> Future Energy Grid

Information and communication technology for the way towards a sustainable and economical energy system

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> CONTENTS

SUMMARY

Germany's change in energy policy can only succeed using smart grids. Germany wants to opt out of nuclear energy by 2022 and rapidly transition to renewable energy sources such as wind and solar power. However, electricity production from these energy sources is sporadic by nature as wind and sun are not consistently available. The current energy grid is not designed for a large number of fluctuating energy sources, therefore these renewable energies can only be integrated into the electricity system on a large scale if the grid infrastructure and storage capacities are upgraded. Information communication technology (ICT) is essential for the future power supply. Energy technology and ICT merge together in a "smart grid", in which the individual infrastructure components communicate with each other and the power consumption and generation intelligently adapt to each other.

ICT is not only an important enabler for the successful integration of renewable energies and therefore for sustainable energy supply. Smart grids can also bolster the efficiency of Germany's energy usage. These grids can make a significant contribution towards a reliable, affordable source of electricity in the long term. Thanks to the combination with ICT, new intelligent applications are available to consumers, which, for example, help save energy or automatically analyse and control power consumption so that they always incur the lowest fees possible. New market models and value chains are emerging which open new opportunities, particularly for small companies, start-ups, and small energy producers. They can participate on the market with innovative, smart services and applications and supply regenerative power to the grid to maximise profits. End customers profit from variable electricity tariffs which correspond to the different loads on the grid during the course of the day and can, for example, use cheap off-peak electricity. Overall, Germany can gain an international competitive advantage via the development and export of sustainable smart grid technologies and establish itself as a leading supplier in this field. Growth and value added will be promoted and jobs will be created.

Regenerative, decentralised and fluctuating – the challenges of developing smart grids

The reorganisation of the electricity infrastructure is associated with immense challenges for policy-makers, business, science and the general public. The coordination of fluctuating power generation and power consumption that changes depending on the time of day is one thing. In addition, power generation will be significantly more decentralised in future. It will no longer be only a few centralised power plants that determine the energy system but numerous dispersed small and micro-plants, such as photovoltaic areas, wind parks, cogeneration units, geothermal and biomass plants which will supply electricity to the system. Futhermore consumers increasingly become producers and operate their own photovoltaic systems, for example. Instead of electricity flowing from large centralised production units to consumers as before, it will now also flow in the opposite direction, from consumers to large producers. The grid infrastructure must be adapted to this "bi-directional" exchange of power: How can electricity from numerous small producers be optimally distributed to equally as many consumers? How can it be guaranteed that there is always sufficient electricity available on the grid, that the grid frequency remains stable and that we can store excess energy in times of surplus production? New intelligent devices, which also must be integrated into the infrastructure, present another challenge. For example, electric vehicles: on the one hand they need electricity but on the other hand they can feed stored, unused electricity from their batteries into the grid during stationary periods, if the power requirement in the system is high. Therefore, the intelligent energy system of the future must network consumers, producers, storage and grid operators. Consequently, the need for metering, automated control and tcommunication between individual components increases throughout the whole system.

The developments outlined to guarantee grid stability and security of supply present a huge technical and economic challenge. The electrical and ICT infrastructures must be

upgraded. While from one perspectivethe new grid's bias towards ICT is a strength, it entails risks: it must be ensured that the virtual part of the infrastructure does not become a gateway for hackers and criminal attacks. As the smart grid is a safety-critical infrastructure, security measures must accompany the development process right from the start. A smart grid does not only transport electricity but also huge amounts of data and information. That is why data protection and information security play a particularly important role in the redesigning of the energy system. Who has access to data at what time and for what purpose should be transparent and comprehensive. It should be impossible for third parties to draw conclusions about individual user behaviour. With all the expenses, electricity must still remain affordable to avoid any disadvantages for Germany as a business location and to maintain the high standard of living. Regulatory measures must be taken and financial incentives must be put into place so that new markets, value chains and jobs can emerge. Besides this, the people in Germany must also contribute to the renewal of the energy system. The consumer must be drawn a clear and transparent picture of what to expect with a smart grid. Without the confidence of the people behind the smart grid's security, the energy grid of the future remains a visionary theory.

Eight theses describe the future of energy supply:

- The change in energy policy is possible, but definitely requires the upgrading of electricity grids into smart grids.
- A successful migration to smart grids requires the efficient synchronisation of many fields of activity and the coordinated interaction of numerous stakeholders.
- The necessary understanding of the system in business, science and politics has not yet been achieved to a sufficient extent.
- The smart grid is developed in three phases: the conceptual design phase, integration phase and merger phase.
- New markets, market roles, value chains and jobs will only evolve if the legal framework is supportive.
- The German way is not practicable without focusing on international development.
- Acceptance is obtained by consumer-friendly dialogue and attractive products.
- The smart grid is a safety-critical infrastructure, therefore security measures must accompany the development process from the beginning

The acatech "Future Energy Grid" STUDY

The theses and following recommendations are based on the acatech "Future Energy Grid. Migration Paths into the Internet of Energy" STUDY. It describes ICT's contribution towards the evolution of a new, intelligent energy system, as well as the challenges and opportunities associated with this. Three very different scenarios are considered, which as a whole show a possible development corridor until 2030.

The first scenario, "20th century", is similar to the present structure in terms of smart grids. The use of ICT is largely restricted to high voltages, i.e. the transmission grid, which includes all the high voltage grid parts and major power plants. Electricity is still mainly generated in large centralised units, usually based on conventional fuels. The infrastructure is developed specifically in the European grid, the integration of national transmission grids, to improve electricity trading across Europe. Only a few modifications are necessary in the distribution network, which includes low, medium and high voltage grid components. Political motiviation to change to energy supply on a regenerative basis would have to alter for this scenario.

The second scenario, "Complexity trap", is characterised by the fact that although the change in energy policy is to be expedited, suitable basic technical and regulatory conditions fail to be created. This leads to the fact that smart grids can only develop inadequately and therefore the development of a fluctuating and decentralised grid supply is delayed. This scenario is characterised by low efficiency and high costs. Its implementation is only likely if the synchronisation of technical and policy developments with the stakeholders involved as well as with controlled interaction and with a monitoring process fail to be established.

In the "Sustainably economic" scenario smart grids are established completely in accordance with the "change in energy policy's" objectives. The integration of renewable energies based on market economy and the transport of electricity is successful. Smart grids intelligently and reliably control the balance between consumption, production, storage and electricity distribution in real time. As a result of new services, also for end users, there is broad acceptance of the new technologies.

The so-called technical ICT migration path is described for each of the three scenarios. It shows which technical development stages must be achieved at what time and which prerequisites must be met for these stages to create the infrastructure foundations to achieve the set energy policy target, i.e. to cover 50 percent of the gross power consumption from renewable sources in 2030.

The migration path into the desirable energy system in the "Sustainably economic" scenario is broken down into three phases: The agenda is set for the following phases in the "Conceptual design phase" by 2015. The basic technical and statutory conditions necessary are strategically planned. In the subsequent "Integration phase" (2015 – 2020) communicative system components, for example decentralised production plants, intelligent household devices or new marketplaces, are increasingly integrated into the existing electricity infrastructure using ICT. The grid is only upgraded accordingly in this phase. In the decade from 2020 to 2030, the "Fusion phase", the communicative system elements are intensively networked with the less communicative system elements, such as the centralised generation units or distribution grids, that a "merged" system has emerged.

Ten recommendations for moving towards smart grids

When considering the three scenarios only the "Sustainably economic" scenario contributes efficiently to the implementation of energy policy targets. If the change in energy policy is to succeed, which is possible in acatech's opinion, then the evolution of smart grids must be promoted by policy-makers, business and science based on the ideas in this scenario; i.e. rapidly and in coordination with all stakeholders. It requires joint, targeted efforts to take the path that leads to the socially desirable "Sustainably economic" scenario and avoid the path towards the "Complexity trap".

acatech therefore specifically recommends:

1. A *"Future Energy Grid" task force* compiles a coordinated and targeted strategy to implement smart grids in Germany. Its members should include representatives from business, science, authorities and civil society bodies, such as non-governmental organisations.

2. A *roadmap* must be compiled for the rapid further development of technologies to enable the timely technical implementation of smart grids.

3. A *national research agenda* identifies the pressing research topics and makes proposals for funding planning. The aim is to create an understanding of the system.

4. A *scientific centre of excellence* must be set up, which gathers information, pools knowledge and significantly contributes to the development of system comprehension.

5. The legislative framework must be adapted. New *market regulations* are necessary. This should include incentives for power generation in line with the market, investments in storage technologies, grids and ICT infrastructures, among other things. The legislative framework for data protection must be further developed.

6. Enhanced *pilot regions* must be established following the trial phase in the six model regions as part of the E-Energy initiative by the Federal Ministry of Economics and Technology (BMWi). Besides the technology issues, innovative concepts for new market regulations should also be tested during these trials.

7. The implementation of the overall strategy and the technology roadmap should be supported by periodic *smart grid monitoring* and should be integrated into the federal government's "Energy of the Future" monitoring process. The monitoring results are used by the federal government to regularly check the measures.

8. *Collaboration with neighbouring states,* for example in the European Network of Transmission System Operators for Energy (ENTSO-E) must be strengthened and the development of technology standards must be expedited as the energy grid does not stop at national borders. Germany should assume a leading position as a pioneer in the transition from the current electricity system to regenerative energies.

9. The general public must be involved in the reorganisation of the energy system. Dialogue forums facilitate exchanges with citizens, who must be fully informed about the new technologies to build confidence in the smart grid.

10. Specialised *skilled professionals* must be trained for smart grids. Particular attention must be paid to the training of jobs at the interface between energy technology and ICT, such as energy computer scientists. The training of existing jobs such as heating engineers or electricians must be adapted.

PROJECT

This position paper was deverloped on the basis of the acatech STUDY *Future Energy Grid. Migrationspfade ins Internet der Energie* (Appelrath et al. 2012).

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1 INTRODUCTION

Due to the recently decided opt out from nuclear energy by 2022 Germany wants to speed up switchover to an energy system, which is based on renewable energies. The use of renewable energies, above all wind and solar energy, is being continuously expanded until 2050. The regenerative share of gross power consumption is supposed to increase from roughly 17 percent at the moment to 35 percent by 2020, 50 percent by 2030, 65 percent by 2040 and finally 80 percent by 2050. If these targets are to be met the electricity system must be reorganised from scratch, as it is not designed for such large amounts of regenerative energy. At the same time as this national reorganisation of the generation structure, the energy market must be liberalised in Europe to promote competition. In this process a continuous reliable and affordable electricity supply must be maintained in Germany.

These ambitious objectives are associated with many technical and political challenges:

The share of fossil fuel primary energy sources, such as coal and lignite, natural oil and gas, of the total energy supply will only be very small in a few decades time. This also means that centralised large units will no longer generate electricity reliably in a controllable way, but generation fluctuations and a decentralised grid supply will shape the system. As wind and solar energy is not always equally available, their power generation is subject to sharp fluctuations.

The electrical infrastructure must first be extensively upgraded to cope with the challenges associated with the switchover.

This infrastructure's organisation and function can be briefly outlined as follows: The transmission grid, which is formed by the whole of maximum voltage grid parts (230 to 380 kV), is used for long distance transport, for example between north and south Germany. The transmission grid is characterised by mostly overhead lines with visible pylons. There are currently four transmission grid operators (TGO) in Germany. The distribution network, where high (110 kV), medium (10 to 40 kV) and low voltage networks (230 to 400 V) are combined, is used for the transport close to consumers or short distance transport. Here the electricity is usually transmitted over underground cables. The number of distribution network operators (DNO) in Germany is significantly higher than the number of TGOs at roughly 866. Out of a total 1.73 million kilometres network length in Germany in 2009, 35,000 kilometres (ca. 2 percent) were allocated to the maximum voltage network and therefore the transmission grid. With 76,800 kilometres (ca. 4 percent) at high voltage level, 497,000 kilometres (ca. 29 percent) at medium voltage level and 1.12 million kilometres (65 percent) at low voltage level, the share for the distribution network is accordingly roughly 98 percent of the whole German network.[1] The connection of different grid sections and voltage levels are controlled by transfer points, switching station and roughly 550,000 transformers.[2]

In the past, electricity flow on the grid was always directed from large producers and therefore the high voltages of the transmission grid to consumers in the low voltages of the distribution network. Electricity flow from lower voltages to higher voltages was not provided for in the infrastructure's design. Although massive ICT use, voltage sensors and automation were necessary in the transmission grids and power plants, they were not necessary in the distribution networks.

More and more infeed at different voltage levels is taking place, due to decentralised grid supply, i.e. power generation in the distribution network: Just under 69 TWh were supplied to the grid in 2010 in a decentralised way from wind and photovoltaic, over 150 TWh are expected for 2030, which often cannot be used locally.[3] Network expansion in the distribution networks is inevitable for this.

1 BNetzA 2010, Pages 84-85.
2 BDEW 2011.
3 cf. DLR/Fraunhofer IWES/IFNE 2010, Szenario 2010 A.

Power generation still follows the load, i.e. power consumption, in many parts today. If the power consumption increases the output of individual power plants is raised or additional power plants are switched on. The same happens in reverse, if the load decreases. Therefore a load managed electricity system exists in Germany, as in all other countries. Consumers can take as much electricity from the grid as they like at any time or as much as is allowed by the physical conditions of the grid infrastructure. Besides other tasks, grid operators have a legal obligation to guarantee a stable uninterruptible energy supply under these conditions.

Whilst upgrading the grid at transmission level alone meets the challenges, both developments, i.e. the fluctuating and decentralised grid supply, lead to the distribution network having to be operated similarly to the transmission grid in future. This means the increased use of metering, automation and intelligent, electronic power components, which can only be managed by innovative ICT.

If it is also taken into account that private and industrial consumers are also increasingly operating generation facilities themselves and alternately using electricity from the grid and feeding it back into the grid and therefore accessing the energy market as both providers and consumers and thus many smaller stakeholders are therefore directly connected to the market via ICT systems in the medium-term, this fits with the idea of a smart grid.

What might technological migration paths into the energy system actually look like based on smart grids? What contribution can ICT make to coping with the technical challenges in the energy system of the future? Although, the technical challenges outlined here are very complex, challenges of a market economy, regulatory and social nature must also be overcome as well: what can and must be done parallel to the development of technology so that the change in energy policy succeeds in the highly industrialised country of Germany and becomes a role model for other countries? How do market regulations have to be designed so that innovative technologies and new market roles can be implemented? How can the general public acquire the necessary understanding of the technologies to be able to get involved in this development? What does the German strategy look like compared to other countries' strategies and what can Germany learn from experiences abroad? These are the concrete questions, which the acatech "Future Energy Grid. Migration Paths into the Internet of Energy" project addresses. The recommendations presented here are based on the results from this project, which appears as an end report parallel to this POSITION paper in the acatech STUDY series[4].

Based on current knowledge answers were formulated in this study as far as possible.

ICT and energy systems technology merge together in a smart grid. Therefore any consideration of the necessary ICT development paths must not neglect the energy systems technology.

As the ICT specific and regulatory challenges mainly result from changes in the distribution network, the study and recommendations presented here focus on distribution networks. Other important aspects for the switchover, for example the evolution of a European overlay grid or the development of new storage options are only touched on briefly.

There are estimates based on the development scenarios for renewable energies and current regulatory conditions, which anticipate roughly 13 to 27 billion euro[5] distribution network development costs within the next ten years. A costs/benefits analysis of smart grids is not currently possible for basic reasons: too many "influencing parameters" are not yet fixed, an estimate of ICT costs is very unclear for

4 Appelrath et al. 2012.
5 E-Bridge 2011.

2030 and not least the smart grid is an idea but not yet a precisely defined factor. Therefore the study has not looked at any quantitative costs or benefits.

A technological migration path needs a target in the future in 2030. As this is not yet known, the scope of possible future developments was broken down into three scenarios.

The following key factors are decisive for the scenarios:

- The development of an electrical infrastructure,
- The availability of a system-wide ICT infrastructure,
- Flexibility of power consumption,
- Energy mix,
- New services and products,
- End consumer prices,
- Standardisation and
- Basic political conditions.

The first scenario ("20th century") is similar to the present structure in terms of smart grids, where the use of ICT is largely restricted to maximum voltages and major power plants. Electricity is still mainly generated in large centralised units, usually based on conventional fuels. The infrastructure is developed specifically in the European grid to improve electricity trading across Europe, in this case no changes or very few changes are necessary to the distribution network. In this scenario political will moves away from the increased use of renewable energies towards a focus on supply my large power plants.

The second scenario, "Complexity trap", is characterised by the fact that although the change in energy policy is is beeing expedited, suitable basic technical and regulatory conditions fail to be created. A lack of implementation strategy and coordination of the legal energy framework in particular pave the way for this scenario. This leads to the fact that smart grids can only develop inadequately and therefore the development of a fluctuating and decentralised grid supply from renewable energies is delayed. It is characterised by low efficiency and high costs.

In the third scenario, "Sustainably economic", smart grids are established totally in keeping with the change in energy policy's objectives. The integration of renewable energies based on market economy and the transport of electricity is successful. Smart grids intelligently and reliably control the balance between consumption, production, storage and electricity distribution in real time. As a result of new services, also for end users, there is broad acceptance of the new technologies.

In describing the ICT developments in the smart grid it must be considered that the future ICT-based power supply takes place at three system levels with different tasks and requirements (cf. Figure 1): the closed system level includes components for the direct maintenance of security of supply. Besides the grid operator there are very few other stakeholders in the closed system level that are well known in addition to them. Typical closed system level components are ICT systems for monitoring and controlling switching operations in the distribution network.

Compared to this there is the networked system level: a great deal of components from a whole host of heterogeneous stakeholders, for example decentralised production plants, intelligent household devices or new marketplaces, interact with the power supply system.

The ICT infrastructure level can be found between both these levels. It guarantees that any component can communicate reliably in real time with any other component.

The acatech STUDY shows which ICT technology fields are required in each system level for future energy supply and what technical advancements must be achieved in these technology fields. In the process, innovations in the ICT infrastructure level's technology fields are the basis for the next steps towards an ICT-based energy system.

The acatech study draws up a migration path for each of the scenarios, which shows, which technical development stages are due at what time and which prerequisites must be created to be able to realise the respective scenario in 2030.

The migration path for the "Sustainably economic" scenario is the most challenging but it is indispensable for the energy generation that for example, policy-makers are currently striving for.

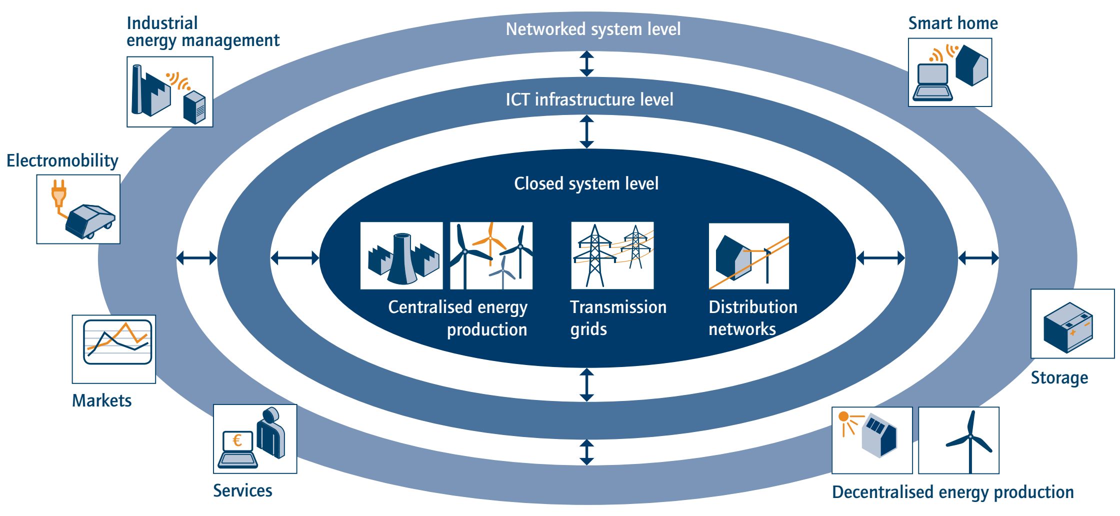
In acatech's opinion it requires joint, targeted efforts to take the path that leads to the socially desirable "Sustainably economic" scenario and avoid the path towards the "Complexity trap".

International developments must be considered, in particular as Germany has to be a pioneer for its planned reorganisation of the energy system into a smart grid. Many of the relevant laws and directives have to be decided at European level. National strategies therefore lead to a dead end. The use of international standards and involvement in their development is necessary to be able to market or also purchase products internationally. The development of a European overlay grid is necessary if the opportunities of the energy system of the future are to be fully exploited.

The change in energy policy strived for can only succeed if the energy system is rapidly reorganised into an ICT-based power supply system. This acatech position paper gives ten recommendations for how to remove obstacles to setting up a smart grid and support the adaptation measures required in acatech's opinion.

These recommendations are derived from the results of the acatech study. The key results are first summarised and emphasised in eight theses.

Figure 1: The development and components of an abstract and simplified system model with selected, fundamental technologies, functions and application areas.



2 EIGHT THESES ON THE FUTURE OF THE POWER SUPPLY

Thesis 1: The change in energy policy is possible, but definitely requires the upgrading of electricity grids into smart grids.

A change in energy policy is a venture for society as a whole. If it is to succeed then the evolution of a smart grid is essential, besides investments in developing the grid. The only way to integrate power generated by extensive fluctuating and also decentralised renewable energy sources successfully and at the same time guarantee the continued very high security of supply is with the help of a communicative electricity infrastructure. There is therefore no alternative to the use of ICT and its merger with energy technology.

With the "Sustainably economic" scenario, the acatech STUDY outlines a smart grid design in Germany over the coming 20 years and derives the technological migration path from today to 2030 from this. Far-reaching developments are required in politics, business and science to implement this migration path into practice and create the necessary innovation and marketing incentives.

There are two other feasible scenarios for the future smart grid. These either do not correspond to the social consensus of switching over to renewable energy sources ("20th century" scenario) or are associated with high costs and losses in efficiency as well as time delays ("Complexity trap" scenario). When considering the three scenarios only the "Sustainably economic" scenario contributes efficiently to the implementation of energy policy objectives. If the change in energy policy is to succeed, which is possible in acatech's opinion, then the evolution of smart grids must be promoted by politics, business and science based on the ideas in this scenario; i.e. rapidly and in coordination with all stakeholders.

Thesis 2: A successful migration to smart grids requires the efficient synchronisation of many fields of activity and the coordinated interaction of numerous stakeholders.

The dynamically changing electricity system already makes it clear today: numerous fields of activity, for example market regulation and the creation of incentives, technological development and implementation, data and infrastructure security, acceptance and the European context, must be reconsidered and adapted for smart grids to evolve. It is necessary to involve these fields of activity using stakeholders from politics, business, civil society organisations, such as non-government organisations, associations and umbrella organisations[6], consumers and science to work out solutions and concepts on which a consensus can be reached. Reaching a consensus within such a broad group of interested parties is a lengthy process, based on experience. Environmental protection and nature conservation interests (for example, maintaining the landscape or protecting birds from injury by wind power plants), as well as the publics' concerns and reservation come up against entrepreneurial objectives and energy policy aims. However, time is pressing and requires swift action. The reorganisation of the energy system is urgent. If this is to be sustainable and at the same time not exceed the tight time frame, then a balance must be found between the involvement of all interest groups on the one hand and an efficient approach on the other hand.

If this kind of synchronisation is not achieved then the "Sustainably economic" scenario cannot become reality. Both the further development of renewable energies and competition on the energy market would be significantly slowed down. Depending on how political will develops the year 2030 would tend to resemble the "Complexity trap" or "20th century" scenarios.

6 The associations and umbrella organisations include among others the Bundesverband der Energie- und Wasserwirtschaft (BDEW), Bundesverband Informationswirtschaft, Telekommunikation und neue Medien (BITKOM), Verband der Elektrotechnik (VDE) with its professional organisations Energietechnische Gesellschaft (ETG) and Forum Netztechnik/Netzbetrieb (FNN), Zentralverband der Elektrotechnik- und Elektroindustrie (ZVEI) and Zentralverband der Deutschen Elektro- und Informationstechnischen Handwerke (ZVEH).

Thesis 3: The whole is more than the sum of its parts, the necessary understanding of the system is still inadequate in business, science and politics.

In principle there are no technological obstacles to implementing smart grids. Even if much of the technology for the long-term development of smart grids still has to be researched and developed, the main challenge is in the understanding and management of the whole system. ICT and energy technology are involved in the energy system but so are also the environment, markets, politics, business and civil society. The interfaces between these areas must be better understood, as the development of smart grids in Germany interconnects markets, business and civil society more than ever before.

A sustainable paradigm shift must be successfully initiated within the "energy system's" complex network in a short time, i.e. from conventional to renewable energies, from centralised to decentralised generation and from a monopolistic structure to increased competition. If this is to succeed then the existing interconnections and dependencies of system components and those between existing and future stakeholders must be known and new interactions must be assessed.

A better understanding of the system can judge the impact of essential decisions better and the decision-making process can be organised more efficiently at the same time. Little understanding of the system leads to very slow development in the best case scenario, as only small steps can be risked when reorganising the system to avoid risks. In the worst case scenario, measures are introduced that are mutually obstructive and lead to inefficiency, high costs and a lack of market incentives. Bringing with it the threat of the "Complexity trap".

Thesis 4: The smart grid is developed in three phases: the conceptual design phase, integration phase and fusion phase.

The study identifies three phases for the migration path for the "Sustainably economic" scenario by 2030: the agenda is set for the following phases in the "Conceptual design phase" by 2015. The basic technical and statutory conditions necessary are strategically planned. In the following "Integration phase" (2015 – 2020) the networked system level components are increasingly integrated into the closed system levels using ICT and the control of the closed system level is realised using ICT. The grid is only upgraded accordingly in this phase. In the decade from 2020 to 2030, the "Fusion phase", the dependencies and networks between both system levels are so intensively networked by the new ICT infrastructure level that a "merged" system has emerged from the system levels.

The agenda for smart grid development is set in the conceptual design phase. The necessary technological developments identified for this time frame are the basis for the next steps. In particular, the technological bases in the closed system level should be developed during this time to be linked later to the networked level. The principles for the required action plans, institutionalisation and distribution of responsibilities must be worked on here with a view to both short-term and long-term development.

Science and research must be involved in the process for developing innovative technologies and solutions in each phase. Besides companies carrying out research, there are several research institutions active in the field of smart grid research. Technology and system research, basic and applied research at universities and external research institutions must be closely coordinated if the necessary technological developments are to happen quickly enough. A consistent reappraisal of the current status of research and knowledge from practice is necessary to be able to strategically develop over the next few years on this basis. Alternative technology and courses of action should be defined and assessed based on the latest consolidated knowledge. However, there is not much time left for this task.

Thesis 5: New markets, market roles, value chains and jobs will only evolve if the legal framework is supportive.

The evolution of smart grids in Germany requires extensive, timely support by legislation. Market regulation, the design of incentives and also standardisation must be highlighted here.

Market regulation

Great value-added potential will result for market players at the interface between the energy market and electricity infrastructure over the next few years. They must establish processes according to new business models. However, according to today's market regulations these are not allowed or do not allow for value-added to be economically realised. Examples of this are the operation of a virtual power plant as an aggregator for decentralised generation units for the provision of an operating reserve and marketing power on the stock exchanges. Services that are geared towards energy suppliers or grid operators include for example the aggregation of load profiles for specific consumer groups, support for the direct marketing of electricity from small generation units or innovative purchasing options using cooperative models or structured purchasing. What a concrete solution might look like is still unclear today for many aspects. In current expert discussions, the ownership unbundling of electricity production and trade as well as grid operations (unbundling) regulated in the Energy Industry Act (EnWG) adopted by the EU since 1998 currently pose an obstacle to upgrading the system. However, in the acatech STUDY it is assumed that political forces will not aim (and also should not aim) to reverse the unbundling. In fact the non-competitive parts (for example promoting renewable energies, grid operation) of the energy market must be regulated so that they support competition in the competitive part (for example, retail, sales) and in particular, do not hinder it.

As a result of their central position in the electricity system, distribution network operators must take on an active and innovative role in supporting the market in the short to medium-term. Laws therefore need to be adapted in order to create the basis for successfully intertwining technology and market development.

Design of incentives

The current Renewable Energy Act (EEG), which gives priority to regeneratively generated electricity and rewards this accordingly, does not differentiate sufficiently according to the time of grid supply. A revision of the EEG must take into account the availability of energy sources in terms of time and location more to achieve an efficient and intelligent supply structure on smart grids and at the same time not put the development of renewable energies at risk. For example, grid supply can be particularly rewarded in the case of power supply shortages. In the process the geographical proximity between generation and consumption should be encouraged, if this can keep energy transport and the associated loss of energy low and prevent further development of the transport infrastructure.

Standardisation

Standards are required to ensure that data flow and the interaction between different system components runs smoothly. The need for standardisation affects electrical system components, such as plugs, switches and generally any interface technology both to and on software products, which for example concern the issue of standardised types of protocols. National norms and specifications must also be adapted to international standardisation. Regulations must be flexible enough to allow for innovation and competition. This already happens successfully with standardisation at field level of electrical grids, for example. However, there is a need for more action in other fields, such as electronic meters and market communication.

Thesis 6: The German way is not practible without focusing on international development.

Germany can learn about the introduction of smart grids by looking at other countries. By comparing Germany with other countries, specific opportunities and challenges for technological development and the need to cooperate, in particular with our European neighbouring countries, become particularly clear. Denmark's experiences with the integration of fluctuating energy sources, mainly wind power, being fed into an electricity system based on conventional generation and end-use structures can be referred to as an example. There is the potential for Germany to become an international technology leader in the field of smart grids in particular as a result of efficient manufacturers, system expertise and also research and development programmes such as E-Energy. However, a looming shortage of skilled professionals could become a hindrance.

Other countries invest significantly more in their infrastructures. This may lead to Germany falling behind.

EU Directives, projects such as DESERTEC or the use of hydropower in Norway or pumped-storage power plants in Austria also clearly show: Germany's path to a new energy system does not stop at national borders. The German electricity grid is integrated into a European grid and closely linked to it. In the near future it must be possible, even more than already today, to trade and transport electricity all over Europe. As a result Germany must coordinate with other European countries during the reorganisation process of its energy system.

Thesis 7: Acceptance results from consumer-friendly dialogue and attractive products

Smart grid technologies do not just have to be wanted by politics but must also be accepted by the general public. Consumers must decide if infringements of consumers' autonomy are permissible and which ones, which data protection concerns are important and to what extent they have to be established in law. Guidelines from policy-makers or experts lead to more problems than difficult and seemingly slower dialogue in the medium-term. If people feel they are being monitored or do not agree with how their data is being handled, this can quickly lead to data evaluation being prohibited.

The topic of data protection therefore plays an important role in terms of acceptance. Who has access to data at what time and for what purpose should therefore be transparent and comprehensible. An important factor for the acceptance of smart grids will be confidence in the secure data exchange between end consumers and energy providers. The consumer must be drawn a clear and transparent picture of what to expect with a smart grid. At this time it is still not clear which data flows to what extent between the system components and who collects, stores and processes it to what extent and in which form (anonymous). Transparent and accepted data protection regulations are necessary to gain consumers' confidence in new technologies and stakeholders' confidence in safe investments.

Thanks to the increasing liberalisation of the energy market and competition between different stakeholders the offering becomes more attractive for end consumers and the growing interaction between all market participants speeds up distribution. The Internet as a modern communication technology is ideally suited as an information source for the pioneering technology of smart grids and is expected by modern consumers with a high affinity to the Internet. Raising end consumers awareness in terms of economical power consumption for ecological and financial reasons will also have a positive effect on the use of smart grid technology.

Thesis 8: The smart grid is a safety-critical infrastructure therefore security measures must accompany the development process right from the start.

The telecommunications network and electricity grid merge together in a smart grid. Against this background, terms such as information security, risk of terrorism and security of supply inevitably spring to mind for those involved. How and where can we protect ourselves against the criminal misuse of ICT? How can the electricity system be protected against ICT breaches that are aimed at security of supply? How can we protect data flow and who is responsible for this protection? Particularly critical trouble spots regarding these aspects must first be identified in the new infrastructure. Responsibilities must be clarified early and regulations for information security must be promptly adapted to requirements and at the same time also monitored and controlled.

The use and further development of security standards and security technology is a prerequisite for further technological developments in all fields in all phases of the migration path for the "Sustainably economic" scenario.

3 TEN RECOMMENDATIONS FOR THE DEVELOPMENT OF SMART GRIDS IN GERMANY

1. Recommendation:

A *"Future Energy Grid"* task force compiles a coordinated and targeted strategy to implement smart grids in Germany.

The federal government appoints a *"Future Energy Grid" task force*. This is constituted for a fixed term of three years and draws up proposals for action for policy-makers, business and science. The task force must be able to act independently with clearly formulated objectives and within a time frame that includes milestones.

The task force's main tasks are as follows:

- To develop a coordinated and targeted strategy for the implementation of smart grids in Germany
- To network and pursue cooperation between stakeholders from science, business, politics and civil society
- To develop plans to reorganise and adapt the regulatory market framework with an appropriate timetable
- The integrated consideration and evaluation of system changes
- To identify and prioritise important fields of research and financial and legislative requirements.
- To regularly formulate up-to-date recommendations for action (milestones) to policy-makers.
- To clarify three questions: Where do we stand? How do we reach our target? What has to be done immediately?

The design of the content and structure of the conceptual design phase (2012 to 2015) and the introduction into the integration phase for the development of smart grids in Germany by 2012 should take place at the start of the three years and as soon as possible.

The task force members are representatives from universities and external academic institutions, professional associations, companies, civil society bodies as well as non-government organisations and authorities, plus other important stakeholders, if applicable. All important fields of activity, for example standardisation, market regulation and data security should be incorporated into the task force's work by expert representatives. During its existence the task force works closely together with the permanent "Energy Networks for the Future" platform set up by the BMWi and supports it in its work. In contrast to the platform, the task force aims to reach a consensus between the stakeholders and make proposals for dealing with dissent as soon as possible within its tight time frame. This process must be designed transparently and publicly.

The task force's work extends to the rapid establishment of principles for the development of smart grids in Germany. Once it is dissolved the task force's results and work, for example on the monitoring of the implementation process, are passed on to the permanent platform.

The task force's organisation and structure must be designed appropriate to purpose. For example, it can be broken down into different thematic working groups and coordinated by a steering committee. The steering committee members should be high ranking decision-makers from the represented fields of activity and interest groups, if possible.

2. Recommendation:

A roadmap must be created for technical implementation.

The development phases for the evolution of smart grids must be defined in a *technology roadmap*. The paths and ideas outlined in the study as examples can serve as the basis for this.

In concrete terms the priority in the conceptual design phase from today until 2015 is to develop and use the technology necessary to upgrade the ICT infrastructure level and create the bases to further develop the closed system levels. Different system alternatives must also be drawn up, compared, analysed and evaluated here. Standardisation and information security issues must be clarified in advance for this. The networked system levels' developments can initially be prepared and then left to the market. As explained in the theses, the system context and alignment towards the migration path plays an important part. The German Federal Office for Information Security (BSI) protection profile must also be created from this point of view.

A significantly advanced development phase of technologies for the ICT infrastructure is then urgently required in the integration phase (2015 to 2020). Fields of technology at this level play a key role in the complex interaction between different technologies. The creation of bases for these fields of technology should therefore take high priority in the action plan. Other core technologies, for example grid automation or the development of forecast systems, must also be dealt with for this reason.

The developments necessary to prepare for the fusion phase (2020 to 2030), for example regional energy marketplaces, systems communication, control modules and the optimisation of industrial energy consumption, must already be initiated today.

The roadmap should also focus on the implementation of security standards and technologies for the purpose of data protection, preventing criminal misuse and security of supply.

The roadmap should re-evaluate the existing infrastructure in light of the new requirements. The convergence of energy infrastructures for the cable-based energy transfer of electricity, gas and heat ("hybrid grids") must especially be checked. The possibilities for storing energy and using the existing infrastructure and technologies must also be checked.

The roadmap should be true to the motto "strengthening strengths" and expedite technological development with the aim of becoming a *leading international supplier*.

Germany should also aim to become the leading market, at least for select top quality smart grid technologies.

Communication strategies and investment roadmaps should also be prepared parallel to the technological roadmap. Content requirements cannot be derived at this point based on the technically based acatech STUDY. Powerful consortia should draw up proposals for this in short-term studies.

The "Future Energy Grid" task force should be responsible for drawing up the roadmap and it should be an integral part of the overall strategy drawn up by this committee.

3. Recommendation:

A *national research agenda* identifies the pressing research topics and makes proposals for funding planning. The aim is to create an understanding of the system.

The targeted and coordinated drafting of sustainable solution concepts is required to achieve the intended energy policy objectives and the smart grids necessary for these. The fragmented funding landscape in the energy environment must be standardised to quickly and efficiently draw up proposed solutions and the different expertise must be managed. Research activities must be pooled. Therefore a national research agenda should be drawn up based on the analysed and evaluated actual status. The research agenda requirements are:

- To identify and prioritise pressing research topics
- To draw up proposals for funding planning; geared towards making the greatest possible contribution to problem solving from a system's point of view and increased understanding of the system

An important part of the research agenda is to develop specific *research programmes* and *to direct research funding*. Research programmes should prioritise different research tasks according to their specific contribution to smart grids in Germany and coordinate future research activities accordingly. Funding should range from current urgent short-term projects on restricted themes to long-term projects. The current lack of economic model studies for the costs/benefits analysis of the change in technology should be supported as much as technological bases and the analysis of consumer behaviour. The issue of linking existing gas and district heating transport infrastructure as well as other energy infrastructures to the electricity infrastructure should play an important role in the research.

Proposals from the Union of German Academies of Sciences and Humanities for future research focuses are summarised in the Energy Research Programme[7]. The key points of this advisory opinion from 2009 regarding the systemic focus of research activities are still valid today, despite the decision to opt out from the use of nuclear energy. The topic of smart grids that was not dealt with in any depth in this is therefore dealt with comprehensively in the acatech STUDY and these recommendations.

acatech sees a huge opportunity for Germany to establish itself as a worldwide leading supplier of smart grid technologies with development initiated by the energy policy.

In this context, acatech also recommends increasing the necessary understanding of system contexts using specific research programmes. In the process knowledge must be implemented immediately in a smart grid reference architecture, i.e. a template for the efficient interaction between technologies and processes applicable to other regions. This also includes the co-development of international standards to guarantee security in the new infrastructure.

4. Recommendation:

A *scientific centre of excellence* gathers and provides information and in particular makes this available SMEs and significantly contributes to the development of system expertise.

The c*entre of excellence's* objective will be to work out the actual status in research and initiatives and constructively look at the future of energy research. The centre of excellence's main job is to gather and process information from research projects and make this available to a broad range of interest groups. The centre of excellence contributes significantly to the understanding of the system and development of system expertise by consistently providing results. In this context, the centre of excellence should act as a contact point for SMEs and an information centre to develop the database in a viable way for companies that do not carry out their own research. Research projects shall be required to provide the centre of excellence with their findings. It is not the centre's job to carry out its own research activities. A centre of excellence should be able to quickly make a sound contribution to the task force's strategy.

The centre should be set up and borne by the responsible ministries.

5. Recommendation:

New *market regulations* and incentives for power generation in line with the market, investments in storage technologies, grids and ICT infrastructures are required. The legislative framework for data protection must be further developed.

acatech recommends a *redesign of market regulations* with the aim of creating short to medium-term market regulations that ensure balance and the merging of market and

7 Leopoldina/acatech/BBAW 2009.

grid aspects in the distribution network. The redesign must offer solutions to the following questions:

- How will investments in rationing and efficiency be rewarded?
- How can it be facilitated that aggregated demand and storage capacities can be offered on the markets?
- How can producers of fluctuating renewable energies be rewarded for their price reducing effect?
- How can renewable energies be better integrated into the market?

In addition, medium-term planning for the modification of the statutory framework should be coordinated with the action plan schedule in the technology roadmap.

In acatech's opinion, the design of incentives should basically be geared towards *ruling out knock-on effects* and *keeping the number of instruments low*. The EEG should be revised and more *incentives for power generation in line with the market as far as possible* should be put in place. This affects conformity in terms of both time and space. Electricity should be able to be produced and provided when it is needed by consumers. If this is not the case then the demand should be able to be adapted to the current supply. If possible, electricity should also be consumed close to production, as the need to physically develop the grid and transport losses can then be reduced. The incentives put in place should motivate electricity producers (or aggregators) to invest in storage technologies, which they combine with generation units on site and in suitable power supply equipment for connection and integration. Financial incentives should also be created for grid operators to upgrade their grids with a basic ICT infrastructure. An integral part of this infrastructure is also the "data hub", which allows authorised stakeholders to access production, consumption and system data.

The federal government has recognised early that the process for developing smart grids must be accompanied and/or prepared for with legal regulations on information security. Therefore a protection profile is currently being drawn up by the BSI for smart meter technology. acatech welcomes these steps in principle but also recommends considering the requirements of the electronic smart meter in a future energy system and taking a look at our European neighbours with further development.

Many proposals from pilot and research projects on the efficient control of the energy system are based on the use of metering data from the private sector and contradict the valid German Data Protection Act (BDSG). The proposals for adapting the BDSG should be checked and quickly adopted into law, if applicable.

6. Recommendation:

E-Energy model regions must be expanded to include more *pilot regions* with other subjects of investigation.

The concept of E-Energy model regions should be intensified building on the knowledge gained there and new issues, and expanded regionally. Other technological questions should be answered and innovative concepts for market roles in a competitive environment should be tested using exemption clauses for market regulation with the help of *pilot regions*. They can provide valuable knowledge about the feasibility and efficiency of linking existing grid infrastructures for electricity, gas, heat/cooling and fuels. Storage capacities could be expanded and if applicable economic costs could be reduced by merging these infrastructures. A sound costs/benefits analysis must be compiled for specific technology modules to support this.

These regions make it possible to check and specify the catalogue of instruments and at the same time contribute to raising the understanding of the system. The focus on feasibility and efficiency will be clarified by the step from model to pilot region. The aim should be to achieve and represent the pilot region's competitiveness. As a result the combinations of regulatory measures, technologies and stakeholders tested would become showcases and motivate other regions and countries to emulate them. Appropriate funding and support programmes must be provided.

The knowledge from pilot regions should contribute to identifying and concretising so-called "no regret" measures for investments in the energy system and its reorganisation. This means measures that are highly likely to have a positive impact on all possible future developments. The following investigatory questions must take priority: How can the new functions and market roles of smart grids be reconciled with the requirements for unbundling the energy market and other political requirements? What part will the grid operator play in future? What will data flow be like and how will it be organised? How can the compliance with statutory provisions for data protection be monitored? Which technical options are feasible and economical to balance out fluctuations and storage?

Comprehensive national demonstration projects provide an opportunity to put the technical feasibility of solutions to the test, as they can be seen as the preview phase[8] to testing for subsequent market launches. They thus form the basis for export and participation on foreign markets.

7. Recommendation:

The implementation of the overall strategy and the technology roadmap should be supported by monitoring.

The aim of monitoring should be to investigate, quantify and analyse the smart grid's contribution towards an affordable, ecological and at the same time socially acceptable, i.e. sustainable energy supply in the narrower sense. The guarantee of security of supply should also be monitored for smart grid development and job developments and value added opportunities should be ascertained.

Smart metering technology must be subject to a costs/benefits analysis as part of the monitoring before a possible large scale roll-out. Current studies indicate that the benefit of a wide-scale implementation of smart meters is to be assessed as low. The widespread use of smart meter technology is not necessary for the development of smart grids.[9,10] In particular, the assessment called for by the EU Directive 2009/72/EC by 3rd September 2012 should be carried out quickly, as there is considerable doubt whether the roll-out called for in the directive (equipping 80% of consumers with smart meters by 2020) is nationally economically or ecologically worthwhile.[11,12]

The monitoring should be led by science but in collaboration with authorities, businesses, associations and NGOs and be an operative interface to the task force's work. The monitoring geared specifically to the process of smart grid development should be an integral component of the "Energy of the Future" monitoring process set up by the BMWi and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in 2011, which shall accompany the whole process of the change in energy policy. The monitoring must start soon and continuously accompany the reorganisation process and even the conceptual design phase.

Knowledge is incorporated into continuous monitoring and the revision of the strategy and roadmap. Annual status reports allow for an accurate description and analysis of the reorganisation process and the possibility to quickly steer the federal government in case of changes in strategy. Monitoring can be broken down into different thematic

8 ECJRCIE 2011.
9 Nabe et al. 2009.
10 Rohlfing 2010.
11 Schäffler 2011.
12 Bothe et al. 2011.

working groups according to the different fields of activity, for example into socio-economics, ecology, economics and technology. The preparations and initial situation analysis must already take place at the start of the conceptual design phase.

8. Recommendation:

German smart grid development requires international cooperation for example within the umbrella organisation of the European Network of Transmission System Operators for Energy (ENTSO-E).

The cross-border links between the national energy grids and the need for electricity transport to neighbouring countries forces Germany to not only think and act nationally but also internationally when developing smart grids. Consequently, a whole range of aspects has to be considered.

Standardisation at European and international level must be addressed as early as possible and binding solutions must be produced quickly. The German Commission for Electrical Engineering, Electronics and Information Technology have already set the agenda for this in DIN and VDE (DKE) with the standardisation roadmap and additional organisational measures as well as very active cooperation at international level. To expedite the successful implementation of the technology roadmap, Germany should assume a leading position in international standardisation as a pioneer in the switching over of the electricity system to regenerative energies. This requires avoiding national strategies, declaring the use and development of standards as mandatory in research and pilot projects and supporting the research and development of standards and tools using funding programmes. This could in turn contribute to German companies, in particular SMEs, becoming possible leading suppliers.

Lessons learnt from other countries, for example Denmark with its high percentage of wind energy, should be identified and more intensively used. Cooperation and sharing good practice in the International Smart Grid Action Network (ISGAN) could be helpful for this. Naturally, the projects planned at European level, such as the development of transfer points and the pan-European grid must be expedited.

9. Recommendation:

Involving and informing citizens creates acceptance.

The general public must be sufficiently informed about the process and its complexity so that they can be involved in shaping the change in energy policy. The opportunities, challenges and obstacles must be communicated and discussed extensively and non-judgementally. The profitability of investments and smart grid technologies' contribution to and benefits for the change in energy policy and for every single citizen must be made clear. Knowledge of these facts, i.e. "acceptability" is a basic prerequisite for the acceptance of measures and technologies by the general public.[13]

acatech therefore recommends creating *acceptability as the basis for acceptance*. More public relations work is necessary for this. Besides business and civil society organisations it is mainly the state and federal authorities' obligation to extensively and directly inform citizens. acatech proposes establishing citizen forums on specific topics and creating new formats for participation and open-ended dialogue between political decision makers, experts and the general public. Information for the public should also go hand in hand with their integration into a participatory decision-making process though. The public's involvement in discourse about society as a whole will help to significantly increase the sustainability of measures. The term, change in energy policy, must be made understandable for the general public using concrete examples and challenges. This should contribute to the demystification of the smart grid idea. The Federal Ministry

13 acatech 2011.

of Education and Research (BMBF) is taking the first step in this direction using public dialogue. Other steps must follow and clearly go beyond the ministry's format. Public reservations towards infrastructure measures are partly already known. However, arguments such as interference with the landscape by wind parks (blots on the landscape) or animal protection (for example, birds injured by wind parks) have a totally different focus to the issues against ICT, which tend to be about security issues, for example data security and data protection.

10. Recommendation:

The training and education offensive must start soon.

The need for skilled professionals to operate and develop the new technologies was not analysed in the acatech STUDY. However, the importance of an education and training offensive was highlighted in several expert workshops and other studies, for example the VDE.[14]

Skilled professionals have to be educated and trained for the introduction of technologies, for example the smart meter or intelligent household devices and their control. They can directly and professionally advise and inform end consumers and therefore build up confidence in the technology and raise acceptance.

Technologies that are not immediately obvious for end consumers, for example in the distribution network, are also important for development. Enough specialist skilled professionals are needed to pursue the proposed migration path.

The current state of technological development and the latest standards must be reflected in the education and training of skilled professionals. Skilled professionals with specialist smart grid knowledge must be trained not just internally by companies but also at external education institutions. As a result building services engineers must be familiar with systems and functions and internalise the symbiosis between ICT and the energy infrastructure. Heating engineers, electricians, building engineers etc. must be adequately educated and trained. Particular attention must be paid here to the training of jobs at the interface between energy technology and ICT (for example, energy computer scientists). An appropriately qualified workforce must be created for manufacture, development and operations.

[14] VDE 2011.

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