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Decarbonisation through digitalisation

Proposals for Transforming the Energy Sector

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Decarbonisation through Digitalisation

Proposals for Transforming the Energy Sector

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The University of Bayreuth was founded in 1975 and is one of the most successful younger universities in Germany. Over the past few decades it has earned an excellent international reputation in research and teaching due to its interdisciplinary subject areas. The subject area *Energy research and energy technology* not only deals with the future-oriented topic of energy from a natural and engineering science standpoint, but also in terms of socio-political, economic and legal aspects.

The Project Group Business & Information Systems Engineering of the Fraunhofer FIT has proven expertise at the interface of Financial Management, Information Management and Business & Information Systems Engineering. The ability to combine methodological know-how at the highest scientific level with a customer-focused and solution oriented way of working is our distinctive feature.

TenneT is among the leading electricity grid operators in Europe and committed to ensuring a highly secure and reliable energy supply, 24 hours a day, 365 days a year.

As the first cross-border transmission system operator, TenneT is planning, building and operating an almost 24,000 kilometre-long high and extra-high voltage grid in the Netherlands and large parts of Germany and supports the European energy market through 16 interconnectors to neighbouring countries. TenneT belongs to the largest investors in the European energy transition and contributes to shaping a sustainable, reliable and affordable energy supply system fit for the future, in which digitalisation plays an essential role. With currently about 5,700 internal and external employees and corporate values of responsibility, courage and networking, TenneT ensures that over 42 million end users in Europe are supplied with stable power that they can rely on every day.

The University of Bayreuth is one of the first higher education institutes in Bavaria to adopt a binding sustainability strategy to reduce carbon emissions.[1] As part of an internal initiative, the Fraunhofer Gesellschaft pursues the goal of getting carbon-neutral by 2030.[2] The transmission system operators have already committed themselves to reducing their carbon footprint while continuing to guarantee a very high security of supply and offering fair energy prices.[3]

[1] See Universität Bayreuth 2021.
[2] See Fraunhofer 2021.
[3] See TenneT 2020.

SUMMARY

The successful and rapid achievement of sustainability and climate protection goals is increasingly getting into the focus of political, economic and societal action. Against this background, energy industry is contributing to decarbonisation in Germany and throughout Europe and will continue to do so. In fact, it already makes a significant contribution to the *Paris Agreement* and the European *Green Deal*. In this light, the next transformation phase towards a sustainable energy system is inevitably linked to the modernisation and especially to the digitalisation of energy industry.

The aim of this thesis paper is to intensify the discussion on the digitalisation of energy industry and, in particular, to outline recommendations for flexible and proactive action by all stakeholders. The University of Bayreuth, the Project Group Business & Information Systems Engineering of the Fraunhofer FIT and the European transmission system operator TenneT share the vision of climate-neutral economic growth based on the innovative strength of European economy. In 2021, decarbonisation is already shaping the digitalisation of energy industry. Further to the steps initiated in recent years to push energy industry towards greater sustainability in the course of energy transition, the main concern is now to accelerate sustainable growth while at the same time keeping the energy supply secure and economical. A crucial building block in this development is the electrification of additional sectors.

Accordingly, we discuss the role of grid expansion with respect to sector coupling and emphasise the digitalisation of end-to-end energy industry processes. In this context, we see decentralised digital identities as a promising way of bridging the current digital gap and addressing the need of digital certificates for thorough decarbonisation. Given the urgency of climate policy action, we recommend an appropriate innovation policy that makes it possible to test promising solutions in an agile way and draw conclusions rapidly. Finally, we offer an overview of the monitoring of carbon emissions in grid expansion projects. This paper is aimed at political decision makers, energy industry stakeholders and all citizens interested in energy policy.

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FOREWORD

Dear readers

The successful and rapid achievement of the sustainability and climate protection goals defined in the *Paris Agreement* and the European *Green Deal* is increasingly getting into the focus of political, economic and societal action. The decarbonisation of the energy sector is set to make a key contribution to this goal and is inevitably associated with the modernisation and especially with the digitalisation of the energy sector.

The aim of this thesis paper is therefore to intensify the discussion on the digitalisation of the energy sector and to outline recommendations for political support for flexible and proactive action by all stakeholders. In doing so, the European transmission system operator TenneT, the University of Bayreuth and the Project Group Business & Information Systems Engineering of the Fraunhofer Institute for Applied Information Technology (FIT) bring together a model of climate-neutral economic growth based on the innovative strength of the European economy. Climate protection presents itself as a positive sum game in which it is possible to do everything better. However, in the case of a shrinking economy, there is a risk of losers and thus social conflicts over distribution, which will make it much more difficult to achieve the climate targets. Given the irreversible nature of the damage, this risk is unacceptable. Both academic and non-academic research offer a diversity of promising digital innovations for carbon-neutral economic growth that must now be implemented and tested consistently in the various sectors of economy.

In 2021, the energy sector is already dominated by decarbonisation: following the steps initiated in recent years to push energy industry towards greater sustainability in the course of energy transition, it is now a matter of *accelerating* sustainable growth while at the same time keeping the energy supply secure and economical. Continuous digitalisation of energy sector processes is a decisive component in achieving this goal. This paper is aimed at energy sector stakeholders, political decision makers and citizens interested in energy policy.

We hope you will enjoy reading it and warmly invite you to get into a dialogue with the authors.

Prof. Dr. Stefan Leible (President, University of Bayreuth) and Dr. Ingo Schmidt (Director Regulatory Affairs, TenneT TSO GmbH)

INTRODUCTION

After successfully pushing the electricity system in Germany towards renewable energy the transmission system operators (TSOs) are now facing another major challenge: the comprehensive and rapid decarbonisation of the European electricity system. As significant and neutral stakeholders in the energy sector TSOs are set to play a special role here. Their traditional tasks include providing the infrastructure, expanding it appropriately and operating it safely and affordably. As a result of energy transition a new task has occurred: to integrate renewable energy into the system. The electrification of further industry sectors, buildings and transport is currently taking place under the key term *sector coupling*. Carbon emissions will become a key indicator in this new world of combined sectors, in which the significance of electricity for the decarbonisation of the overall economy is constantly increasing.

In order to put the leading principles of decarbonisation – not only of energy industry, but of the entire economy – into practice, specifications related to location and time for the carbon content of electricity will become more and more important to economic stakeholders, alongside abstract price information from the *EU Emissions Trading System* (EU ETS) for electricity certificates. This requires the energy sector and politics to work closely together to ensure that this information can and will continue to be provided in a verifiable and transparent manner. The fields of science and research are already supporting this today and providing significant impetus for actively shaping the future.[4] Digitalisation is an essential instrument in decarbonising the energy sector.

This thesis paper demonstrates how digital technologies can be used in a targeted manner to support and accelerate the transformation of the energy sector. In order to use the current and future potential of digitalisation in the best way possible, appropriate foundations must be laid today. This means that technical, economic and regulatory obstacles in particular must be rapidly identified and addressed.

Combating the global warming crisis is a battle which cannot be postponed. The speed at which the energy supply system is transformed must therefore increase rapidly without jeopardising security of supply and affordability. New and promising solutions must be brought forward earlier for testing in the market. Such an approach will allow concepts to be assessed and revised in good time in order to quickly implement the best solution. This would appear to be vital especially in the highly dynamic field of climate and energy policy and against the backdrop of rapidly developing information technologies. In short, the energy sector needs agile forms of testing more urgently than ever, although new approaches such as parallel testing of different approaches should also be considered. The aim and purpose of this thesis paper is to name and explain key action areas as well as to introduce recommendations for action to economic and political discussions.

[4] See, for example, the digital certificates for green electricity which can be differentiated by time and location. The University of Bayreuth has been developing these certificates with partners in the *InDEED* research project since 2020. *InDEED* is sponsored by the Federal Ministry for Economic Affairs and Energy (BMWi).

1. SECTOR COUPLING AND GRID EXPANSION

The importance of electricity on the path to a climate-neutral society is steadily increasing. If renewable energy is used consistently and to its full extent, electricity-based solutions such as electromobility in the transport sector demonstrate higher efficiency than traditional combustion engines. The same applies to heat pumps compared to central heating boilers in the heating market. According to forecasts electricity consumption in Germany will double by 2050 in this regard.[5] The establishment of a hydrogen economy for industry will play a major role in the increase in power consumption.[6] Electricity will become a driver for sector coupling in Europe.

The electrification of the industrial, building and transport sectors calls for the steady expansion of electricity grids in Germany and Europe. The targeted use of the flexibility potential of battery storage, heat pumps, electrolysers and electromobility is no alternative to expanding the electricity grid; instead, these are necessary supportive measures to make sure that the future energy supply system can be operated efficiently and reliably. A more intensive European electricity trading will also have to contribute to compensating for high, fluctuating electricity feed-in rates over different areas and timespans.

The efficient use of digital technologies can optimise grid operations by utilising a large number of built-in sensors, improved coordination of individual system components and by increasing the efficiency of existing processes. For instance, system controls based on artificial intelligence (AI) could make it possible to analyse large volumes of data in near real time and thus allow grid operations to be adjusted flexibly. It is also conceivable that AI and robotics will be used increasingly to maintain system components (for example grid equipment) in the future.

A smart energy policy must be both anticipatory and reliable. The expansion of the power grid required to decarbonise the industrial, building and transport sectors must therefore be pursued and implemented resolutely. At the same time, the public has to be kept informed about the necessity of this measure. The political sphere needs to gain acceptance for grid expansion and make the potentials of digitalisation available across sectors.

[5] See Agora 2020; BEE 2021; BDI 2018; dena 2018.
[6] See Agora and Wuppertal Institut 2019.

2. DECENTRALISATION REQUIRES BRIDGING THE DIGITAL GAP

Prioritising the consumption of electricity from photovoltaics (PV) and wind turbines is a fundamental and systemic challenge coming from the *seasonality* of energy supply and demand. Both the generation and reconversion of hydrogen as well as the use of large storage power plants are much-discussed solution options in Europe. TSOs are essential for accomplishing the required export and import of energy into and out of the respective countries over the coming years.

To achieve the *short-notice* equalisation of energy demand and supply millions of decentralised consumption and generating units must be incorporated into the energy system as active market participants. Their vertical integration ranges from electric vehicles, heat pumps and electrolysers for system services through to participation by decentralised units such as PV plants and home-based PV storage systems in local, regional or national energy trading markets. In an ideal real-time energy economy decentralised units should be able to switch competently and dynamically between own consumption, system services and trading markets. As a general rule, the more participants and more frequent the interactions – i.e. the larger and more liquid the markets – the more effective, affordable and climate-friendly the overall system. Blockchain technology can help in this regard. For instance, several European TSOs (TenneT, Swissgrid, Terna, APG etc.) are currently working on the cross-country, blockchain-based crowd-balancing platform *Equigy*. This digital data platform gives *prosumers* in Europe the chance to make the flexible capacities of their electric vehicles, heat pumps or home battery storage systems available to system services in an unbureaucratic, simple and secure way by means of aggregators.[7]

Decentralised systems will contribute to a higher utilisation of the grids by providing flexibility (see Chapter 1). The flexibility potential could be raised and enhanced through real-time and resilient digitalisation concepts in the sense of a reactive grid management.

Overall, the integration of (small) generation plants "behind" the current meters requires a flexible regulating framework able to learn, both for the range of system services and for their approval of competitive energy trading markets (see Chapter 4).

Today, there is still a significant *digital gap* in terms of the technical requirements for systematic market integration and the use of grid contributions from decentralised systems. I.e. shifting a generation plant from own use through to provision of system services or to participation in energy trading sometimes still requires the corresponding processes on paper and is, most of all, extremely time-consuming. In this context, the dynamic equalisation of energy demand and supply, involving millions of transactions per day and performed by millions of decentralised consumption and generating units, will require different, primarily faster and more efficient forms of interaction. The exchange of information between distribution system operators (DSOs) and TSOs must also continue to be developed for this purpose and undergo end-to-end digitalisation in the respective process chain in the same way as congestion management and market communication. A key element in this process is that market participants themselves and the rights to which they are entitled need to be *able* to be verified in real time in order to ensure an interaction that minimises transaction costs and is secure and dynamic. Digital personal and machine identities are becoming an important focal point in the emerging real-time energy economy.

The lack of digital identity proofs at device or machine level is currently one of the most pressing obstacles to digitalisation – not only in the energy sector.

The German Federal Government has recognised this problem and is working at full speed to establish an ecosystem of digital, decentralised identities fitting into what is known as the *European Digital Identity Initiative*. Decentralised approaches

[7] See Equigy 2021.

envisage a system by which users manage their own identities and certificates. So-called self-sovereign identities (SSIs) ensure that the verification and use of certificates do not have to be monitored by an individual body, such as an internet platform operator.[8] Within the framework of the German Federal Government's blockchain strategy the Project Group Business & Information Systems Engineering of the Fraunhofer FIT is currently investigating the use of SSIs for digitally establishing a trust chain, for example between a PV plant, a smart meter and the market master data register. This is part of the *Blockchain Machine Identity Ledger* project run by countless partners from the energy sector under the leadership of the Deutsche Energie-Agentur (dena).

This will considerably accelerate the process of switching plants between own use and offering system services (amongst other aspects). The project is aiming at solutions capable of providing the necessary, secure and scalable authentication of market participants, such as electric vehicles or heat pumps. SSIs are one of the solution options that will make it possible for pre-qualified plants to dynamically switch between market segments in the future. The political sphere should therefore continue developing digital SSI solutions for machine identities as a major priority while ensuring interoperability with other domains and ecosystems as well as pushing ahead with the smart meter gateway roll-out (keeping in mind the secondary condition of expandability) and maintaining operation of existing measurement and control equipment.

[8] See Strüker et al. 2021.

3. DIGITAL CERTIFICATES FOR DECARBONISATION

From an information technology point of view it is only a small step from digital proof of persons and machines to digital proof of origin and use. Given economic stakeholders' increasing need of information related to location and time about the carbon content of energy, digital carbon certificates promise considerable added value and enhanced welfare. For example, they allow for digitally verifiable and simple billing, whether through EU ETS certificates and German fuel emissions trading certificates on the one hand or through parameters such as heat, electricity or hydrogen on the other hand. After all, in order to reduce the carbon footprint of companies carbon volume and compensation decisions must increasingly be made during production processes. Divisible, billable and digital carbon certificates promise to make for active control at production level and thus incentive-based management of CO_2.

On the basis of real-time monitoring fine-grained data on electricity use and feed-in, for example in the case of electromobility, can be used for a better grid management. At the same time, digital certificates can make it possible to clearly differentiate hydrogen by *colour coding*, for example, and thus trade it on the energy market as coloured hydrogen of various qualities.[9] In light of the considerable national gap in green power this could not only accelerate entry into a hydrogen economy, but also empower companies to influence products and services actively and directly at process level via carbon controlling instead of simply fulfilling passive requirements and documentation obligations.

The benefits of a digital end-to-end link between carbon trading and carbon decisions in service provision or in purchase decisions by end customers are accompanied by complex requirements such as the avoidance of non-payment, duplicate counting and fraud. The rights and obligations to be accorded to the market participants should therefore be verified so as to facilitate targeted provision of this information in the future.

Carbon prices will only be able to have their intended steering effect if they are directly taken into account in the economic decisions of households and companies. At present, the path towards raising the carbon price is not sufficiently steep in either the EU ETS or in emissions trading for transport and heating (Fuel Emissions Trading Act – BEHG), meaning that the consumption behaviour of households and companies may change rapidly. Due to the time pressure inherent in the transformation of the energy sector it must be ascertained whether and how digital proofs of origin and use can succeed in bridging the gap between carbon trading systems and the need of carbon information for household decisions as well as for the management of production processes. The development of innovative, scalable and expandable concepts is a political task that must be tackled as a priority due to its overall importance to society.

[9] Colour-coded hydrogen is manufactured in electrolysis plants in the same way as green hydrogen. Electricity, however, can come from different sources, i.e. from gas, coal and nuclear power plants. So far, blue and turquoise hydrogen obtained from natural gas have not been included generally.

4. AGILE SANDBOX TESTING AND LEARNING

Grid operators have to adapt flexibly to new tasks that will need to be overcome in the future when operating and expanding the power grid. This calls for the use of modern instruments developed within a policy of innovation. In specific terms, the question is how science and research in particular can cooperate more closely with grid operators and the energy sector in order to test digital innovations for grid operations quickly, in a targeted way and in the broadest sense, as well as to learn from the findings and make for the rapid implementation of applications.

"Real-world laboratories" or "sandboxes" are among these instruments available.[10] They are already used successfully as test spaces for the interaction between innovative technologies and regulation in Germany. They allow for solution concepts that are currently only partially compatible with the existing legal and regulatory framework to be tested under real conditions.[11] The results of these experimental spaces, which are limited in time or location, lay the foundation for the further development of the legal framework based on evidence.[12] When it comes to power grids in particular, it is not just about testing digital innovations under real-world conditions but also about providing insight into future regulations to legislators. Particularly valuable in this respect are special projects for the further development of business models under real conditions and projects of significance to the whole energy sector, such as the development of digital carbon certificates.

In order to appraise the opportunities and risks of digital innovations more rapidly and *transfer* them into regulatory design requirements the real-world laboratory instrument should be further developed and expanded to include the *speedboats* variant. These agile and lean test spaces should ideally run for one to two years and be *capable* of being set up upon the recommendation of scientific institutions and the energy sector within a few months. If there is an urgent need to gain regulatory knowledge, consideration should also be given to testing several concepts in parallel projects for selected issues. The consistent use of information technologies together with the automation of progress measurement/assessment via AI and smart contracts (for example) can help prevent malpractice and undesirable consequences. In addition, the use of information technologies can also directly support systematic learning and the ongoing development of solutions.

In principle, a systematic and fast-learning innovation policy assisted by the modern forms of regulation described here will support the rapid creation of the financial framework to help future-oriented, innovative ideas become ready for the market. Otherwise, if the regulatory uncertainties persist, there is a risk that the urgently needed investments in digital technologies will not be undertaken.

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[10] The authors use the term *real-world laboratory* in the sense of a *regulatory sandbox* and thus follow the conclusions of the Council of the European Union on regulatory sandboxes and experimentation clauses (see Rat der Europäischen Union 2020).

[11] See BMWi 2021b.

[12] For example, the Norwegian and British energy regulators extensively and successfully use the *regulatory sandbox* instrument for pilot projects.

5. CARBON EMISSIONS OF GRID EXPANSION MEASURES

Carbon emissions will become a key indicator in this world of combined sectors, where the significance of electricity for the decarbonisation of overall economy is constantly growing. Like its predecessor the amended Climate Protection Act of 2021 envisages annual carbon reduction targets per sector and defines permitted emission volumes for the energy sector. In real terms, this shift in the target architecture of energy transition means that infrastructure measures, such as grid expansion, alongside expanding renewable energy and increasing energy efficiency[13], will in future be measured more closely by their indirect contribution to achieving the climate protection targets.

However, a debate on the extent to which intelligent, digital control of power grids – so-called *smart grids*[14] – can be a substitute for grid expansion misses the point. As the need for grid expansion measures in a sector-coupled world will inevitably increase (see Chapter 1), the relevant question is which combination of *smart grids* and grid expansion will be the most effective in achieving the explicit carbon reduction targets. Based on these carbon reduction targets, future approaches to solutions must therefore allow specific measures and decisions to be derived. The contribution agile regulation can make to the development and corresponding test spaces of these approaches has already been mentioned in Chapter 4.

A concrete starting point for relevant solutions is an end-to-end digitalised CO_2 monitoring. This can also lay the foundation for an appropriate appraisal of measures and projects in the energy sector. Comprehensive end-to-end digitalisation of processes could and should be capable, for example, of realistically modelling and transparently visualising the carbon effects of grid expansion on other sectors in light of electrification/sector coupling.

This way of simulating the urgent and necessary grid expansion measures specified in grid development plans, including their impacts on the energy supply grid as a whole, would make it possible to control the corresponding effects on the carbon footprint in a transparent and targeted way. Digital applications can record, visualise and document grid expansion progress accordingly in the form of CO_2 monitoring, which in turn contributes to achieving targets. Solutions which contain digital personal/machine identities and proofs of use as well as information related to location and time promise considerable added value for transparent data storage and processing that is accessible to all stakeholders (see Chapter 3).

The reporting of CO_2 risks and the inclusion of key energy figures in annual reports are already shaping the sustainability reporting of a growing number of companies. In the medium to long term, CO_2 equivalents and thus the individual CO_2 budget will have a direct impact on companies' economic calculations. This means that responsibility for implementing decarbonisation is gaining importance for stakeholders in the energy sector, that is that market control mechanisms are strengthened. Considering the urgency of political climate protection measures the digital approaches presented as examples offer efficient and effective options for transparently controlling and focusing grid expansion toward the key indicator of carbon reduction. With its proposals regarding decarbonisation through digitalisation this paper lays another building block for shaping the targeted and sustainable transformation of the energy sector.

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[13] See BMWi 2021a.

[14] A power grid can be described as intelligent if there is an exchange of information between electricity production, consumption and storage with the goal of dynamic controllability.

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Prof. Dr. Jens Strüker is professor for Information Systems and Digital Energy Management at the University of Bayreuth and one of the directors of the Fraunhofer Blockchain Lab. He also holds a leading position in the Project Group Business & Information Systems Engineering of the Fraunhofer Institute for Applied Information Technology (FIT). In research, teaching and practice Prof. Strüker investigates the potential of digital technologies for the (energy) industry. He is concerned with the question of which degrees of freedom information technologies offer for a real-time energy economy and for effective climate protection.

Dr. Martin Weibelzahl is head of a research group at the Research Center Finance & Information Management and the Project Group Business & Information Systems Engineering of the Fraunhofer FIT. The focus of his research lies on the field of digital energy and mobility. He investigates how our economy and society can be decarbonised in a sustainable, secure, and affordable way using various digital technologies, and the role the future design of the energy market will play in this context.

Marc-Fabian Körner is a research assistant and doctoral candidate at the University of Bayreuth and in the Project Group Business & Information Systems Engineering of the Fraunhofer FIT. His research concerns the digital transformation of the energy sector. He primarily focuses on questions related to the verifiability of carbon emissions and the potential of digital technologies for targeted sector coupling.

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Axel Kießling has been Head of Strategy & Partnerships – Digital and Flexibility Development at TenneT TSO GmbH since July 2020. He and his team are responsible for the portfolio management of all TenneT flexibility projects. His primary interests lie in the development of new flexibility options based on decentralised producers and consumers and in seeking the deployment of new technologies such as blockchain technology.

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Mike Hermann is a qualified engineer in energy technology and works as Senior Advisor European Regulation at TenneT TSO GmbH. He has been working in regulation management at this company for over ten years with a focus on European energy policy. He previously held various positions in German energy sector associations (DVG, VDN, BDEW) and was involved in grid development in a TSO. Mike Hermann has a large network of contacts and extensive expertise regarding technical and grid management issues specific to TSOs.

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