

# BLUEPRINTS FOR THE ENERGY TRANSITION



# EXECUTIVE SUMMARY

Away from fossil fuels and into renewable energies: This fundamental transition is the core of the German 'Energiewende'. By 2045, Germany wants to supply climate neutral energy in an economically and environmentally friendly manner. This includes ambitious expansion goals for renewable energies and decarbonisation of the industrial, heating, and transport sectors. The German federal government aims to increase the share of renewable energies in the electricity sector to 80 percent and in the heating sector to 50 percent by 2030. It also plans to double the domestic electrolysis capacity goal for the production of green hydrogen from five to ten gigawatts by 2030. The end of the era of the internal combustion engine is also scheduled for 2035.

These measures are essential in view of the increasing climate crisis and for compliance with the Paris Climate Agreement. At the same time, they pose numerous challenges for the future energy system that need to be overcome.

## Initial situation and current challenges

The starting point is the need for further integration of renewable energies into the energy system, which in turn requires a fundamental structural transformation of the energy system. Instead of the current electrical power supply system, which is predominantly centrally organised with a few large conventional power plants, there will be a transition to a decentralised power generation system with a variety of smaller, geographically distributed renewable power systems. Those, however, will supply electricity less reliably due to their dependence on the weather conditions.

This development affects generation and conversion technologies, grid levels, generation sites, and flexibility options. The more decentralised a power system is, the more power generation plants are connected to the grid at a lower voltage level or at the distribution grid level, requiring distribution grid operators to take on new tasks and assume more responsibility for system stability. The mismatch between the time and location of generation and of consumption requires increased transport and distribution capacities. In addition, the increasing number of decentralised power generation plants connected at lower voltage levels results in changed load flows in the grid. This can lead to network bottlenecks that endanger supply security, grid stability, and system stability and reduce energy efficiency. For this reason, it will also be necessary in the future to encourage operators of decentralised plants to benefit the system and maintain flexibility in addition to expanding the power grid.

In addition to the challenges posed to the grid, the increasing decentralisation of the energy system is leading to a transformation in market activity, i.e. to changes in energy flows and at the stakeholder level. This is accompanied by the need to adapt market structures and develop new flexibility options, for example in the industrial sector or in households.

As the proportion of decentralised components increases, so does the degree of complexity in the energy system, in particular because coordinating a large number of stakeholders is a very complex process. A higher level of digitalisation is essential in order to manage the energy system efficiently. Artificial intelligence, autonomous and self-learning systems, and information and communication technologies can automate and simplify processes. However,

future smart grid solutions face the difficulty of having to integrate an extremely large number of heterogeneous systems. This problem will be almost impossible to solve without common standardisation processes. Finally, the interconnection of heterogeneous application systems also increases the risk of cyber-attacks.

The energy transition is a socio-technical transformation process, which means that the desired transformation of the energy system not only encompasses the physical infrastructure, but also influences and shapes society as well as (political) governance structures. As a result, promoting public acceptance and the willingness of citizens to participate under these new technical and structural conditions of the energy system will be central tasks in the future. Equally relevant are considerations regarding the extent to which the roles and functions of state institutions, economic stakeholders, civil society organisations, and scientific institutions will have to change during the transformation process of the energy system.

## SINTEG sets new standards for the energy system of tomorrow

In light of these key challenges to the current energy transition, intelligent and innovative approaches to solutions are needed. This is precisely where the SINTEG funding programme comes into play: from 2016 to 2021, 300 companies, universities, and municipalities researched and tested the technical feasibility and practicality of new technologies and processes in the areas of system integration, flexibility, system stability, smart power grids, new market and governance structures, and social participation and acceptance measures.

SINTEG operated far away from the academic ivory tower and addressed real practical problems, which is why research centres worked hand in hand with companies and public institutions. Different decentralised energy plants were built, connected to each other, and digitally controlled and monitored. New software solutions, smart home applications, and storage methods were developed. Digital market platforms and smart grids were created. All these were tested and evaluated in terms of their practicality and economic efficiency in companies, neighbourhoods, and private households.

After four years of intensive project work, it was possible to take stock, collect results, and transfer them into scalable blueprints. Five synthesis areas – the SINTEG Syntheses of Results – were written at the end of the funding programme and summarise the substantial number of findings and blueprints. These reports help to ensure users, i.e. energy suppliers, industrial companies, grid operators, etc., and political decision-makers will have the most important factors in mind from the start when planning and implementing measures to integrate renewable energies into the energy system and allow them to benefit from the practical application experience gained in the five SINTEG showcase regions. The following overview of the synthesis reports shows which factors are significant drivers of the change towards a climate-neutral and progressive energy world and where there is still a need for action.

## 5 key factors for a successful system integration

The main challenge to further integrate renewable energies into the energy system is, i.e. answering the question of how to ensure it will be possible to use the low-carbon electricity supply at the right time and in the right place. To answer this question, the SINTEG showcase regions developed approaches to solutions that can be categorised into five overall action fields.

### 1. MAKING ELECTRICITY USE AND SUPPLY MORE FLEXIBLE

The increasing proportion of fluctuating renewable energies in electricity generation and the decreasing contribution of controllable conventional generation facilities increase the need for new and still largely untapped potential for flexibility, especially on the demand side and in the area of decentralised storage. Demand-side flexibilities can be leveraged via load management methods and sector coupling technologies (power-to-X), for example via flexible control of electric cars, heat pumps, or industrial processes. On the demand side in particular, potentials for flexibility often remain untapped even today due to their heterogeneity and more complex cost structures. How flexibilities can be exploited and integrated and whether or not their application is economically viable was tested in the SINTEG showcases. Findings on various flexibility options are presented in detail in the first synthesis report “Flexibility Potential and Sector Coupling”<sup>1</sup>.

One finding from the numerous SINTEG demonstration projects and field tests is that in many cases it is technically feasible to construct and operate new and flexible plants or even to make existing plants more flexible. Solutions for the integration and control of flexible plants, for example to supply heat to neighbourhoods in the overall system, have also been tested. In the future, though, it will be important to further accelerate the rollout of smart electricity meters in order to be able to leverage small-scale flexibility potential. In the future, the flexibility of entire buildings could be bundled in a package through the further development and implementation of the digital grid connection concept developed in SINTEG.

Due to their considerable output, many processes in trade and industry are well suited for use as flexibility options for the future electricity system. The SINTEG showcases highlighted successful examples of flexibilisation for general purpose technologies and production processes. Just like in the household sector, the use of (IT) infrastructures for multiple purposes can increase the economic efficiency of flexibilisation in trade and industry.

Despite the proven technical feasibility and an increasing demand for flexibility in a low-carbon energy system, barriers currently exist for decentralised flexibilities that prevent their large-scale deployment. The viability of business models for flexibility providers was critically evaluated in the context of SINTEG. This is due to the currently low potential for revenue when providing flexibility in combination with comparatively high investment and activation costs as well as the high burden placed on electricity through fees, taxes, and levies. This competitive disadvantage of electricity compared to other energy sources makes it particularly difficult for sector coupling technologies to become profitable. From a technical standpoint, the delayed rollout of smart electricity meters and smart meter gateways has been an obstacle to

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<sup>1</sup> Available in German only. See link in the disclaimer below.

allowing plants to become more flexible. The standardisation of digital interfaces between different components is another crucial factor for leveraging and harnessing flexibilities.

## RECOMMENDATIONS FOR ACTION:

- When leveraging flexibility, the focus should be on adding value for flexibility providers and, wherever possible, on the use of (IT) infrastructures for multiple purposes. Providing flexibility in combination with consumption monitoring or the digitalisation of production processes, for example, can increase the economic efficiency and make stakeholders more willing to participate.
- In many cases, viable business models for flexibility require additional incentives and the elimination of barriers such as prequalification requirements to ensure flexibility potentials can be leveraged economically.
- The accelerated rollout of smart metering systems and the standardisation of digital interfaces and components should be vigorously promoted to create the basis for flexibility

## 2. MARKETING FLEXIBILITIES AND COORDINATING THEM TO BENEFIT THE GRID

Without effective integration into the overall system, flexibilities can only provide the overall system to a limited extent with relief and make a relevant contribution to climate protection. For this reason, the SINTEG showcases not only tested individual technical components, but also the complex interactions of various flexibility options and stakeholders in extensive field tests, especially for the purpose of grid congestion management at the distribution grid level. Coordination mechanisms are a necessary prerequisite for this. The creation of new market platforms, for example, can allow the supply and demand of flexibilities to be coordinated through the market price. The most important steps for the successful implementation of such platforms were described in detail in several blueprints in the second synthesis report “Flexibility mechanisms”<sup>2</sup>.

The key finding from the prototype implementation is that flexibility platforms are technically feasible. However, they are vulnerable to strategic bidding strategies by market participants. Accordingly, the SINTEG showcases addressed this problem by designing countermeasures, although the effectiveness of these could not be demonstrated in the project’s context. Nevertheless, most showcase participants appeared to be in favour of making the necessary adjustments to the regulatory framework to pave the way for competitive flexibility platforms in Germany.

In addition to local flexibility platforms for grid operators, the SINTEG project addressed numerous other solution approaches in the context of the growing demand for flexibility and for better coordination of flexibilities, starting with system services ranging from decentralised plants and battery storage to the use of innovative grid resources and forecasting systems for the distribution grid.

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Similarly, to the case studies mentioned above, the project experience gained from the SINTEG showcases demonstrated that technical implementation is feasible. Technical challenges such as the integration of system services by decentralised plants into the existing grid equipment were analysed and practical solutions were developed. Innovative grid operating equipment that has only been put to the test in a few cases, for example digital grid controllers or controllable local grid transformers, has also been successfully used in some individual projects. In addition, SINTEG has tested innovative forecasting methods that are particularly important for the coordination of decentralised plants in the distribution grid.

From a broader perspective, despite existing research gaps, SINTEG was able to contribute to the gradual advancement of the technologies and successfully network the numerous stakeholders (grid operators at different grid levels, market players, and plant operators). This formed the foundation for the further discussions and testing processes needed to solve the complex coordination tasks of the future.

## RECOMMENDATIONS FOR ACTION:

- Flexibility platforms should be included in Article 13 of the Energy Industry Act (EnWG) as an additional congestion management instrument.
- The remuneration for flexibility providers should be acknowledged for regulatory purposes in the Incentive Regulation Ordinance (ARegV) as cost components that cannot be influenced. This would enable the efficient use of regional flexibilities to reduce system costs.
- Financial compensation for on-demand flexibility must be regulated in coordination with the balancing group manager (BGM).
- Flex platforms should be taken into account when issuing an ordinance to specifying Article 14a of the Energy Industry Act (EnWG) in more detail.
- Measures against strategic bidding strategies should be introduced.
- Optimal design of the spinning reserve system service at a European level should be ensured over the long term.
- In the area of reactive power, there should be a common understanding in the industry regarding interfaces and protocols for transmitting control commands.
- Measures must be developed and implemented together with distribution grid operators that lead to greater data transparency by collecting network status data.
- Research projects should be promoted that seek to bridge the asymmetries in data access between network operators and market players, for example through data and service platforms.
- The provision of data should be supported by regulation to improve energy forecasts. This would enable improved access to public data as required by regulation (e.g. to the market master data register (MaStR)) using interfaces. A discussion between the responsible Federal Network Agency and industry should be initiated in order to identify starting points for improvements.

### 3. CONTROLLING THE ENERGY SUPPLY INTELLIGENTLY AND SAFELY

The transformation of the electricity system is only possible through the comprehensive use of information and communication technologies (ICT). Just how central ICT solutions actually are becomes clear, for example, in connection with the need for electricity demand flexibilisation, which would be impossible without the automated control of a large number of small consumers.

In the future, the goal will be to link the entire energy supply system at all network levels in such a way that flexibilities can be marketed securely and almost in real time. This means it will be necessary to create a system of subsystems that combines the capabilities and resources of the subsystems to develop a new system with additional functionalities. Future smart grid solutions, though, are faced with the challenge of having to integrate an extremely large number of heterogeneous systems. Ideally, the heterogeneous systems will operate independently but work well enough together to solve complex problems reliably and as automatically as possible without compromising IT security.

It will be crucial to be able to seamlessly integrate the individual ICT applications and solutions. For this reason, individual SINTEG showcases modelled the overall architecture of all smart grid components and basic technologies to avoid discontinuities in the system. These components and technologies are comprised of the communications infrastructure, ICT platforms and services, as well as control and regulation mechanisms. In addition, procedures for standardisation, interoperability, increased resilience, IT security, and personal data protection were developed and tested.

Based on the results of these activities, blueprints were developed, and the results published in the third synthesis report “Digitalisation”<sup>3</sup>. The five showcases focused on specifically advancing the existing basic ICT technologies and gained valuable, well-documented experience in the process. Above all, the showcases contributed to defining a suitable system architecture for the ICT overlay infrastructure, determining the data requirements for new business models, implementing the requirements for secure information management systems for critical infrastructures in the energy system, as well as gaining experience in the areas of complexity, scalability, and resilience and testing important infrastructure components such as smart metering systems and smart meter gateways in ‘real laboratories’.

#### RECOMMENDATIONS FOR ACTION:

- Large-scale rollout of a smart meter is needed.
- Establishing marketability and creating acceptance among potential users is a core aspect of digitalisation. Thus, local trades should be involved and appropriate training for installers should be offered.
- The need for open standards should be followed up in cooperation with the appropriate standard defining organisations (SDOs). The SINTEG results should be incorporated into the next version of a standardisation roadmap.
- Designing suitable future scenarios that are also reliable and include technical aspects.

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- Long-term funding of energy research programmes and corresponding special programmes.
- The complexity of digitalisation must be taken into account through systems engineering and continuously managed during operations.
- Transferring the SINTEG results into (inter)national standards and preserving the knowledge gained therein is essential.
- IT security is a highly relevant design characteristic that must be considered right from the start in the critical infrastructure (CRITIS) environment.
- The influence of regulations on technical developments must always be taken into account and anticipated.
- Policymakers must ensure that suitable scenarios of the future can also be designed reliably from a technical perspective.

#### 4. CREATING INNOVATIVE JOINT PROJECTS AND PRACTICAL TEST SPACES.

In order to develop innovations and new technical solutions and introduce them to the market, companies and research facilities need to test them, ideally under real conditions. Legislators should also be involved and learn what new legal requirements the energy system of tomorrow will bring. Against this background, the German Federal Ministry of Economics and Energy adopted a regulatory sandbox strategy in December 2018. The overarching goal was to provide science, industry, and administrations with a new tool for testing technologies, problem solutions, or change processes – the so-called regulatory sandboxes.

The SINTEG showcases have done important pioneering work for regulatory sandboxes. “Test and learn” was the slogan that accompanied the four-year project of the five SINTEG showcases and its consortia from the very beginning. Depending on the object studied, new technologies, innovative products, applications, and business models were tested in trial operations or field tests conducted under real conditions together with future users. Their experience was compiled in the fourth synthesis field report “Pioneer for Regulatory Sandboxes”<sup>4</sup> and then transferred to blueprints. They are primarily intended for entrepreneurs, researchers, and local political authorities who aim to design and implement a regulatory sandbox as a test space for innovation and regulation in the future.

One of the main findings from the SINTEG project: regulatory sandboxes are worth the effort! They provide insights on how technical systems should best be set up, how they behave after being put into operation, and how they can be optimized. Testing the practical suitability of decentralised power plants or other technical solutions is an essential prerequisite for subsequent scaling. Real operations also make it possible to combine simulated and real values and therefore enable scalability tests. This in turn helps to validate scenarios and models. Another benefit is that numerous components of the energy system actually interact, and therefore promote systematic practice in the energy system as well as its structural transformation. Furthermore, new application and business fields and attractive flagship projects

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that attracted huge interest within and beyond the regions emerged in the context of SINTEG. The regulatory experimentation clause motivated many partners to participate in the showcase projects, which ultimately created a strong, interdisciplinary network of experts. In addition, the SINTEG regulatory sandboxes offered legislators important insights for future legislation and ongoing standardisation processes regarding the sustainable transformation of the German energy system.

The showcases also encountered barriers to the implementation of regulatory sandboxes for the energy system: The first lesson learned was that it is impossible to test everything during the live operation of energy systems because of supply security restrictions. Furthermore, some individual technologies such as smart meter solutions were not available yet in their final form. The size of the showcases also made it difficult to maintain flexibility, and special attention had to be paid to the efficient coordination of all the partners involved. The application of the experimentation clause also posed various challenges to the project partners. These challenges are addressed in the following recommendations.

## RECOMMENDATIONS FOR ACTION:

- In future regulatory sandboxes, it should be clearly defined from the start how extensively the real environment should be utilised.
- A scalability and transferability analysis should be planned into the initial phase of a regulatory sandbox.
- Start-up companies should become more involved in the innovation process.
- To formulate experimentation clauses and ordinances, the funding body should implement a design process in advance with the participation of experts from the field of energy law, similarly to the process used in SINTEG.
- Sandbox regulations, e.g. a regulatory innovation zone, should promote systematic innovation.
- The funding programme design should also plan additional resources for set-up, project management, and overall coordination of the model projects as well as support for start-up companies and accompanying research.

## 5. PROMOTING CITIZEN PARTICIPATION AND TECHNOLOGY ACCEPTANCE

The energy transition is embedded in a variety of socio-economic structures. During the transformation of the energy system, institutional settings, commercial applications, the behaviour of private consumers, and society's approach to energy and technologies will have to evolve further. For this reason, the transformation of the energy system in Germany can only succeed if the new components of the future energy world are also incorporated into society as norms and values. In other words, the enormous individual and societal transformations required to build a climate-neutral energy system will not be possible without broad acceptance among the general population.

With this in mind, the five model regions tested various methods and measures for promoting social acceptance. The goal was to gain insights into key influencing factors and develop blueprints based on these insights for positively influencing acceptance in the context of the energy transition. These insights were summarized in the fifth synthesis report “Participation and Acceptance”<sup>5</sup>.

As a result, the catalogue of measures ranged from marketing-based communication tools, information events, and technology-based participation formats with gamification elements to traditional acceptance research.

An initial starting point of the SINTEG showcases was the communication and content-based discussion of technologies, their methods of operation, and their possible effects in the context of a smart and climate-neutral energy system. Based on surveys and face-to-face dialogues with test customers in individual participation and acceptance subprojects, the financial benefits of the ‘acceptance object’ and the guiding economic principles of the ‘acceptance subjects’ were identified as positive influencing factors on the attitudes, usage, and actions regarding new energy technologies. In addition to the cost-benefit factor, the showcases’ projects also showed that environmental awareness and emotional attachment to a region and to a group of like-minded people (community) can foster people’s willingness to innovate and positively influence their attitude toward the energy transition. The provision of participatory processes, stakeholder-specific communication, and attractive price signals were key elements in getting private households to become involved in an integrated and dynamic energy system. In addition, it was determined that the interaction of acceptance research and accompanying social science research provides a good knowledge base for designing and effectively implementing tailor-made dialog, information, and participation formats oriented towards the needs, attitudes, and characteristics of the target groups relevant in SINTEG.

## POLICY RECOMMENDATIONS:

- Promote pilot projects and studies on the effectiveness of financial and/or non-tangible benefits.
- Implement community-building measures for interconnecting regional energy transformation projects and the general population.
- Develop education and training strategies.
- Get citizens more involved in shaping the energy transition, for example via platforms, citizen councils, and citizen conferences.
- Integrate the findings from acceptance and participation subprojects into future application-oriented energy research projects.

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Blueprints for the energy transition.  
Executive summary of the 5 syntheses of results on the SINTEG Funding Programme.

Elaborated on behalf of the  
Federal Ministry for Economics and Climate Protection

## IMPRINT

Further information on the SINTEG funding programme at [www.sinteg.de](http://www.sinteg.de). The synthesis of results is divided into five synthesis areas – the synthesis reports. These are available in German via the following links:

[Synthesis report 1: Flexibility potentials and sector coupling](#)

[Synthesis report 2: Grid-serving flexibility mechanisms](#)

[Synthesis Report 3: Digitisation](#)

[Synthesis report 4: Pioneer for real laboratories](#)

[Synthesis Report 5: Participation and Acceptance](#)

The synthesis was developed under the leadership of Guidehouse in a project consortium with the participation of AIT Austrian Institute of Technology, ifok, OFFIS – Institut für Informatik, RE-xpertise, and the Wuppertal Institut.



### Disclaimer

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