/20	Corusa, Predel, Schöne **Permutation-Based Residential Short-term Load Forecasting in the Context of Energy Management Optimization Objectives;** in: Proceedings of the Eleventh ACM International Conference on Future Energy Systems // Melbourne, June 2020
▶	**08/20**	**Best-Practice-Manual – Flex identifizieren! (Best Practice Manual: Identifying Flexibility Options, available in English);** WindNODE findings and recommendations // Berlin, August 2020
	08/20	Reinisch **Perspektivenwechsel auf die Energiewende (Change of perspective on energy transition);** 1st edition // Berlin, August 2020

09/20
Schaloske, Maeding
Flexibility and corresponding steering technologies as important elements of the energy transition: Regulatory and technical solution approaches;
in: CIRED Berlin 2020 Workshop // Berlin, June 2020

▷ 05/20
Beucker, Hinterholzer
Effects of ICT-Enabled Flexible Energy Consumption on the Reduction of CO_2 Emissions in Buildings;
in: ICT4S 2020 – 7th International Conference on ICT for Sustainability // Bristol, May 2020

02/20
Koch, Letzgus
Beitrag von Informations- und Kommunikationstechnik zum intelligenten Energiesystem (The contribution of information and communication technologies to the intelligent energy system);
TU Berlin, Department of Energy Systems // Berlin, February 2020

01/20
Doderer, Schäfer-Stradwosky, Antoni, Metz, Knoll, Borger
Denkbare Weiterentwicklungsoptionen für die umfassende Flexibilisierung des Energiesystems und die Sektorenkopplung (Possible further development options for the comprehensive flexibilisation of the energy system and sector coupling);
Policy Paper, IKEM // Berlin, January 2020

01/20
Grüttner, Hörnig
Wärmepumpen als Baustein einer system- und netzdienlichen Wärmewende im WEMAG-Netzgebiet (Heat pumps as a building block of a system and grid-friendly 'heat transition' in the WEMAG grid area);
in: LEE-Fachtagung 2020 // Rostock, January 2020

01/20
Voß
Datenanalyse von Haushalts- und Gebäudelastprofilen: Distanzmaße, Prognosefehler und Mittelwerte im Kontext von Smart-Meter-Daten im Niederspannungsnetz (Data analysis of household and building load profiles: Distance measures, forecast errors and mean values in the context of smart meter data in the low-voltage grid);
in: Tagungsunterlagen des SINTEG Science Lab 2020, pp. 33–37, Conexio GmbH // Berlin, January 2020

12/19
Töpfer, Weber
Untersuchung zur vollregenerativen Stromversorgung mit Wasser-Speicherkraftwerken (Investigation of fully regenerative power supply with water storage power plants);
in: ETG-Journal // Berlin, December 2019

11/19
Wessolek, Kluge
Energy meets Art – ein WindNODE-Projekt (Energy meets Art – a WindNODE project);
Art catalogue of the WindNODE subproject 9.2.3 // Berlin, November 2019

11/19
Knorr, Schütt, Strahlhoff, Kroschewski, Siegl, Werner, Willner, Eckert, Wolf, Lämmel, Hasse
Weiße Flecken in der Digitalen Vernetzung der Energiewirtschaft – IuK-Ansätze und –Lösungen (White spots in the digital networking of the energy industry – ICT approaches and solutions);
Study, Fraunhofer Institute for Energy Economics and Energy System Technology IEE and Fraunhofer Institute for Open Communication Systems FOKUS // Kassel and Berlin, October 2019

10/19
Rangelov, Tcholtchev, Lämmel, Schieferdecker
Experiences Designing a Multi-Tier Architecture for a Decentralized Blockchain Application in the Energy Domain;
in: ICUMT 2019, Issue 11 // Dublin, October 2019.

09/19
Anke, Dierstein, Hladik, Möst
Begleitstudie WindNODE – Lastverschiebungspotenziale in Dresden (Accompanying study WindNODE – Load shifting potentials in Dresden);
in: Schriftenreihe des Lehrstuhls für Energiewirtschaft der Technischen Universität Dresden, Volume 16, TU Dresden // Dresden, September 2019

09/19
Scheller, Alkhatib, Kondziella, Graupner, Bruckner
Future merit order dynamics: A model-based impact analysis of ambitious carbon prices on the electricity spot market in Germany;
in: IEEE Conference Proceedings, 16th International Conference on the European Energy Market // Ljubljana, September 2019

09/19
Johanning, Bruckner
Blockchain-based Peer-to-Peer Energy Trade: A Critical Review of Disruptive Potential;
in: IEEE Conference Proceedings, 16th International Conference on the European Energy Market // Ljubljana, September 2019

08/19
Seefried, Müller, Förster
Regional Analysis of Potentials of Flexibility Options in the Electricity System for the Study Regions Prignitz in Brandenburg and Anhalt-Bitterfeld-Wittenberg in Saxony-Anhalt;
in: Journal of Sustainable Development of Energy, Water and Environment Systems // Berlin, August 2019

08/19
Beucker
Reduktion von CO_2-Emissionen im Gebäudebestand durch digitales Energiemanagement (Reduction of CO_2 emissions in existing buildings through digital energy management);
Policy paper, Borderstep Institute // Berlin, August 2019

07/19
Bohne, Renger, Wessolek
New pedotransfer function ("CRC") for the prediction of unsaturated soil hydraulic conductivity using soil water retention data;
in: Journal of International Agrophysics // Lublin, July 2019

06/19
Lombardi, Komarnicki, Zhu, Liserre
Flexibility options identification within Net Zero Energy Factories;
in: 13th IEEE PowerTech 2019 // Milan, June 2019

06/19
Beucker, Hinterholzer
Building Energy Management Systems and Their Role in the Energy Transition Results from Research Projects and Applications in Germany;
in: ICT4S 2019 – 6th International Conference on ICT for Sustainability // Lappeenranta, June 2019

06/19
Elvers, Voß, Albayrak
Short-Term Probabilistic Load Forecasting at Low Aggregation Levels using Convolutional Neural Networks;
in: 13th IEEE PowerTech 2019 // Milan, June 2019

06/19
Voß, Jain, Albayrak
Subgradient Methods for Averaging Household Load Profiles under Local Permutations;
in: 13th IEEE PowerTech 2019 // Milan, June 2019

05/19
Süße, Prell, Stoldt, Strehle, Richter, Schlegel, Putz
Load and energy management for factories through multi-stage production planning and optimization;
in: Procedia CIRP, Volume 80 / 2019, pp. 257 – 262 // Indiana, May 2019

05/19
Kertscher, Stieger, Koch, Quade, Rönneburg
Aktive Blindleistungssteuerung – Systemdienstleistung aus dem Verteilnetz (Active reactive power control – system service from the distribution network);
ETG summit 2019 // Esslingen am Neckar, May 2019

05/19
Süße, Stoldt, Schlegel, Putz
Decision support for planning techniques in energy efficiency projects;
in: Procedia CIRP, Volume 69 / 2018, pp. 306 – 311 // Copenhagen, May 2019

▹ 04/19
Kondziella, Graupner, Bruckner, Doderer, Schäfer-Stradowsky, Koch, Letzgus, Erdmann, Guder, Holst
Marktdesign, Regulierung und Gesamteffizienz von Flexibilität im Stromsystem – Bestandsaufnahme und Herausforderungen (Market design, regulation and overall efficiency of flexibility in the electricity system - stocktaking and challenges);
Policy Paper, University Leipzig, TU Berlin, Siemens AG // Berlin, April 2019

04/19
Hermann, Teich, Kassel, Kretz, Neumann, Leonhardt, Junghans
Blockchain in decentralized local energy markets;
in: Popplewell, Thoben, Knothe, Poler, Enterprise Interoperability VIII – Proceedings of the I-ESA Conferences 9, Springer // Berlin, April 2019.

03/19
Caro-Ruiz, Lombardi, Richter, Pelzer, Komarnicki, Pavas, Mojica-Nava
Coordination of optimal sizing of energy storage systems and production buffer stocks in a net zero energy factory;
in: Applied Energy, Volume 238, pp. 851 – 862 // March 2019

02/19
Doderer, Kondziella, Koch, Guder
Technologieneutralität und ökologische Wirkung als Maßstab der Regulierung von Flexibilitätsoptionen im Energiesystem (Technological neutrality and ecological impact as a benchmark for regulating flexibility options in the energy system);
in: Energiewirtschaftliche Tagesfragen, Volume 69, issue 1/2 // Berlin, February 2019

▸ 02/19
Thesenpapier Flexibilität (Thesis paper on flexibility);
WindNODE findings and recommendations // Berlin, February 2019

12/18
Anke, Möst, Kupke, Graebig, Franke
Bewertung lokaler und kommunaler Flexibilitätspotenziale: Verbundprojekt WindNODE (Evaluation of local and municipal flexibility potentials: Joint project WindNODE);
in: BWK Das Energie-Fachmagazin, Issue 12/2018, VDI Fachmedien // Düsseldorf, December 2018

12/18
Reinisch
Energie und Kunst – Visionen einer gelungenen Energiewende (Energy and art – visions of a successful energy turnaround);
Art Catalogue // Berlin, December 2018

10/18
Voß, Bender-Saebelkampf, Albayrak
Residential Short Term Load Forecasting Using Convolutional Neural Networks;
in: IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm) // Aalborg, October 2018

10/18
Voß, Haja, Albayrak
Adjusted Feature-Aware k-Nearest Neighbors: Utilizing Local Permutation-Based Error for Short-Term Residential Building Load Forecasting;
in: IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGrid-Comm) // Aalborg, October 2018

		10/18	Teich, Kretz, Neumann, Hermann **Blockchain in dezentralisierten Energiemärkten (Blockchain in decentralised energy markets);** in: 25th Interdisciplinary Scientific Conference Mittweida (IWKM) // Mittweida, October 2018
		09/18	Behnert, Bruckner **Cost effects of energy system stability and flexibility options: an integrated optimal power flow modeling approach;** in: Working Paper No. 155, ISSN 1437-9384, Faculty of Economics and Management Science, University of Leipzig // Leipzig, September 2018
	▶	09/18	**WindNODE Report 2018 – Who we are and what we do.;** WindNODE overview at project half time // Berlin, September 2018
		08/18	Blasius, Wang **Effects of charging battery electric vehicles on local grid regarding standardized load profile in administration sector;** in: Applied Energy, Volume 224, pp. 330 – 339 // August 2018
		07/18	Doderer, Schäfer-Stradowsky **Bestandsaufnahme der rechtlichen Hemmnisse und Anreize für die umfassende Flexibilisierung des Energiesystems (Inventory of legal barriers and incentives for full energy system flexibility);** Policy Paper, IKEM // Berlin, July 2018
		04/18	Raue, Strehle, Stoldt, Schlegel, Richter, Lange **Mehrstufiges multikriterielles Job Shop Scheduling – Heuristik zur Lösung des Job-Shop-Problems unter energetischen und wirtschaftlichen Zielgrößen (Multi-level multi-criteria job shop scheduling – heuristics to solve the job shop problem under energetic and economic targets);** in: wt Werkstatttechnik online, Issue 4/2018, pp. 210 – 216, VDI Fachmedien // Düsseldorf, April 2018
		03/18	Doderer, Steffensen, Schäfer-Stradowsky **Power to Heat – Eine Chance für die Energiewende (Power-to-Heat – An opportunity for the energy transition);** Policy Paper, IKEM // Berlin, March 2018
		03/18	Behnert, Bruckner **Causes and effects of historical transmission grid collapses and implications for the German power system;** in: Institute for Infrastructure and Resources Management (IIRM), University Leipzig // Leipzig, March 2018
	▷	02/18	Schabel, Fichter **Inkubationsprogramme in der Energiewirtschaft. Merkmale, Erfolgseinschätzungen und Gestaltungsansätze (Incubation programmes in the energy sector. Characteristics, assessments of success and design approaches);** Study, Borderstep Institute // Berlin, February 2018
		11/17	Pelzer, Richter, Lombardi, Komarnicki **Energy intensive industry as the backbone for demand side flexibility;** in: International ETG Congress 2017 Die Energiewende – Blueprints for the new energy age, pp. 611 – 616 // Bonn, November 2017
		11/17	Hempel, Fischer, Veit, Hommel, Kretz, Dziurzik, Bodach **Energiewende im Niederspannungsnetz – Modellregion Zwickau (Energy system transformation in the low voltage grid – Zwickau model region);** in: International ETG Congress 2017 Die Energiewende – Blueprints for the new energy age, pp. 538 – 543 // Bonn, November 2017
		10/17	Steffan, Heinrich, Safarik, Honke **Highest Efficiency Ice Storage for Solar Cooling Systems – Experiences with a Vacuum Ice Slurry Cold Thermal Energy Storage;** in: International Conference on Solar Heating and Cooling for Buildings and Industry // Abu Dhabi, October/November 2017
		10/17	Safarik **Regenerative Energien: Neue Möglichkeiten durch Flüssigeis (Renewable energy: New possibilities through liquid ice);** in: Wirtschaftsbild Spezial: Moderne Gebäudetechnik 2017, p. 23, Union Betriebs-GmbH // Rheinbach, October 2017
		09/17	Markert, Bohne, Facklam, Wessolek **Pedotransfer-functions of soil thermal conductivity for the textural classes sand, silt and loam;** in: Soil Science Society of America Journal // Washington, September 2017
		08/17	Hommel, Blumhagen, Leonhardt, Werler, Bodach, Zacharias, Demmler, Bilsing **Experiences from an e-mobility project in a local power grid with redox-flow energy storage system;** in: IEEE // San Francisco, August 2017
		06/17	Graupner, Behnert, Reichelt, Kühne, Bruckner **Transmission grid stabilization using virtual power plants;** in: 14th International Conference on the European Energy Market (EEM) // Dresden, June 2017
		06/17	Maeding **Intelligente Messsysteme: Vernetzte Endkunden und sichere Kommunikation (Intelligent metering systems: networked end customers and secure communication);** in: Nicole Egert (Publisher), Innovation. Integration. Intelligent. Auf dem Weg in die Energiewirtschaft 4.0, p. 265 // Berlin, June 2017

List of Abbreviations

AC	Alternating Current
Ah	Ampere-hour
AI (KI)	Artificial Intelligence (Künstliche Intelligenz)
App	Application
AS (SDL)	Ancillary Service (Systemdienstleistung)
ASEW	Arbeitsgemeinschaft für sparsame Energie- und Wasserverwendung GbR in the VKU
Berlin Partner	Berlin Partner für Wirtschaft und Technologie GmbH
BMS (GLT)	Building Management Services (Gebäudeleittechnik)
BMWi	Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie)
BNetzA	German Federal Network Agency (Bundesnetzagentur)
BSI	Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik)
BSR	Berliner Stadtreinigung AöR
BTU	Brandenburg University of Technology Cottbus-Senftenberg (Brandenburgische Technische Universität Cottbus-Senftenberg)
BVG	Berliner Verkehrsbetriebe AöR
BWB	Berliner Wasserbetriebe AöR
CEMS (KEMS)	Communal Energy Management System (Kommunales Energiemanagementsystem)
CHP (KWK)	Combined Heat and Power (Kraft-Wärme-Kopplung)
CLS	Controllable Local System
CoCo (KoKo)	Coordination Committee (Koordinierungskomitee)
DAI-Labor	Distributed Artificial Intelligence Laboratory of Berlin Technical University
DC	Direct Current
DER	Distributed energy resource
DGE (DNE)	Dynamic Grid Editor (Dynamischer Netzeditor)
DKE	German Commission for Electrical, Electronic & Information Technologies of DIN and VDE (Deutsche Kommission Elektrotechnik in DIN und VDE)
DIN	German Institute for Standardization (Deutsches Institut für Normung)
DSO (VNB)	Distribution System Operator (Verteilungsnetzbetreiber)
e2m	Energy2market GmbH
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
EDM	Energy Data Management
EnWG	German Energy Industry Act (Energiewirtschaftsgesetz)
EMS	Energy Management System
EMT	External Market Participant (Externer Marktteilnehmer)
EnSys	Department of Energy Systems of TU Berlin (Fachgebiet Energiesyssteme der Technischen Universität Berlin)
ESC (EVU)	Energy Supply Company (Energieversorgungsunternehmen)
EUREF	European Energy Forum
FMM (ESM)	Feed-in management measures (Einspeisemanagementmaßnahmen)
FOKUS	Fraunhofer Institute for Open Communication Systems
GIS	Geo-Information System
GTAI	Germany Trade and Invest – Gesellschaft für Außenwirtschaft und Standortmarketing mbH
GW	Gigawatt
GWA	Gateway Administrator
GWh	Gigawatt-hours
H2	Hydrogen
HCS4 (HKS4)	High-security Communication Scenario 4 (Hochsicheres Kommunikationsszenario 4)
HKWG Cottbus	Heizkraftwerksgesellschaft Cottbus mbH
HV	High Voltage
I&C (IuK)	Information and Communication Technology
IEE	Fraunhofer Institute for Energy Economics and Energy System Technology
IFF	Fraunhofer Institute for Factory Operation and Automation
IIRM	Institute for Infrastructure and Resources Management of Leipzig University (Institut für Infrastruktur & Ressourcenmanagement der Universität Leipzig)
IKEM	Institut für Klimaschutz, Energie und Mobilität e. V.
ILK	Institut für Luft- und Kältetechnik gGmbH
iMSys	Intelligent metering system
IoT	Internet of Things
IPv6	Internet Protocol Version 6
IRPMS (IBMS)	Intelligent Reactive Power Management System (Intelligentes Blindleistungsmanagementsystem)
ISO	International Organisation for Standardisation
IWU	Fraunhofer Institute for Machine Tools and Forming Technology
K	Kelvin
KRITIS	Critical Infrastructure Ordinance
kV	Kilovolt
kVA	Kilovolt-ampere
kW	Kilowatt
kWh	Kilowatt-hours
kW_p	Kilowatt-peak
LCA	Life Cycle Assessment
LEAG	Lausitz Energie Kraftwerke AG
LV	Low Voltage
MEG	Mitteldeutsche Erfrischungsgetränke GmbH & Co. KG
MES	Manufacturing Execution System
MDM	Meter data management
MHz	Megahertz
MU (SW)	Municipal Utility (Stadtwerke)
MV	Medium Voltage
MVA	Megavolt-amperes
Mvar	Megavar
MW	Megawatt
MWh	Megawatt-hours
NABEG	Grid Expansion Acceleration Act (Netzausbaubeschleunigungsgesetzes)
NGO	Non-Governmental Organisation
OKFN	Open Knowledge Foundation Deutschland e. V.
OPD	Overall project description
P2P	Peer-to-Peer
PBP (PRL)	Primary Balancing Power (Primärregelleistung)
PDF	Portable Document Format
PLC	Powerline Communication
PMO	Project Management Office
PPE	Personal Protective Equipment
PtC	Power-to-Cold
PtH	Power-to-Heat
PtX	Power-to-Value
PV	Photovoltaics
R&D (F&E)	Research and Development (Forschung und Entwicklung)
RE (EE)	Renewable Energy (Erneuerbare Energie)
RLI	Reiner Lemoine Institute gGmbH
RLM	Recording power measurement (Registrierende Leistungsmessung)
SAIDI	System Average Interruption Duration Index
SBA	Search-Based Application
SCR	Smart Capital Region
SENSE	Department for Sustainable Electric Networks and Sources of Energy of TU Berlin
SIMBA	Simulation platform for the mathematical modeling, simulation, optimization and management of wastewater treatment plants
SINTEG	Intelligent Energy Showcase – Digital Agenda for the Energy Transition (Schaufenster Intelligente Energie – Digitale Agenda für die Energiewende)
SINTEG-V	SINTEG Ordinance (SINTEG-V)
SLP	Standard Load Profile
SME (KMU)	Small and Medium-sized Enterprises (Kleine und mittelständische Unternehmen)
SMGW	Smart Meter Gateway
SP (TAP)	Subproject (Teilarbeitspaket)
SPD	Subproject description
StromNEV	The Ordinance on Electricity Grid Fees (Stromnetzentgeltverordnung)
TWh	Terawatt-hours
TCS (GHD)	Trade, Commerce and Services (Gewerbe, Handel und Dienstleistungen)
ThEGA	Thüringer Energie- und GreenTech-Agentur GmbH
TSO (ÜNB)	Transmission System Operator (Übertragungsnetzbetreiber)
TLS	Transport Layer System
TU	University of Technology (Technische Universität)
UAS (FH)	University of Applied Sciences (Fachhochschule)
V	Volt
VDE	Verband der Elektrotechnik Elektronik Informationstechnik e. V.
VDTC	Virtual Development and Training Centre
VHPready	Virtual Heat and Power Ready
WFBB	Wirtschaftsförderung Land Brandenburg GmbH
WHZ	West Saxon University of Applied Sciences Zwickau (Westsächsische Hochschule Zwickau)
WS (AP)	Workstream (Arbeitspaket)
XDEMS	Dynamic Energy Management System
ZIEL	Smart Energy and Load Management (Zukunftsfähiges Intelligentes Energie- und Lastmanagement)

Glossary

The **workstream** coordinators facilitate the exchange of information and ideas between subprojects in the same workstream, act as liaisons with the project coordination team and advise them on technical matters.

WindNODE is organised from an administrative perspective into nine **workstreams**, which bundle subprojects with thematically similar objectives. Together, they provide a comprehensive view of the intelligent energy system from generation to consumption.

The **associated partners** participate in the work of WindNODE with specific project contributions but do not receive any financial support.

The **visitor sites** are an instrument developed by WindNODE to live up to the showcase concept of the SINTEG funding programme. At these locations, interested visitors can learn more about the energy transition and its technical, economic, legal and social challenges as well as the solution approaches taken by WindNODE. Specific demonstrators open their doors and invite visitors to take a look.

An **experimentation clause** gives authorised partners freedom within the regulatory framework to experimentally try out their solution approaches. For example, the SINTEG-V makes it possible to test load flexibility strategies without suffering higher grid charges due to the rigid structure of the regulatory framework. Thus, solutions that appear interesting from a system perspective but are not yet practical within today's legal environment can be tested, and insights can be gained into the further development of the regulatory framework.

The **Coordination Committees** address topics that are relevant across workstreams. They should not only provide an avenue to consolidate results within the joint project, but also contribute to policy discussion outside of WindNODE.

The **steering committee** is the decision-making and supervisory body of WindNODE. Seven institutional partners collaborate to define the strategic orientation of the project and oversee the WindNODE project coordination.

The **political patronage** of WindNODE has been taken up by the Minister Presidents of the five eastern German states and the Governing Mayor of Berlin. At the staff level, an intensive exchange of ideas takes place between the ministries of the participating states and WindNODE.

The term **reality lab** refers to a new, third pillar of public research funding in Germany. In contrast to basic research and applied research, reality labs prioritise research into the practical implementation and scaling of solutions that are nearing market readiness. They are designed to take a holistic approach that incorporates technical, economic, social and regulatory aspects. One special aspect of the SINTEG reality labs is the so-called experimentation clause of the SINTEG-V ("SINTEG Ordinance" based on § 119 of the German energy industry act (Energiewirtschaftsgesetz, EnWG).

The five joint projects funded within SINTEG are referred to as **showcases.** This term makes reference to the generational project that is the energy transition, which requires the support of the entire population. The showcases should thus give all stakeholders an opportunity to see and experience the scientific, technical and economic progress being made on the path to an energy supply system of the future.

The abbreviation **"SINTEG"** stands for the funding programme "Intelligent Energy Showcase – Digital Agenda for the Energy Transition" of the Federal Ministry for Economic Affairs and Energy. Over the period 2017-2020, SINTEG seeks to develop blueprints for the future of energy supply.

The **SINTEG-V,** or the "SINTEG Ordinance", is the experimentation clause of the SINTEG funding programme based on § 119 EnWG. The clause enables authorised partners within the SINTEG programme to experiment with their power generation and consumption units by offering a mechanism to compensate for economic losses.

The functional and technical work of WindNODE takes place within the fifty **subprojects,** where one or more project partners work with associated partners and subcontractors to move the energy transition forward.

The **subcontractors** are assigned specific tasks in the project by individual project partners but do not receive any direct financial funding from SINTEG.

The **project coordination** of WindNODE is undertaken by 50Hertz Transmission GmbH, which has established a five-person "Project Management Office" (PMO) for this purpose.

The **project partners** are fully engaged with the project work and receive financial support under the SINTEG funding programme.

The name **WindNODE** originates from the slogan "Windenergie als Beitrag Nordostdeutschlands zur Energiewende" (wind energy as a contribution of northeastern Germany to the energy transition).

Picture Credits

Publishing Information

ABOUT WINDNODE

WindNODE is part of the funding programme "Intelligent Energy Showcase – Digital Agenda for the Energy Transition" (SINTEG) of the Federal Ministry for Economic Affairs and Energy (BMWi). The showcase region encompasses the six eastern German states, including Berlin. The work in WindNODE is carried out under the patronage of the leaders of the participating states. Over a period of four years, from 2017 to 2020, more than 70 partners have jointly developed transferable model solutions for the intelligent energy system of the future. WindNODE showcases a network of flexible energy users who are able to structure their electricity consumption according to the fluctuating availability of wind and solar power. The goal is to integrate large quantities of renewable energy into the energy system while at the same time keeping the electricity grids stable.

More information at:
www.windnode.de/en

ABOUT SINTEG

With the funding programme "Intelligent Energy Showcase – Digital Agenda for the Energy Transition", the Federal Ministry for Economic Affairs and Energy (BMWi) seeks to show what the future of energy supply could look like. The idea behind SINTEG is to develop and demonstrate transferable model solutions for a secure, economical and environmentally friendly energy supply system that integrates fluctuating energy generation from renewable sources. Suitable solutions from the model regions should serve as examples for broader implementation throughout Germany and beyond. In the five showcase regions, partners from the energy industry are collaborating with members of the information and communication technology industry. Since 2017, more than 300 companies, research institutions, municipalities, regions and German states have been working together on implementing the future vision of the energy transition.

More information at:
www.sinteg.de

Project Management Jülich | Forschungszentrum Jülich GmbH (PtJ) supports the five SINTEG showcases in the execution of their projects.

More information at:
www.ptj.de/projektfoerderung/sinteg

The WindNODE Report and its slipcase are climate-neutral print products.

Klimaneutral Druckprodukt
ClimatePartner.com/14336-2101-1001

FSC www.fsc.org MIX Paper from responsible sources FSC® C130050

Publisher

WindNODE Project Management
c/o 50Hertz Transmission GmbH
Project Director: Markus Graebig (V.i.S.d.P.)
Heidestraße 2, 10557 Berlin

T +49 30 5150 2805
F +49 30 5150 2877

info@windnode.de
www.windnode.de/en

WindNODE is part of the funding programme "Intelligent Energy Showcase – Digital Agenda for the Energy Transition" (SINTEG) of the Federal Ministry for Economic Affairs and Energy. The project coordinator of WindNODE is 50Hertz Transmission GmbH

50Hertz Transmission GmbH
Heidestraße 2, 10557 Berlin

T +49 30 5150 0
F +49 30 5150 2199

info@50hertz.com
www.50hertz.com

Chair of the Supervisory Board
Christiaan Peeters

Management
Stefan Kapferer (CEO),
Dr Frank Golletz, Dr Dirk Biermann, Marco Nix,
Sylvia Borcherding

Registered office
Berlin

Commercial register
District Court of Charlottenburg, HRB 84446

CONCEPT AND DESIGN

Heimrich & Hannot GmbH,
Dajana Bittel (Project Management),
Florian Hoyer (Layout and typesetting),
Tom Petritt (Production)

EDITORS

Markus Graebig (WindNODE-PMO),
Michael Wolfram (WindNODE-PMO)

TRANSLATION

Kate Miller,
Dàmir Belltheus Avdic

PRINTING

Druckerei Thieme Meißen GmbH

WindNODE

www.windnode.de/en

Projektträger Jülich
Forschungszentrum Jülich

SINTEG
SMART ENERGY SHOWCASES

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag