# Energy scenarios: Designing the renewable world of tomorrow together

**Theresa Gothe[1], Anne Schierenbeck[2]**

[1] University of Applied Sciences Osnabrück (Germany)

[2] University of Applied Sciences Osnabrück (Germany)

**Abstract**

If you are thinking in terms of the goal, you can take the right intermediate steps and avoid bad decisions. Studies show that a supply from 100 % renewable energies is achievable by 2045 in Germany. The coupling of sectors plays a prominent role in this, as does the short-term to seasonal storage of energy. The use of the 100prosim simulation tool in target group-oriented workshops can help people to understand the interrelationships between energy production and the use side more clearly. The energy system of the future is developed jointly in a participatory process using the scenario technique. This article gives an insight into the use of the tool combined with the workshop methodology and summarises the experiences of numerous workshops and practical applications with different stakeholders.

*Keywords: scenario, 100 % renewable, coupling of sectors, simulation, workshops, future energy system*

## 1. Introduction

The energy transition is complex and, in addition to technical adjustments and innovation, requires a social change process. The German climate protection plan stipulates that the implementation of the action plan and its further development should be linked to social discourse processes (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2016). Even if almost 90 % of Germans support the expansion of renewable energies (Agentur für Erneuerbare Energien, 2021), there is often resistance to the concrete implementation.

Studies from Prognos, Öko-Institut, Wuppertal-Institut on behalf of Agora Energiewende (2021), the German Energy Agency, dena (2021) and the Wuppertal Institute (2020) show that a complete decarbonisation of Germany is possible. In order to achieve an energy supply from 100 % renewable energies, their expansion is essential. In addition, energy storage, energy networks (for electricity and heat) and the infrastructure for hydrogen must be expanded (Bundesnetzagentur, 2019; Siemens, 2020). Energy savings through efficiency and sufficiency are inevitable. The expansion of renewables is associated, inter alia, with a high demand for land, which could result in competition for its use (Weyberg, 2021). The need for a renewable energy supply, therefore, poses particular challenges for regions with high energy requirements in relation to land area (Niepelt, 2021). There is not only competition for use, but also conflicts of interests and goals.

Participation and an open discourse are essential for the sustainable and effective implementation of the energy transition (Ried et al., 2017; Schreiber, 2012, Renn 2015, Ernst 2017, Fraune et al. 2019). Ried et al. (2017) state that the development of new structures in the energy supply represents a very complex challenge that requires a lot of specialized knowledge. There is a lack of this knowledge which must be compensated for, especially among municipal decision-makers (Rohe and Chlebna, 2021). Confidence in the procedures and competence of key actors in the energy transition on site, such as local administration and politics, is also closely linked to local acceptance (Hübner et al., 2020).

Transformation research shows that model-based energy scenarios can be combined with systematic elaborations of social and political contexts (Schmidt-Scheele et al., 2019). One method for involving experts and stakeholders is the scenario technique. This technique is particularly useful for looking at long-term future developments, since it does not make any statements about *one* future but considers several alternative possible futures (Wassermann and Niederberger, 2015). It is particularly suitable for the analysis of complex topics and their realistic development possibilities. This also applies when the aim is to understand the future together more effectively (Minx and Böhlke, 2006). The interactive methodology with due regard to the scenario technique (Meinert, 2004) provides room for different points of view and helps to create a future scenario that is considered jointly


doi:10.18086/eurosun.2022.19.01 Available at http://proceedings.ises.org

acceptable. This strength makes the tool interesting for a wide range of target groups. In this context it is very important to communicate about the assumptions made in the model and to make clear which input parameters on which base are used to make the model more valid and trustful.

The use of the 100prosim simulation tool in target group-oriented workshops is explained in this article. The scenario technique of so-called 'backcasting' is used in the application of the tool. What the future should look like in the best case – which means here a carbon neutral energy production based on renewables without any nuclear or fossil energy sources – and how this scenario can be achieved is determined in the backcasting process (Robinson, 1982). The aim of the workshops is to help people to understand the complexity of the energy transition and get to know the interrelationships between energy production and energy use.

Various workshops with different stakeholders were conducted and evaluated in the last three years. The research questions in this article are: In which areas of application was the 100prosim modelling tool used in connection with workshops and which results can be stated?

## 2. Tool and workshop methodology

The 100prosim is an open source Excel simulation tool. The software is offered and continuously developed by the registered association "Erneuerbare Energie-Szenarien e.V." (www.ernes.de). The 100prosim tool reflects the use of energy across all sectors and establishes expansion targets. All energy needs should be covered by renewable energies in a target year determined by climate protection requirements, such as 2040. The data basis of the tool is a report for the state government of Lower Saxony (Niedersächsisches Ministerium für Umwelt und Klimaschutz, 2015).

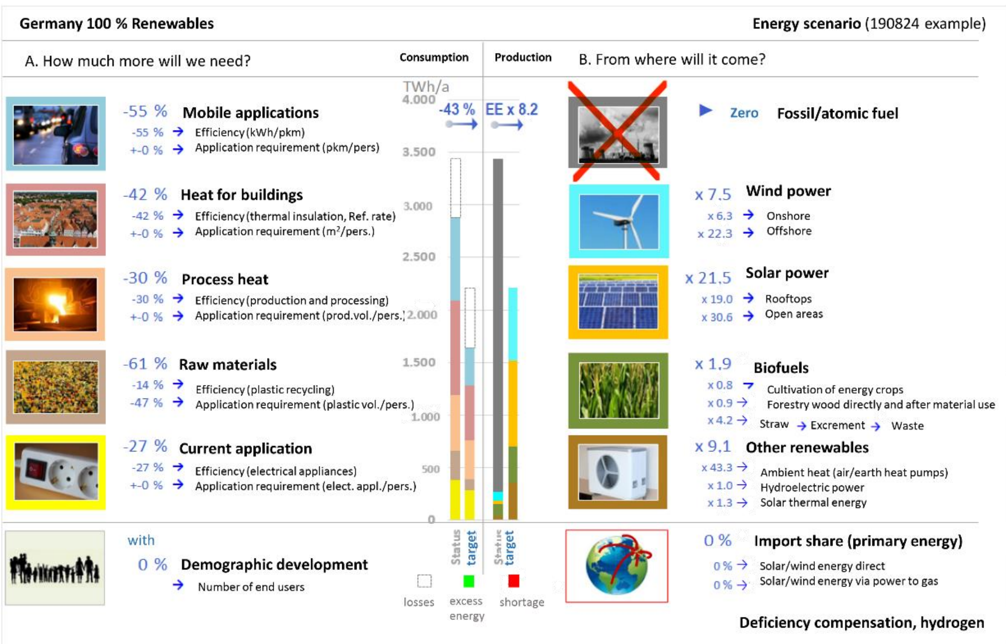



**Fig 1: User interface 1 of the 100prosim modelling tool.**

Energy consumption and production are illustrated graphically in the future scenario in comparison to the status, as shown in *Figure 1*. Among other things, energy losses, surpluses and deficits are visualised and the connections between the individual sectors and the consumption and production side are shown. The necessary generating and storing technologies, the extent of their use and the changed utilisation structures compared to today become clear. Sector coupling with electricity as a central element will also become tangible.

The energy consumption side includes the sectors of mobile applications, building heat, process heating and electricity applications. Hydrocarbon-based raw materials used in the industry are also included. These are synthesized from green hydrogen in the model. On the one hand, efficiency is taken into account, for example, through the technological potential in the area of drives and alternative fuels (Gmelin et al., 2008) and the technology used (Fraunhofer IWES/IBP, 2017). On the other hand, sufficiency plays an important role in the model, for example, concerning the size of heated living area or the number of kilometres driven by cars or flown by planes.

Regarding the energy production side, the energy requirement in the target year will be covered completely without fossil fuels or nuclear energy sources. The energy production is based on wind and solar power and biofuels from energy crop production. Ambient heat is used to supply heating to buildings using heat pumps. Hydrocarbon-based raw materials and fuels are synthesized from hydrogen. The current figures for the installed capacity of the individual technologies are taken into account for the energy production through renewables (Fraunhofer-Institut, 2020; Marktstammdatenregister, 2020) as well as the potential and respective space requirements (Bundesverband Windenergie, 2011; Deutsche Windguard, 2017). The power efficiency levels and their developments of the specific technologies are also considered accordingly (FGW, 2015; Fraunhofer ISE, 2011). Different sectors or energy production sources can be adapted in the user interface 2 of the 100prosim modelling programme (shown in *Figure 2*). Influencing variables, such as the population, are included in the simulation to calculate the energy consumption and production. The tool also takes into account the detailed land use, for example, for grain (Regionalstatistik, 2020), grassland (Johann-Heinrich-von-Thünen Institut, 2012) and forest (Umweltbundesamt, 2014).

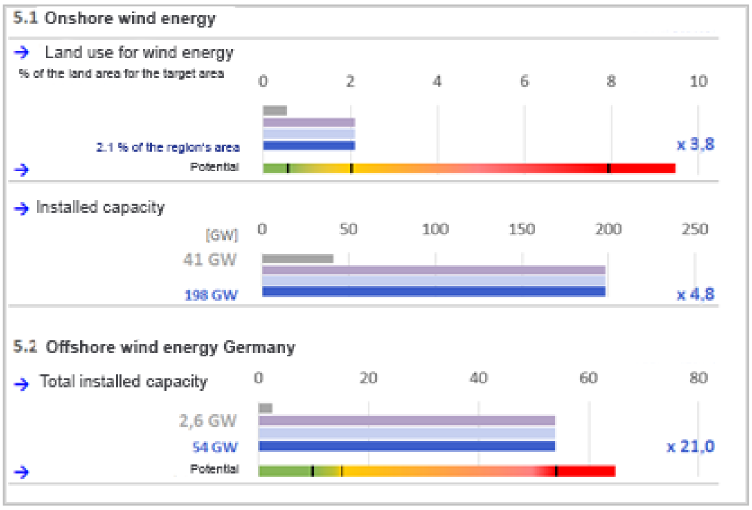



**Fig 2: User interface 2. In this case, for wind energy. There is a more detailed visualisation for each sector and technology.**

A scenario for energy supply in the future is jointly developed under guidance and moderation in the workshops. The workshop methodology is characterised by a co-operative and moderated way of working and aims to stimulate the discussion and increase the participants' knowledge in the area of energy transition. Most of the workshops were conducted during the COVID-19 pandemic and were carried out completely digitally. These workshops had a uniform structure, as shown in *Figure 3*. After a presentation about the climate crisis, $CO_2$-budget and –emissions in different sectors in Germany as well as the energy transition in general, the interactive part follows. Here, the participants use the digital voting platform Mentimeter to vote on various values in the areas of efficiency and sufficiency (e.g. the application of electric or hydrogen drives in the mobility sector or the expansion of wind power). These values are discussed and transferred directly into the scenario. The model of the future energy system makes simplifications in the area of grids and storage so that ad hoc changes in the workshops are visible directly.


**Fig. 3: Scheme of workshop methodology**

After working on the energy consumption side, the graphical user interface shows whether the assumptions made result in supply gaps and how large the shortfall is. The participants then look at the energy production side and can adjust the technologies installed based on the land available. In order to create a balance between consumption and production, the tool can carry out an automatic alignment based on either onshore wind turbines or open space solar power systems. In the end of the workshop, a future scenario for energy supply is jointly discussed and developed.

The 100prosim tool – in combination with the workshop methodology described – was applied in various fields: Workshop concepts at secondary school to master's degree level have been developed and implemented in a project funded by the Lower Saxony Ministry of Science and Culture. Four different energy scenarios were developed by workshop participants and analysed in the context of this project. Twelve digital workshops with various stakeholders were conducted and evaluated in another project that ran from June 2020 until August 2021. The workshops were recorded in their entirety using the Zoom video conferencing software and transcribed anonymously for the qualitative evaluation of their communicative content. The transcription of the workshops is done with the software MAXQDA. The evaluation is based on the theory of qualitative content analysis by Kuckartz (2016).

## 3. Results

3.1 Substantially expand wind and solar power, reduce energy use

As described earlier, the simulation tool compares the energy consumption across all sectors with the energy production required to cover it. Various input values e.g. the area for wind energy or solar power plants can be varied in order to achieve full supply from renewables. The corresponding effects on other sectors are illustrated directly after each change, making the interrelationships in the energy system understandable.

As shown in *Figure 3*, the 100prosim tool demonstrates a comparison of energy consumption (left) and energy production (right) regarding scenario 4 from *Figure 4* and *5*. Values in blue next to the individual areas indicate the energy quantities required/produced in the target year 2040 compared to today. With a halving of demand compared to business as usual, 33 % of the total electricity demand would still have to be imported, with expansion rates of 11 GW per year for wind power and 15 GW per year for solar power. The building heating demand is almost completely covered by heat pumps and a renovation rate of over 4 % per year is assumed, which would reduce the building heating demand massively. The switch to electric vehicles in the mobility sector allows for large energy savings.

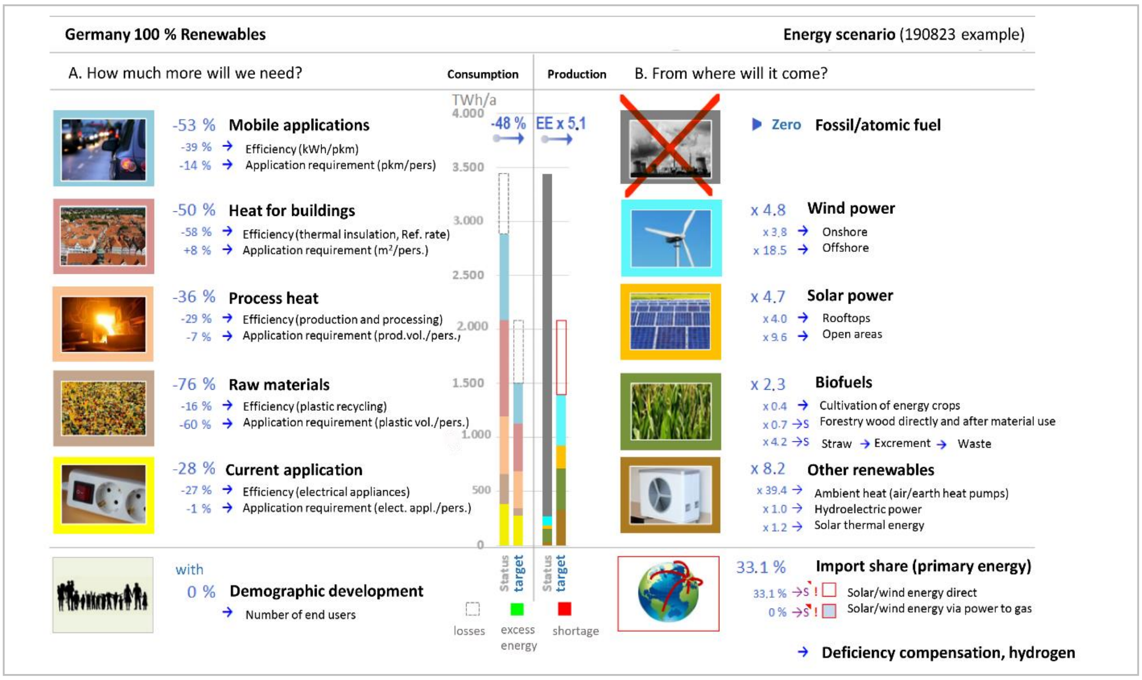
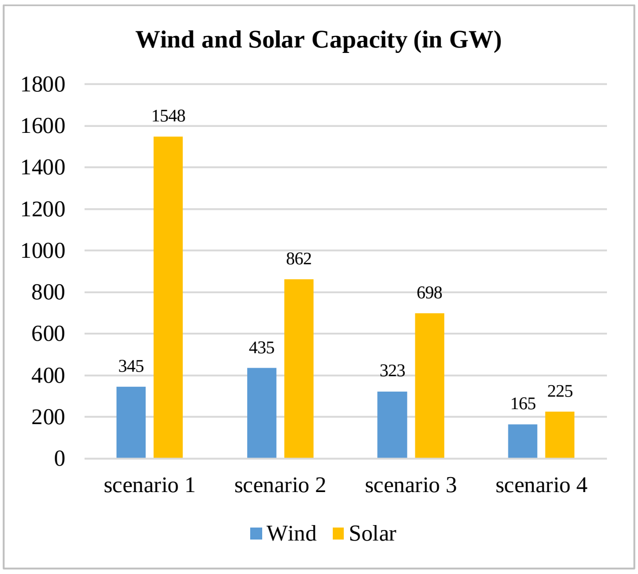



**Fig. 3: Illustration of the overview page "Cockpit 1" from the100prosim modelling tool. Parameters adapted as in scenario 4.**

In the workshops, participants can adjust the capacity of wind and solar power installed and see the impact of the change immediately. As shown in *Figure 3*, the scenarios have in common that wind and solar power will be the main pillars of the future energy supply. The installed capacity of wind power (onshore and offshore) ranges from

166 GW in scenario 4 to a maximum of 435 GW in scenario 2.



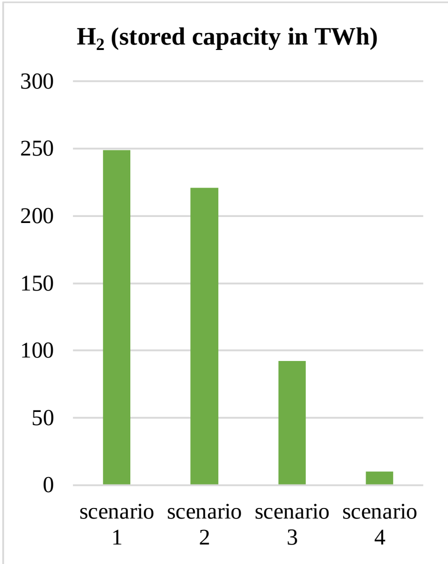




**Fig. 4: Results of four different scenarios created in workshops with different target groups using 100prosim showing the installed capacity of wind power (onshore + offshore) and solar power (rooftop + open space). With the exception of scenario 4 (import of approx. 700 TWh/a), the primary energy demand indicated on the right is completely covered by renewable energies within its own area (reference Germany).**

**Fig. 5: Amount of green hydrogen storage (stored capacity in TWh) to compensate for power shortage phases.**

The excess production of electricity on many days (especially in summer) is converted in 100prosim through electrolysers into hydrogen and is stored. In times of shortage, the hydrogen is converted back into electricity. Accordingly, both the electrolysis capacity necessary and the storage capabilities required emerge from the model. Green hydrogen, which is stored on a large scale underground in salt caverns, serves to compensate for periods of power shortage. This is also visualised in the tool, as shown in *Figure 6*. In order to minimise the storage capacities required, the generation of wind versus solar power should not be neglected.

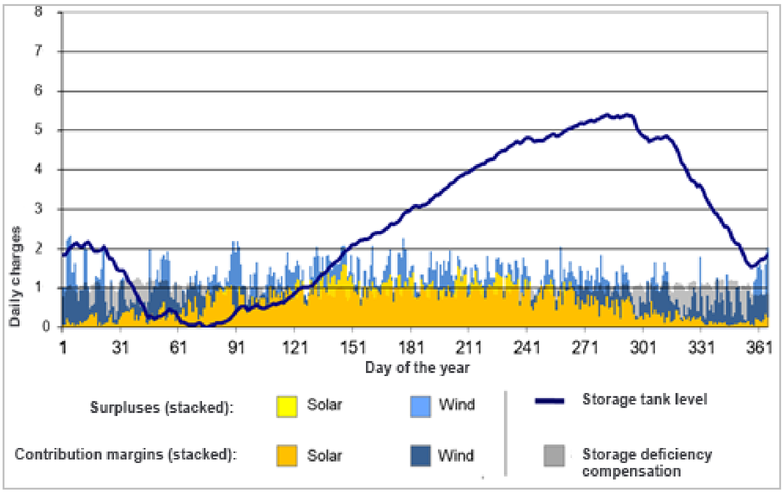



**Fig. 6: Visualisation of annual electricity generation and consumption in 100prosim**

A homogeneous, positive attitude regarding the assessment of solar installations on roofs was shown in the qualitative evaluation of all twelve workshops. The participants basically agree with the expansion of solar systems on roofs and still see a lot of potential here.

An ambivalent attitude towards the expansion of solar plants in open spaces can be observed in the workshops. The negative attitude in the workshops goes hand in hand with land consumption. In the context of careful and efficient land use, agrivoltaic systems are mentioned as a sensible approach by stakeholders from the agricultural sector.

Regarding wind power, participants of the workshops assumed that the expansion of offshore wind farm areas will increase in the future. This rise is justified by various aspects: on the one hand, due to greater social acceptance and, on the other hand, due to the potential of such installations. Furthermore, the fact that no land area is taken up is mentioned. Heterogeneous opinions prevail regarding the expansion of onshore wind energy. Critical voices report individual experiences with the loudness of the turbines and the shadow cast. The sympathy towards onshore wind energy plants is reflected mainly in the fact that an expansion of wind energy is demanded and potential is seen in it, thus, the further promotion of the plants is advocated.

The participants generally express the opinion that existing renewable energy plants, such as wind power and biogas, should continue to be promoted. Distance regulations and restrictions for onshore wind energy plants, which make some plants impossible, are questioned and the lack of expansion in southern Germany is criticised. In addition, it is said that photovoltaic systems on roofs should be further expanded. Participants, therefore, actively propose solutions: exemplarily, tendering and approval procedures should be simplified, European Union-wide standards for expansion targets should be agreed upon and new technologies should be adequately promoted.

The analysis facilitates the definition of suitable measures to reach the target set. The challenges for society are manifold and the necessary number and capacity of generating, converting and transmitting plants is large, which is why workshop participants see the energy transition as a joint task.

### 3.2 Application in university teaching

The 100prosim simulation tool was used with students in the Bachelor’s and Master’s degree programmes.

The workshops in the Bachelor’s programmes were conducted in a seminar room at the university. The model is shown to the participants via laptop and beamer and posters are used for the discussion. The students get together in groups of two and go from poster to poster. They discuss the respective topic, jointly determine the value for the parameter and mark it with a dot on the poster. A framework for the selection is given by specifying the scale in the presentation. This is justified in the tool by deposited studies. The students define their target values for different areas: increasing the energy efficiency in the areas of process heating, space heating and electricity use with a sticky dot per group.

The creation of the energy scenario is divided into two course sessions in the module “Introduction to Energy Economics” at the Master's level. The students have the task of creating their own individual scenario between the first and second session. In the second session, the individual scenarios are then combined into several group scenarios and, finally, a joint scenario is created in the plenary session.

Very ambitious expansion goals are set. By contrast, lifestyle restrictions are rarely targeted. However, the more wind and solar energy needed to meet the energy demand, the greater the electrolysis capacity for hydrogen and the corresponding storage volumes must be in these scenarios. An increased use of biogas can reduce the amount of hydrogen needed to compensate for the shortage.

The Bachelor students felt rather overwhelmed by the high complexity of the tool. According to them, they need more time in which to understand the tool more comprehensively. It becomes clear here that it is very important in the three-hour course session to explain the functioning of the tool well in advance and also during the application. The number and the changes between the applications PowerPoint for the presentation, Mentimeter for the queries and the different views of the simulation tool should be reduced to a minimum during an online seminar to allow the participants a better chance to understand.

The Master’s students criticised the superficial application. They would have liked to discuss the results in more detail. It is also noted that the scenario includes unrealistic goals and, therefore, what is realistically feasible should be discussed. In addition, they students criticised that the model does not take into account some points, such as fuel cell mobility and free-field solar thermal energy.

The evaluation of both application shows the high value of the tool in terms of knowledge transfer for participants with little or no prior knowledge. The interactivity of the application was very positively received. The 100prosim tool in combination with the learning method applied increased the motivation for the subject and the satisfaction with the course generally among the Bachelor students.

An important result is that working in small groups increases the activity and participation of all students. Discussions take place in which individual preferences and prior knowledge are exchanged. Additionally, the positive feedback is that the creation of energy scenarios helps students to gain an overview and understand interrelationships better. According to the students, it is also possible to understand the effects of changes in the system. The application helps them be able to assess expansion targets.

3.3 Use case policy advice

The ever higher targets for reducing greenhouse gas emissions at both a European and federal level require concrete action at the local level. The "planetary boundaries" in spatial planning and development have to be taken into account. One of them is the change of land use – for example, for fields, settlements or photovoltaic plants and bioenergy (Desing et al., 2019). Regional planning in Germany plays a crucial role in the planning and expansion of renewable energies on-site and the implementation of a federal energy policy (Wirth and Leibenath, 2017). The area of tension is between the economic incentives at the national level and the spatial planning options that are more local and regional (Klagge and Arbach, 2013). Land and use competition (e.g. in the designation of areas for wind energy plants or open-space photovoltaic plants) plays a decisive role in this context and poses challenges for regional planning.

The registered association "Erneuerbare Energie-Szenarien e.V." carried out about 30 workshops directed at processes of regional development, organised by or with the participation of political bodies, local or state administrations and energy agencies. Five of these workshops in Lower Saxony, Germany, gave concrete impulses and suggestions for later spatial planning processes.

Different points of view could be introduced and tested immediately in workshops with experts from the field of political consultancy using 100prosim. The direct experience of the effects on the energy balance made it possible to develop a common view within a short period of time. The holistic view of the energy system makes it clear that the 100 % target places much higher demands on politics and society than is generally realised. In addition to the rate of expansion, this concerns, first and foremost, the idea of sufficiency, i.e. a reduction in energy consumption over and above increases in efficiency. Fields of action can be found, for example, in the size of living space or individual mobility.

## 4. Conclusion

The workshops have shown that the methodology is very well-suited to understand the energy system of the future and its challenges. The limited availability of land for energy production is made clear. The visualisation of the abstract topic through the graphics of the software also conveys to the participants, inter alia, the limits of energy-saving possibilities through efficiency and the important role of sufficiency in the context of the energy transition. Stakeholders expressed different opinions in the workshops, but these cannot be attributed to specific groups for the time being, but are spread across all workshops. Advocacy for or criticism of individual technologies are mostly justified by personal experience.

The use of the 100prosim simulation tool ensures that the future scenarios are created within the limits of what is technically possible on the space available. Source information is available for each parameter, therefore, this tool is highly trusted. In principle, the energy transition is often supported, but limits, obstacles and risks are also strongly emphasised in some cases. However, the tool cannot be understood and operated without guidance due to the complexity of the energy system. In addition, the database must be constantly updated due to technical innovations and the interrelationships of the dynamic energy sector.

The experience with the tool and the workshops shows that it is also possible to conduct the workshops both online and offline. The method has to be slightly adapted and materials or techniques prepared accordingly. But is has to be noted that to achieve a more effective discussion, it is better to conduct the workshops offline in a 'real' workshop setting.

The concepts developed for courses at a Bachelor's and Master's level are suitable for increasing the understanding of the energy system as a whole. By reflecting on and discussing different areas, it is also possible to experience that the energy transition is not a purely technical project, but must be accepted and implemented politically and socially.

It also became apparent that there are still gaps in the knowledge in some areas. The discussions about hydrogen was one such example. Many people were not yet aware of hydrogen as a long-term energy source and its use in industrial processes. Many were also not aware of the increased energy input for the production of hydrogen. Additionally, people also need more information about the energy transition in the sectors of transport or heating. Neutral, independent and target group-specific information is urgently needed.

In order to get closer to the participants and their own possibilities for action, the authors suggest that future projects look at expansion targets and energy consumption at the district or municipal level. Accordingly, a new version of the tool is being developed and not only the energy transition in Germany or a federal state, such as Lower Saxony, can be discussed, but also on a smaller scale regional level. This avoids thinking of “the others” first when it comes to the necessary expansion or behavioural changes. What needs to be done in one’s own municipality or district becomes more concrete.

## 5. References


Agentur für Erneuerbare Energien, 2021. Zustimmung für den Ausbau der Erneuerbaren Energien bleibt hoch. https://unendlich-viel-energie.de/themen/akzeptanz-erneuerbarer/akzeptanz-umfrage/zustimmung-fuer-den-ausbau-der-erneuerbaren-energien-bleibt-hoch (accessed 25 August 2022).

Bundesnetzagentur, 2019. Netzentwicklungsplan Strom 2030, 2nd draft, https://www.netzentwicklungsplan.de/de/netzentwicklungsplaene/netzentwicklungsplan-2030-2019 (accessed 1 July 2022).

Bundesverband Windenergie e.V. /Fraunhofer IWES, 2011. Potenzial der Windenergienutzung an Land. Long version. ISBN: 978 3 94257993.

Desing, H., Widmer, R., Beloin-Saint-Pierre, D., Hischier, R., Wäger, P., 2019. Powering a sustainable and circular economy, an engineering approach to estimating renewable energy potentials within earth system boundaries. Energies 12(24), 4723; https://doi.org/10.3390/en12244723.

Deutsche Energie-Agentur GmbH (Hrsg.) (dena, 2021). „dena-Leitstudie Aufbruch Klimaneutralität“ www.dena.de/newsroom/publikationsdetailansicht/pub/abschlussbericht-dena-leitstudie-aufbruch-klimaneutralitaet/ (accessed 1 July 2022).

Deutsche Windguard, 2017. Status des Offshore Windenergie-Ausbaus in Deutschland; Varel, https://www.wind-energie.de/sites/default/files/attachments/page/offshore/20180117-factsheet-status-offshore-windenergieausbau-2017.pdf (accessed 1 July 2022).

Ernst, A., 2017. Beteiligungsprozesse im Zuge der Energiewende: Zwischen Anspruch und Wirklichkeit [Participation Processes within the German Energy Transition (Energiewende)]. ET. Energiewirtschaftliche Tagesfragen.

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, 2016. Klimaschutzplan 2050. Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung. https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_bf.pdf (accessed 25 August 2022).

Fraune C., Knodt M., Gölz S., Langer, K., 2019. Einleitung: Akzeptanz und politische Partizipation – Herausforderungen und Chancen für die Energiewende, in: Fraune, C., Knodt, M., Gölz, S., Langer, K. (Eds.), Akzeptanz und politische Partizipation in der Energietransformation. Springer VS, Wiesbaden, pp. 1-26.

Fördergesellschaft Windenergie und andere Erneuerbare Energien FGW e. V., 2015. Veröffentlichung der EEG-Referenzerträge. http://www.wind-fgw.de/eeg_referenzertrag.htm (accessed 1 May 2022).

Fraunhofer IWES/IBP, 2017. Wärmewende 2030. Schlüsseltechnologien zur Erreichung der mittel- und langfristigen Klimaschutzziele im Gebäudesektor. Studie im Auftrag von Agora Energiewende.

Fraunhofer-Institut für Solare Energiesysteme, 2020. Wege zu einem klimaneutralen Energiesystem, https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Fraunhofer-ISE-Studie-Wege-zu-einem-klimaneutralen-Energiesystem.pdf (accessed 1 May 2022).

Fraunhofer ISE, 2011. Wärmepumpen Effizienz - Messtechnische Untersuchung von Wärmepumpenanlagen zur Analyse und Bewertung der Effizienz im realen Betrieb. Kurzfassung. http://wp-effizienz.ise.fraunhofer.de/download/wp_effizienz_endbericht_kurzfassung.pdfrgieausbau-2017.pdf (accessed 1 May 2022).

Gmelin, T.C., Hütting, G., Lehmann, O., 2008. Zusammenfassende Darstellung der Effizienzpotenziale bei Flugzeugen unter besonderer Berücksichtigung der aktuellen Triebwerkstechnik sowie der absehbaren mittelfristigen Entwicklungen. Im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit. http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Verkehr/workshop_effizienz_flugverk_studie.pdf (accessed 1 May 2022).

Hübner, G., Pohl, J., Warode, J., Gotchev, B., Ohlhorst, D., Krug, M., Salecki, S., Peters, W., 2020. Akzeptanzfördernde Faktoren erneuerbarer Energien. Bundesamt für Naturschutz. 10.19217/skr551. https://www.bfn.de/sites/default/files/BfN/service/Dokumente/skripten/skript551.pdf (accessed 8 September 2022).

Johann-Heinrich-von-Thünen Institut, 2012. Thünen-Report 17 – Berechnung von gas- und partikelförmigen Emissionen aus der deutschen Landwirtschaft 1990 – 2012. http://www.ti.bund.de/media/publikationen/thuenen-report/Thuenen-Report_17.pdf (accessed 1 May 2022).

Klagge, B., Arbach, C., 2013. Governance-Prozesse für erneuerbare Energien Hannover. = Arbeitsberichte der ARL 5. URN: http://nbn-resolving.de/urn:nbn:de:0156-37935.

Kuckartz, U. 2016. Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung, Beltz Verlagsgruppe, 69 469 Weinheim. ISBN: 9783779943860.

Marktstammdatenregister, 2022. https://www.marktstammdatenregister.de/MaStR (accessed 1 May 2022).

Meinert, S., 2004. Denken in Alternativen – Scenario-Workshops als didaktischer Ansatz in der Politischen Bildung, in: Gust, M., Seebacher, U.G. (Eds.), Innovative Workshop-Konzepte, Erfolgsrezepte für Unternehmer, Manager und Trainer. USP Publishing, pp. 239-255.

Minx, E. & Böhlke, E., 2006. Denken in alternativen Zukünften. 61. 14-22.

Niedersächsisches Ministerium für Umwelt und Klimaschutz, 2015. Stellungnahmen und Anmerkungen der Mitglieder des Runden Tisches zum Szenario 1 des Gutachtens Energieszenarien 2050. http://www.umwelt.niedersachsen.de/energie/rundertisch/dokumente/stellungnahmen135092.html (accessed 1 July 2022).

Niepelt, R., 2021. Woher kommt der grüne Wasserstoff? In: Themen 202. Mit Wasserstoff zur Klimaneutralität – von der Forschung in die Anwendung, Forschungsverbund Erneuerbare Energien (FVEE), Berlin, ISSN 0939-7582.

Prognos, Öko-Institut, Wuppertal-Institut, 2021. Klimaneutrales Deutschland 2045. Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann. Zusammenfassung im Auftrag von Stiftung Klimaneutralität, Agora Energiewende und Agora Verkehrswende. Online: https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_04_KNDE45/A-EW_209_KNDE2045_Zusammenfassung_DE_WEB.pdf. (accessed 8 September 2022).

Regionalstatistik, 2020. Statische Ämter des Bundes und der Länder: Regionaldatenbank Deutschland, Online Angebot Genesis, https://www.regionalstatistik.de/genesis/online/logon (accessed 2 July 2022).

Renn, O., 2015. Akzeptanz und Energiewende: Bürgerbeteiligung als Voraussetzung für gelingende Transformationsprozesse. JCSW, 56, 133-154.

Ried, J., Braun, M., Dabrock, P., 2017. Energiewende: Alles eine Frage der Partizipation? Governance-Herausforderungen zwischen Zentralität und Dezentralität. ZFE. 41(3), 203-212.

Robinson, J.B., 1982. Energy backcasting. A proposed method of policy analysis, Energy Policy 10(4), 337-344.

ISSN 0301-4215, https://doi.org/10.1016/0301-4215(82)90048-9.

Rohe, S., Chlebna C., 2021. „Wir haben die Vorgaben seit Jahren erfüllt!“ – Regionale Entscheidungsträger und die Windenergie. Energiewirtsch. Tagesfr. 71(9).

Schmidt-Scheele R., Bauknecht, D., Poganietz W.-R., Seebach, D., Timpe, C., Weimer-Jehle, W., Weiss, A.,2019. Leitmotive und Storylines der Energiewende – Wie Stakeholder-Positionen systematisch in Transformationspfade integriert werden können, TATuP. TATuP. 28(3), 27-33.

Schreiber, M., 2012. Bewertungskriterien einer optimierten Energieversorgung regionaler Verbünde mit hohen Anteilen erneuerbarer Erzeugung. Z. Energiewirtsch. 36, 257-265. https://doi.org/10.1007/s12398-012-0090-4

Siemens, 2020. Whitepaper Wasserstoffinfrastruktur – tragende Säule der Energiewende. https://www.get-h2.de/wp-content/uploads/200915-whitepaper-h2-infrastruktur-DE.pdf (accessed 28 August 2022).

Wassermann, S., Niederberger, M., 2015. Methoden der Experten- und Stakeholdereinbindung in der sozialwissenschaftlichen Forschung. Springer Fachmedien, Wiesbaden.

Umweltbundesamt, 2014. Treibhausgasneutrales Deutschland im Jahr 2050. http://www.umweltbundesamt.de/publikationen/treibhausgasneutrales-deutschland-im-jahr-2050-0 (accessed 28 August 2022).

Weyberg, S., 2021. Fläche: Die Währung der Zukunft. Vortrag auf den Niedersächsischen Energietagen in Hannover am 203 November 2021. https://www.efzn.de/fileadmin/documents/Niedersaechsische_Energietage/Vortr%C3%A4ge/2021/NET2021_Weyberg.pdf (accessed 6 July 2022).

Wirth, P., Leibenath, M., 2017. The role of regional planning in dealing with wind power conflicts in Germany and prospects for spatial research. Spat Res. Plan. 75(4), 389-398. doi: 10.1007/s13147-016-0436-1.

Wuppertal Institut, 2020. $CO_2$-neutral bis 2035: Eckpunkte eines deutschen Beitrags zur Einhaltung der 1,5-°C-Grenze. Bericht. Wuppertal. https://epub.wupperinst.org/frontdoor/deliver/index/docId/7606/file/7606_CO2-neutral_2035.pdf (accessed 28 August 2022).