



# DELPHI ENERGY FUTURE 2040

Delphi-study on the future of energy systems  
in Germany, Europe and the world by the year 2040



# **DELPHI ENERGY FUTURE 2040**

Study report

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## INTRODUCTION

Energy systems worldwide are undergoing a phase of fundamental transformation. Policymakers, businesses and consumers are wondering: How will electricity and heat be supplied in the future and how will mobility needs be met? What are the key drivers, actors and dynamics that shape future developments? How can we design strategic solutions for problems that will only emerge as we progress through the next three decades? And how can we anticipate and identify opportunities we are not even aware of today?

The many studies on this topic have not provided us – the BDEW German Association of Energy and Water Industries, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and PricewaterhouseCoopers (PwC) – with full answers: as sectoral analyses they tend to view individual industries, states or resources in isolation. In our “Delphi Energy Future 2040” study, we chose a methodologically different approach to gain insights into what the global energy future in 2040 and beyond might look like.

We want to broaden a debate that so far has mostly focused on technical and policy aspects and examine the interdependencies between different areas of society. Aiming to break down the national parameters that, particularly in Germany, shape the current discussion on adapting or redesigning energy systems, we venture a comprehensive look at future energy systems from a global point of view. To this end, we conducted a worldwide Delphi survey with more than 350 energy experts from 40 countries and all areas of society contributing their knowledge and experience.

Based on these results, we developed possible future story lines that provide food for thought and constitute more than a mere trend extrapolation. With these visions of the future we intend to give impetus to political debate and to help answer the question what steps policymakers, managers and consumers can take today to create a secure, sustainable and economically viable future energy system together.

The results of this extraordinary study offer exciting insights into a worldwide discussion that evolves around the core question posed in the “Delphi Energy Future 2040”: “What future awaits the energy systems in Germany, Europe and the world in the year 2040 and beyond?”

With this study report we wish to offer food for thought and inspiration to visualise the future of complex energy systems as they might take shape tomorrow.



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## THINKING IN ALTERNATIVES – HOW DOES THE DELPHI METHOD WORK?

The Delphi method is a tool of strategic foresight. In complex thematic areas shaped by a high degree of uncertainty the Delphi method is used to provide orientation. Especially where long-term developments are concerned, a Delphi can help to identify potential opportunities and risks and serve as an early warning system for decision-makers in politics and business. The Delphi method was developed on the assumption that data-based forecasts derived as a mere extrapolation of statistical trends are insufficient to adequately assess long-term future developments. The aim of a Delphi study is rather to describe possible crucial future developments based on the personal assessment and experience of experts from various spheres. Offering fresh perspectives and guidance, the method assists decision-makers in actively shaping the future.

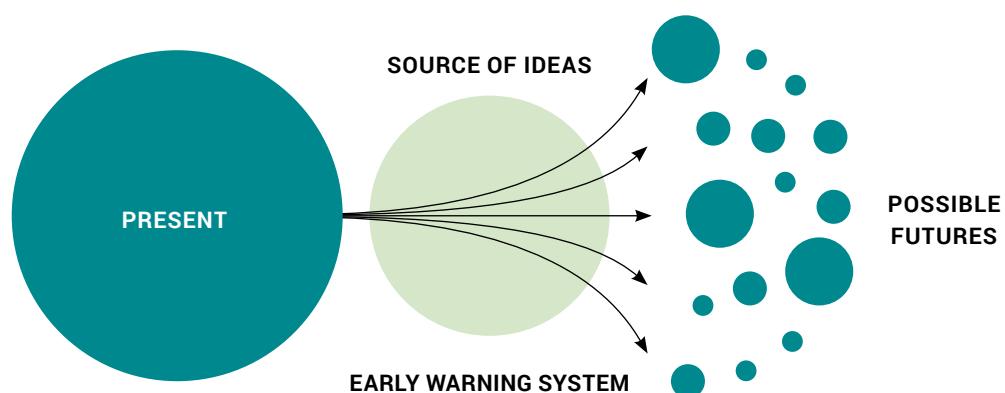
A Delphi study consists of certain key elements: Based on interviews with specialists, theses on potential future developments are formulated and submitted to a large panel of experts. This large expert panel evaluates and comments on the theses in at least two rounds. In the second round the answers and comments of all other experts are made available to all participants, who are thus able to further develop their own opinion based on their co-participants' input. Thus, a structured group communication process emerges. The surveys' anonymous nature ensures that the process is not influenced by the seniority, prominence or dominance of individual participants – as can sometimes be observed in face-to-face debates typically held as part of workshops or conferences.

Given that they connect specialists from different areas of expertise, Delphi surveys can combine different perspectives and identify potential trend breaks. As dissenting individual opinions are shown, too, scenarios that are not supported by the majority of respondents can also be taken into account.

Our "Delphi Energy Future 2040" study also benefits from these advantages. Examining its central question, "what future awaits the energy system in Germany, Europe and the world in the year 2040 and beyond?", the study focuses on fundamental future changes and transformations in the energy sector worldwide.

Starting in late 2014, we conducted in-depth interviews of up to several hours with more than 80 distinguished national and international experts from the energy sector as well as with specialists from the fields of politics, business, science and social organisations. Based on their expectations, we developed bold theses describing different aspects of a potential energy future as it might look like in the year 2040.

These theses were then submitted to a panel of more than 350 international experts, who evaluated them in a written survey, rating each thesis in terms of its overall likelihood, timescale and regional impact. After completing the first survey round, the experts were asked to re-assess all theses in light of the first round's results. Where their opinion varied from the median response, the experts were asked to provide reasons for their thesis evaluation. Based on this second survey round, we developed brief future story lines describing various perspectives for the period to 2040. These reflect the common interpretation of the survey results by the project partners BDEW, GIZ and PwC. ■



## HOW TO READ THE STUDY RESULTS

The heart of our “Delphi Energy Future 2040” is the catalogue of 56 theses on how energy systems might evolve in the future. These theses were developed out of interviews with more than 80 experts from different disciplines and were then evaluated by more than 350 international energy experts. They were asked three different types of questions to assess the theses:

- For most theses, the experts were first asked to indicate how likely they thought it was that the future scenario in question would actually take place. If the respondents believed that the development was “likely” or “certain” to happen, they were then either asked when they would expect this to take place – before 2025, by 2040 or after 2040. Alternatively, they were asked where they thought this would take place, that is which region of the world would be affected. In this case the participants could indicate more than one region.
- The survey also included so-called “versus” theses, where opposing trends were described by way of presenting a thesis and a corresponding antithesis. In this case the experts were asked to indicate which of the two trends they would consider more likely to take place.
- In a third case, the respondents were asked in an open question to list the “game changer” technologies they believed would be most important for the energy future.

The detailed results for each individual thesis are listed in this study report from page 14 onwards. The explanatory notes interpret the pictured graphs for each thesis and show interesting parallels and contradictions with other theses. This allows readers to form their own interpretation of the results and to draw their own conclusions.

Also, on pages 6 to 13, some exemplary story lines are outlined that describe the future as it might take shape based on the results of the Delphi. These possible paths of development reflect the interpretation of the results by BDEW, GIZ and PwC. They are not meant as mutually exclusive visions of the future but, on the contrary, intended to instruct and encourage readers to develop their own interpretations. ■

# POSSIBLE FUTURES – FINDINGS FROM THE DELPHI ENERGY FUTURE 2040

How are the production, distribution and consumption of electricity and heat going to change? What will the future of mobility look like? How will developments in society change the way we use energy – and how will new energy technologies impact society?

The following future story lines depict selected interpretations of the Delphi results by the three project partners. They describe possible drivers, actors and dynamics in the energy sector worldwide. These story lines are not mutually exclusive visions of the future but are rather intended to inspire and encourage readers to develop their own answers in light of the evaluation of the theses provided by the experts.



## CLIMATE ACTION GAINS MOMENTUM

The year 2040 sees the largest CO<sub>2</sub>-emitting countries in the world united: a series of ecological disasters, followed by humanitarian crises and political radicalisation in the regions most affected have led industrialised countries to take decisive action and change course. Governments all over the world are promoting the development of sustainable and climate-friendly energy systems powered by wind, sun and water. During times of economic downturns and even full-blown economic crises they keep to their ecological targets – among other reasons because they are increasingly recognising the economic potential of sustainable energy policies, namely low electricity production and infrastructure costs as well as independence from imports.

What is more, governments can act safe in the knowledge that they have their populations' support. Consumers in industrialised countries and emerging economies are exerting pressure. Sustainability is becoming the decisive competitive factor in the markets. Non-sustainable forms of production are considered unethical and are rejected. The carbon emissions that have been generated in manufacturing and transporting products and services are now a standard information indicated on all product labels. For more information, please read theses 6, 7, 24 and 32.

## CHINA AND INDIA ARE CHANGING COURSE

India and China, the two most populated countries in the world, have undergone a fundamental transformation in response to these developments. These Asian heavyweights are not only catching up fast with industrialised countries in economic terms but are in the process of surpassing them or even already have surpassed some of them. Their growing and ever more confident urban middle classes are demanding that their governments adopt an environmentally friendly course of development. City air pollution, a tangible symptom of an outdated model of development, is not only prompting the middle classes to protest. Political calls for decisive action to reduce environmental pollution are also

raised in response to the high costs generated for the Indian and Chinese economies and their healthcare systems. High particulate air pollution, primarily stemming from the combustion of fossil energy sources for the generation of electricity and heat as well as for transport purposes, has become an economic problem.

Given the size and dynamics of the Chinese and Indian markets, their switch is having resounding effects far beyond Asia. Chinese and Indian demand for natural gas as a substitute for coal is driving a global shale gas boom; China itself, but also countries such as Argentina, Algeria or South Africa, have become major producers alongside the USA. China is also becoming the world's largest developer and exporter of sustainable energy solutions: electric mobility has received a massive boost driven by the ambition to make city transport sustainable. Thanks to technological innovation, mostly in the field of battery technology, the distance electric cars can travel on a single charge has been considerably improved. Digital traffic control and the fusing of traffic with urban power supply systems are enabling high efficiency gains.

Energy transitions all over the world have delivered on their promises: countries that have strongly promoted renewable energy sources top the list of the most competitive economies in the year 2040. The renewable energy boom has allowed them to abandon subsidies for fossil energy sources and nuclear power. India and China, which are among those nations that have implemented their own energy transitions, are pursuing active, constructive climate policies – and are the driving forces behind the implementation of a global climate regime imposing binding and ambitious carbon emissions reduction targets. For more information, please read theses 4, 8, 36 and 46. ■

## GLOBAL CLIMATE TREATY IS DELIVERING EFFECTIVE RESULTS

The period until 2040 has marked a turnaround in international climate protection efforts. A global regime aimed at averting another bout of unchecked global warming finally is a reality. Industrialised nations, developing countries and emerging economies, greenhouse gas emitters large and small have agreed binding rules for the protection of the earth's climate, setting national decarbonisation targets and creating mechanisms for the monitoring of governments' compliance with these targets. Major industrialised countries and emerging economies have committed themselves to significantly reduce their emissions of greenhouse gases.

The global nature of this climate deal is preventing environmentally harmful industries from relocating to countries with less strict policies and thereby to benefit from more relaxed rules elsewhere. Carbon leakage, a problem associated with climate policies of limited regional effect, has thus been avoided. Regional pricing schemes for carbon emissions from all sectors of the economy are effectively controlling and limiting climate gas emissions, with various models being applied – tax- and certificate-based as well as trade-based mechanisms. Besides Europe and North America, China is among those pioneering such systems. For more information, please read theses 11 and 12.

## A FUNCTIONING CLIMATE REGIME IS DRIVING INVESTMENT

Steadily falling costs and the superior competitiveness of renewable sources of energy have made it easier for states to agree to a global climate regime without any fear of suffering economic disadvantages. Determined implementation of the agreement and the existence of emission pricing schemes have given another boost to renewables. This further increases their economic momentum. Investment streams are redirected, with enormous sums going into research and development in order to be able to serve the new markets. Return

targets of investors and the aim to produce affordable power are more and more the main factors that drive the promotion of renewables. Economic benefits have trumped over climate protection as the key motive – to the benefit of both. For more information, please read thesis 9.

## TECHNOLOGICAL INNOVATION

Extensive research and changed incentive structures have brought about a new generation of renewable energy technologies that are not only more efficient but also available at lower prices. Photovoltaics, integrated into the facades of buildings, windows or objects, electricity storage and information and communication technologies cause long-term changes to the rules of the energy game. The worldwide promotion of renewables led to additional economies of scale: renewable energy sources operating in conjunction with storage units are now the generation technology with the lowest electricity production costs. For more information, please read thesis 35. ■

## DEMAND FOR FOSSIL ENERGY SOURCES IS DROPPING SHARPLY

With the energy sector having undergone profound political and technological changes, the world in 2040 has come close to achieving a transformation of energy systems all around the globe. Energy generation from fossil energy sources, which used to be the norm, has been replaced in many countries by new, mostly decentralised systems based on renewables. The energy transition is not only limited to the power sector. The heating/cooling and transport sectors have also been transformed. The period until 2040 has seen an unprecedented development: a decoupling of the demand for fossil energy sources from total energy demand. Industrialised countries and emerging economies are using less oil, coal and natural gas despite having doubled their energy demand. For more information, please read theses 5 and 33.

## CAUSES OF THE DECLINE IN DEMAND

The driver behind these developments is a global climate regime under which individual states have agreed to binding and ambitious decarbonisation targets. This political change of course also marks a turning point for the world of finance. Institutional investors have divested their capital from fossil resources and are now funding renewable energy projects and companies – “fossil” and nuclear energy investments come at too high a risk. Especially in Europe, a politically motivated strategic diversification of the energy sector is underway, which further reinforces this development. Russian oil and natural gas have become considerably less important for the European energy sector by 2040.

More importantly, though, the economic competition between renewables and fossil energy sources has produced a clear winner by 2040: wind, solar and hydropower. Oversupply of affordable renewable energy has resulted in electricity increasingly displacing oil and natural gas in many industrial processes as well as in heating and mobility applications. A technological

“tipping point” was reached when electric mobility made its breakthrough with the help of innovative storage systems. Renewables are now bringing mobility even to remote areas whose fuel supply used to be dependent on lengthy and complex fuel transportation. For more information, please read thesis 36.

## THE CONSEQUENCES: PRODUCING COUNTRIES ARE DESTABILISED

Even though the fall in demand has not caught fossil fuel producing countries unprepared, the speed of the transformation has surprised especially those countries whose economies still largely rely on sales of oil and natural gas. A rapid loss in important export and public revenue has plunged them into economic crises compounded by a devaluation of national currencies and soaring inflation, which give rise to unemployment, poverty and social unrest. Prolonged social and political instability is further dampening the prospects of an economic recovery. As a result, producing countries are competing fiercely for market shares in an ever-smaller global market for fossil energy sources.

The geopolitical balance is shifting: driven by a rapid expansion of renewable energy infrastructure, new raw materials have become scarce, among them silver, copper and rare earth elements. Individual states and multilateral cooperation initiatives that have been quick to secure resource supply agreements have an important advantage. The energy transition has delivered new opportunities for many. But for others it has brought turmoil, economic risks and dangerous uncertainties. For more information, please read theses 16 and 21. ■

## AFRICA: TECHNOLOGY ENABLES IMPORT-INDEPENDENCE

For many developing countries the transition to renewables in the period to 2040 has not represented a move to another system as much as an opportunity allowing them to build a decentralised, cost-effective and secure supply system in the first place. This is the case for many countries in sub-Saharan Africa, for example, where electricity supply systems used to be characterised by low electrification rates, few centralised power stations, fragmented infrastructure and network overload.

Energy systems in 2040, by contrast, are decentralised systems based on renewable energy sources and storage that allow for the creation of "energy islands" operating mostly independent of centralised interconnected systems. Thanks to advances in photovoltaics and storage technology, electricity can now be generated at prices not even the most efficient conventional power stations can compete with. Decentralised forms of renewable energy generation deliver the largest benefits where existing energy infrastructure has been only rudimentary as they do not require complex transmission and distribution networks. Particularly sub-Saharan developing countries, where existing interconnected systems are weak and not extensive, profit from this development. Installation, maintenance and operation of the new systems no longer require expert skills. All necessary knowledge – even during failures or disturbances – is conveyed in the form of online training.

Easier access to capital, also through microcredit lending, is a central factor. International funds endowed with climate money have aligned their approach to these needs and offer microfinancing opportunities. Crowdfunding platforms close problematic financing gaps by providing both equity and debt.

Not all African countries have been able to fully seize the opportunities by 2040. But: many factors point towards the emergence of decentralised energy systems largely operating on renewable energy sources especially in decentrally organised African states. The idea that nuclear energy could be an alternative, however, has turned out to be an illusion: due to its incalculable associated costs nuclear energy is no longer considered an option; the lengthy and complex decommissioning projects in the industrialised world act as a deterrent, preventing

developing countries from following their example. Even though coal, oil and natural gas continue to be available at low prices in 2040, they hardly endanger the renewables' momentum. These simply have the better arguments on their side now that using local renewable resources is the more economically viable approach and also makes countries independent from energy imports, whereas the creation and maintenance of fossil-based, centralised infrastructures is a highly cost-intensive enterprise. Adopting their own energy transitions tailored to their specific needs does not only allow developing countries to shake off their dependence on energy imports or foreign expertise but also to keep their energy prices stable in the long term. For more information, please read theses 35 and 38.

## BLOOMING LANDSCAPES OR CONTINUED URBANISATION?

Lack of access to energy for lighting, heating, cooling, cooking and communication purposes – which used to be a development obstacle obstructing progress for more than 2 billion people – has been largely overcome by 2040, thanks to decentralised forms of renewable energy. As a result, small businesses and medium-sized commercial and industrial enterprises are being developed, for example in the areas of food processing. Not only can health stations be operated but access to communication and lighting promotes education and training. In Africa, value creation at the local level has made many rural communities and municipalities independent from central government transfers in 2040. Local investment decisions, for example on the construction of roads or community centres, are increasingly taken by the affected communities themselves, which ensures that investment projects meet local needs and requirements. As municipalities thrive economically, this enhances their political status, improving the chances of increased social participation and stabilisation.

In 2040 countries that have opted for decentralised energy systems are holding another trump card: their systems are more resilient to natural disasters or acts of terrorism and thus provide a higher level of supply security. Many – not all – developing countries in Africa are now in a position to develop their own technological solutions to accommodate their needs. This also comprises establishing management and technical know-how as well as creating research and development facilities. For more information, please read theses 23, 29 and 45. ■

## STORAGE IS THE GAME CHANGER

Storage systems are at the centre of all technologies needed to implement the energy transition. Decentrally operated high-performance storage facilities – in other words: batteries – are now affordable, generally available and easy to install, thanks to a rapid decline in prices. In rural Africa they are used in solar containers and help to buffer power output. In the power systems of industrialised countries they provide ancillary services on a broad scale in conjunction with renewables, thereby taking over this role from fossil-fired power stations. The world of electric mobility has been turned upside down: the latest generation of electric cars available in 2040 can travel up to 3,000 kilometres and is recharged using electrical induction. Combustion engines are hardly sold any longer as a result. Instead, used but still powerful batteries from electric vehicles are being sold in a global second-life market, which further pushes down the prices of this technology. The price/ performance dynamics prevailing in the computer chip industry at the start of the century now apply to power storage as well.

Power storage is at the centre of a cluster of mutually reinforcing technologies. It is not only driving a decentralisation of power generation but it also makes new generations of photovoltaics technology more economically viable, thin-film on facades for instance. Information and communication technology, which is needed for interconnection and stabilisation purposes, is another factor reinforcing this development. Electric mobility is the field where the enormous versatility of these new technologies is demonstrated most clearly: electric vehicles in 2040 are a storage facility, buffer, control unit and application all in one. Consistent advances in the development of these technologies have meant that high-performance renewable installations are now sold in retail stores and can be installed by users themselves. This further increases the number of "prosumers" – renewable installations are becoming a matter of lifestyle. The decentralised structures, in turn, have socio-political effects: municipalities and social bottom-up movements are gaining momentum. And not only in the developing world and in emerging economies but very much so in industrialised countries, too.

The immense amounts of data collected for control purposes in decentralised energy systems have attracted IT firms to a market that enables them to use their expertise and play to their strengths. Managing volatile electricity markets requires strong skills in the field of automated data processing: in power markets characterised by high levels of disintegration, continuously metered customers and real-time pricing, smart meters and appliances will assume the role of optimising demand. Energy trade is also expected to be organised along the lines of traditional exchanges, using fully automated trading systems. The threat: as digitalisation spreads, the risk that criminal data breaches and acts of cyberterrorism might unsettle the markets also increases. Creating a regulatory framework that facilitates extensive security measures will be a central regulatory task in order to ensure security of supply and thus remain internationally competitive.

Even economies with very power-intensive industrial sectors are now using large storage units – that is battery power plants – to secure system stability. The vast oversupply of electricity generated from renewables is made available for other uses through sector coupling – an "all-electric society" is thus emerging, which uses renewable power instead of fossil energy sources for heating and mobility purposes, too. Economies that have yet to electrify entire regions are building decentralised energy supply systems based on cellular structures. For more information, please read theses 33, 34, 38, 51, 53, 54 and 55. ■

## NEW REGULATORY REGIMES HAVE EMERGED

When it comes to energy policy, Europe has become one of the key global players in 2040. The European Union has adopted a common foreign energy policy. With its joint strategic infrastructure investment projects and resource supply agreements with third countries, it is an important global competitor for increasingly scarce raw materials, such as silver, copper and rare earth elements, all of which are essential components in the new energy world. Internally, the EU has developed largely harmonised domestic energy policies. These were developed on the basis of a highly efficient super grid interconnecting the member states – a single European “copper plate”. Europe has seized the economic opportunities delivered by its energy transition particularly well.

In the “old” continent, energy generation, grids and energy trading activities are most strictly organised at the supra-regional level. The predominant motive: using cross-border infrastructure to ensure optimum use of shared resources. The “North Sea Grid”, for example, now connects the largest wind energy producers with Norwegian storage facilities and large demand centres on the continent.

The alternative approach, a renationalisation of the energy supply, has not caught on globally. Recognising the fact that systems based on renewables require different structures, closing off national energy systems is not only rejected in Europe but in other parts of the world as well. Instead, new, multilateral governance structures have thus been created not only in Europe but also in the Americas and the ASEAN region, with the aim of optimising the energy supply and creating a framework that fits the new systems. These new structures serve a single purpose: to integrate energy systems across borders and implement joint infrastructure investment projects – especially investments in grid-infrastructure and flexibility options. It were these cooperation initiatives and new governance structures that not only facilitated the implementation of regional pricing schemes for carbon emissions but enabled their emergence in the first place.

A third level of self-governance has emerged below the multinational and super-regional governance levels where prosumers, flexible producers, network operators, data managers and social groups work together to organise their decentralised generation activities, especially in the cities. The hope that decentralised renewable energy systems might strengthen democratic self-governance structures at the local level has not been disappointed. However, this dynamic is most powerful where strong know-how, resources, infrastructure and social structures existed before: in the urban centres of Europe and North America. Here citizens are working to create highly efficient “sustainable cities”, with populations sharply reducing their individual mobility needs and satisfying their own energy demand mostly by “prosuming” – assisted by small and flexible power stations – and using smart microgrids in a system of “neighbourhood generation”.

The energy supply systems in Europe and North America, but also in parts of China and Asia, are now organised in cellular structures. Interconnected “islands” of the size of a city or medium-sized region are generating their energy from solar and wind power, assisted by storage units and a minor share of flexible, conventional reserves, with the latter primarily being provided by gas-fired power stations. For more information, please read theses 13, 14, 15, 18, 29, 38 and 39. ■

## THE ECONOMIC EMANCIPATION OF THE ENERGY TRANSITION

In 2040 climate protection and the causal relationship between environmental and social disasters are still a key driver of the energy transition. The existence of an effective international climate protection treaty has been an outcome of this debate. But the energy transition is also beginning to go beyond its original rationale. It is now no longer propelled by climate goals alone but also as a measure of industrial and development policy. Renewable investment projects carried out to build the required infrastructure, such as storage and grids, and decentralised energy generation structures are thus increasingly driven by a wide range of social, technological and economic trends all pointing in the same direction. The commercial and economic arguments are convincing enough to ensure the promotion of renewables even in regions where climate protection alone would not be a sufficient motivator.

The enormous pressure to improve environmental protection exerted by the middle classes in countries like China is one of these trends. So is the aspiration of African and Asian countries to stop their population's migration into the cities by building flexible and reliable decentralised energy supply systems operating for example on a combination of photovoltaics and storage technologies. "Leapfrogging" hopes are driving energy transition initiatives, especially in Africa. Turning to renewables has been the solution for many countries to overcome infrastructure deficits and create resilient decentralised energy supply systems. And not least, in 2040 renewable energy sources operating in conjunction with affordable high-performance storage units have become the most cost-effective way to generate electricity. Large-scale, centralised and highly subsidised generation systems, in contrast, are putting too great a strain on the national budgets of many states, which is why many countries have abandoned fossil technologies for fiscal reasons alone.

States that have strongly promoted renewables are in a far better position in 2040 than a quarter of a century earlier. They are dominating the list of the most competitive economies in the world. Above all because the energy transition has come

to not only mean a switch to more climate-friendly energy but also to energy that is produced at a marginal cost of close to zero. This has reverberating effects impacting entire economic systems: excess electricity is now powering mobility and heating, displacing petroleum in many industrial processes and opening up new chemical applications. In 2040 an "all-electric society" has already become a reality in many countries.

The new renewable economy is not entirely a "brave new world", though. It may be based on a new economic rationale – but it is still an economic rationale. New shortages are produced, with important raw materials such as silver, copper and rare earth elements becoming increasingly scarce as renewables and renewable infrastructures, such as smart grids or storage systems, are promoted and expanded all over the world. Many industrialised countries and emerging economies are therefore competing for strategic commodity partnerships with resource-rich countries – while traditional producers of fossil resources are on the brink of falling into crisis. For more information, please read theses 1, 8, 18, 21, 33, 35 and 45. ■

# EVALUATION OF THE RESULTS

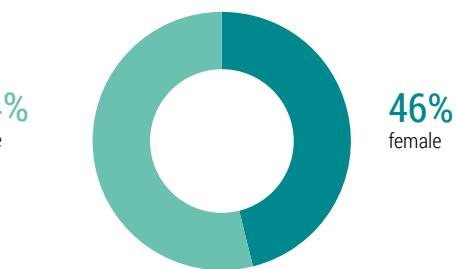
In total more than 350 experts from more than 40 countries participated in the evaluation of the Delphi theses. Each expert was asked twice to provide their assessment. During the second round they had the opportunity to review the anonymised evaluations provided by other participants and revise or specify their own assessment.



## COMPOSITION OF THE DELPHI EXPERT PANEL

Nearly half of all responses were provided by women. Given that one criterion for participation in the survey was that participants be experts in their field or decision-makers, almost all respondents are aged 35 or older, with 53% being more than 50 years of age. The majority of experts are from Germany and Europe but other regions are also represented: Asia, Africa, North, Central and South America, and the Middle East. The majority of experts have a business/association or public sector background. But many respondents also come from the fields of science and civil society. The range of industries represented in the expert panel was also very broad: other than energy policy specialists and experts from all stages of the energy supply chain, which were the fields of expertise most frequently stated, the expert panel also included decision-makers from the IT sector, the chemical industry, the financial services industry, urban planning and the media.

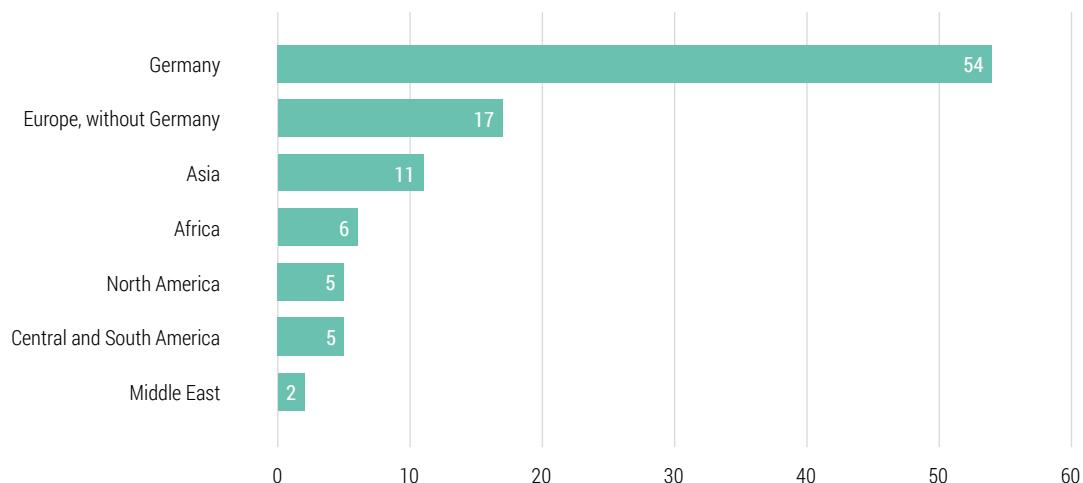
### SEX (IN %)



### SECTORS (IN %)



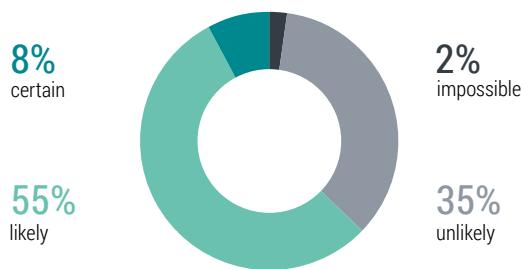
### REGIONS (IN %)



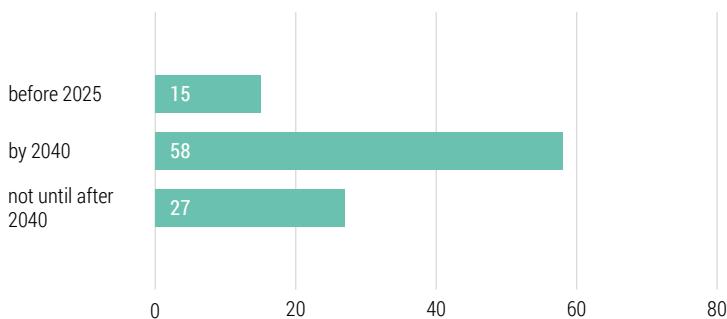
## THESIS 1

**By 2040 developing countries and emerging economies will have abandoned subsidies for fossil energy sources and nuclear power in view of the significant strain on national budgets.**

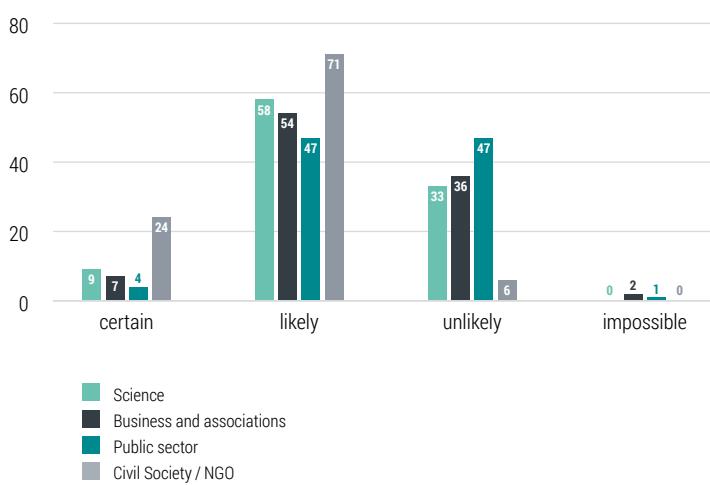
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## EMERGING ECONOMIES TO MAKE THE SWITCH

A majority of the experts surveyed believe that developing countries and emerging economies will have cut subsidies for fossil energy sources and nuclear power on a broad scale by 2040 – for both macroeconomic and fiscal reasons. Civil society and NGO experts have a significantly more optimistic view on this than public sector respondents. German experts are far more sceptical than non-German experts.

## RENEWABLE ENERGY SEEN AS A REAL ALTERNATIVE

This evaluation correlates with the assessment that states which have promoted renewable energy sources will be among the most successful economies in 2040 (thesis 18). Macroeconomic benefits and independence from fossil fuel imports are seen to become the key factors driving the trend to build sustainable energy systems (thesis 9). Even more so as experts expect renewables-plus-storage to be the generation technology with the lowest electricity production costs worldwide (thesis 35) – which would make renewable energy a real alternative, also for developing countries (thesis 45).

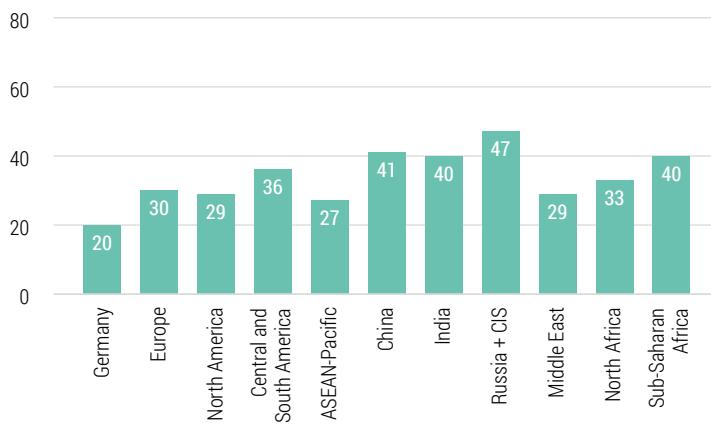
## THESIS 2

**By 2040 many governments will have notably scaled down their ecological targets as a result of a series of economic crises: climate protection will be of secondary importance, with growth and employment issues being the first priority.**

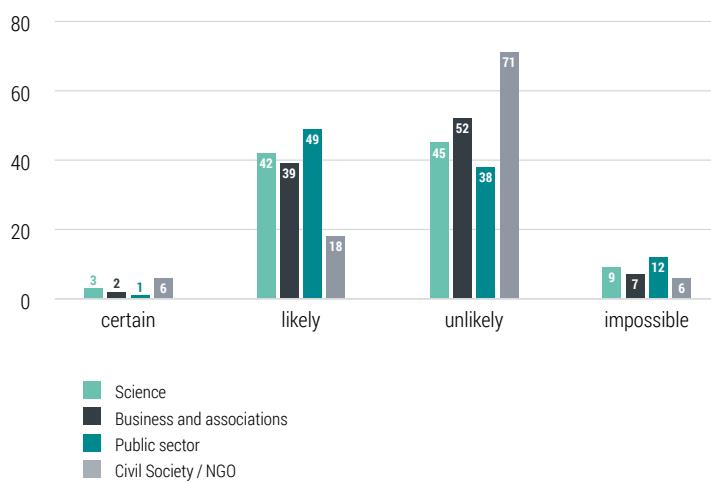
### WILL THIS THESIS ACTUALLY TAKE PLACE?



### WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



### HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



### CLIMATE PROTECTION DESPITE ECONOMIC CRISES

More than half of all experts surveyed believe that climate protection will remain a priority of many countries, even in times of slow economic growth – especially in Europe, North America and the ASEAN-Pacific region. Another large group, however, is convinced of the opposite. It is seen as realistic for Russia, Africa, China and India in particular that these regions would prioritize crisis management. Civil society experts are most convinced that the momentum for climate protection as a main driver of policy decisions will be strong enough to also prevail in times of economic crises.

### COUNTRIES ARE RETHINKING THEIR POSITIONS

The belief that climate protection will continue to be a primary goal even in economically challenging times is supported by the fact that the majority of respondents expects a global climate protection regime to be in operation by 2040 (thesis 11). What is more, the large majority of respondents thinks that a series of ecological disasters will have led countries to fundamentally rethink their positions (thesis 7). A large majority also thinks that the influence of the middle classes will be a significant factor that will lead to more climate and environmentally friendly policies (thesis 8).

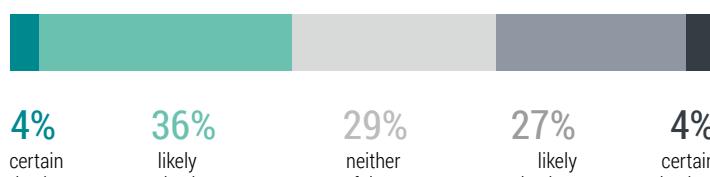
## THESIS 3

**A: By 2040 the prices of fossil energy sources will be at a low level following a prolonged period of oversupply.**

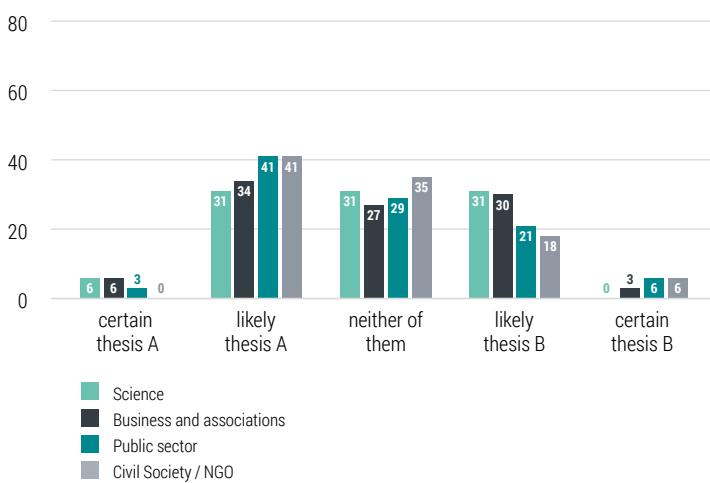
VERSUS

**B: By 2040 the prices of fossil energy sources will have risen drastically in response to increasing scarcity.**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## UNCERTAINTY OVER FUEL PRICES

The responses to our survey do not provide a clear picture when it comes to the long-term development of the prices of fossil energy sources. Almost a third of respondents felt incapable of making a clear assessment or do not see a clear-cut trend. No notable differences in responses can be observed between the individual sectors.

## AN ENERGY TRANSITION THAT IS INDEPENDENT OF PRICE TRENDS

Several other theses were directly or indirectly related to fuel prices. A majority of experts, on the one hand, believes that global energy demand will double in the long term (thesis 5), which should result in rising prices. On the other hand, more experts than not also expect for shale gas exploration and the drive towards renewables to have become global phenomena (theses 4 and 7). The key message: our evaluation of all relevant theses indicates that low commodity prices will not have the potential to slow the trend towards sustainable energy systems, even less so as effective international and regional pricing schemes for carbon emissions are expected to be in place (theses 11 and 12).

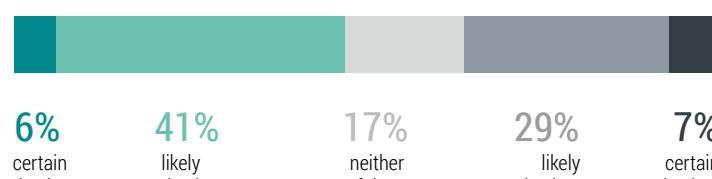
## THESIS 4

**A: By 2040 the “shale gas revolution” will have become a global phenomenon; countries like China, Argentina, Algeria or South Africa will have become major producers alongside the USA.**

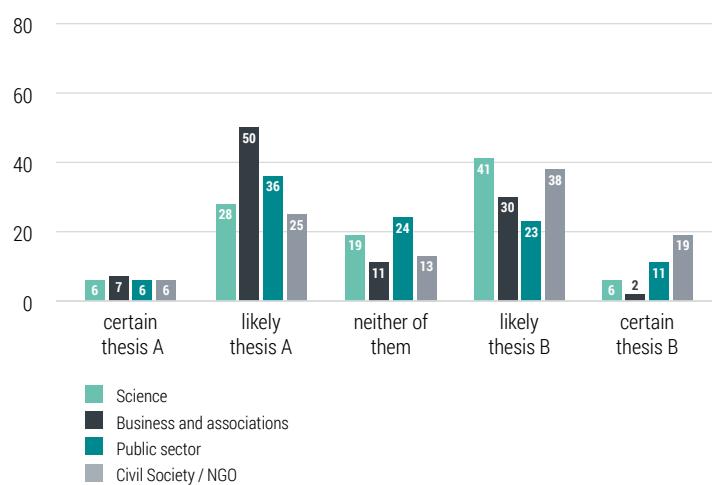
VERSUS

**B: By 2040 the fracking boom, which started in the USA, will already be over and will have had only a minor impact on the development of worldwide energy systems.**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## “SHALE GAS BOOM” TO CONTINUE

The largest group of all experts surveyed considers it likely that many other producing countries will follow the example of the USA and commit themselves to the exploration of shale gas. This expectation is primarily shared by experts from business and the public sector while civil society respondents and scientists largely assume that the fracking boom will run out of steam soon.

## NEGATIVE IMPACT ON TRADITIONAL PRODUCERS

If the “shale gas revolution” were to become a global phenomenon, this should raise the likelihood of the prices of fossil energy sources remaining at a low level (thesis 3). This would have a rather negative effect on traditional producing countries (thesis 20). Among other things, it would also support the expectation that Russia’s importance as a supplier of natural gas for Europe will diminish (thesis 22).

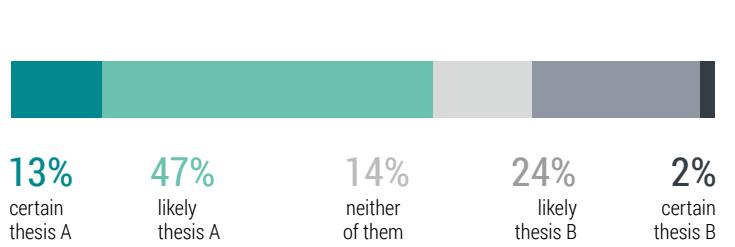
## THESIS 5

**A: By 2040 worldwide economic growth and increased mobility will have caused global energy demand to double compared to 2015.**

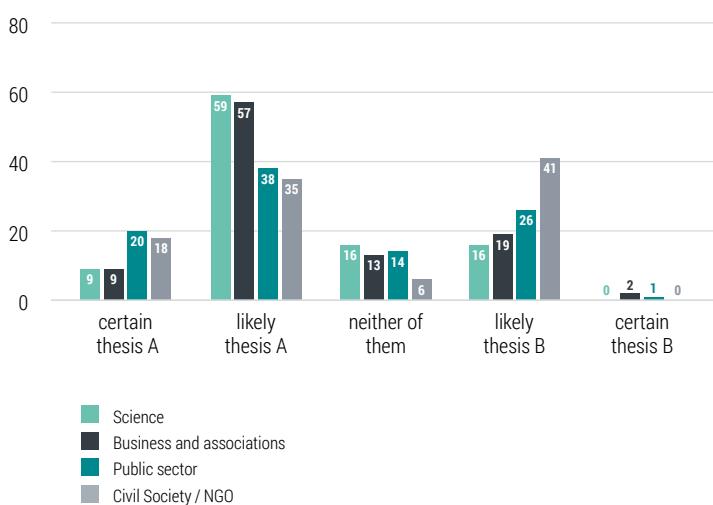
VERSUS

**B: By 2040 global efforts to improve energy efficiency will have stopped the rise in energy consumption.**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## GLOBAL ENERGY DEMAND TO DOUBLE

A clear majority of the experts surveyed believes that it is certain or at least likely that global energy demand will double by 2040. The highest level of acceptance for this thesis is found among scientists, with civil society and NGO experts registering the lowest level of support. Only around one in four experts believes that a worldwide "efficiency revolution" will be able to slow this trend.

## DYNAMIC GROWTH WITH SIDE EFFECTS

The vast share of energy demand growth will take place in developing countries and emerging economies, which might thus increasingly turn to cost-effective renewable solutions that are tailored to their demand (theses 35 and 45). Many experts also see a rapid growth of convenience solutions for private households as a driver of energy demand (thesis 25). If these assessments are taken in conjunction with the expected worldwide promotion of renewables, this may indeed also create problems. A majority of experts believes that the dynamics of energy consumption and energy transition will produce new scarcity – with those raw materials becoming scarce that are still needed in the new world of energy (thesis 21).

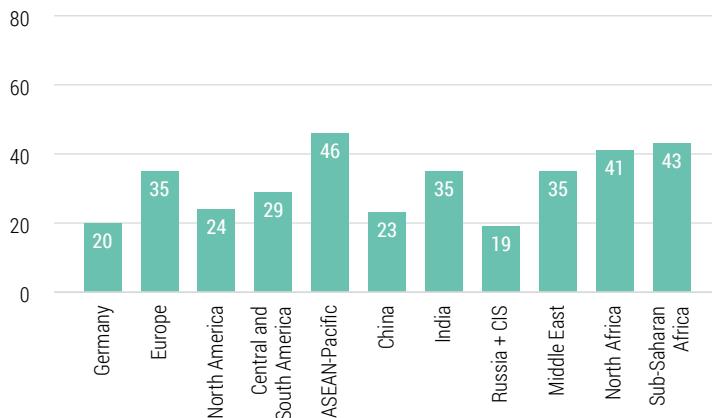
## THESIS 6

**By 2040 a series of humanitarian crises caused by ecological factors, such as the flooding of entire coastal areas and the resettlement of millions of refugees, will have led to the emergence of radical political movements throughout the world.**

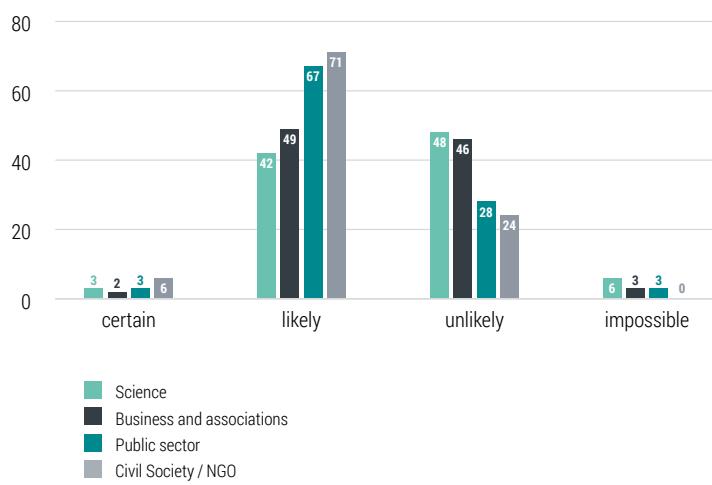
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## HUMANITARIAN CRISES LIKELY

Far more than half of all respondents consider it a realistic scenario that ecological factors may cause humanitarian crises leading to the emergence of radical movements all over the world. Southeast Asia, North Africa and sub-Saharan Africa are among the regions expected to be the most affected. The likelihood of this thesis becoming reality is rated far higher by public and civil society experts than by science and business.

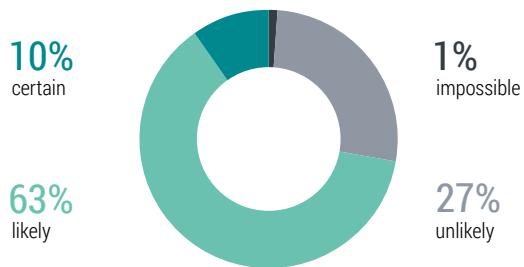
## CLIMATE PROTECTION REMAINS PRIORITY

If calamitous ecological disasters like floods can be attributed to climate change, this will put more pressure on policymakers – climate protection will then continue to be a top political priority (thesis 2). Sustainable energy systems will be promoted by policymakers (thesis 7), as will a global and ambitious climate regime (thesis 11).

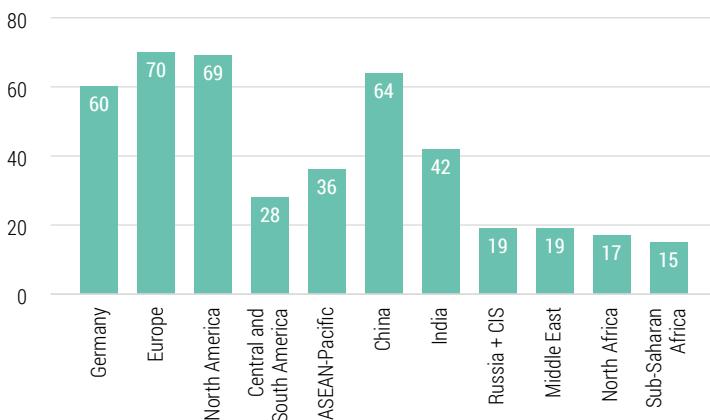
## THESIS 7

**By 2040 the largest CO<sub>2</sub>-emitting countries will have taken decisive action to change course as a result of a series of ecological disasters; sustainable energy systems will have been promoted, economic and energy policies will primarily be aimed at fighting climate change.**

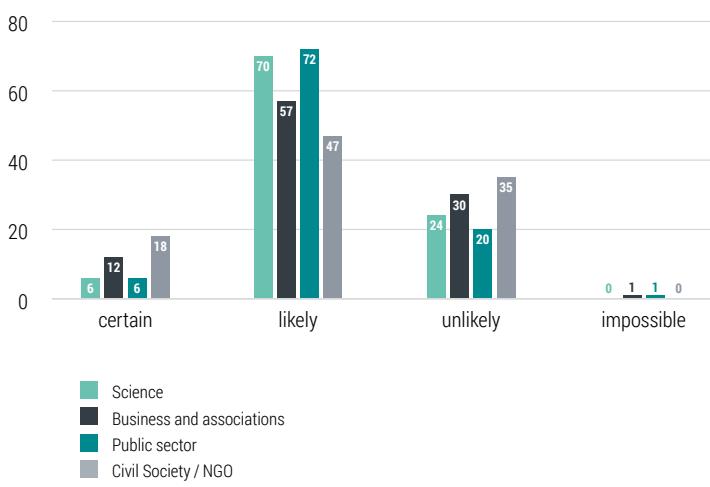
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## KEY COUNTRIES TO CHANGE COURSE

A large majority of experts consider it a likely scenario that (only) a series of climate-induced disasters as presumed for thesis 6 will lead key countries to rethink their position. It is notable that non-German respondents rated the likelihood of this thesis higher than German experts. Political consequences are primarily expected for Europe, North America and China.

## SOCIAL PRESSURE IS GROWING

This scenario fits in with the expectation that the growing middle classes in India and China will exert pressure on policymakers to promote environmental and climate policies (thesis 8). The same trend can also be seen as the driver behind the implementation of an international climate regime and carbon pricing systems in various regions (theses 11 and 12). The social pressure to improve sustainability increases and will become a decisive factor in many countries (theses 24 and 26).

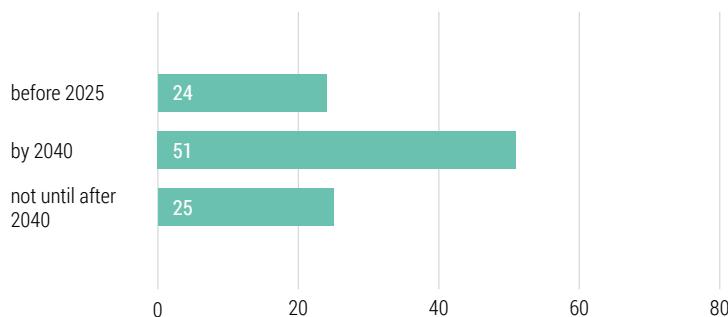
## THESIS 8

**By 2040 the growing middle classes in emerging economies such as China and India will have forced their countries' governments to adopt sustainable energy policies. Policymakers' top priority will be to fight environmental pollution, a rising share of growing energy demand will be met from renewable energy sources.**

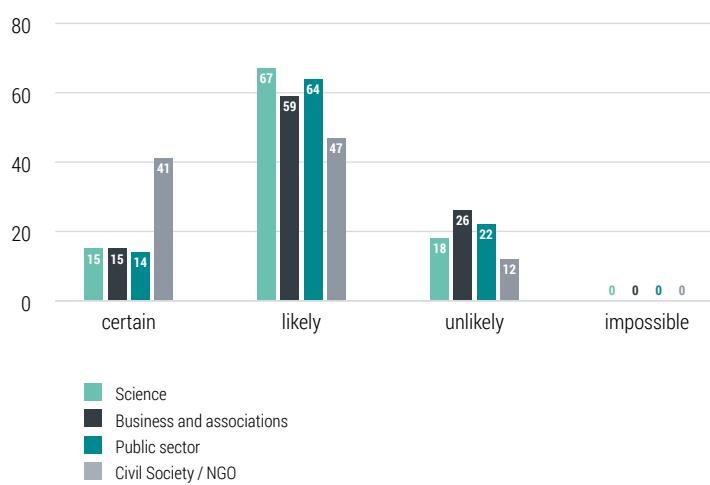
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## CHINA AND INDIA UNDER PRESSURE FROM MIDDLE CLASSES

Most experts believe that social developments and changing values in India and China will be important drivers leading to an energy transition in these large emerging economies, which one in four respondents expects to be the case even before 2040. The different sectors are largely in agreement on this. Civil society experts, however, are the most optimistic.

## FAR-REACHING IMPACT

If emerging economies such as China and India commit themselves to consistent, sustainable energy policies, this can have profound global consequences. It will not only improve the chances of a global climate regime being agreed upon (thesis 11) but will also further China's rise to becoming the world's largest developer of sustainable energy technologies (thesis 46). Countries that were early adopters of these technologies will also benefit given the large new markets that will open up as a result (thesis 18).

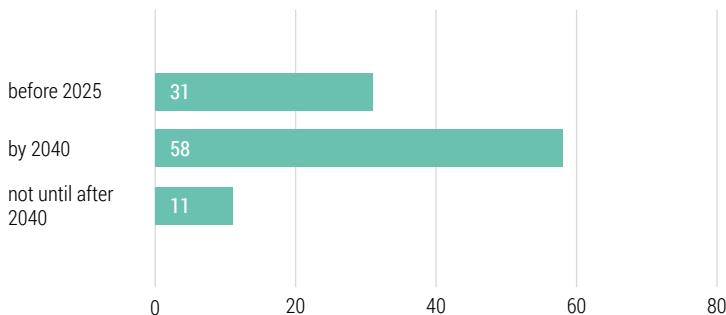
## THESIS 9

**By 2040 economic profitability, investors' interests and independence from imports will be the key considerations driving the trend to build sustainable energy supply systems. Climate protection will no longer be the primary driver and rationale behind this development and will only be of secondary importance.**

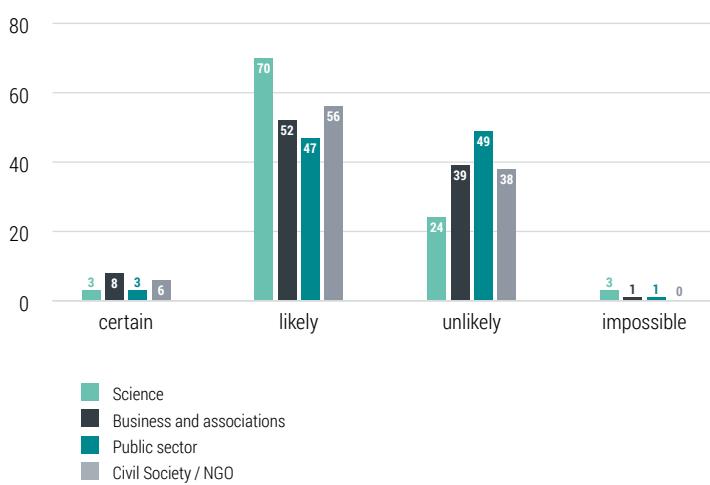
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## ENERGY TRANSITION DRIVEN BY ECONOMIC CONSIDERATIONS

A majority of international experts expects that by 2040 moving towards a sustainable energy system will be a matter of course in many countries for economic reasons alone. Affordable renewable energy will have become an economic factor, as will independence from imports. Many experts see this happening early on. Only respondents from the public sector are slightly more sceptical on average.

## A WIN-WIN SITUATION: CLIMATE PROTECTION AND ECONOMICS

This thesis should be read in conjunction with other theses, for example thesis 7, where a majority assumes that climate protection will continue to be an important rationale. This is a contradiction at first sight only: the climate debate will not lose its importance but it will be supported and furthered by many vital economic arguments. The results for theses 35 and 18 point in the same direction. Renewable energy that is more economically viable will allow emerging economies to abandon subsidies for centralised systems of fossil-fired energy generation (thesis 1).

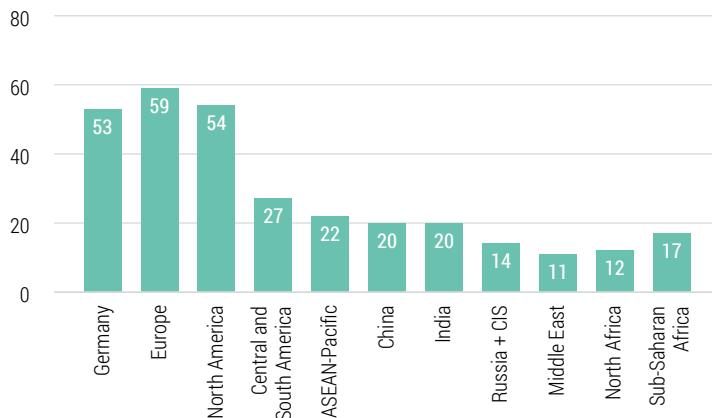
## THESIS 10

**By 2040 women, who will have gained a significantly higher influence on strategic decision-making processes in the energy industry and in the field of energy policy, will have pushed the promotion of sustainable energy use and ensured a closer involvement of a wide range of social stakeholders.**

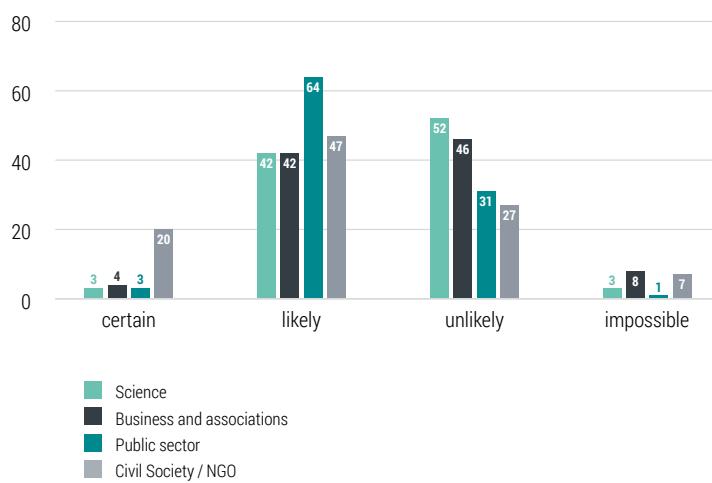
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## THE ROLE OF WOMEN

The experts surveyed are divided on the question what significance an increasing influence of women on decision-making processes in the political, social and business context will have. Slightly more than half of all respondents believe that this would facilitate the move towards sustainable energy systems and ensure a more consistent approach. This development is mainly expected in Germany, Europe and North America. Female experts rate this thesis as far more likely than male experts. Science and private sector experts reject this thesis by a small majority.

## BUILDING SOCIAL PRESSURE

A positive influence of women on the promotion of sustainable energy systems fits in with the expectation that social pressure will build to improve climate protection – not only in Europe and North America but also in emerging economies such as India and China. This is also expressed in the experts' evaluation of theses 8, 24 and 26.

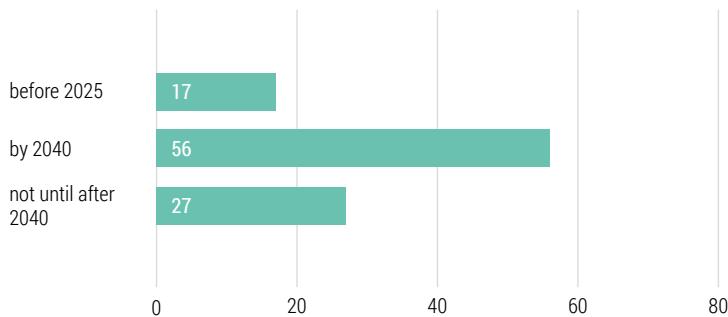
## THESIS 11

# By 2040 a global climate regime with binding and ambitious targets for the reduction of carbon emissions will be in place.

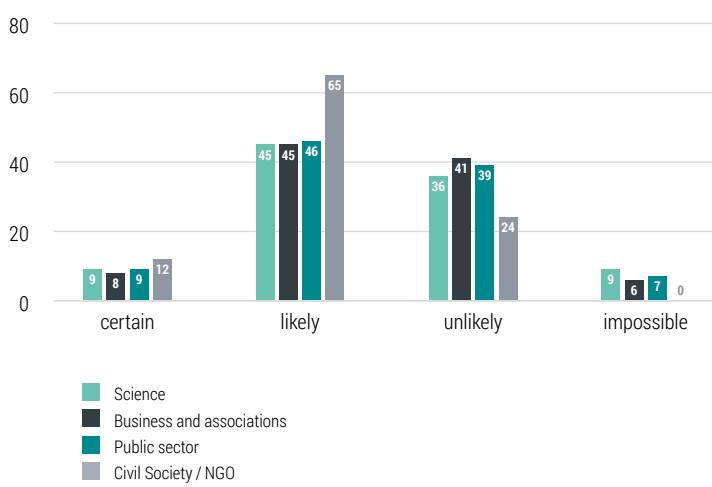
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## A GLOBAL CLIMATE REGIME FROM 2040 FORWARD

The majority of experts is convinced that a global climate regime will be in place by 2040. Yet one in four experts assumes that this will not be achieved until after 2040. Civil society and NGO experts are most convinced that this thesis will become a reality. German respondents tend to be more sceptical about this thesis than non-German experts.

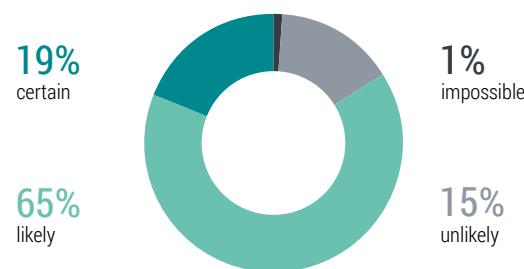
## A DRIVER OF OTHER DEVELOPMENTS

This scenario is an important driver of many developments. As a potential trigger for a new wave of innovation it would increase the chances of thesis 35 coming true. It would also improve the chances of success for renewable energy in developing countries and emerging economies (theses 8 and 45). This thesis is closely related to the implementation of regional carbon pricing schemes (thesis 12).

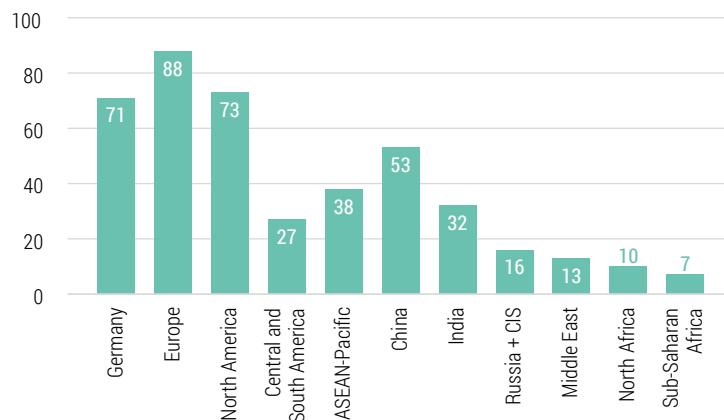
## THESIS 12

**By 2040 an effective regional system for the pricing of carbon emissions (e.g. emissions trading or a carbon tax) will be in operation.**

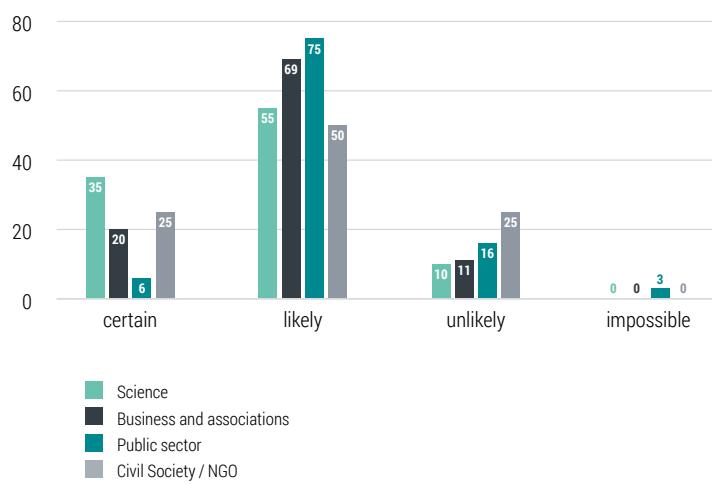
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## REGIONAL CARBON PRICING SYSTEMS IN OPERATION

A very large majority of experts from all sectors considers it at least likely that regional pricing systems for carbon emissions will be in operation by 2040. This is particularly expected to be the case in Europe and North America but also in China. Scientists in particular are highly convinced of this. Only one per cent of experts rules it out in the given time span.

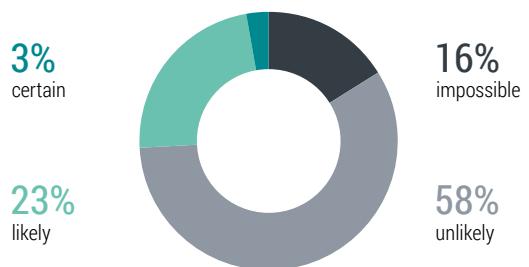
## CARBON PRICES AS A DRIVER OF INNOVATION

Effective regional systems for the pricing of carbon emissions will give a competitive edge to climate-friendly forms of energy generation and create an environment that fosters innovation. This scenario thus supports the expectations for thesis 18 but also affects the rescaling of fossil-fired generation (thesis 39) as well as carbon management technologies (thesis 40).

## THESIS 13

**By 2040 energy supply activities will have been nationalised given that energy security and sovereignty will be the key goals underlying national energy policies; as a result of this, states will also be engaged in energy trading.**

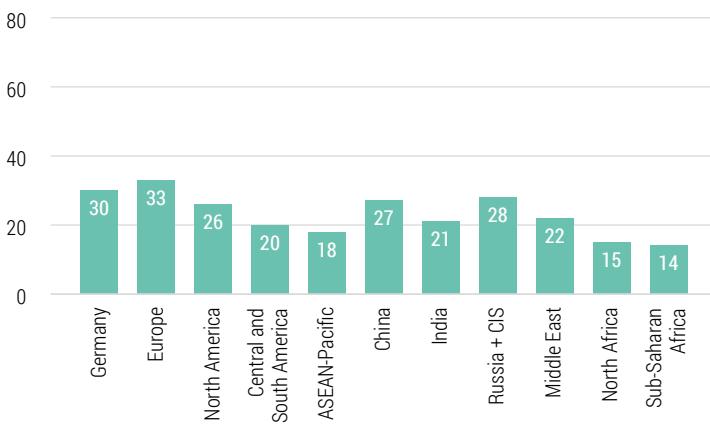
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## NO PROSPECT OF NATIONALISATION

Only few experts believe that a significant number of states will have nationalised their energy supply by 2040 for reasons of energy security. Accordingly, it is not expected that states will engage in energy trading activities, either. This view is shared by experts from all sectors.

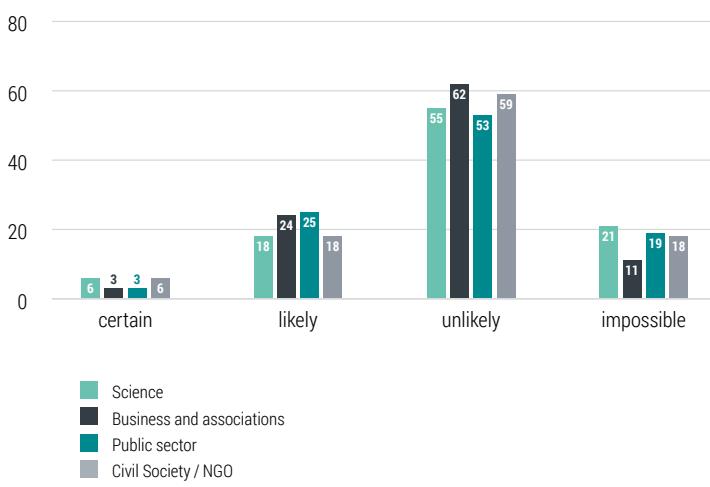
## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## LITTLE ROOM TO WALK ALONE

That this thesis is rejected fits in with the expectations for increased international, supra-regional cooperation in energy matters, an optimum allocation of resources and the financing of required cross-border infrastructure (theses 14 and 15) – all of which leaves little room for national governments to pursue their own, unilateral strategies.

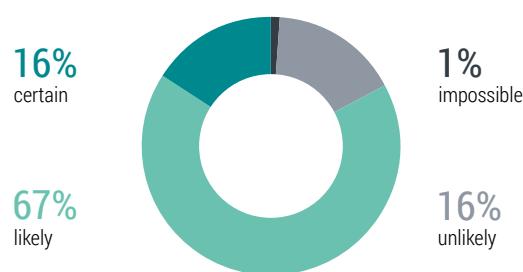
## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



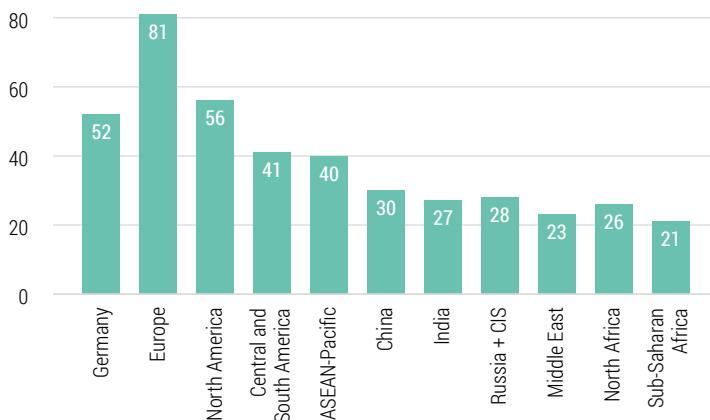
## THESIS 14

**By 2040 new multilateral governance structures will have been created to facilitate the cross-border integration of energy systems and joint infrastructure investments.**

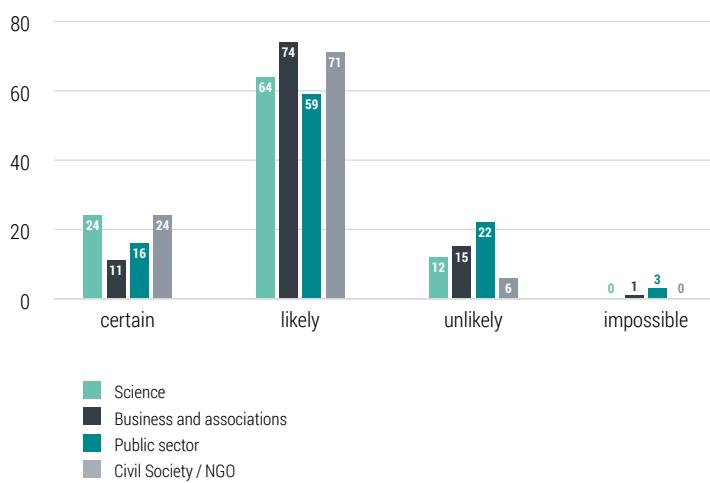
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## NEW MULTILATERAL GOVERNANCE STRUCTURES

A general move towards sustainable energy systems will lead to the development of new governance structures geared towards integrating renewable energy sources in the best way possible – this is the expectation of 83 per cent of experts, who see this particularly for Europe but to a lesser extent also for North, Central and South America as well as for the ASEAN-Pacific region. Experts from civil society and NGOs are nearly in consensus that this will happen.

## INTERNATIONAL COOPERATION TO PLAY A DECISIVE ROLE

Progress, especially progress concerning the governance of the European energy system, is also assumed by experts where they believe in a strong European foreign and domestic energy policy and in the creation of a European super grid (theses 16, 17). The general view is that by 2040 multilateral cooperation will have become a decisive factor for the success of energy transitions, to the detriment of the competences of national governments (thesis 15).

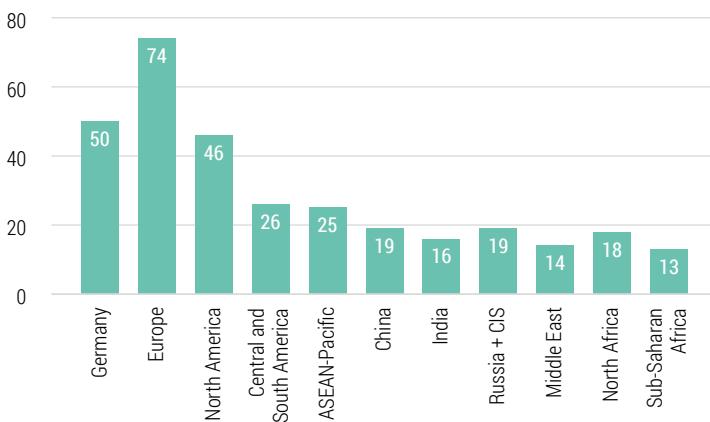
## THESIS 15

**By 2040 energy generation, power grids and energy trading activities will be organised supraregionally based on shared resources (e.g. wind power in northern Europe) without regard to state borders; national systems and monopolies will no longer exist.**

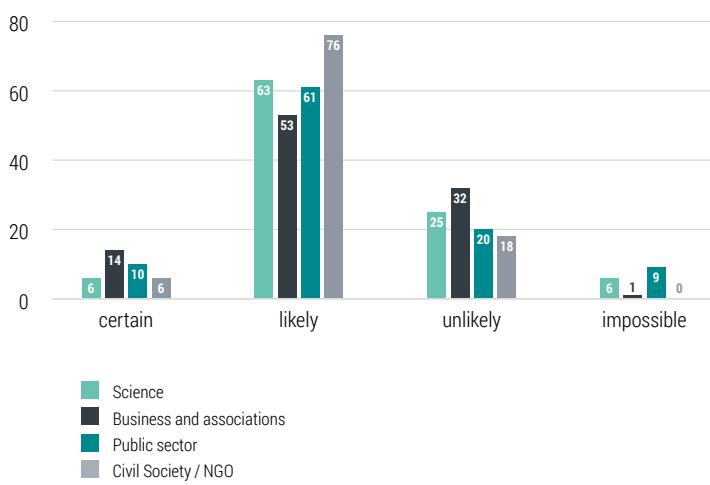
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## SHARED RESOURCES KEY TO SUCCESS

More than two thirds of experts consider it at least likely that an optimum exploitation of the natural resources for renewable energy will, in the future, be the guiding principle determining the organisation of electricity networks. Most experts by far expect this for Europe and North America, with the views of non-German and German respondents being mostly in alignment.

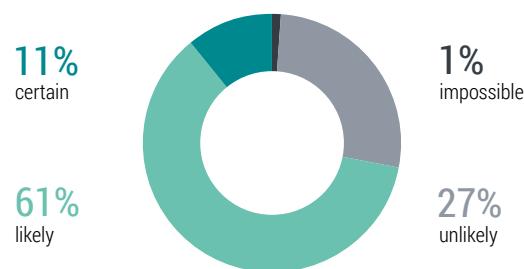
## INTEGRATION THROUGH COOPERATION

This thesis aligns closely with a set of expectations that see multilateral cooperation on the rise in the energy sector (theses 14 and 17, for example). A renaissance of national energy policy is not expected, even less so a nationalisation of energy systems as such (thesis 13), with cross-border governance being seen as the solution of the year 2040 for the challenging task of integrating renewables.

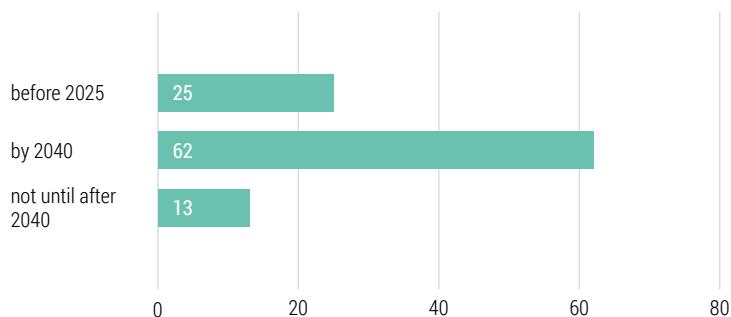
## THESIS 16

**By 2040 Europe will have adopted a common foreign energy policy, including joint strategic infrastructure investments and collective supply deals with third countries for the supply of resources.**

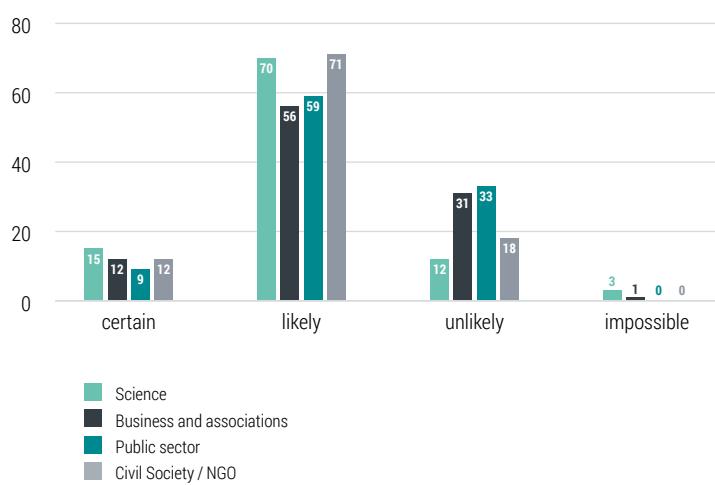
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## ADOPTION OF EUROPEAN FOREIGN ENERGY POLICY A REALISTIC OUTLOOK

A clear majority of experts expects an effective European foreign energy policy to be in place by 2040, in part even earlier. It is notable that the evaluations provided by scientists and civil society as well as NGO experts, on the one hand, and by public sector and business experts on the other hand, are in stark contrast on this. Business and policy-makers are far more sceptical than science and civil society.

## EUROPE'S ROLE TO GROW

Europe is generally seen to play a strong role (thesis 17). This is in line with the assumption that the world of energy in 2040 will be shaped by multilateral cooperation all around the globe (theses 14 and 15). A European Union that is in a position to take effective action is not only needed to create an international climate protection regime (thesis 11) but also to ensure the effective functioning of regional pricing systems for carbon emissions (thesis 12).

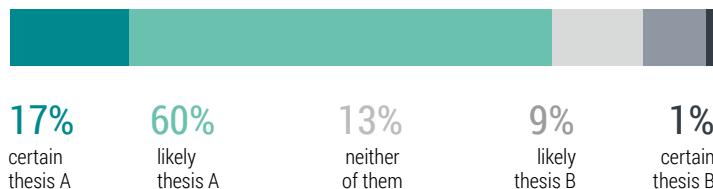
## THESIS 17

**A: By 2040 Europe will have adopted common, harmonised domestic energy policies and achieved an effective internal energy market; a highly efficient super grid will connect the European countries.**

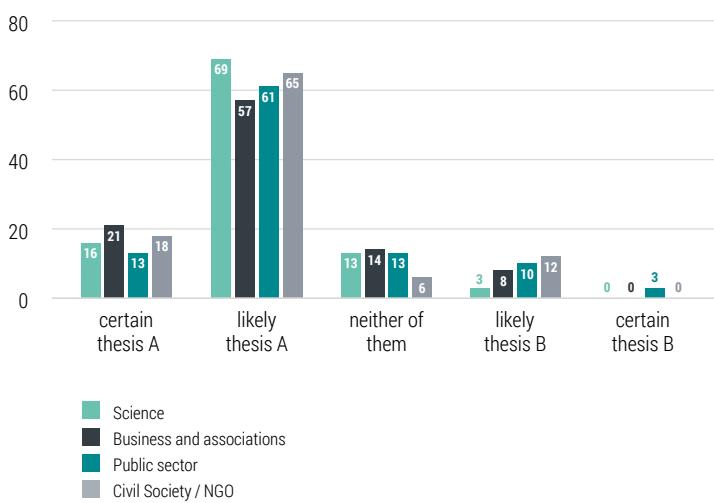
VERSUS

**B: By 2040 the European countries will have re-nationalised their energy policies, with borders being closed off by means of phase-shifting transformers.**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## A HARMONISED INTERNAL ENERGY MARKET

The expectations for developments at European level are remarkable: circa three in four international experts believe that common, harmonised domestic energy policies will have been adopted by 2040, based on efficient technical networks. This is an expectation that is shared by all sectors but is particularly strong among scientists. Only one in ten respondents expects a re-nationalisation of energy policies.

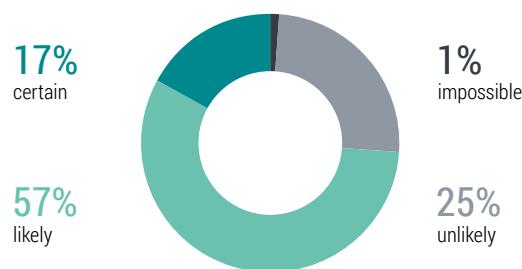
## INTERCONNECTED INFRA-STRUCTURE TO FACILITATE ENTRY OF NEW ACTORS

This scenario is most closely related to the expectations for a growing role of multilateral governance in the energy sector (thesis 14, among others). In many regards the experts surveyed expect that by 2040 the most important energy transition decisions will be taken at supranational level. Other exciting relationships also emerge: an interconnected Europe, connected by a super grid, places high demands on system management and the balancing of supply and demand, and could thus facilitate the rise of IT companies as key players in the new energy world (thesis 51).

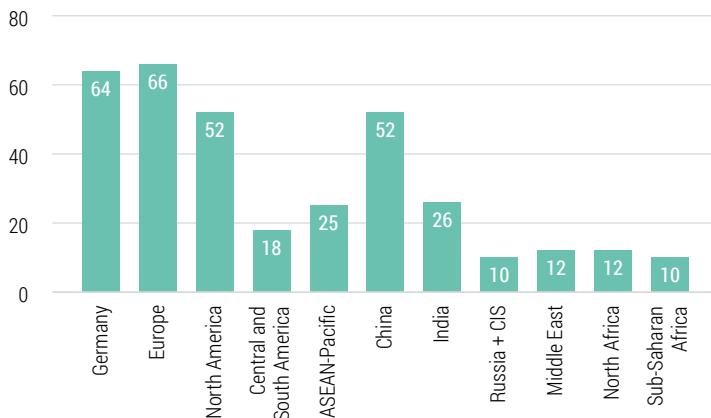
## THESIS 18

**By 2040 states that have strongly promoted renewable energy sources will have improved their economic position enormously and will be dominating the list of most competitive economies.**

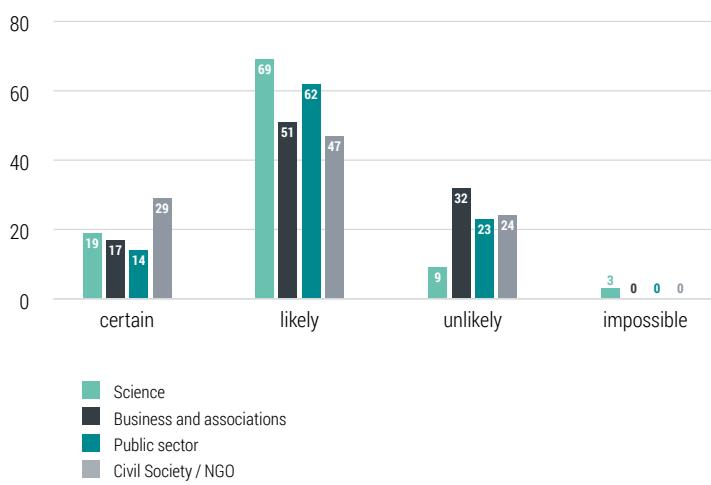
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## MACROECONOMIC BENEFITS

While the experts surveyed generally assume that climate protection will continue to be the key rationale behind energy transition initiatives in 25 years' time, another considerable majority believes that economic arguments will also become more important. Approximately three in four experts believe that economies which decided to promote renewable energy will be in a far better position by 2040. This positive development is not only expected for Germany, Europe and North America but also for China and (to a limited extent) India.

## ECONOMICS SHAPING THE DEBATE

If a consistent promotion of renewable energy promises to deliver macroeconomic benefits, this will become an important argument alongside climate protection for moving to a sustainable energy system. This expectation is also supported by the results for thesis 9 and, in part, thesis 44. The same applies with respect to the promotion of renewables in emerging economies (thesis 8) and developing countries (thesis 45).

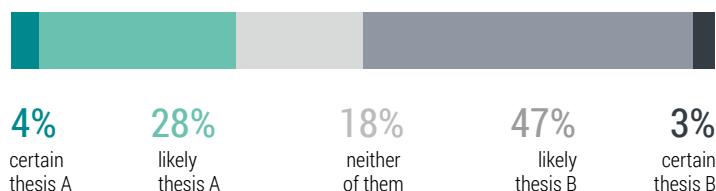
## THESIS 19

**A: By 2040 a growing world population and rising levels of wealth will have intensified the rivalry for finite energy resources; outbursts of violent conflicts within individual countries and between different nations will be an increasingly frequent occurrence.**

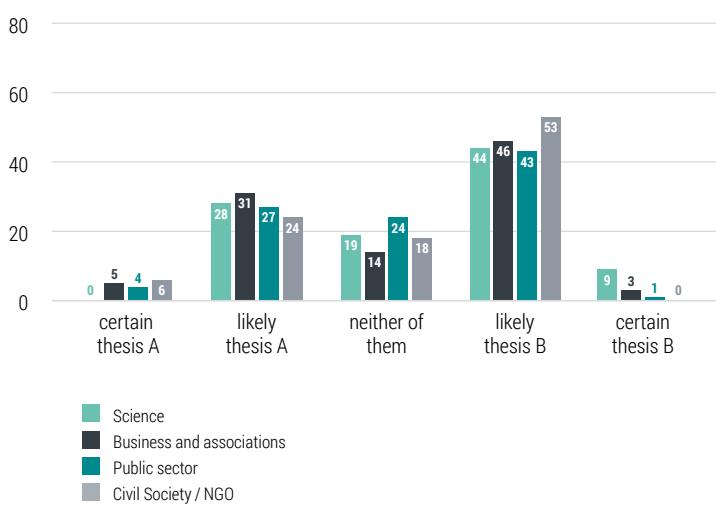
VERSUS

**B: By 2040 improvements in energy efficiency and more sustainable supply systems will act as counterbalancing factors mitigating or preventing the scarcity of resources, which is why there will be no large conflicts despite a sharp increase in global energy demand**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## NO VIOLENT CONFLICT EXPECTED

The majority of international respondents is optimistic in its expectations regarding the emergence of violent conflict as a result of rivalry for increasingly scarce fossil resources. Half of all experts assume that a more widespread use of efficiency technologies and the global availability of renewable energy sources will mitigate or even prevent new scarcity. Experts from outside Germany are considerably more optimistic about this than German experts.

## RENEWABLES PREVENT ENERGY POVERTY

The absence of scarcity in energy supply supports the expectation that energy poverty will not become more widespread (thesis 30), not even in the developing world, for example in Africa, where most population growth is expected to take place (thesis 45). Improvements in energy efficiency and increased use of renewable energy sources will then be able to counterbalance even a rapid growth in energy demand (thesis 5). Though they may also lead to a fall in the demand for fossil energy sources and thus contribute to a destabilisation of producing countries (thesis 20).

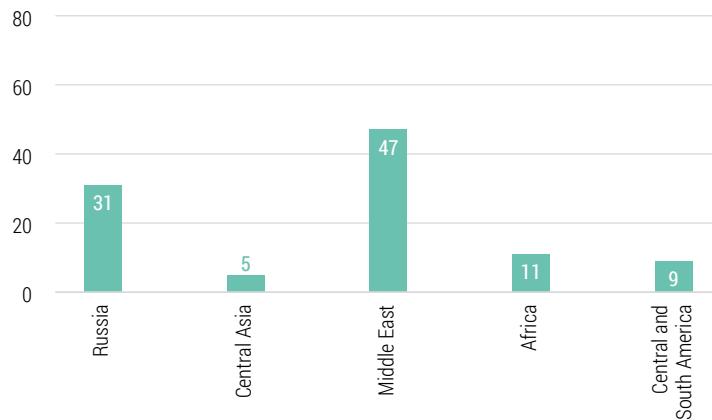
## THESIS 20

**By 2040 the falling demand for fossil energy sources in industrialised and emerging countries will have led to a destabilisation of producing countries.**

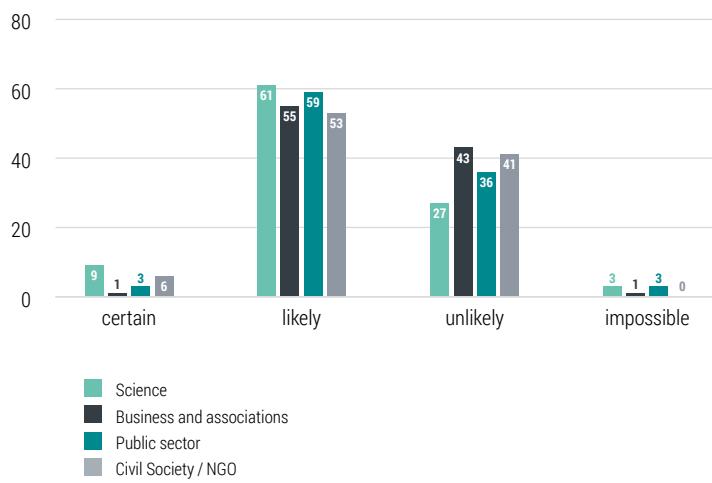
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## PRODUCING COUNTRIES TO EXPERIENCE THE DOWNSIDES

A general energy transition will not necessarily deliver benefits for all countries. The by far largest group of experts considers it likely that countries which have traditionally been producers will not be able to fundamentally transform themselves within the next 25 years and that they will face serious challenges due to falling demand for fossil fuels and stagnating prices. Problems are expected for the Middle East and Russia in particular.

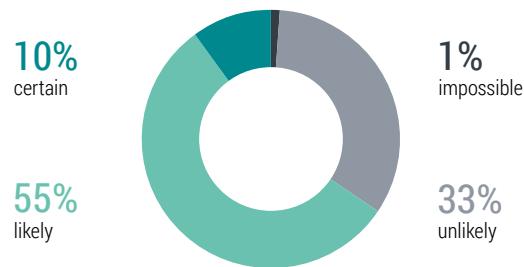
## UNCERTAINTY OVER FUEL PRICES

This scenario should be evaluated against a backdrop of uncertainty over the long-term development of fuel prices (thesis 3). The widely expected global shale gas boom would put even more pressure on prices (thesis 4). The general expectation is that renewable energy sources operating in conjunction with storage units will in many areas be more cost-effective than fossil fuels (thesis 35).

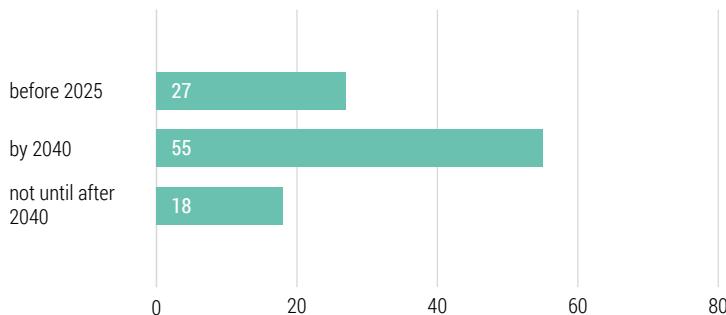
## THESIS 21

**By 2040 important resources (silver, copper, rare earth elements) will be in greater demand and will have become increasingly scarce as a result of a worldwide promotion of renewable energy sources and expansion of electricity networks. Many industrialised countries and emerging economies will be competing for strategic commodity partnerships with resource-rich countries.**

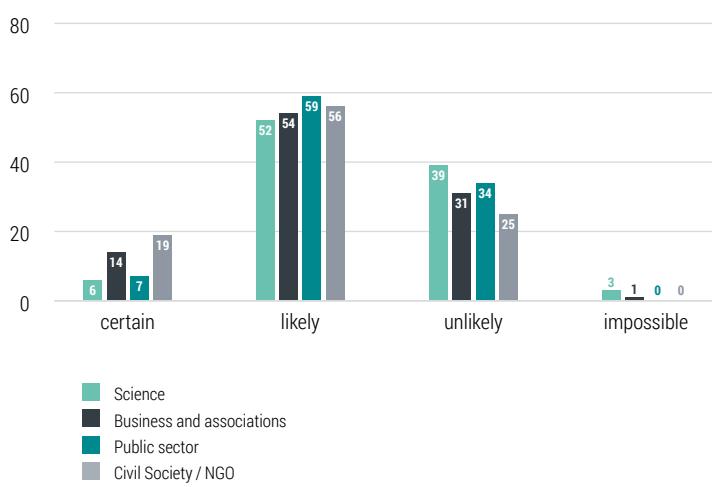
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## RENEWABLE ENERGY TO CAUSE NEW SCARCITIES

Roughly two thirds of all experts surveyed expect resources to become scarce by 2040 – those elements which are used for generation and storage and which are essential, for example for electronic control systems. Even so, scientists doubt this thesis more than other sectors, with German experts also having more reservations than non-German experts.

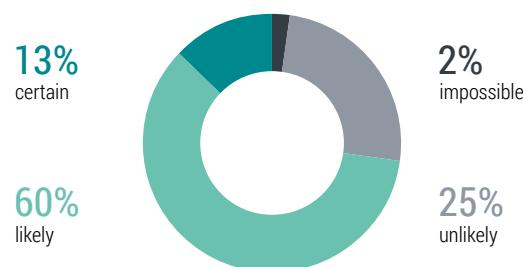
## ENERGY TRANSITION BUILDS ON MANY PREREQUISITES

This development might have a dampening effect on other expected developments, for example the growing economic viability of renewables (thesis 9), the increase in macroeconomic competitiveness brought about by energy transitions (thesis 18) or the assumption of an “all electric society” (thesis 33). It appears that many prerequisites must be met before an energy transition can deliver its benefits, which also shows in the experts’ scepticism about a “leapfrogging” by African countries (thesis 45).

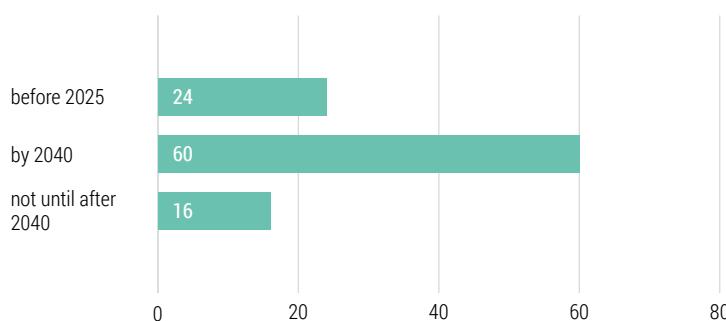
## THESIS 22

## By 2040 Russia will have become much less important as a supplier of natural gas and oil for Europe compared to 2015.

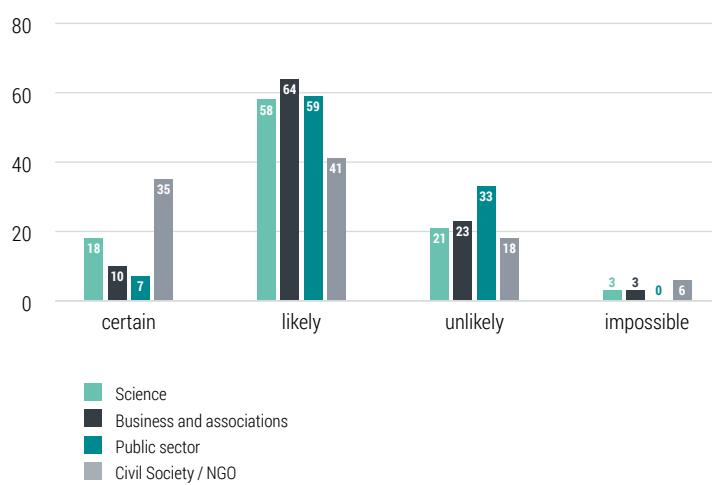
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## EUROPE TO SHAKE OFF ITS DEPENDENCIES

The majority of experts believes that Europe will have freed itself from its dependence on Russian fuel imports by 2040. This view is most prevalent among civil society experts. Russia will thus have to focus on other export markets and will face no easy road in view of global market trends and the infrastructure investments this requires.

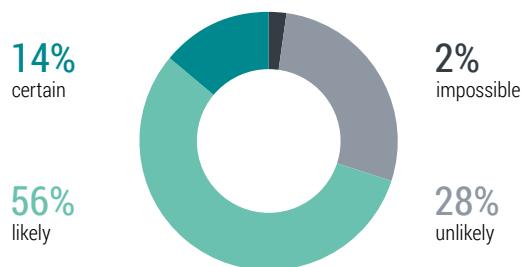
## A SHIFTING BALANCE OF POWER

The expected prolonged worldwide shale gas boom (thesis 4) could result in the same outcome, as could an increasingly confident and differentiated European foreign energy policy (thesis 16). The risk that producing countries such as Russia will be destabilised will increase (thesis 20).

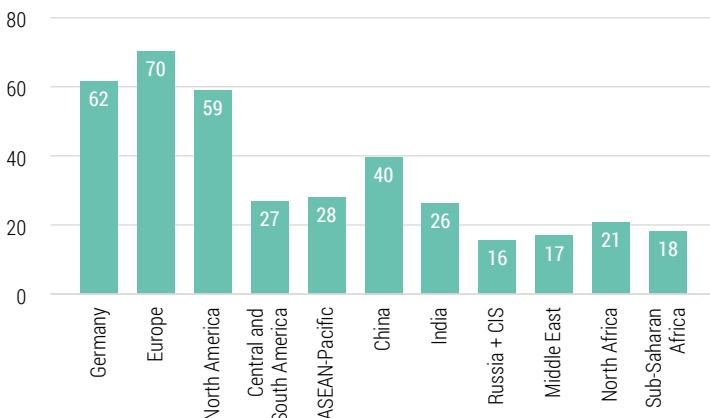
## THESIS 23

**By 2040 the generation and supply of energy will have been decentralised and made more flexible, which will have led to the emergence of structures that are more resilient to crises and acts of terrorism.**

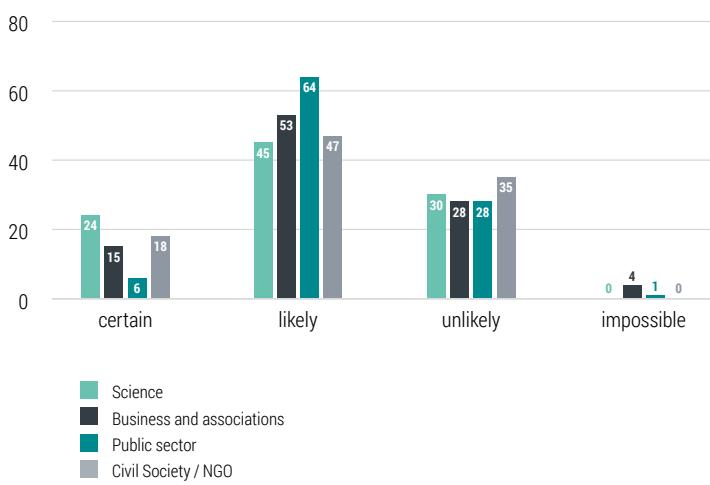
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## RENEWABLES PROVIDE A SHIELD AGAINST CRISES

Two out of three respondents believe that decentralised forms of energy generation based on renewable energy sources will have been the key to making energy supply systems in Germany, Europe and North America but also in China more resilient to crises and acts of terrorism by 2040. Both German and international experts are convinced that this is a third important positive impact an energy transition will have, besides climate protection and macroeconomic developments.

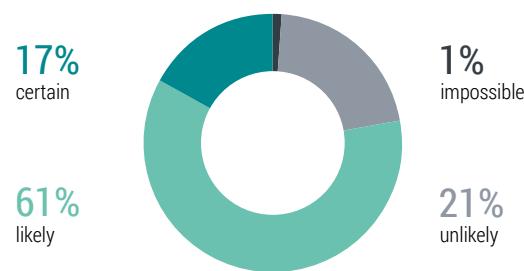
## RISKS OLD AND NEW

This scenario is consistent with the expectation that emerging economies and developing countries will abandon centralised systems of energy generation from fossil sources for various reasons (thesis 1). It strengthens the position of those who believe that Africa will "leapfrog" and promote renewable energy sources (thesis 45). We must, however, debate the significance of new risks that were unknown in the past, such as criminal data breaches and cybershocks (thesis 53).

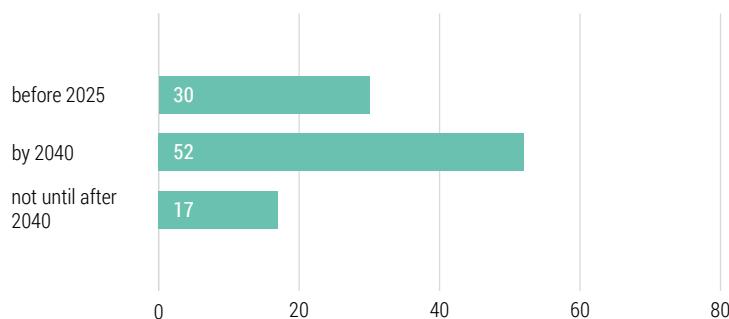
## THESIS 24

**By 2040 consumers will expect businesses, products and services to be sustainable on a comprehensive scale. Non-sustainable forms of production will be considered unethical.**

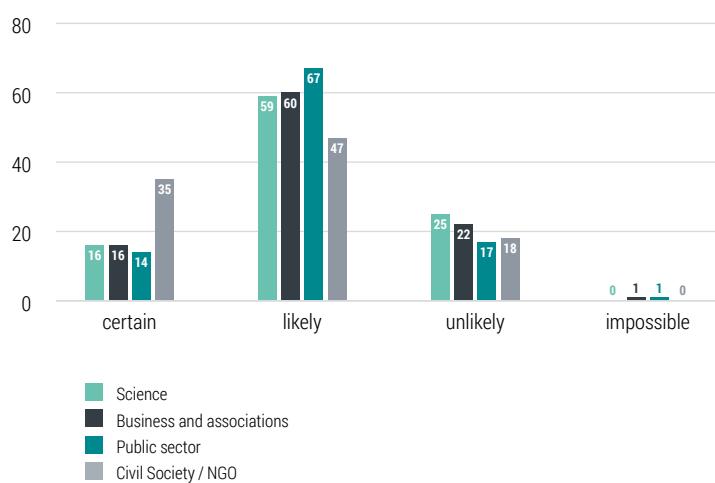
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## PRESSURE FROM CONSUMERS TO GROW

The civil society in particular is convinced that consumer behaviour and demand will create considerable pressure on businesses to ensure the sustainability of all products and services, including energy, by 2040 at the latest. Overall, four out of five experts believe this to be true. Only 1 per cent considers it as unrealistic.

## NEW PATTERNS OF CONSUMPTION

Experts also see very concrete changes in consumer behaviour and consequences for the marketing and design of products (theses 26 and 32). Many see the political influence of consumers as a decisive factor in India and China, too (thesis 8), which is why political breakthroughs are also expected on an international scale (theses 11 and 12).

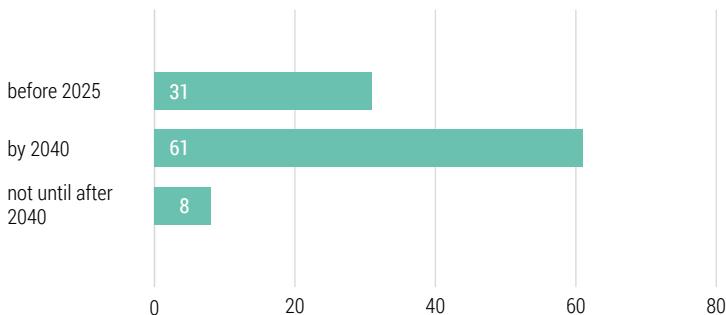
## THESIS 25

**By 2040 energy consumption will have risen significantly as private households will have stepped up their use of convenience solutions (mobility, increased automation of homes, heating etc.).**

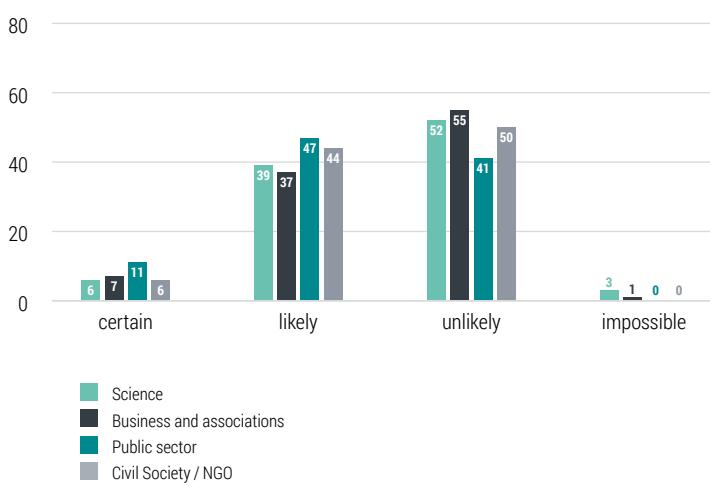
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## CONVENIENCE AS A DRIVER OF CONSUMPTION?

The experts surveyed are divided on the question whether increased use of connected appliances by private households but also new applications such as electric mobility will lead to a rise in energy consumption. About half of them support and reject this thesis, respectively, with those believing it to be true expecting it to happen rather before 2040. Business respondents in particular tend to consider this scenario as unlikely.

## OPTIMISED CONSUMPTION

Other theses and related expectations rather indicate that private consumers' awareness of sustainability matters is growing (theses 24 and 26). The internet of things and customer demand management, also through real-time pricing, indicate that the trend is for private households to optimise their consumption, at least in industrialised countries (theses 52 and 54).

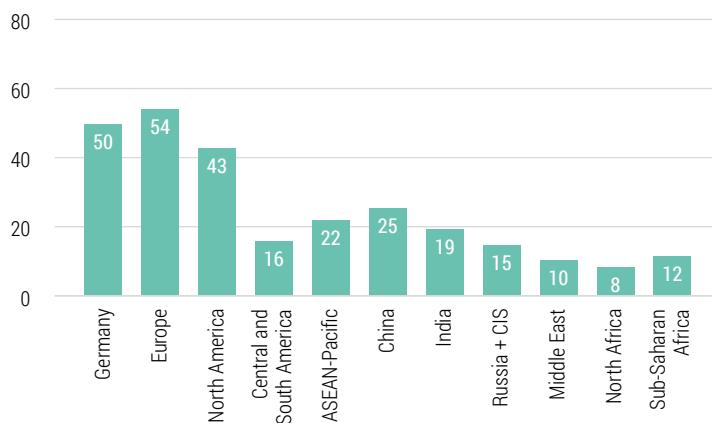
## THESIS 26

**By 2040 changing values in society will have turned the “sharing economy” into a reality; the new paradigms will be ecological efficiency, consumer restraint (sufficiency) and the dematerialisation of production.**

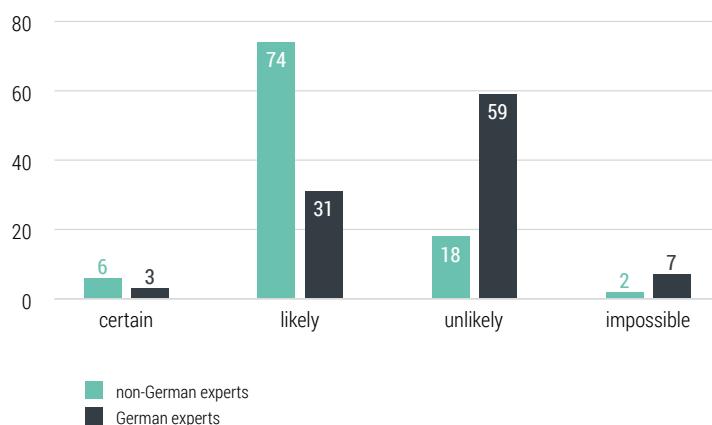
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO GERMAN AND NON-GERMAN EXPERTS EVALUATE THIS DEVELOPMENT? (IN %)



## SCEPTICISM PREVAILS IN GERMANY

Experts generally expect that by 2040 citizens will be more aware of sustainability issues and largely supportive of moves towards a sustainable energy system. A more extreme paradigm shift towards consumer restraint and a sharing economy, however, is only expected by roughly half of all experts. And evaluation of this thesis also varies depending on the respondent's country or region of origin: Germans tend to be sceptical, while non-German experts believe a sharing economy to be rather likely.

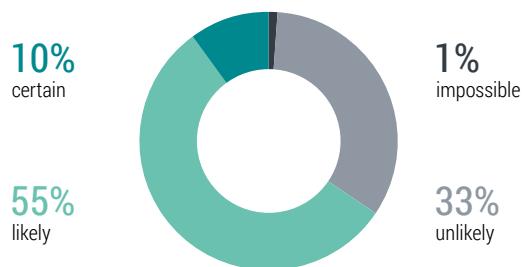
## A METROPOLITAN PHENOMENON

This thesis should be considered in conjunction with the experts' evaluation of theses 10 and 24. It may be a phenomenon only catching on in developed metropolises (thesis 27), which provide ideal conditions for their citizens to develop new models of working, living and doing business (thesis 29).

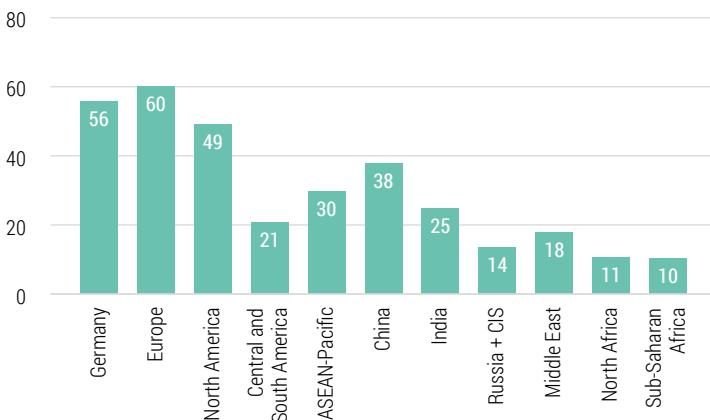
## THESIS 27

**By 2040 highly efficient “sustainable cities” will have emerged, with populations that have sharply reduced their individual mobility needs and that satisfy their energy demand by acting as prosumers in smart microgrid systems (“neighbourhood generation”).**

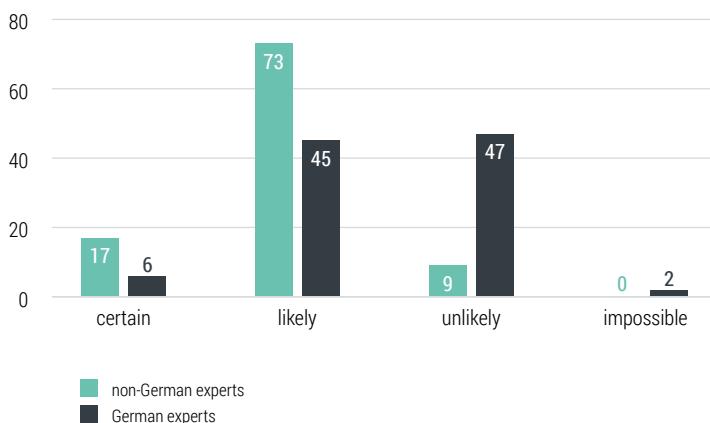
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO GERMAN AND NON-GERMAN EXPERTS EVALUATE THIS DEVELOPMENT? (IN %)



## A NEW TYPE OF CITY

Nearly two thirds of experts see a new and highly efficient type of city emerging in Europe, North America, China and Asia. These cities reduce their energy demand by intelligently connecting devices and appliances at all levels. The scepticism shown by approximately one in three experts is most likely an expression of doubt as to the large-scale implementation of this model, with doubt particularly prevalent among German experts.

## NEW PREFERENCES AND TECHNOLOGIES

This scenario is related to the assumption that preferences, especially those of urban middle classes, will change all over the world (theses 8, 24 and 26). Those who believe such a scenario to be likely also have the expectation that a move towards decentralised renewable energy will have a positive effect on society's self-governance capabilities (thesis 29). New technologies, particularly those affecting urban areas, would provide a foundation for this scenario (theses 36, 37, 52 and 54).

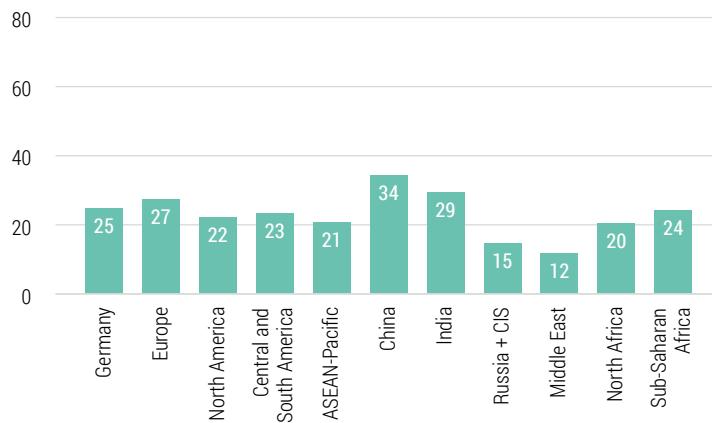
## THESIS 28

**By 2040 the population's migration into the city will have been stopped, with decentralised energy systems offering new perspectives for the development of rural areas.**

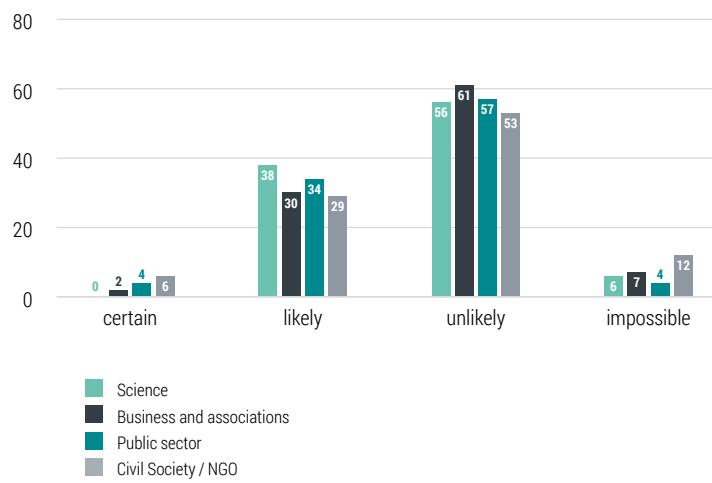
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## MIGRATION INTO THE CITY CONTINUES UNCHECKED

A general transition towards sustainable energy systems, especially more widespread use of decentralised forms of electricity generation, will bring new opportunities for economic development but cannot be the solution to all problems: only around one third of experts believe that the population's migration into the city will have been stopped by 2040, mostly in China and parts of Africa. Almost two thirds believe this to be unlikely or impossible, though, irrespective of their professional background.

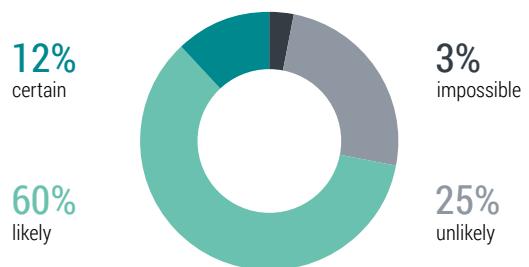
## IMPACT LIMITED TO CERTAIN REGIONS

Doubts also exist when it comes to the capability of African countries to achieve independence by creating decentralised renewable energy systems (thesis 45). It is generally accepted that renewables can indeed meet the necessary technological and economic requirements when operating in conjunction with storage technologies (thesis 35). But the positive effects of the new technologies on society are rather seen in Europe and North America than in developing countries and emerging economies (thesis 29).

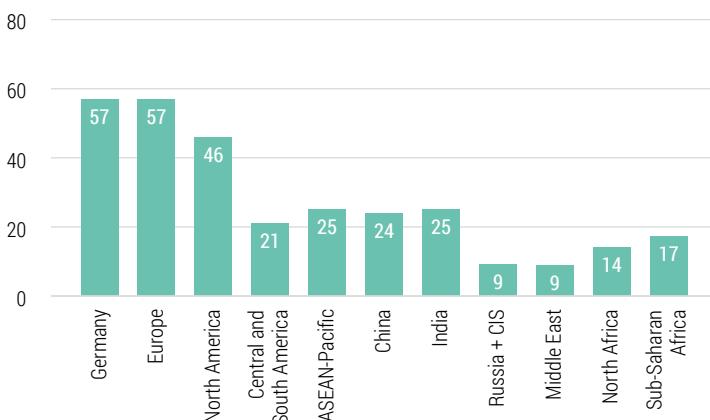
## THESIS 29

**By 2040 distributed generation with renewable energies using battery storage will have led to the emergence of new democratic self-governance structures at the local level. Municipalities and social bottom-up movements will have gained momentum.**

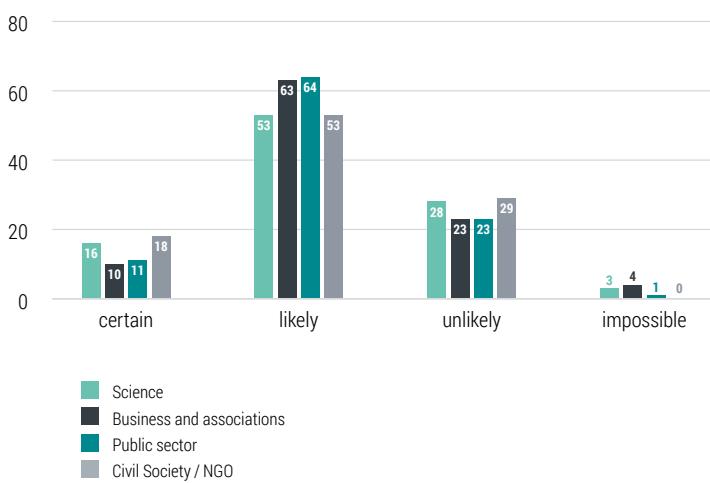
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## A STRENGTHENING OF LOCAL DEMOCRACY

The potential opportunities for the development of local communities that might arise from decentralised forms of renewable energy generation are being widely discussed. This thesis, suggesting a new wave of democratic, local self-governance, has been developed against this background. The surprise: more than 70 per cent of experts consider this scenario to be realistic but primarily see it happening in developed countries in North America and Europe.

## DECENTRALISATION ON MULTIPLE LEVELS

Other technical, political and economic factors point towards similar trends: For example, national governments are no longer seen as the central actors (theses 13, 14 and 15), with multi-lateral governance and decentralisation assumed to be concurrent developments. Decentrally generated electricity will become more affordable (theses 35 and 38) – and might even increasingly be funded by citizens themselves.

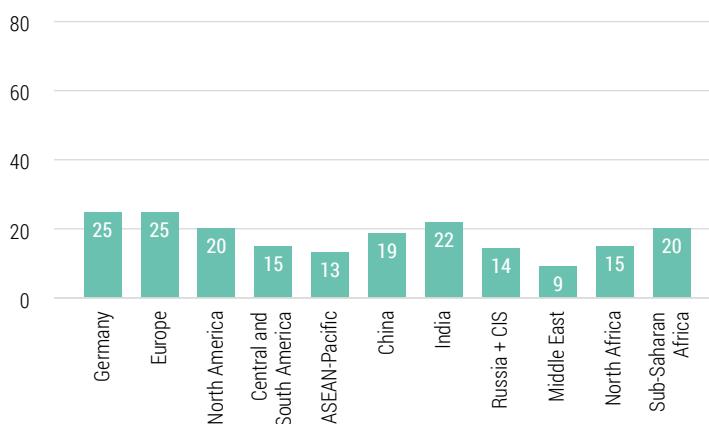
## THESIS 30

**By 2040 large parts of the population will have fallen into energy poverty and lost out on the benefits of the energy transition as a result of rising prices of fossil energy sources, high costs of renewable energy generation and expensive efficiency technologies.**

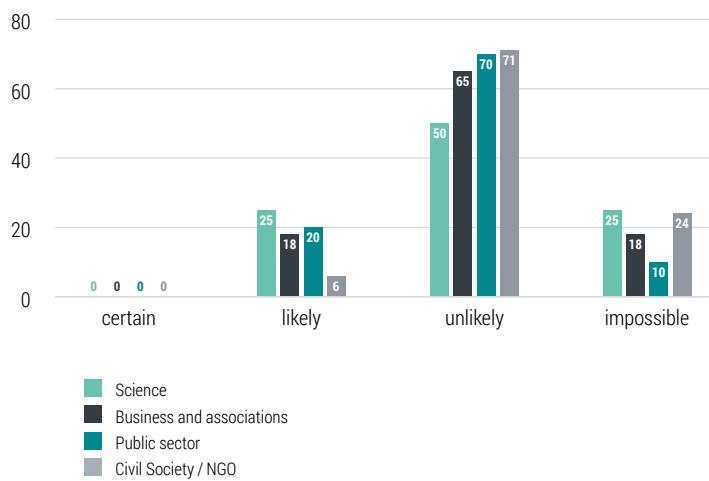
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## NO ENERGY POVERTY EXPECTED

A huge majority of experts from all spheres of business and society do not believe that energy poverty is on the rise. The most sceptical view in this respect prevails among scientists. Optimism is expressed for all regions of the globe.

## AN AFFORDABLE ENERGY TRANSITION

The majority of experts neither believes that the prices of fossil energy sources will escalate nor that there will be conflicts about their availability (theses 5 and 19). Careful optimism also prevails in relation to renewables (theses 35 and 47). This trend will counter-balance the expected growth in global energy demand.

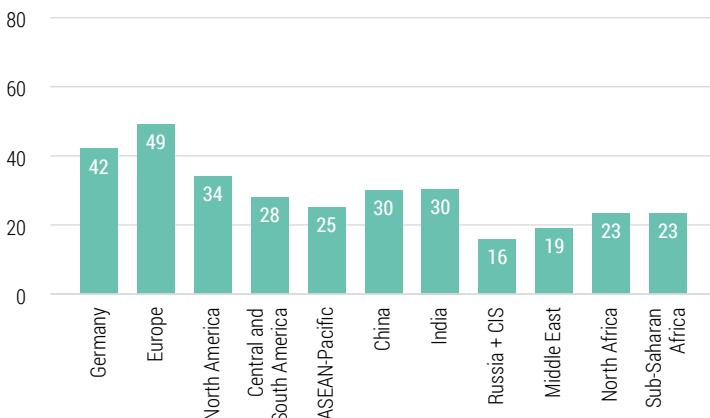
## THESIS 31

**By 2040 bioenergy technologies relying on renewable resources will have failed to succeed due to land rivalry with the food industry, a lack of acceptance by the population and economic disadvantages.**

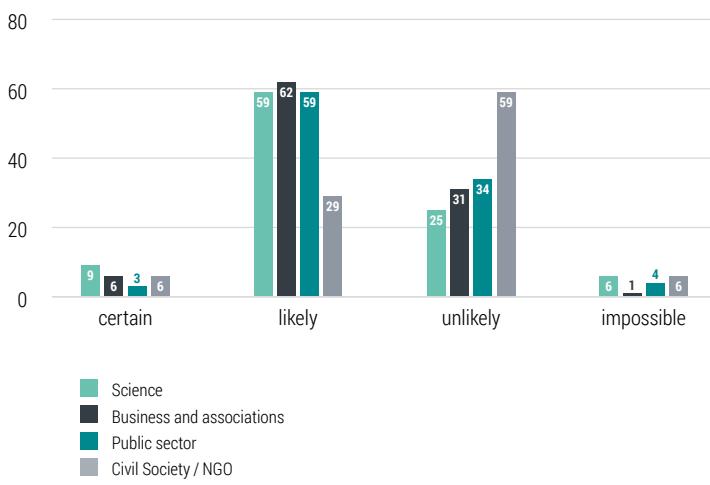
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## ROLE OF BIOMASS IS DIMINISHING

63 per cent of experts, and thus a clear majority, are convinced that use of biomass for energy purposes will not prevail for various reasons. Acceptance issues and conflicts over resource utilisation are not only seen for Germany and Europe but also for many other regions of the world, albeit to a lesser extent. Only one group is of a clearly different opinion: civil society and NGO experts are convinced of the opposite.

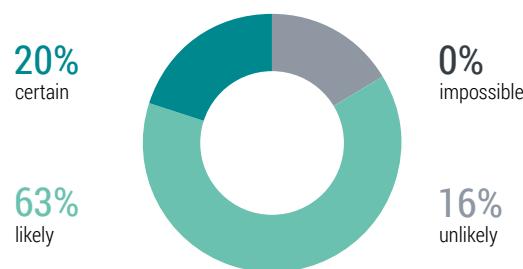
## AMBITIOUS CRITERIA

The experts surveyed are especially optimistic about photovoltaics (PV) and wind power, which are seen as having high acceptance levels and the potential to deliver efficiency improvements all over the world. This is particularly true for PV technology used in connection with storage systems (theses 35 and 37). Growing ethical awareness might also result in a more critical view of biomass insofar as rivalry with the food industry over resource utilisation is assumed (theses 24 and 26).

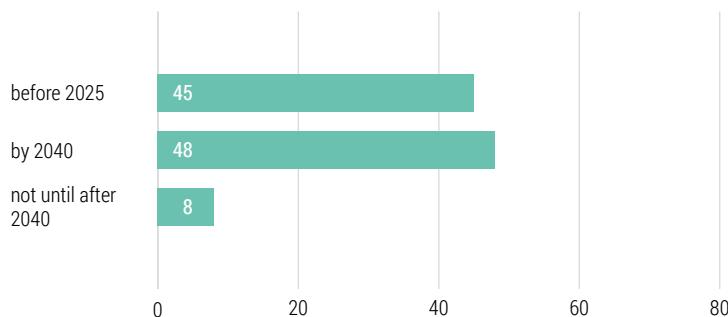
## THESIS 32

**By 2040 the carbon emissions that have been generated in manufacturing and transporting products and services – including mobility – will be a standard information indicated on product labels.**

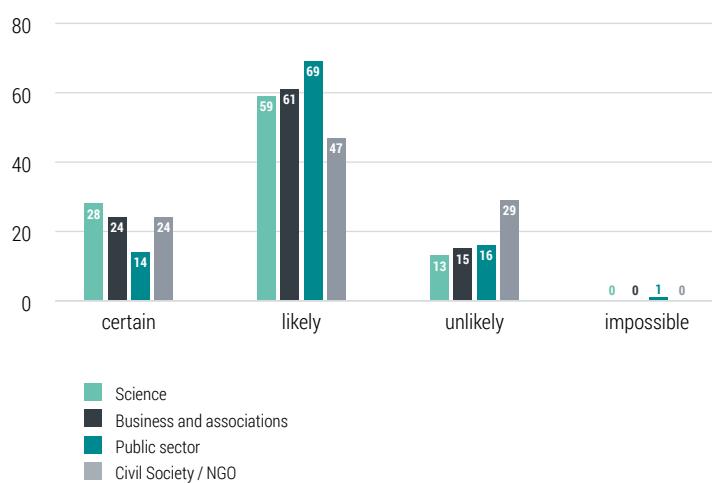
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## CARBON FOOTPRINT ON PRODUCT LABELS

In 2040, the carbon emissions that have been generated in manufacturing and transporting products will be a standard information indicated on all product labels. Not even 20 per cent of international experts see this differently. Almost half of all experts even expect this to happen by 2025. Agreement on this is shared by all sectors, only civil society experts are slightly more sceptical.

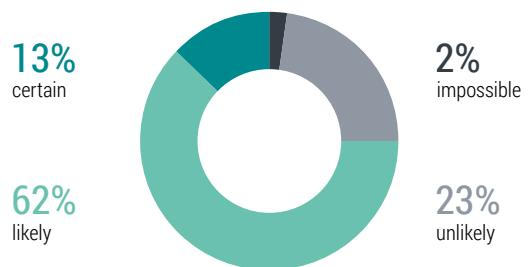
## CONSUMPTION AND CLIMATE IMPACT

This scenario is a reflection of the general expectation that in the future consumers will place very high demands on the sustainability of products, services and, especially, energy (theses 8, 10, 24 and 26). Matters of consumption and climate impact will be interwoven in the minds of consumers, a trend which will be further driven by customised pricing (theses 52 and 54).

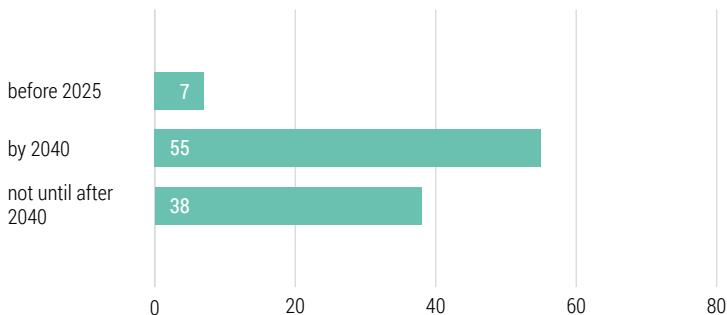
## THESIS 33

**By 2040 an “all electric society” will have become a reality. Electricity, especially power generated from renewable sources, will also provide mobility and heating, and will have displaced petroleum and natural gas in many industrial processes.**

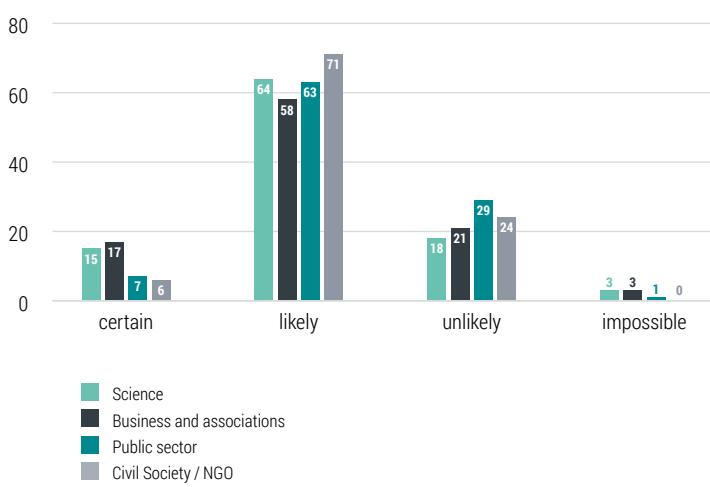
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## ELECTRIFICATION OF MOBILITY AND MANUFACTURING

The respondents to our survey share a general confidence in technological progress as a driver of the promotion, interconnection and application of renewables. Hence three in four experts believe that electricity generated from renewable sources will have displaced oil and natural gas in the fields of heat production and mobility as well as in industrial applications by 2040. “Excess power” available due to the intermittency of renewables will be put to good use, even if many experts do not see this until well after 2040.

## GROWING VERSATILITY

A multidimensional use of electricity from renewable energy sources is also indicated by other theses. The general expectation is that economic viability, flexibility and self-sufficiency will be the main aspects driving energy transitions (thesis 9). Technological breakthroughs and decreasing costs of the corresponding systems are expected to open up new fields of application (theses 35 to 37).

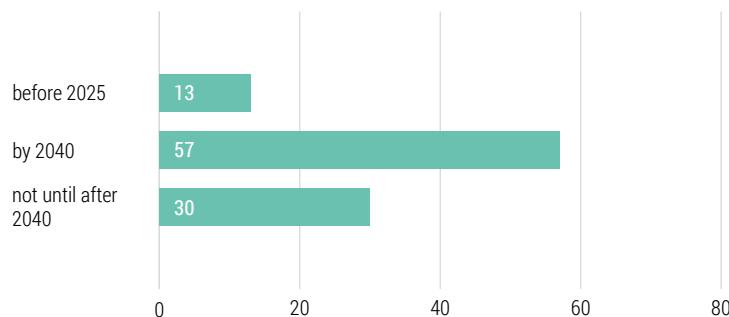
## THESIS 34

**By 2040 battery storage facilities providing frequency control services will have taken over the role of conventional power stations in maintaining system stability.**

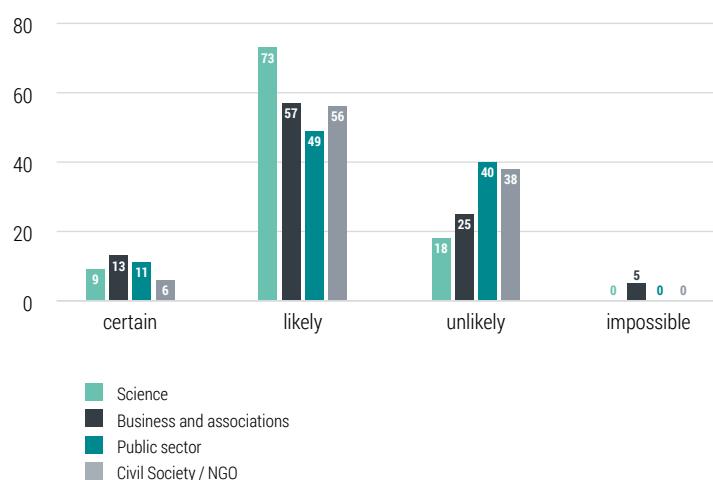
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## BATTERIES TO REPLACE POWER STATIONS

By 2040, large battery storage systems will have replaced conventional power generation as a provider of system stability. More than two thirds of experts are of the view that this will be one of the technological developments driving the trend towards sustainable energy systems – one of the critical game changers. A considerable number of respondents, however, see this development only for later, after 2040. Science and business show particular optimism in this regard.

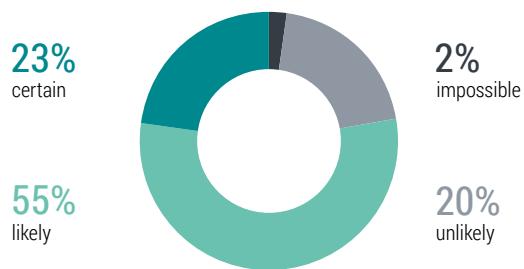
## SYSTEM SOLUTIONS TO FACILITATE THE SWITCH

Reliable system solutions based on renewable energy are a prerequisite for developing countries and emerging economies to abandon fossil sources of energy by 2040 and develop their own systems (theses 1 and 45). Conventional power stations can then become smaller and more flexible (thesis 39). Sustainable cities, new cellular structures and an electric mobility boom (theses 27, 36 and 38) are all further aspects of this scenario.

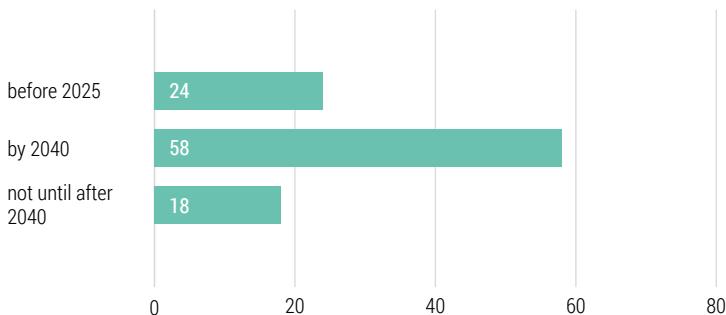
## THESIS 35

**By 2040 renewable energy sources operating in conjunction with storage units will be the generation technology with the lowest electricity production costs. High-performance customer generation facilities will be sold in retail stores and can be installed in a matter of minutes.**

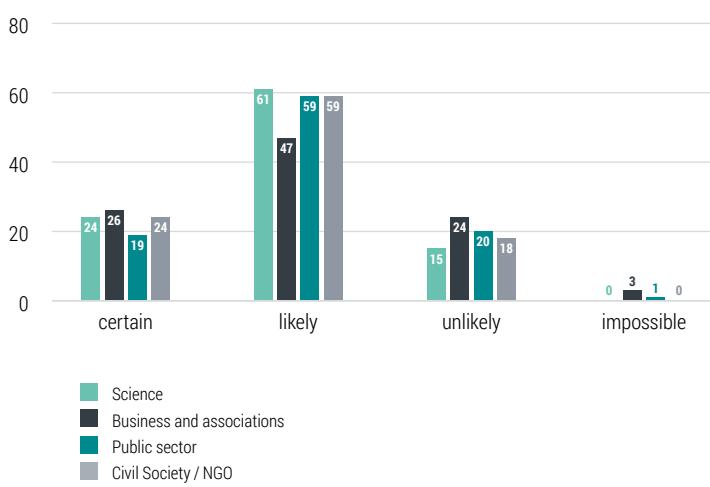
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## ECONOMIC VIABILITY IS KEY

On this thesis, which raises the very central question of the economic viability of renewable energy sources, there is resounding agreement. The competitiveness of renewables in relation to conventional forms of generation is their breakthrough argument as it makes them a viable alternative for countries that are seeking to become more independent from fossil fuel imports. This, in turn, further increases acceptance by “prosumers”.

## STORAGE IS A GAME CHANGER

The economic viability of renewables is a decisive factor that will determine whether we will be able to satisfy a rapidly growing energy demand and how so (theses 5 and 9) and it is also an important premise for the expectation that energy poverty will not surge (thesis 30). Especially high-performance storage technologies are considered to be the key game changers by 2040 (thesis 43).

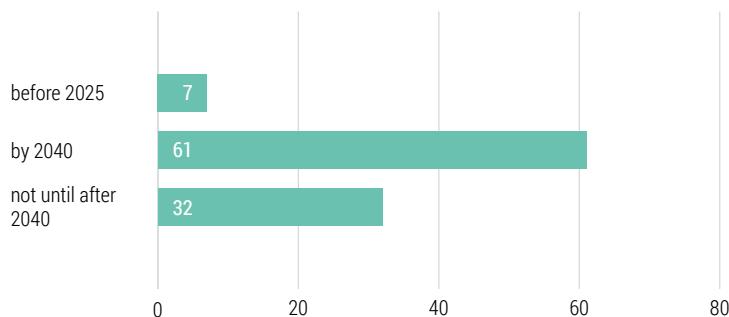
## THESIS 36

**By 2040 thanks to new battery technologies, electric vehicles will be able to travel distances of more than 3,000km per charging cycle and will be rechargeable within a time span of no more than a few minutes by means of electrical induction.**

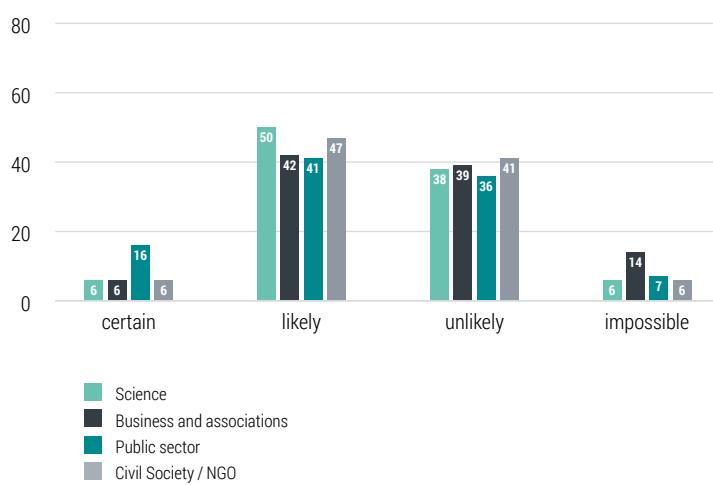
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## ELECTRIC MOBILITY TO COME OUT ON TOP

When it comes to electric mobility, the experts surveyed are divided on whether rapid technological progress will have been achieved by 2040. Yet more than half of them consider it realistic that electric vehicles will be able to travel distances that even combustion engines cannot compete with, which will thus be put into second place in terms of convenience and practicability. Even if this key breakthrough moment is seen by most to come rather after 2040.

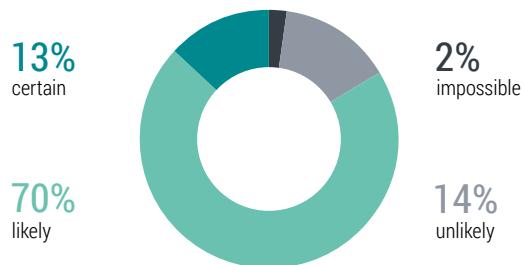
## A CORNERSTONE OF A NEW SYSTEM

A scenario of high-performance electric mobility technologies fits in with the belief that an all electric society will emerge by 2040 (thesis 33). Advances in storage technology are a prerequisite if renewables are to also take over the role of maintaining system stability (thesis 34). By 2040, storage will have become the most important of all game-changing technologies (thesis 43).

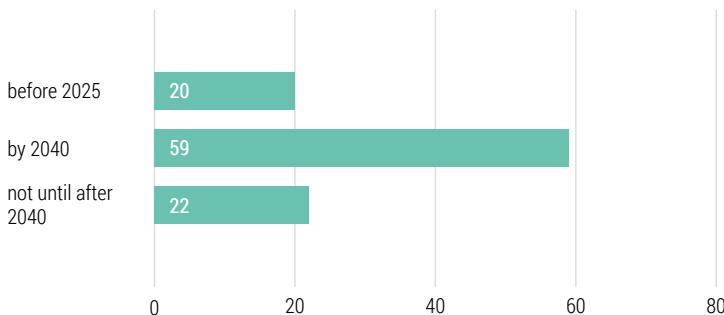
## THESIS 37

**By 2040 thin-film and organic photovoltaics technologies will be the “game changers” driving a decentralisation of energy generation; power-generating windows and facades will be conquering the market.**

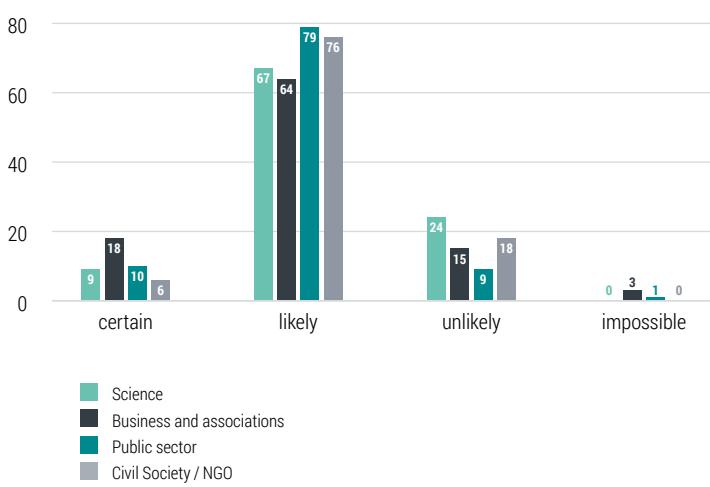
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## PV IS A GAME CHANGER

The absolute majority of experts assumes that disruptive new photovoltaic (PV) technologies will be a market success by 2040 and another factor that will facilitate a decentralisation of power generation. These new technologies will “change the rules of the game” by opening up completely new PV applications. Both German and non-German experts share this view.

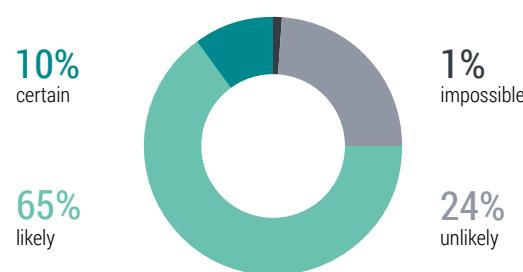
## FRESH PERSPECTIVES

Thin-film and organic photovoltaics technologies will have conquered the market. They will be a cornerstone of an expected “all electric society” (thesis 33). As they become more economically viable, they will further drive decentralisation (thesis 35) and create the right conditions for the emergence not only of partly self-sufficient cellular energy systems but also of sustainable cities (thesis 27). Especially decentrally organised developing countries could benefit from this (thesis 45).

## THESIS 38

**By 2040 the energy supply system will be structured in a cellular way: interconnected cells and “islands” of the size of a city or medium-sized region will generate their energy from solar power, wind power, storage units and a minor share of conventional reserves.**

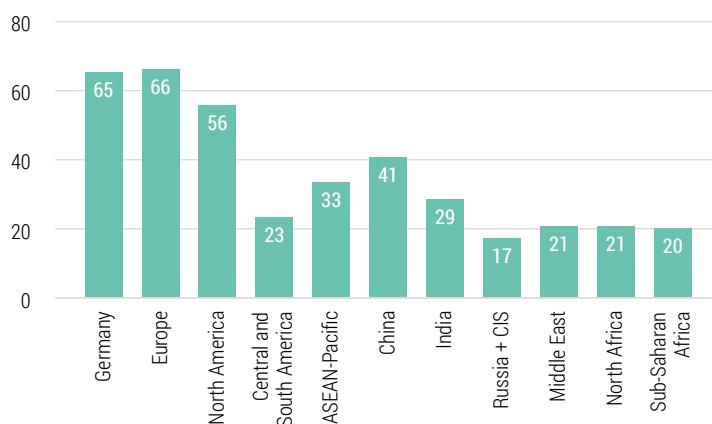
## WILL THIS THESIS ACTUALLY TAKE PLACE?



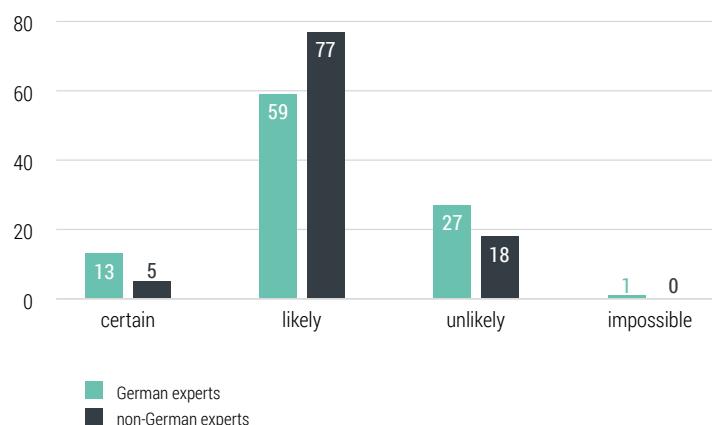
## CELLULAR STRUCTURES TO EMERGE

The very vast majority of respondents believe this thesis to be likely. They primarily expect it to happen in Germany, Europe, North America and China. No significant differences in response can be observed between the individual sectors.

## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO GERMAN AND NON-GERMAN EXPERTS EVALUATE THIS DEVELOPMENT? (IN %)



## FLEXIBILITY ON THE RISE

In the context of other theses, decentralisation, increased flexibility and customisation are seen as trends that will also affect the pricing of energy (theses 48, 49 and 54). This scenario can also be viewed in conjunction with the expectation that the internet of things will ultimately also coordinate electricity production and consumption (thesis 52). Also, funding of energy investment projects is expected to become more fragmented and decentralised (thesis 56).

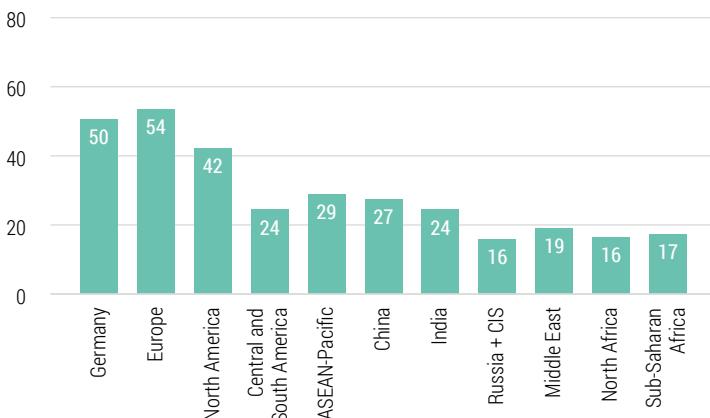
## THESIS 39

**By 2040 the field of conventional fossil-fired power generation will also operate on a reversed scale: formerly large power stations will have become small and flexible units, with a typical generation capacity of no more than 100MW.**

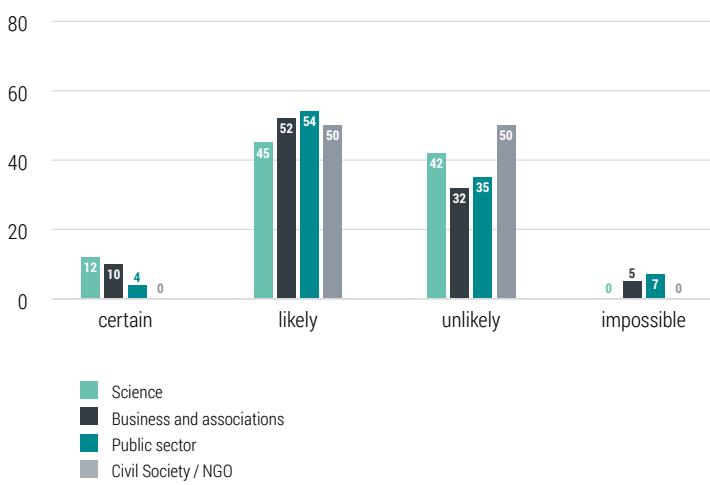
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## POWER STATIONS TO BECOME SMALL AND FLEXIBLE

Almost two thirds of experts assume that the conventional power generation fleet, especially in Europe, Germany and North America – but to a lesser extent also in Asia – will be dominated by small, decentralised units. German experts rate the likelihood of this slightly higher than experts from other countries.

## NEW STANDARDS

Small fossil-fired power stations fit in with the expectation that future energy supply systems will be structured in a cellular way (thesis 38). Energy companies are seen to lose their dominant status, which will move to “prosumers” and new actors (thesis 50). If conventional generation were to actually operate on a reversed scale, this would mean that energy investment projects could effectively be funded by small crowd- and community-based funds and micro-financing initiatives (thesis 56).

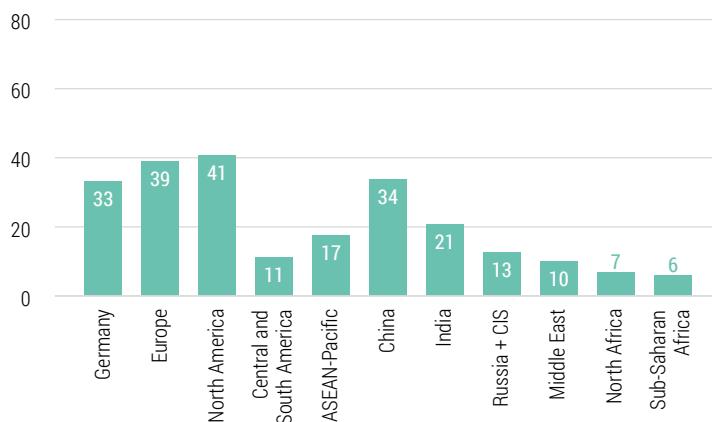
## THESIS 40

**By 2040 carbon capture and storage systems will have been able to reconcile the goals of climate protection with the use of fossil energy sources. New applications for stored CO<sub>2</sub> are being developed in the field of carbon chemistry.**

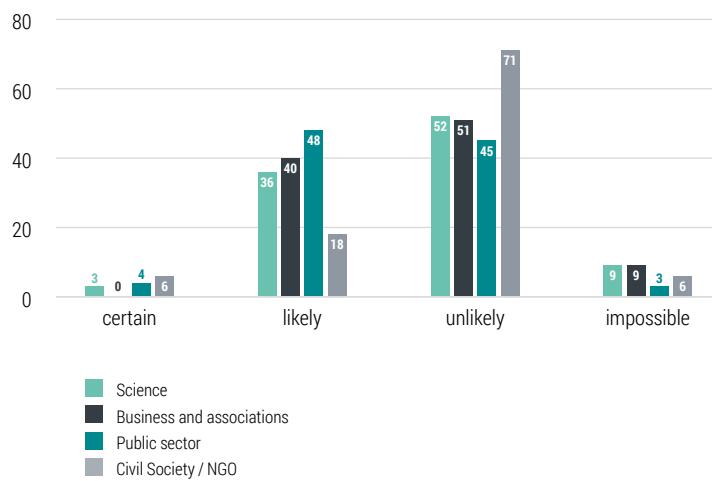
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## NOT MUCH HOPE FOR CCS

Slightly more experts than not consider it unlikely or impossible that CCS systems will be deployed on a notable scale, with the stored CO<sub>2</sub> being used in industrial applications. Experts who do believe this to be a realistic scenario see it for North America, Europe and China. There is a stark contrast between German experts and their non-German colleagues in this matter: the majority of German respondents rate the likelihood of this thesis becoming a reality as unlikely.

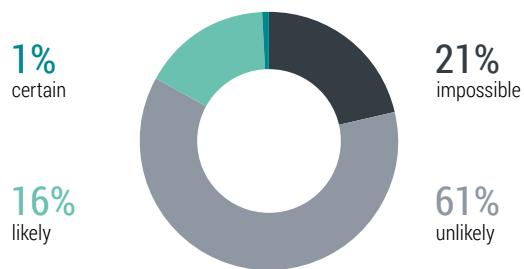
## SWITCH EXPECTED

An evaluation of the overall expectations held by experts shows clearly that the majority assumes countries to make the switch from conventional to renewable energy sources (thesis 1). A future role for fossil-fired power stations is only seen insofar as their structures and functions are adjusted, too (thesis 39).

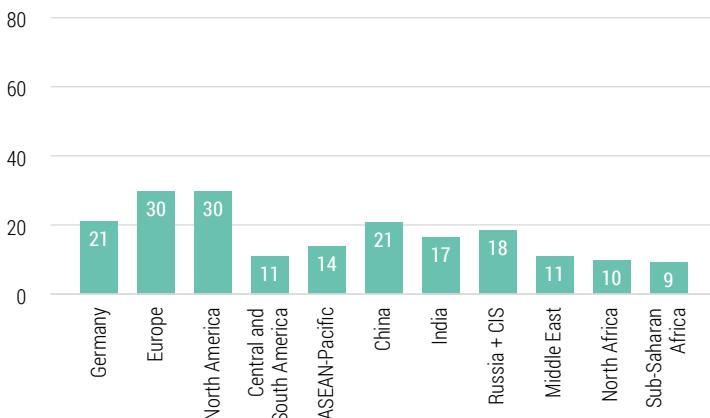
## THESIS 41

**By 2040 nuclear fusion will have made its breakthrough and will be providing the baseload in industrialised and emerging countries.**

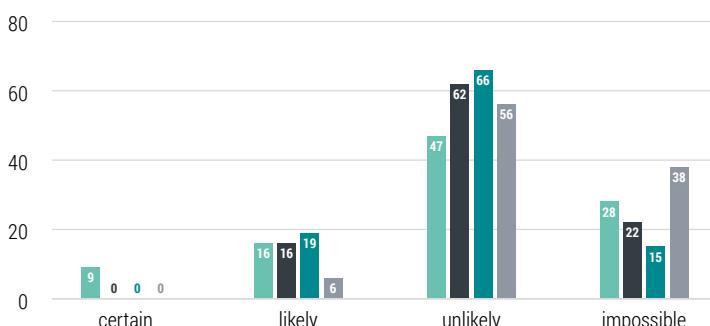
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)




  
 Science  
 Business and associations  
 Public sector  
 Civil Society / NGO

## NO FUTURE FOR NUCLEAR FUSION

The vast majority of respondents consider it unlikely or impossible that this thesis will become a reality. Nearly one in five experts believes that nuclear fusion can make its breakthrough in Europe and North America, if anywhere. International and German respondents are in complete alignment on this thesis.

## LARGE-SCALE TECHNOLOGIES UNATTRACTIVE

The experts surveyed are sceptical about the manageability and attractiveness of large-scale technologies, nuclear ones in particular. Developing countries and emerging economies are seen to abandon their highly subsidised systems for a variety of reasons (thesis 1). At the same time, the electricity production costs of renewables and their performance capability in conjunction with storage (theses 34 and 35) will have hit levels that make highly complex large-scale technologies unattractive in comparison even in economic terms. Energy transitions will have become a positive economic factor by 2040 (thesis 18) and will have made systems more resilient (thesis 23).

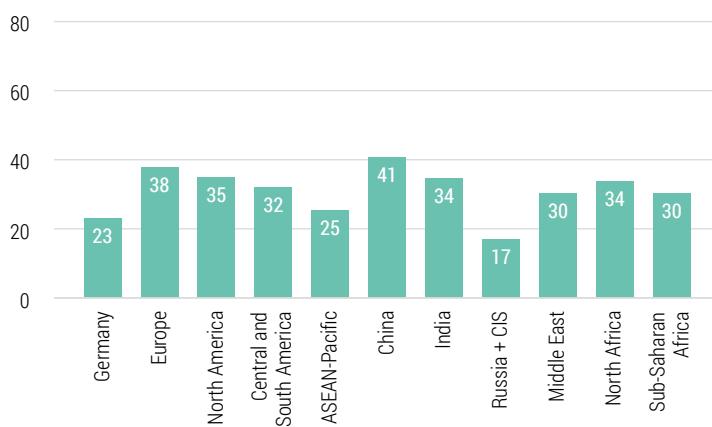
## THESIS 42

**By 2040 the operation of hydropower plants and thermal power stations with high cooling requirements will be limited due to increasing water scarcity.**

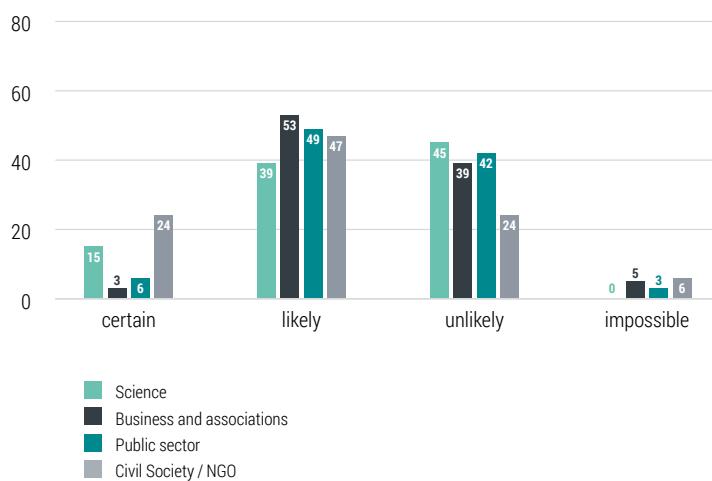
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## EXPERTS ARE UNCERTAIN

On the likelihood of this thesis the experts surveyed are again divided. To the extent that increasing water scarcity is expected to result in limitations, this is especially assumed for China and parts of Europe but also for North America, India and North Africa. A slightly higher proportion of German respondents believe this thesis to be unlikely, compared with international experts.

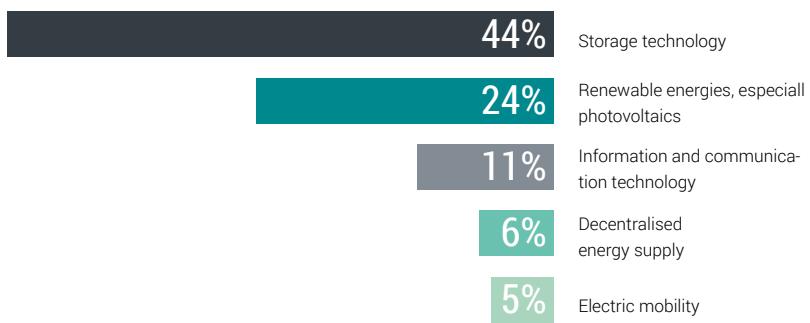
## ACCELERATING THE SWITCH

If this scenario was true, it would accelerate the phase-out of fossil energy sources and nuclear energy in developing countries and emerging economies significantly (thesis 1). It would also confirm the expectations of those experts who believe that the African countries will "leapfrog" (thesis 45).

## THESIS 43

# By 2040 the following game-changing technology will have fundamentally transformed energy systems:

## TOP 5 GAME CHANGER



## STORAGE CHANGES EVERYTHING

Advanced storage technologies with a considerably improved performance and a broader range of applications are seen by experts to be the most important game changer facilitating an energy transition, followed by renewable energy sources themselves – a mutually reinforcing dynamic. Information and communication technology is considered a third key factor driving the creation of new systems. Electric mobility as an applied technology still ranks among the top five factors.

## A KEY DRIVER

Storage is an important factor in many other scenarios, from decentralisation (theses 23 and 28) to the economic viability and system integration of renewables (theses 34, 35 and 38) through to their impact on society (thesis 29). Whether systems based on renewable energy sources will become a true alternative and deliver economic opportunities for the developing world and emerging economies will also depend on the prices and performance capability of the storage technologies available in 2040 (theses 1 and 45).

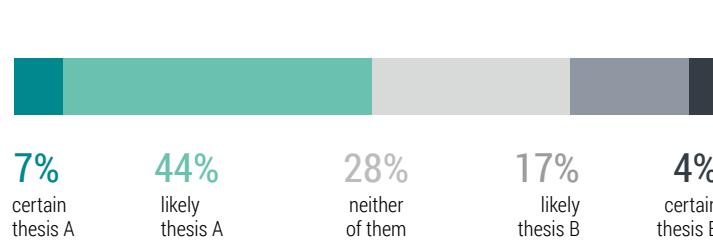
## THESIS 44

**A: By 2040 Germany will have become the world's leading country in the management of energy systems largely built on renewable energy sources, and will be the largest exporter of energy technology.**

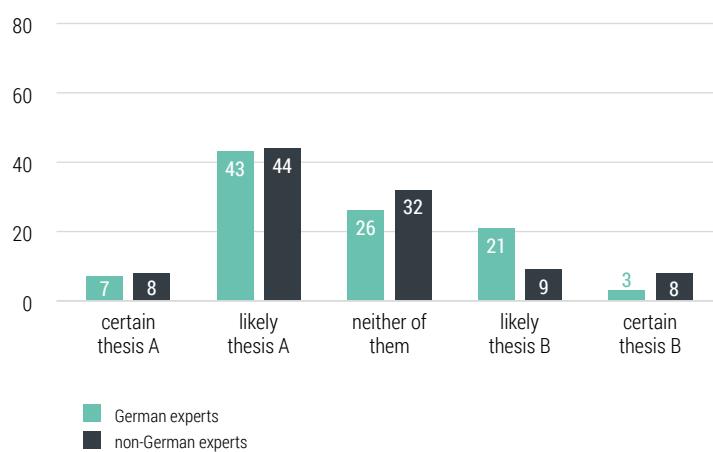
VERSUS

**B: By 2040 any hopes that the German energy transition might be successfully exported around the world will have been shattered; the supposed "model" will be considered a rather unattractive option given its high level of complexity, rising subsidies and acceptance issues.**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO GERMAN AND NON-GERMAN EXPERTS EVALUATE THIS DEVELOPMENT? (IN %)



## EXPERTS DIVIDED ON GERMAN MODEL

A small majority of experts believes that by 2040, Germany will have become the international leader in renewable energy systems. Only one in five is of the view that Germany's Energiewende model is an unattractive option for other countries. Yet 28 per cent of experts are not clearly decided in favour of either of the two alternatives.

## THE ALLURE OF SIMPLE SOLUTIONS

International experts evaluate Germany's chances primarily in the context of growing global competition for innovation, especially with China (thesis 46). Also, many experts are of the view that it might be more attractive for other countries to develop their own systems based on "frugal" innovation (thesis 45). So – as is indicated by many expectations – it is decentralised solutions that are affordable and easy to implement rather than highly complex system solutions that make an energy transition an attractive option.

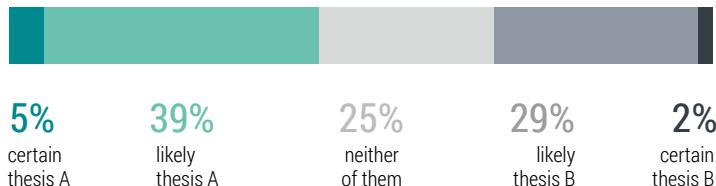
## THESIS 45

**A: By 2040 the African countries will have achieved independence from international commodity markets thanks to a promotion of decentralised forms of renewable energy generation, and will be developing new energy systems themselves (frugal innovation).**

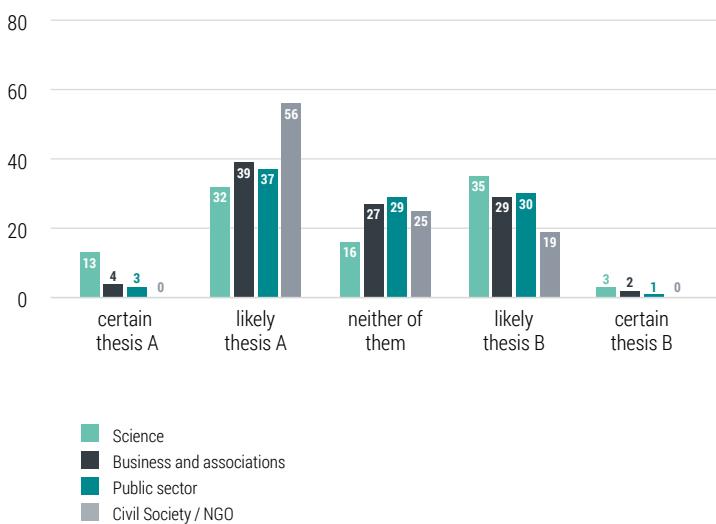
VERSUS

**B: By 2040 the high investment costs of renewable energy projects, a lack of investors and insufficient levels of qualification will have prevented Africa from “leapfrogging”. Its energy mix will be dominated by fossil sources of energy.**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## OPPORTUNITIES AND RISKS

44 per cent of the experts surveyed believe that African countries will be able to build their own, decentralised energy systems. But then there is also a great deal of scepticism: one in four cannot decide clearly in favour of either alternative, one in three considers a “leapfrogging” scenario to be unrealistic or at least unlikely. Civil society and NGO experts are significantly more optimistic.

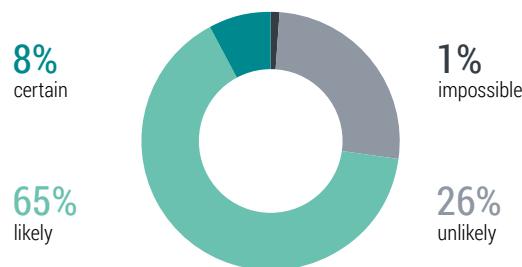
## MANY CONTINGENCIES

The likelihood of this thesis would rise if more affordable and higher-performing decentralised renewable energy generation technologies were available (theses 34 and 35). Expected macroeconomic benefits could also be a motive (thesis 18). Thesis 56 on the funding of energy investment projects can also be seen to fit in this context – but here experts’ opinions are divided.

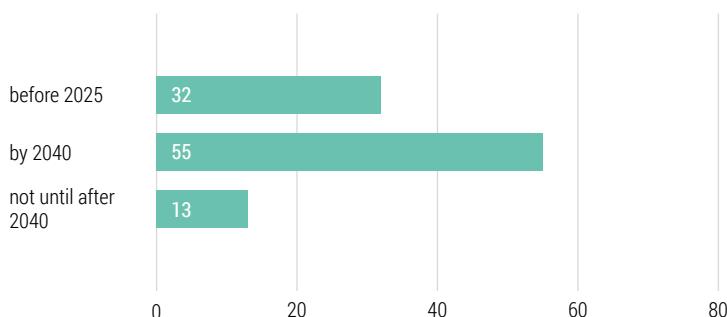
## THESIS 46

**By 2040 China will have become the world's largest developer of sustainable energy technologies and the leading innovator in this field.**

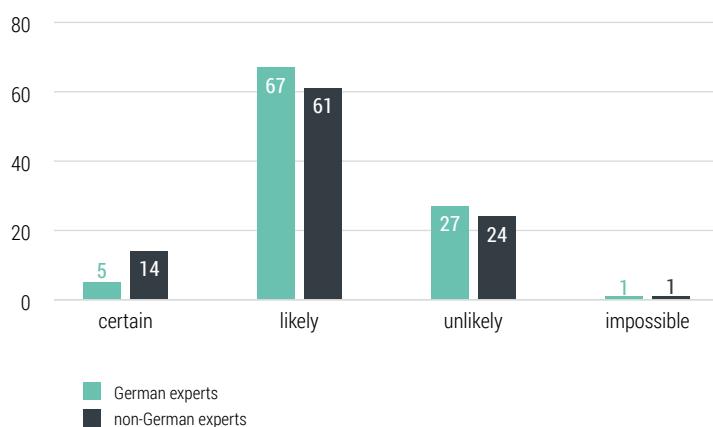
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO GERMAN AND NON-GERMAN EXPERTS EVALUATE THIS DEVELOPMENT? (IN %)



## A DOMINATING ROLE FOR CHINA

Nearly three in four respondents expect China to have become the world's largest developer of sustainable energy technologies by 2040 and the leading innovator in this field. As many as one in three even believes this to be the case before 2025. Experts from all sectors as well as German and international respondents are largely in agreement on the evaluation of this thesis.

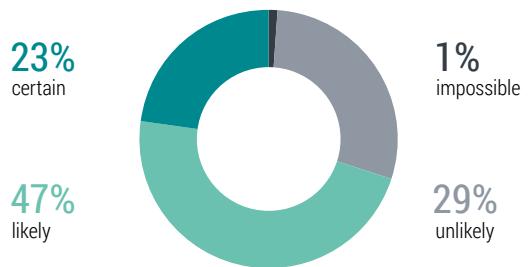
## MIDDLE CLASS TO EXERT PRESSURE

China's rise in this area will also be driven by growing pressure of its middle class to provide a higher level of environmental protection (thesis 8). It is also related to the existence of an effective international climate protection regime (thesis 11). China's leading role will present a challenge to Germany – the German Energie-wende model might thus not be successfully exported around the world as a matter of course (thesis 44).

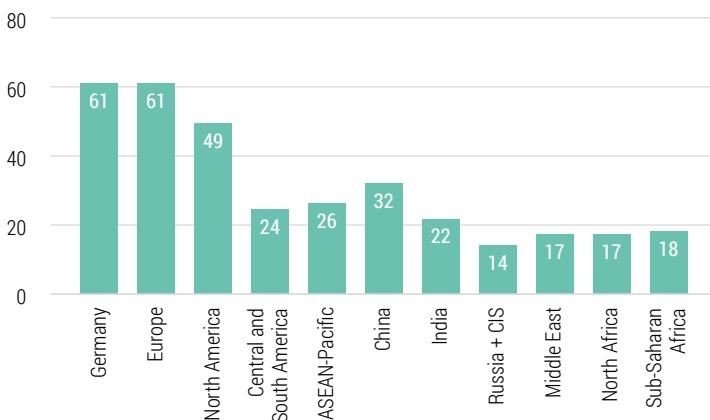
## THESIS 47

**By 2040 the unit price of electricity will have become of secondary importance in view of the low marginal costs of renewable energy generation, which will be dominating the market.**

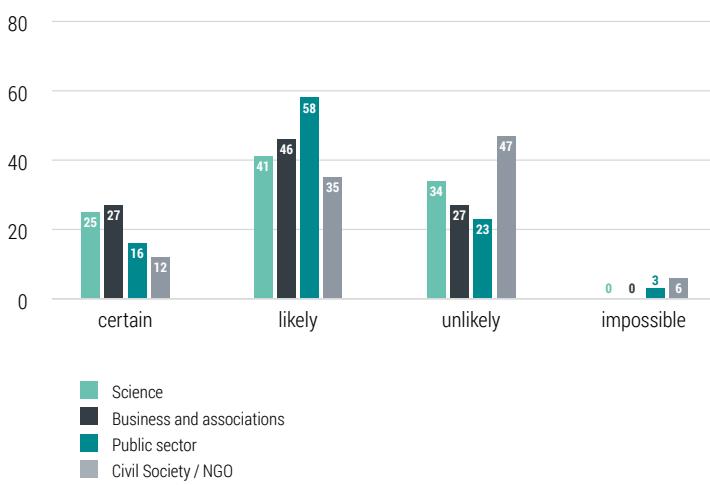
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## MARGINAL COSTS APPROACHING "ZERO"

More than two thirds of the experts surveyed consider it certain or at least likely that the unit price of electricity will have become of secondary importance in Germany, Europe and North America. To a lesser extent this is also seen for China. Civil society experts have more reservations: more than half of them believe this to be unlikely.

## IMPACT ON CONSUMPTION?

This scenario would raise the likelihood of an "all electric society" coming true (thesis 33), and it would also affect pricing structures (thesis 48). Where electricity can be offered at low marginal cost, this can also have an influence on the use of new convenience solutions by private households – and might thus lead to a rise in their energy consumption (thesis 25).

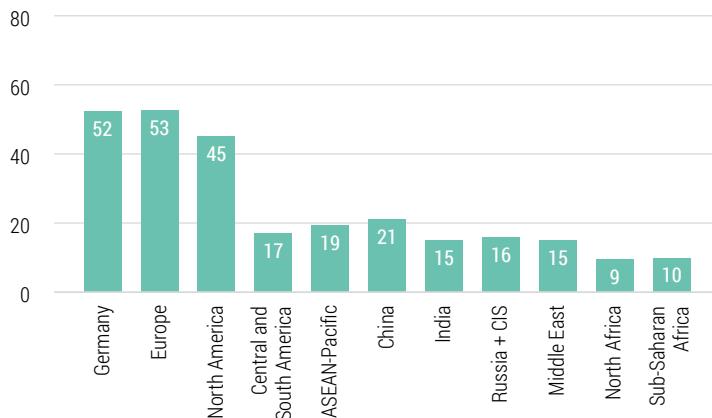
## THESIS 48

**By 2040 consumers will pay flat rate fees for electricity which depend on their average consumption and individual supply security needs and requirements.**

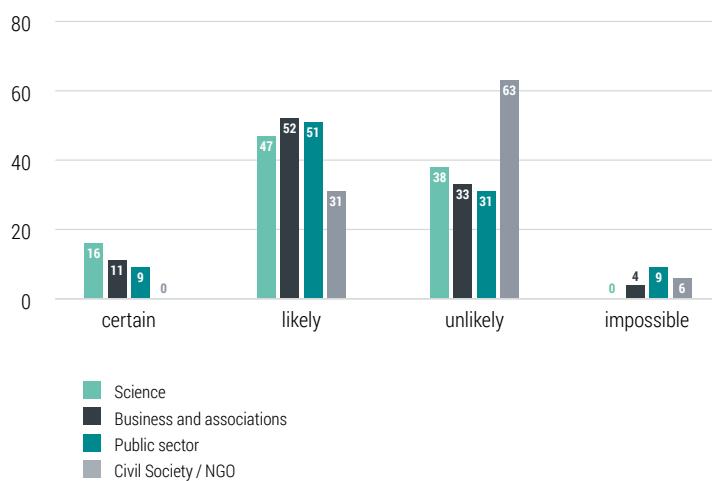
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## FLAT RATES ARE COMING

A majority of experts believes customised flat rate fees to be the best fit for systems mostly operating on renewable energy and producing large quantities of energy at nearly zero marginal cost. The likelihood of this happening is rated as "likely" or "certain" for Germany, Europe and North America. Civil society experts show far more scepticism in this regard than experts from other sectors. Also, international experts consider this to be less likely than their German colleagues.

## UNIT RATES TO BECOME A THING OF THE PAST

This scenario is related to the expectations for theses 25 and 47, among others: Only a minority of experts expects that the use of new convenience solutions will lead to a drastic increase in energy consumption of private households, yet many see unit rates for electricity becoming obsolete. Also, a very vast majority of experts believes that power markets will be characterised by a high level of disintegration, continuously metered customers and appliances as well as "real-time pricing" (thesis 54).

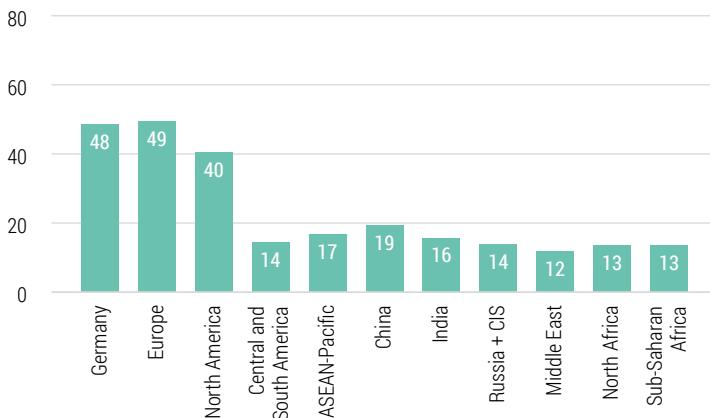
## THESIS 49

**By 2040 one consequence of the expansion of intermittent renewable energy generation will be that uninterrupted availability of electricity will no longer be a standard service offered by energy companies but will have become an extra service to be purchased separately by the customer.**

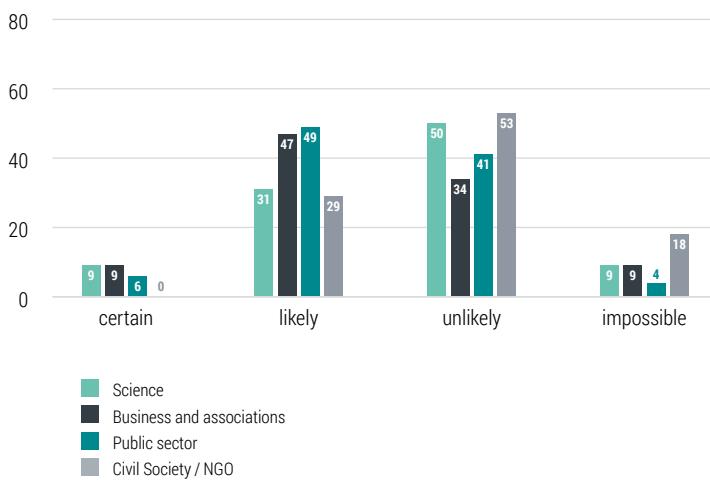
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## THE PRICE OF SECURITY?

On this experts are split right down the middle: about half of all experts believe that supply security will, in the future, be priced and marketed as a service in its own right – or not. Those who believe that security will come at its own price expect this to be the case in Germany, Europe and North America. International experts tend to view this as less likely.

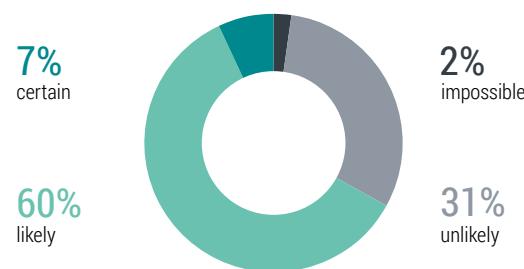
## CUSTOMISED PRICING

This thesis can also be read in conjunction with the question on energy poverty (thesis 30), which experts consider as unrealistic. It is also related to the expectations concerning continuous metering of customers and real-time pricing (thesis 54) – expectations that might support the assumption that data and IT firms will become more important players in such systems (thesis 51).

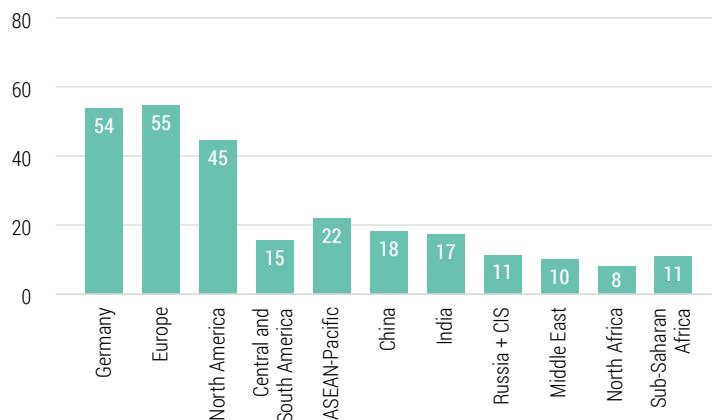
## THESIS 50

**By 2040 only a few technical functions, such as operation of the networks, will remain within the sphere of responsibility of traditional energy companies, while electricity will be generated by many small producers and network management will have become the domain of international IT companies.**

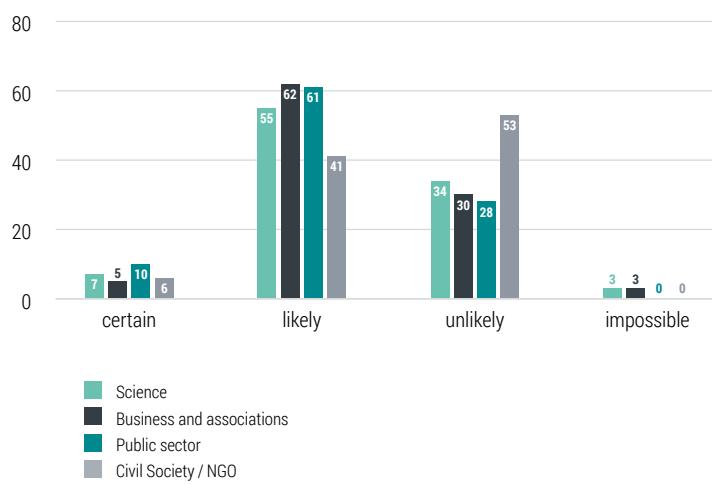
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## ENERGY COMPANIES ON THE DEFENSIVE

Two in three respondents expect traditional energy companies to be reduced to the role of network operation. New actors are considered likely or certain to enter the markets in Europe, Germany and North America. German and non-German experts are in agreement on this question, while civil society respondents tend to rather see opportunities for energy companies.

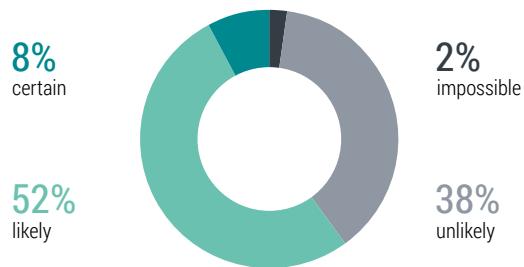
## NEW BUSINESS MODELS

In a different context the experts surveyed expect internet majors to be among the largest energy players of the future (thesis 51). Flat rates (thesis 48), continuously metered customers and real-time pricing (thesis 27) are all trends that fit in with their business models.

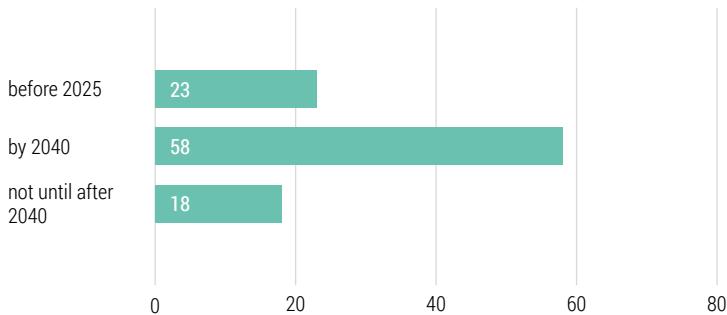
## THESIS 51

**By 2040 major internet companies and the data and IT industry will have become the largest energy players given their capability to process large data volumes and their ability to manage supply and demand on an automated basis.**

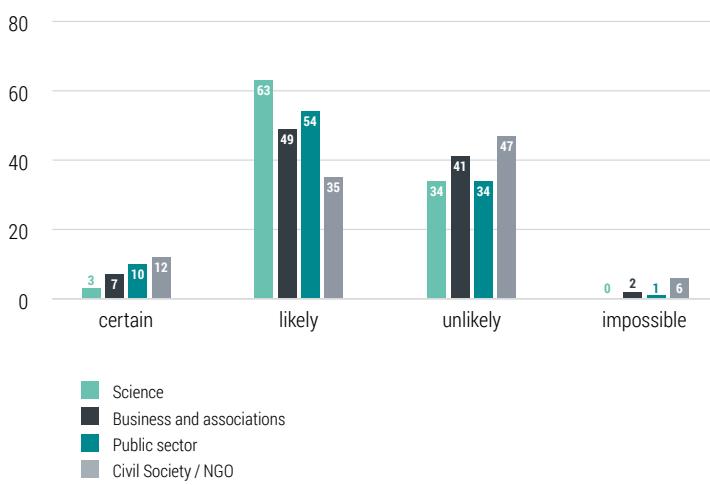
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## IT INDUSTRY TO PLAY ITS TRUMP CARDS

A 60 per cent majority of experts believe it to be likely or certain that the major players dominating the energy industry in 2040 will have their background in the data and IT industry. In part this is seen as a long-term trend occurring after 2040 rather than before. German and international experts share this expectation; the opinions of science and civil society experts, however, are relatively far apart.

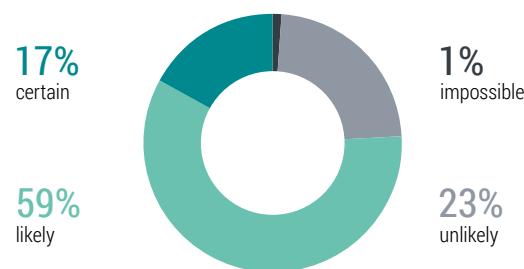
## NO DATA GROWTH WITHOUT RISK

Many experts even go so far as to see the IT industry following in the footsteps of traditional energy companies (thesis 50). The internet of things (thesis 52), which is expected to increasingly take over the function of managing energy supply and demand, will allow data firms to shine in their core area of expertise. In contrast, where data is playing an ever more important role, this might also make energy supply infrastructure more vulnerable to criminal data breaches and acts of cyberterrorism (thesis 53).

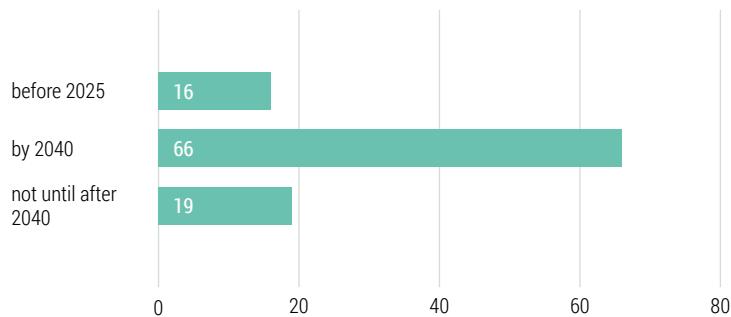
## THESIS 52

**By 2040 the “internet of things” will have come to also coordinate power generation and consumption; all electrical appliances will autonomously report their energy demand online and respond to supply and price movements.**

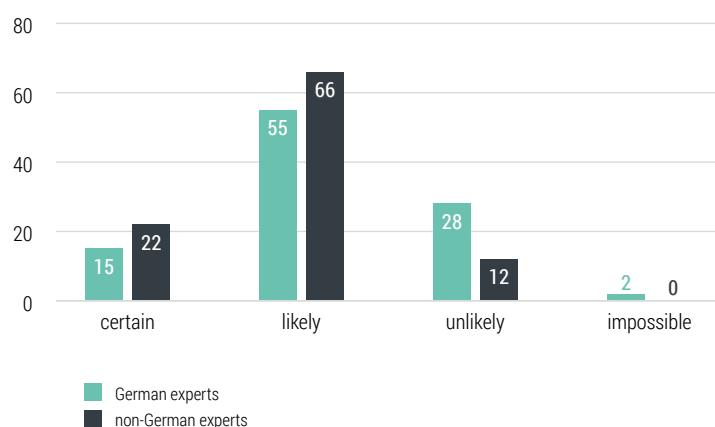
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## BY WHEN WILL THE THESIS TAKE PLACE? (IN %)



## HOW DO GERMAN AND NON-GERMAN EXPERTS EVALUATE THIS DEVELOPMENT? (IN %)



## ENERGY AND THE INTERNET OF THINGS

Three in four experts consider it likely or certain that by 2040 the internet of things will closely connect all parts of the energy world right down to appliance level and that most energy processes will be controlling themselves autonomously. One in five, however, rather sees this as a long-term trend taking place after 2040. German experts are more sceptical about this than international respondents.

## AN AUTOMATED AND CONNECTED FUTURE

In 2040, households will be using a wide range of connected convenience and mobility solutions (thesis 25) – the natural domain of IT and data firms, which will be able to develop new pricing and charging models on this basis (theses 51 and 54). Energy trading will undergo a similar transformation, with fully automated trading systems being created and based on complex algorithms (thesis 55).

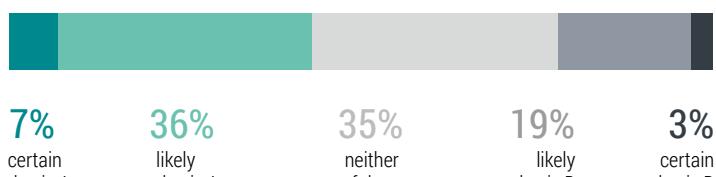
## THESIS 53

**A: By 2040 criminal data breaches and cyberterrorism will cause power outages and system shocks all over the world.**

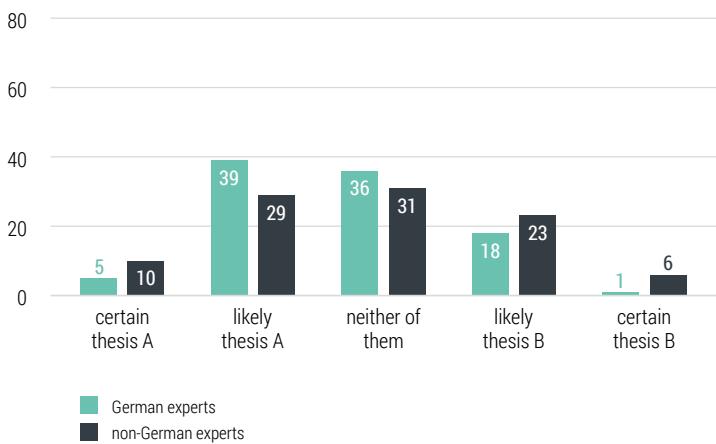
VERSUS

**B: By 2040 security gaps allowing a misuse of energy data will have been closed.**

## WHICH OF THE TWO THESES (A, B) WILL TAKE PLACE?



## HOW DO GERMAN AND NON-GERMAN EXPERTS EVALUATE THIS DEVELOPMENT? (IN %)



## LIMITED CYBER RISKS

Overall, the experts surveyed tend to neither embrace the drastic "cybershock" scenario nor fully support the optimistic thesis that the problems associated with criminal data breaches will have been solved. The largest group does indeed emphasise the risks, but no less than 35 per cent consider both extreme scenarios to be unrealistic. The future security situation is also evaluated differently by the individual sectors: while the majority of public and civil society experts tends to support the risk-oriented scenario, science as well as business and associations appear not to be clearly decided in favour of either approach and choose to respond with a "neither nor".

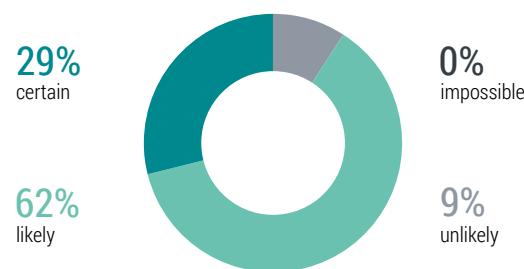
## HIGHLY CONNECTED

International experts generally expect the future world of energy to be shaped by highly (inter-) connected infrastructures, autonomous control processes and data growth (theses 38, 52, 54 and 55, among others). By 2040 data-based networks will have become a key factor even at the European level (thesis 17).

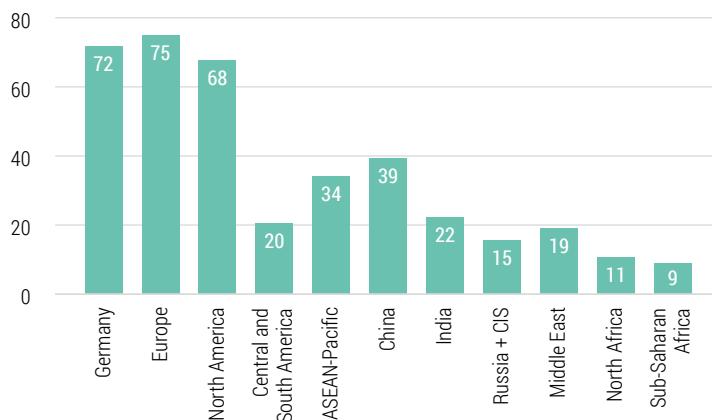
## THESIS 54

**By 2040 the power market will be characterised by a high level of disintegration, load profiled customers and real-time pricing; smart meters and appliances will enable users to optimise their consumption.**

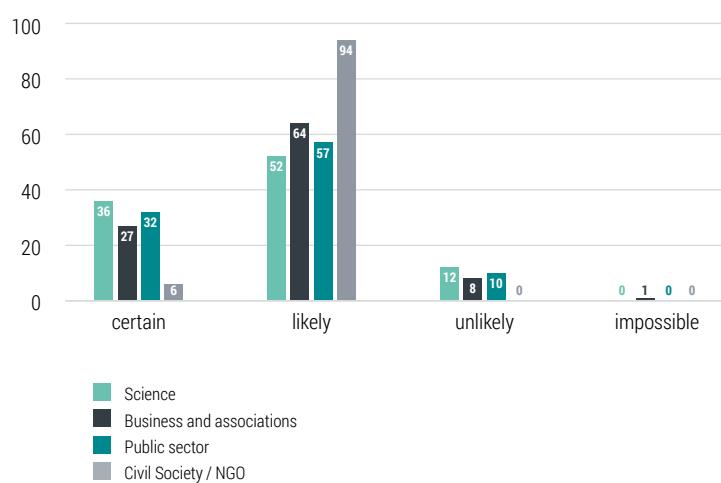
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## MARKETS SHAPED BY HIGH LEVEL OF DISINTEGRATION

Nearly all respondents expect the power markets in Germany, Europe and North America to be characterised by a high level of disintegration, continuously metered customers and real-time pricing by 2040. Both German and non-German experts share this view. The same perspective is seen for China and other Asian regions.

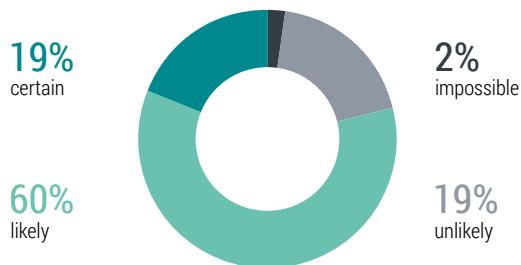
## MANY DRIVERS

New convenience solutions used in households need to be coordinated and connected in an optimal way even if they do not lead to a direct increase in energy consumption (thesis 25). New pricing models will emerge, which may also comprise customised components offering individual levels of supply security (thesis 48). The internet of things will provide the technical foundation for optimising consumption and measuring demand in real time (thesis 52). Smart power markets will be dominated by IT firms (thesis 51).

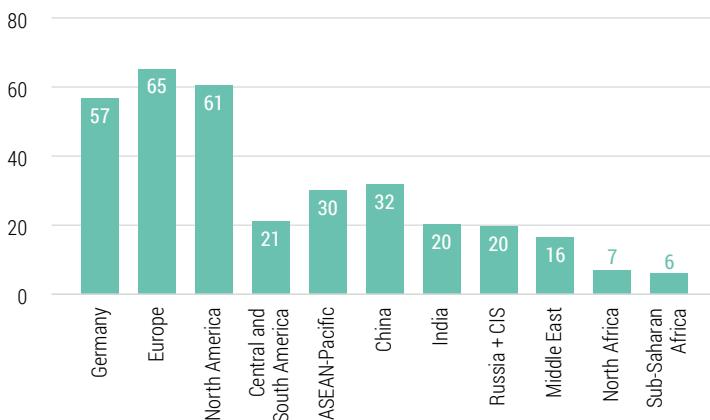
## THESIS 55

**By 2040 energy will be traded in fully automated trading systems based on complex algorithms, just like any other exchange-traded product.**

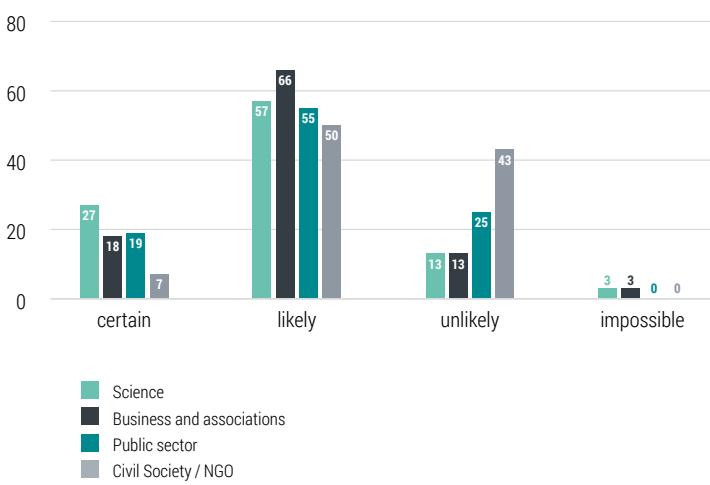
## WILL THIS THESIS ACTUALLY TAKE PLACE?



## WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



## HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



## FULLY AUTOMATED TRADING SYSTEMS

Three in four international experts believe that it is likely or certain that the European, North American and German wholesale energy markets will follow the evolution of modern exchanges and ultimately trade energy in fully automated trading systems based on complex algorithms. German and non-German respondents are in full agreement on this. Civil society and NGO experts tend to be more sceptical.

## OPPORTUNITIES FOR IT FIRMS

Where energy is traded in fully automated trading systems based on complex algorithms, good opportunities will arise for large IT firms to bring their key skills to this market (thesis 51). Other scenarios also point in this direction, for example the expectation of power markets that are characterised by a high level of disintegration and real-time pricing (thesis 54).

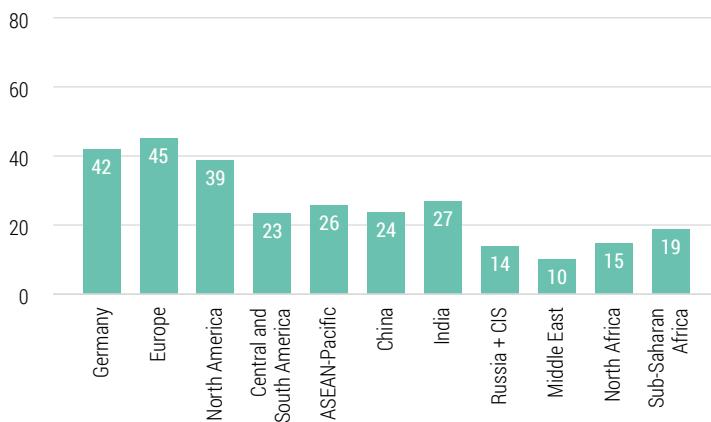
## THESIS 56

**By 2040 the trend to decentralise energy systems will have resulted in a situation where the majority of energy investment projects are no longer funded by large investors but rather by small crowd- and community-based funds or micro-financing initiatives.**

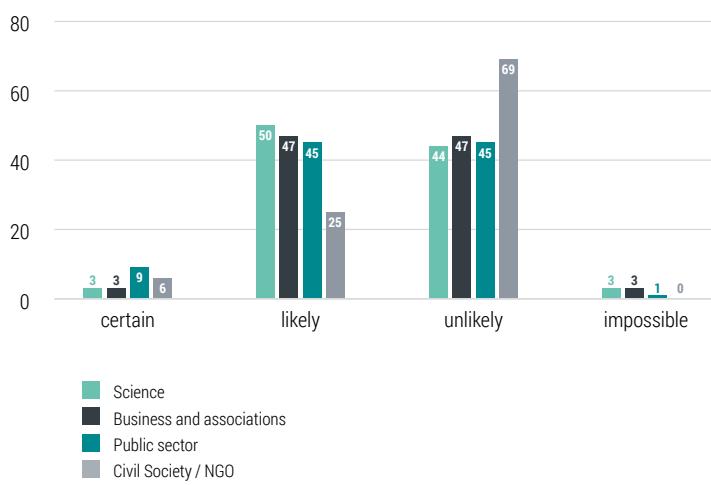
### WILL THIS THESIS ACTUALLY TAKE PLACE?



### WHERE WILL THE DEVELOPMENT TAKE PLACE? (IN %)



### HOW DO EXPERTS FROM DIFFERENT SECTORS EVALUATE THIS DEVELOPMENT? (IN %)



### EXPERTS ARE DIVIDED

The experts surveyed are almost exactly split down the middle on whether micro- and crowdfunding will succeed in the energy sector. German respondents tend to consider this as unlikely. Experts who do believe that future energy investment projects are likely or certain to be largely financed through small funds assume that this will primarily be the case in Europe, Germany, North America and India.

### DECENTRALISATION AS THE GENERAL CONTEXT

A more fragmented finance base for energy infrastructure projects can be related to several other theses, for example those on the creation of decentralised structures and the success of "frugal" innovation in Africa (thesis 45). It belongs in the same context as the expectation that a move towards decentralised systems operating on renewable energy will also provide new impetus for local self-governance structures (thesis 29). The technical foundations on which these developments will build are evaluated in the context of other theses (thesis 38, for example).

## THE PROJECT PARTNERS



German Association of Energy  
and Water Industries

### GERMAN ASSOCIATION OF ENERGY AND WATER INDUSTRIES (BDEW)

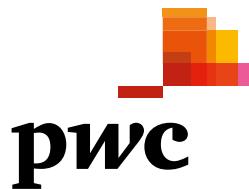
The German Association of Energy and Water Industries (BDEW), Berlin, represents over 1,800 companies. The range of members stretches from local and communal through regional and up to national and international businesses. It represents around 90 per cent of the electricity production, over 60 per cent of local and district heating supply, 90 per cent of natural gas as well as 80 per cent of drinking water extraction as well as around a third of wastewater disposal in Germany.



Deutsche Gesellschaft  
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## ACKNOWLEDGEMENTS

Our special thanks go to the 80 distinguished experts listed below, who have shared their expertise and expectations for the future with us in interviews taking up to several hours. We also thank the more than 350 experts who have repeatedly evaluated our theses and provided their comments. This study is based on their knowledge and experience and would not have been possible without their time and commitment.

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**Prof. Dr. Uwe Leprich**, Institut für Zukunftsenergiesysteme GmbH

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